Australian Government
Productivity Commission

Public Safety Mobile Broadband

Productivity Commission Research Report

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The Productivity Commission

The Productivity Commission is the Australian Government's independent research and advisory body on a range of economic, social and environmental issues affecting the welfare of Australians. Its role, expressed most simply, is to help governments make better policies, in the long term interest of the Australian community.

The Commission's independence is underpinned by an Act of Parliament. Its processes and outputs are open to public scrutiny and are driven by concern for the wellbeing of the community as a whole.

Further information on the Productivity Commission can be obtained from the Commission's website (www.pc.gov.au).

Foreword

Mobile broadband offers significant potential to improve how police, fire, ambulance and other public safety agencies deliver their services, saving lives and property. Live video streaming between a fire crew and central command, for example, enhances situational awareness and facilitates the efficient deployment of resources, driving productivity gains and better officer safety. However, public safety agencies have made only modest use of mobile broadband to date due to concerns that the quality of commercial services is insufficient to support 'mission critical' situations.

Against this background, the Commission has been asked to examine the best way to deliver a 'public safety grade' mobile broadband capability. The report considers the relative costs, benefits and risks of a range of options, including deploying a dedicated network, relying on commercial networks, or pursuing some combination (or hybrid) of the two.

Our study has found that — on first principles — the most efficient, effective and economical way of delivering a public safety mobile broadband capability is by relying on commercial mobile networks (and spectrum). The technology required to deliver such a capability exists today, although the precise service standards that would be achieved are uncertain. Small-scale pilots would help jurisdictions resolve this uncertainty, gain confidence in a commercial approach and develop a business case for a wider-scale roll out.

If governments decide to put in place a public safety mobile broadband capability there are implementation challenges. Competitive procurement will be essential to deliver value for money and to reduce the risk of being locked in to a single supplier. And interoperability between jurisdictions and agencies is within reach, but will depend on jurisdictions agreeing to common interoperability protocols and making arrangements for sharing information and network capacity among agencies.

The study has benefited from input and submissions from many stakeholders in the government, public safety and business sectors. We are grateful to all those who have given their time to share their experiences and expertise with the Commission.

Jonathan Coppel
Presiding Commissioner

December 2015

Terms of reference

Public Safety Mobile Broadband

I, Joseph Benedict Hockey, Treasurer, pursuant to Parts 2 and 4 of the *Productivity Commission Act 1998,* hereby request that the Productivity Commission (the Commission) undertake a study into the best way to secure a mobile broadband capability to meet the long term needs of Australia's public safety agencies (PSAs): the police, fire, ambulance and emergency services.

Background

A robust and effective mobile broadband capability is a critical enabler for Australia's PSAs.

Since June 2011, the Commonwealth has worked with jurisdictions and PSAs - through the Council of Australian Governments (COAG) Public Safety Mobile Broadband (PSMB) Steering Committee - to consider how best to deliver a strong PSMB capability. On 19 April 2013, COAG transferred responsibility for PSMB from the Steering Committee to COAG Senior Officials and, in doing so, noted the need for PSAs to have adequate capabilities to respond efficiently and effectively when disasters occur.

Delivering a PSMB capability is complex and involves using scarce and valuable resources, such as radiocommunications spectrum, to further the public interest. To inform this work and ensure the best path forward, the Commonwealth considers it appropriate to undertake a rigorous analysis of the most efficient, effective and economical means of developing Australia's PSMB capability.

Scope of the study

The Commission is to undertake a 'first principles' analysis of the most efficient, effective and economical way of delivering this capability by 2020, to coincide with the nationally agreed framework to improve government radio communications, including interoperability.[1] Particular regard should be given to:

[1] This is outlined in the COAG-endorsed National Framework to Improve Government Radiocommunications Interoperability 2010-2020.

1. The most cost-effective combination of private and public inputs, services and expertise to deliver the capability. This should include an assessment of the relative costs, benefits and risks of:
   (a) deploying a dedicated PSMB network
   (b) an approach that is fully reliant on commercial networks, and/or
   (c) a combination of the two.
2. The ability for the capability to:
   (a) be nationally interoperable, within and across agencies and jurisdictions
   (b) operate in both metropolitan and regional Australia
   (c) integrate voice communications that are traditionally carried on narrowband networks
   (d) maintain integrity and security of communications
   (e) ensure accessibility, priority and sufficient capacity for PSAs, particularly during periods of peak demand and during a localised incident
   (f) be resilient and maintain continuity of service including under adverse operating circumstances
   (g) consider the sustainability of arrangements in the context of rapidly changing technology and increased demand, including convergence of voice and data services
   (h) be cost-effective, in terms of both capital and operating cost
   (i) be nationally available by or before 2020, and
   (j) be compatible with a variety of end-user devices.
3. Relevant domestic and international reports and experiences (e.g. work underway through the Asia Pacific Telecommunity Wireless Group (AWG), International Telecommunication Union (ITU), 3rd Generation Partnership Project (3GPP) and implementation of similar capability in other countries) that may be applicable to Australia.

In conducting the analysis, the Commission is to have regard to the Australian Communications and Media Authority's (ACMA) role as the independent national regulator and technical expert on communications matters, with final decision-making responsibility for allocation of and conditions of access to spectrum. The Commission should also, where practicable, have regard to the Government's broader review of the spectrum policy and management framework.

Based on information provided by PSAs about their operational requirements, the ACMA has previously conducted an engineering analysis into the spectrum requirements for a PSMB capability. This analysis was carried out within parameters established by the Public Safety Mobile Broadband Steering Committee (PSMBSC) and the Terms of

Reference for that committee. However, spectrum alone will not achieve a PSMB capability as infrastructure and supporting networks with compatible end-user equipment are required. The Commission's analysis is concerned with an overall consideration of the most efficient, effective and economical way of delivering this capability, including a re-evaluation of user needs and project requirements given the passage of time.

Process

The Commission is to consult broadly, including with industry and non-government stakeholders, state and territory governments, and PSAs and relevant Commonwealth agencies.

The Commission will produce a draft and a final Report, both of which will be published. The final Report is to be provided to the Government within nine months of the receipt of these Terms of Reference.

J.B. HOCKEY

Treasurer

[Received 25 March 2015]

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Abbreviations

2G	Second generation
3G	Third generation
3GPP	3rd Generation Partnership Project
4G	Fourth generation
5G	Fifth generation
ACCC	Australian Competition and Consumer Commission
ACMA	Australian Communications and Media Authority
APT	Asia-Pacific Telecommunity
ARP	Allocation and Retention Priority
BAU	Business as usual
bps	Bits per second
BSS	Business Support System
CAD	Computer Aided Dispatch
CBA	Cost–benefit analysis
CBD	Central business district
COAG	Council of Australian Governments
COW	Cell on wheels
ESN	Emergency Services Network
GB	Gigabyte
GHz	Gigahertz
GPS	Global Positioning System
GRN	Government Radio Network
GSM	Global System for Mobile Communications
GWN	Government Wireless Network
HF	High frequency
HSDPA	High-Speed Downlink Packet Access
IC	Industry Commission

IoT	Internet of Things
IP	Internet protocol
IT	Information technology
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union radiocommunications sector
kbps	kilobits per second
LMR	Land mobile radio
LTE	Long Term Evolution
M2M	Machine-to-machine
MAPL	Maximum allowable propagation loss
MB	Megabyte
Mbps	Megabits per second
MDN	Mobile Data Network
MDT	Mobile Data Terminal
MFB	Metropolitan Fire Brigade
MHz	Megahertz
MIMO	Multiple Input Multiple Output
MVNO	Mobile Virtual Network Operator
NBN	National Broadband Network
NCCGR	National Coordinating Committee for Government Radiocommunications
NPV	Net present value
OECD	Organisation for Economic Co-operation and Development
OSS	Operations Support System
P25	Project 25 digital radio
PC	Productivity Commission
PLMN	Public Land Mobile Network
PPDR	Public protection and disaster relief
PSA	Public safety agency
PSMB	Public safety mobile broadband
PSMBSC	Public Safety Mobile Broadband Steering Committee
PTT	Push to talk

QoS	Quality of service
RAN	Radio access network
SA1	Statistical Area Level 1
SA2	Statistical Area Level 2
SES	State Emergency Service
SIM	Subscriber Identity Module
SMS	Short Message Service
TETRA	Terrestrial Trunked Radio
UHF	Ultra High Frequency
USIM	Universal Subscriber Identity Module
VHF	Very High Frequency
WCDMA	Wideband Code Division Multiple Access
WLAN or Wi-Fi	Wireless local area network

Glossary

Capacity	The volume of data that can be transmitted over a mobile communications network at a given point in time
Commercial approach	Delivery of public safety mobile broadband over one or more mobile carrier networks
Coverage	The geographic area or population over which a mobile network can be accessed to a given standard (such as from within buildings or via a vehicle radio)
Dedicated approach	Delivery of public safety mobile broadband over a dedicated network only
Dedicated network	A Public Land Mobile Network that is built and operated specifically for the use of public safety agencies
Dedicated spectrum	Spectrum set aside for use on a dedicated public safety mobile broadband network
Delivery option	A specific way of delivering public safety mobile broadband (within a deployment approach)
Deployment approach	A broad way of delivering public safety mobile broadband, such as through a dedicated network, commercial network(s), or a combination (hybrid)
Geotype	A class of geographical area that, for the purpose of quantitative analysis, is deemed to have certain characteristics relating to the demand and supply of PSMB
Hybrid approach	Delivery of public safety mobile broadband over some combination of dedicated network(s) and mobile carrier network(s)
Interoperability	The ability of public safety personnel in different agencies or jurisdictions to communicate over a mobile communications network(s)
Land Mobile Radio	A type of mobile communications network that provides voice and narrowband data communications, usually for the exclusive use of public safety agencies

Mobile carrier network	A mobile broadband network, operated by a commercial entity, that delivers services to customers
Mobile communications network	Any communications network where permanent infrastructure has been deployed to allow users to wirelessly send and receive voice or data communications
Mobile Virtual Network Operator	A company that resells services from mobile carriers directly to consumers
Network accessibility	The ability of users to establish a connection to a mobile communications network, even when it is congested
Overflow	The ability for public safety mobile traffic to be carried over a mobile carrier network once the capacity of a dedicated network has been reached
Prioritisation	The ability to give some voice or data traffic preference over other traffic
Public Land Mobile Network	Any mobile communications network under the control of a single operator
Public safety mobile broadband	Mobile broadband services that meet specific capacity, coverage and quality of service standards for public safety
Radio	Any device that can wirelessly send and receive information over a mobile communications network
Resilience/ reliability	The ability of a mobile communications network to provide and maintain an acceptable level of service, including in adverse circumstances
Ruggedise	To make end-user devices resistant to heat, pressure or water
Security	The prevention and/or rectification of disruption and interception of communications over a network
Spectrum	Radiofrequency spectrum used to transmit and receive information over a mobile communications network
Standalone network	A communications network that is not integrated with any other network

OVERVIEW

Key points

- Public safety mobile broadband (PSMB) holds considerable potential to improve how the police, fire, ambulance and other public safety agencies (PSAs) deliver their services. It will allow frontline officers to access high-speed video, images, location tracking and much more.
- PSAs currently rely on their own radio networks for voice communications and some low-speed data. Mobile broadband use has been modest due to concerns that the quality of commercial services is insufficient to support 'mission critical' operations.
- The network capacity that PSAs require is uncertain. PSAs are seeking a higher quality of service than what is currently available on commercial networks. However, the standards required (in terms of coverage, reliability, security, priority access and so on) are not specific.
- There are many ways to provide a PSMB capability, including the construction of a dedicated network, a commercial approach, or some combination (hybrid) of the two.
  - A dedicated network would give PSAs access to and control over their own PSMB network using their own parcel of spectrum.
  - A commercial approach would mean that PSAs obtain PSMB services from one or more of the commercial mobile carriers through a contract for service.
- The Commission has undertaken an illustrative evaluation of the costs of several specific delivery options over a 20-year period. The cost of a dedicated network is estimated to be in the order of $6.2 billion, compared to $2.2 billion for a commercial option. Even the lowest-cost hybrid option is about 32 per cent more expensive than a commercial option.
- A commercial option is cheaper because it requires significantly less new investment than a dedicated or hybrid option, as considerable existing infrastructure could be used or shared.
- Risk factors also influence the relative merits of different options.
  - A dedicated network would likely take longer to deliver, offers less flexibility to scale up network capacity in the short term and risks future technology upgrades being delayed.
  - There are risks arising from limited competition and supplier lock-in under a commercial approach, and the precise service levels that could or would be achieved are uncertain.
- The benefits of each option are not expected to vary markedly, since the options under evaluation have been designed to deliver a similar level and quality of PSMB capability.
- On first principles, a commercial approach represents the most efficient, effective and economical way of delivering a PSMB capability to PSAs.
- Small-scale pilots would help jurisdictions gain confidence in a commercial approach; gauge the costs, benefits and risks of PSMB; and develop a business case for a wider-scale roll out.
- Competitive procurement is essential. Splitting up tenders, leveraging infrastructure assets and insisting on open technology standards can help governments secure value for money.
- Achieving interoperability will require jurisdictions to agree on common protocols covering matters such as network technology, spectrum, end-user devices and applications. And to make the most of PSMB, PSAs within each jurisdiction will need to agree on protocols for sharing information and — where a PSMB capability is shared — network capacity.
- Australian Government intervention in spectrum allocation is not necessary to support a PSMB capability. Spectrum should be priced at its opportunity cost to support its efficient use.

Overview

Police, fire, ambulance and other emergency services (collectively 'public safety agencies', or PSAs) currently rely on their own land mobile radio (LMR) networks for most of their communications. These networks deliver voice and some data services, such as text messaging. They are reliable, resilient and secure, but they do not support high-speed data (such as video-based applications or the sharing of large files) and often they are not interoperable across agencies.

Mobile broadband technology opens up new ways for PSAs to access a vast range of information sources while in the field (such as video, images, location tracking and biometrics). This represents a significant opportunity to save lives and property, improve officer safety and drive productivity gains in the delivery of public safety. However, use of mobile broadband by PSAs is relatively modest compared to other sectors of the economy, and it is unlikely to increase significantly until a 'public safety grade' service is available.

The technology required to deliver such a service exists today. But considerable investment is needed to deliver it to the quality standard that PSAs expect, and some elements are yet to be demonstrated on a large scale or during emergencies. More work needs to be done to pilot parts of the technology and to build the business case for a wider-scale roll out.

What has the Commission been asked to do?

This study is about identifying — by way of a first-principles analysis — the most efficient, effective and economical way of delivering a public safety grade mobile broadband capability to PSAs by 2020, giving consideration to:

- the need for the capability to be reliable and secure, nationally interoperable across jurisdictions and agencies, provide PSAs with priority access, and operate in both metropolitan and regional Australia
- the relative costs, benefits and risks of alternative options for deploying a public safety mobile broadband (PSMB) capability — including deploying a dedicated PSMB network, an approach that is reliant on commercial networks, or some combination of the two
- relevant domestic and international reports and experiences.

The Commission has not been asked to evaluate whether a PSMB capability should be delivered to PSAs — rather, the focus is on *how* best to deliver such a capability. The

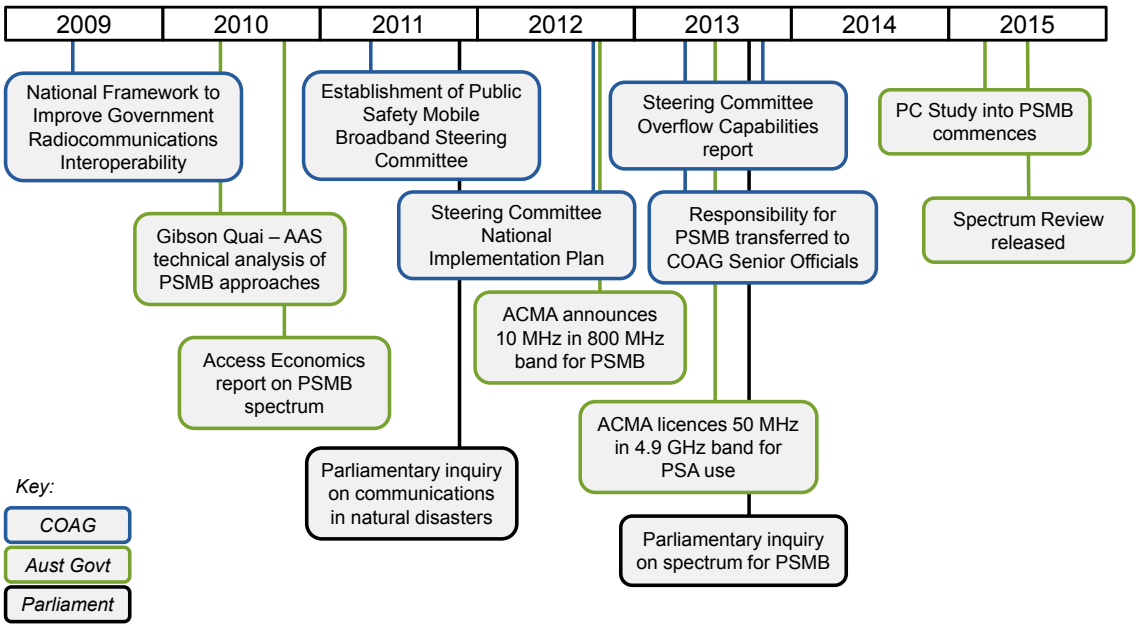
Commission's findings do not, therefore, answer the question of whether a PSMB capability is in the best interests of the community.

PSMB is not a new issue

This study is being undertaken in the context of earlier work relating to PSMB (figure 1). The Commission has drawn on these reports, which include work by state and territory governments and the Australian Government, done under the auspices of the Council of Australian Governments. The more substantive reports include:

- a detailed technical analysis of the costs of delivering PSMB under different options, commissioned by the Australian Government in 2010. Only limited parts of this analysis have been made public
- two reports produced by the Public Safety Mobile Broadband Steering Committee, which was established by the Australian Government in 2011 to consider the most effective and efficient way to deliver a PSMB capability. Neither of these reports has been released publicly.

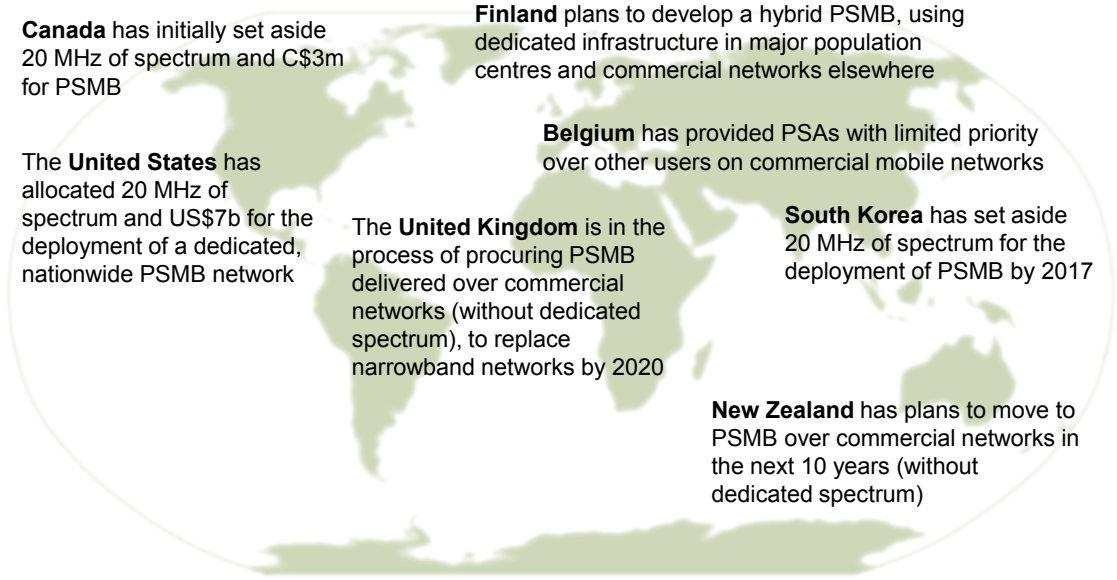
Figure 1 **Previous developments relating to PSMB**



Many countries are in a similar position to Australia

Several other countries are investigating, planning or implementing a PSMB capability. The specific approach taken differs across countries (figure 2). The United States, Canada and South Korea have announced that they intend to construct dedicated PSMB networks. By contrast, the United Kingdom and Belgium are pursuing commercial solutions to deliver PSMB.

Figure 2 **International approaches**



The communication needs of PSAs

Voice is the primary means of communication

Historically, voice has comprised the bulk of PSA communications, alongside paging systems (which support one-way broadcasts) and narrowband (low-speed) data services such as computer aided dispatch and text messaging.

Voice, paging and narrowband data are all supported by different types of LMR networks. These networks are usually built for the exclusive (or dedicated) use of PSAs and are specifically designed to meet their needs. LMR networks have extensive coverage and have proven to be reliable over decades of operation.

However, LMR networks also have weaknesses, including that they are often not technically interoperable across agencies and jurisdictions. The shortcomings of non-interoperability were revealed in recent large-scale natural disasters where public

safety officers found that their communications equipment did not function when they crossed a state border. Even where officers are co-located, agencies have found it difficult or impossible to share information in the field (or have needed expensive network bridging equipment to do so). These experiences have led to repeated calls for interoperable communications systems.

Mobile broadband offers significant potential benefits

Public safety operations are increasingly dependent on information and the communication needs of PSAs are evolving accordingly. Even though mobile broadband technology is in its infancy, PSAs are already using mobile broadband applications in some areas and relying on commercial mobile networks to do so (box 1).

Box 1 How are PSAs using mobile broadband applications?

Fire and Rescue NSW is using mobile broadband for:

- Automatic Vehicle Location services, which can facilitate faster vehicle dispatch
- a 'First Responder' in-vehicle tablet application that provides officers with in-field intelligence and remote access to operating guidelines and databases
- in-vehicle applications for voice and video communications and inventory checks.

Victoria Police is using a mobile application that simplifies family violence reporting processes. It allows officers to pre-populate reporting forms with data already captured and stored in databases. As information is entered into the reporting forms, the relevant database entry is updated instantaneously.

The Ambulance Service of NSW uses mobile broadband to check and update electronic patient records in transit. This reduces the time spent on administrative tasks and enhances the quality of services delivered to patients.

Greater use of mobile broadband by PSAs could fundamentally change how they deliver their services, especially in 'mission critical' situations (box 2). The prospective benefits in terms of cost savings and improved public safety outcomes (such as lives saved or injury and property damage avoided) are manifold.

- The ability for ambulance officers to remotely access medical records or send images to the hospital could speed up treatment and save lives.
- Giving police officers the ability to access databases when in the field, and to collect and transmit key evidence, can significantly reduce time spent on administrative tasks.
- Providing firefighters with access to maps, building plans and locations of hazardous materials can help them locate incidents more quickly and identify how best to respond.
- More effective information sharing between agencies and the community can improve the situational awareness of public safety officers and the preparedness of community members.

Box 2 **What is 'mission critical'?**

The term 'mission critical' has many meanings. For example, a mission critical situation could refer to PSA activities or operations where reliable communications are necessary to avoid loss of life, serious injury or significant damage to valuable or strategic assets.

Alternatively, mission critical can be used to describe certain properties of communications systems (such as resilience, priority and security) that make them fit for purpose in PSA operations. What is meant by a mission critical land mobile radio *voice* network is relatively well accepted. However, there is less clarity about what is implied by a mission critical mobile broadband *data* network.

For this study, the Commission has used 'mission critical' to refer to public safety activities or situations where lives are on the line (that is, where there is a material risk of loss of life or severe injury).

Moreover, mobile broadband technology will continue to evolve and improve, creating further opportunities to enhance the efficiency and effectiveness of public safety activities. For example, new and emerging 'machine-to-machine' applications that allow monitoring, data collection and automated action by machines can provide public safety officers with better information and free up resources for other uses.

However, PSA uptake of mobile applications has been modest and piecemeal to date. This reflects concerns about the quality of service offered by the commercial mobile carriers — Telstra, Optus and Vodafone (box 3). Critical issues include the ability of PSAs to get access to — and sufficient capacity on — commercial networks during times of congestion and the reliability of commercial networks relative to LMR networks. The consensus among participants is that PSAs are unlikely to make significant investments in, or widespread use of, mobile broadband until these concerns are addressed.

Delivering a PSMB capability

The delivery of a PSMB capability relies on action by governments, PSAs and mobile carriers, regardless of the deployment approach. Without all of these entities playing their role, a PSMB capability is likely to be less efficient (and deliver fewer benefits) than it otherwise would, or may not eventuate at all.

State and territory governments have primary responsibility for public safety

Responsibility for public safety and emergency management mainly rests with state and territory governments. The Australian Government's direct public safety responsibilities include national security, border control and oversight of some PSAs (such as the Australian Federal Police). Each jurisdiction has the discretion to set its own public safety policy agenda — along with the accompanying institutional and funding arrangements —

and is responsible for deciding whether and how to facilitate a PSMB capability for its PSAs.

Box 3 Mobile broadband service quality has many dimensions

A number of dimensions (or characteristics) of mobile broadband service quality are important to PSAs.

- Accessibility — the ability of PSAs to get on to a mobile network, even when it is congested.
- User prioritisation — systems that prioritise certain PSA users, devices or applications over other mobile traffic on (or seeking access to) a network.
- Network coverage — the percentage of the population that resides in the coverage area, or the land area or road distance covered by a network.
- Network reliability (or resilience) — the ability of the network to provide and maintain an acceptable level of service in the face of various faults and challenges to normal operation. Reliability is often measured in terms of availability or network recovery time.
- Security — the techniques, strategies and infrastructure that are in place to uphold the confidentiality and continuity of communications.
- Interoperability — the ability of users to communicate by terminal device with whomever they need, when they need, when authorised. Interoperability has four elements:
  - network interoperability — the ability of different networks to allow for users on each to communicate with each other
  - device interoperability — the ability of an end-user device to work on different networks as required
  - application interoperability — the ability of agencies to communicate and share information with each other through common applications, databases and other software
  - agency interoperability — operational procedures beyond technology that enable agencies to interoperate, such as protocols for sharing intelligence and other information.
- Device compatibility — the ability of officers to access mobile broadband using a wide range of field equipment (such as handsets or in-vehicle devices).
- Voice integration — the ability of mobile broadband networks to integrate and deliver the voice services that PSAs rely on.

Governments could become actively involved in facilitating PSMB in a number of ways. For example, they could:

- directly fund, own and/or operate a dedicated PSMB network
- pay one or more mobile carriers to deliver a PSMB service
- provide additional funding or other inputs to PSAs that would help them to build or purchase a mobile broadband service
- collaborate and coordinate efforts with other jurisdictions to develop technical protocols and platforms for interoperability.

The Australian Government regulates telecommunications and spectrum

The Australian Government is responsible for the regulation and allocation of radiofrequency spectrum (a key input to mobile networks), and for the economic and technical regulation of telecommunications services and infrastructure. These policy and regulatory levers could potentially be used to help facilitate the delivery of a PSMB capability.

For example, some study participants suggested that the Australian Government (through the Australian Communications and Media Authority (ACMA), the agency responsible for regulating, licensing and pricing radiofrequency spectrum in Australia) should intervene to allocate spectrum to the states and territories *at a discounted price* for public safety purposes. Others have proposed that regulation be imposed on mobile carriers to facilitate the delivery of PSMB.

The Commission does not consider that there is a strong case for any material changes to the design or administration of existing regulatory regimes for the purposes of supporting a PSMB capability. Delivering a PSMB capability is not contingent on regulatory change.

Action by PSAs is crucial to the success of PSMB

The success of PSMB directly depends upon the actions of PSAs themselves, irrespective of how it is delivered. As users, PSAs are best placed to identify and demonstrate why government support to facilitate a PSMB capability is in the best interests of the community as a whole. This means documenting how such a capability would be used to modify or enhance public safety operations, and how this translates into benefits for the community.

Once available, it is up to individual agencies to ensure that the capability is used efficiently. This will require a substantial shift in the mentality of how agencies collaborate and operate, especially in terms of sharing information. Where two or more agencies jointly use a PSMB capability, network capacity sharing arrangements will also be required. In effect, this means coming to agreement on how different agencies and officers will be prioritised over a network. Officer education and training, and revision of operational protocols, will also be required.

Delivering a PSMB capability has costs that will ultimately be met by taxpayers. It is important that PSAs (or entities acting on their behalf) are held accountable for any public funds used for PSMB. Moreover, ongoing public funding for PSMB should be contingent on clear evidence that the benefits justify the costs. Monitoring and reporting frameworks, established by relevant governments, can support this.

Commercial carriers are part of the solution

Mobile network infrastructure is extensive, costly and in many cases long lived. There will be significant economies of scale and scope in using existing commercial infrastructure to deliver a PSMB capability, where this is technically and economically feasible. This means drawing on the extensive mobile networks already in place (Telstra, Optus and Vodafone each have a network covering upwards of 95 per cent of the population), as well as infrastructure owned by governments. However, commercial networks are not able to deliver 'public safety grade' mobile broadband services at present: additional investment will be required.

Mobile carriers also have considerable skills and expertise in network design and operation that could be brought to bear on a PSMB capability. Some have already taken an active role in putting forward solutions to meet public safety needs — for example, Telstra has demonstrated a capability called LANES that is designed to give priority services to PSAs.

The Commission's approach — a 'first principles' analysis

The Commission has undertaken a 'first principles' analysis to determine the best way to deliver a PSMB capability. The analysis has involved (figure 3):

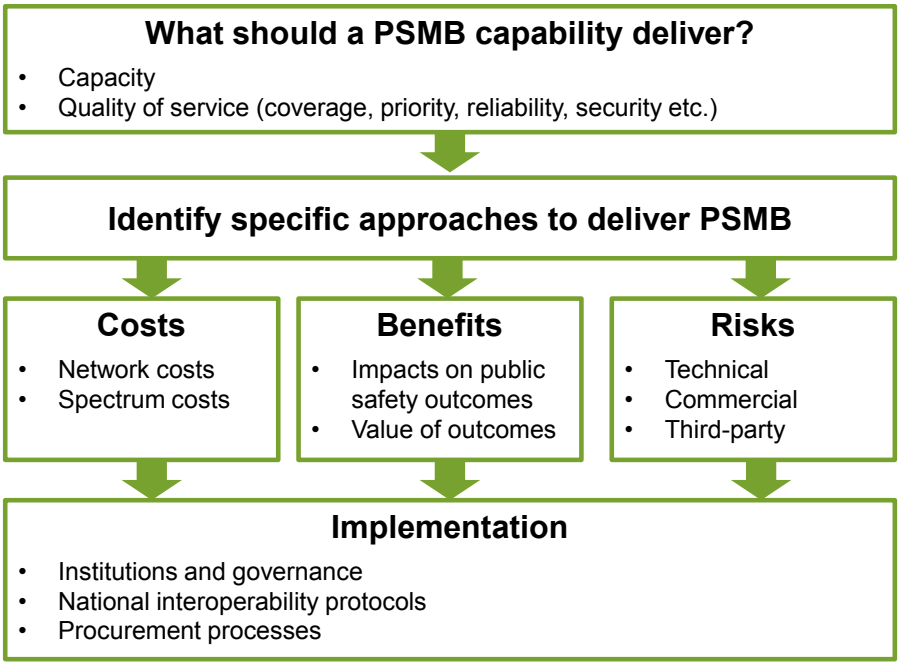
- understanding the mobile broadband requirements of PSAs, taking into account the mission critical nature of public safety work and the service quality requirements this gives rise to
- identifying options that could feasibly meet these requirements, including a dedicated PSMB network, an option reliant on commercial networks, and hybrid options
- evaluating the costs, benefits and risks of each option (from the perspective of the community as a whole)
- considering the implementation challenges and risks associated with PSMB and strategies to overcome these.

Where possible, the costs of each option have been evaluated in a quantitative way, using a network costing approach. This has helped to identify the relative importance of particular cost drivers and the magnitude of specific tradeoffs. However, data limitations mean that the benefits and risks of each option cannot be quantified in monetary terms.

In effect, the Commission has undertaken a cost-effectiveness analysis and supplemented this with a qualitative assessment of the benefits and risks of the delivery options. That said, as the options under evaluation have been designed to deliver a similar level of PSMB capability, the impact of each option on public safety outcomes (and thus its benefits) is not expected to vary markedly.

A key output of the Commission's analysis is a set of principles that would deliver a PSMB capability in a way that is efficient, effective and economical.

Figure 3 **The Commission's framework**



What should a PSMB capability deliver?

A PSMB capability can be described in terms of the amount of network *capacity* that is available to end users (for example, megabits per second) and the *quality* of services delivered (box 3).

PSA demand for network capacity is uncertain

There is widespread agreement among study participants and other stakeholders that PSA use of mobile broadband would increase significantly if a public safety grade service were available — particularly in terms of uplink traffic (that is, sending data from the field), which would be largely driven by video-based applications.

However, detailed information about how PSAs would use a PSMB capability (including the type, composition and volume of mobile applications), and what this implies for PSA demand for network capacity, is limited — as is publicly available information on the benefits of that use. Similarly, while many participants pointed to the importance of a

PSMB capability providing 'sufficient' network capacity, evidence on what this means for the quantum of network capacity is sparse.

There are valid reasons for this. Demand for PSMB will depend on a complex range of factors, including the pricing model and prices that PSAs face, the availability of alternative communications systems (including LMR, Wi-Fi and satellite), PSA procedures and protocols for mobile broadband use and prioritisation, and future technological developments. All of these factors are largely unknown or at a nascent stage of development.

Therefore, to undertake the quantitative analysis, the Commission has made a number of assumptions about the level of network capacity that a PSMB capability might deliver. These assumptions are illustrative only. They are not suggestive of the level of network capacity that jurisdictions should adopt or of PSA demand for mobile broadband.

PSMB must support mission critical operations

While not all PSA activity is mission critical (such as routine or administrative tasks that may be considered operational, informational or business critical), it is not practical to offer PSAs a 'two-tiered service'. Mission critical situations are difficult to predict in advance and situations can rapidly escalate to mission critical as circumstances change. For these reasons, PSAs require communications systems that have the capacity to be used in mission critical situations as a matter of course.

Delivering mission critical voice services over PSMB will take time

It is too early to consider delivering mission critical *voice* services (such as 'push to talk' and 'group calling' applications) over a PSMB network, regardless of the deployment approach. International standards and applications for these services are still being developed, and it will take time to design, test and prove fit-for-purpose handsets and software. Even once these issues are resolved, the case for migrating voice services will depend on a range of other factors, including the lifespan of LMR networks.

All Australian jurisdictions plan to continue operating their LMR networks until at least 2020. Indeed, the Queensland Government recently invested over $450 million in its Government Radio Network, which is expected to operate until 2029. In the meantime, however, it is important that the design and implementation of PSMB networks is compatible with the prospect of integrating mission critical voice services at a later date.

Operationalising the concept of a mission critical data network is difficult

What is meant by a mission critical LMR voice network is relatively well accepted (although not universally defined). However, what is implied by a mission critical mobile broadband data network is less clear. Study participants provided little detail about the specific levels of service quality that are sought, or the way in which the quality characteristics important to PSAs (such as security or network access) should be met.

The Commission has not attempted to define or prescribe the quality standards that a PSMB capability should deliver. In practice, this will vary across agencies and jurisdictions — reflecting their individual circumstances — and across time. However, to undertake the quantitative analysis contained in this report, the Commission has made a number of assumptions that imply certain levels of service quality, and that are common to all of the delivery options under evaluation.

Demand management is crucial to getting the most out of PSMB

PSAs' activities — and their corresponding communications needs — can be broadly classified into 'business as usual' periods and peak periods. Peak periods refer to times where PSAs are responding to major or emergency incidents (a natural disaster or hostage situation) or large planned events (such as New Year's Eve or the Melbourne Cup) in addition to business as usual.

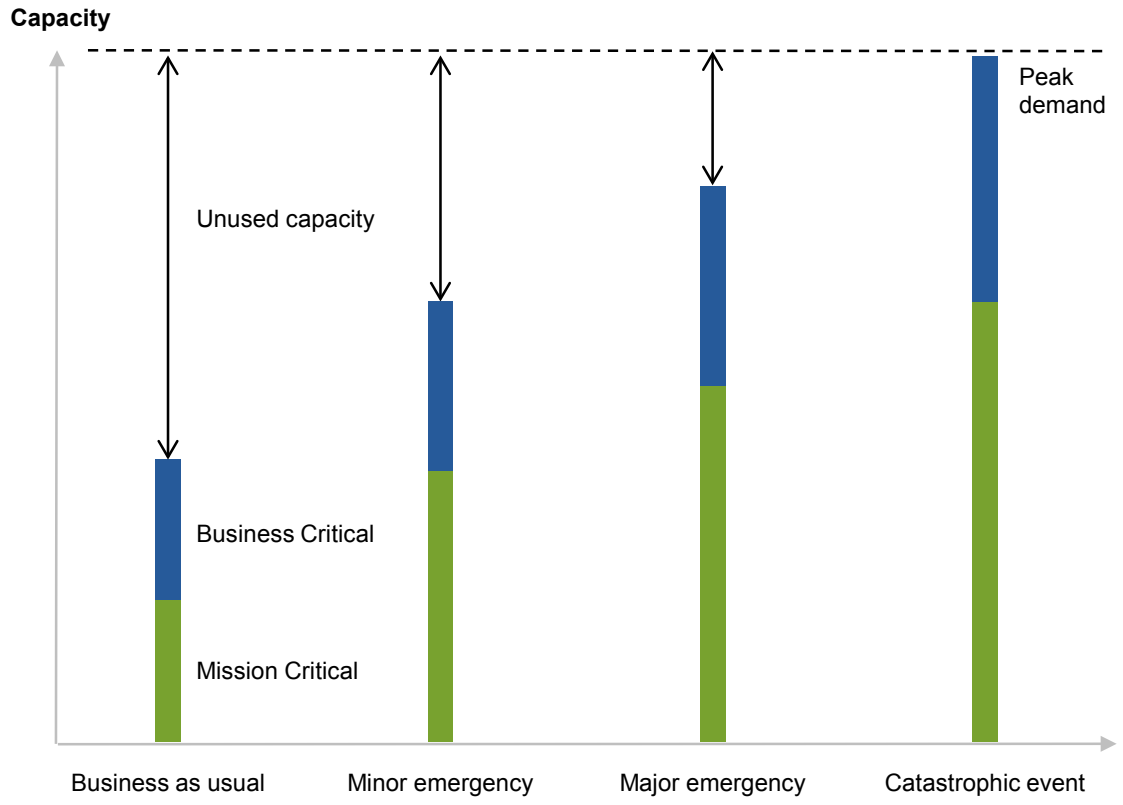
Many peak demand periods for PSAs are unpredictable in timing, location, severity and incidence (as is the nature of crisis and emergency). Moreover, PSA communications increase significantly (and by as much as ten- or twenty-fold) during peak periods compared to 'business as usual' periods. A mobile broadband capability that caters for relatively infrequent peak events would be very expensive, as it would lead to low levels of capacity utilisation (figure 4) and high marginal costs per megabyte of data transmitted.

Dimensioning a mobile network to meet lower levels of demand does not necessarily mean that networks would be severely congested during peak periods, or that important demand would go unmet. Indeed, not all PSA demand needs to be met in real time. Strategies to reduce PSA demand during peak periods — such as using 'store and forward' or 'compression and broadcast' of video-based applications, or offloading traffic to alternative networks (fixed or Wi-Fi) — are crucial to getting the most out of a PSMB capability.

Efficiency should be the guiding objective

There is no single definition of a public safety grade mobile broadband capability — a range of capacity levels and service quality standards could feasibly apply. However, delivering a PSMB capability has costs, and many of these costs increase exponentially with capacity and service standards.

Figure 4 **Meeting peak demand implies significant network capacity**



It is in the best interests of the community for individual jurisdictions to pursue a capability that reflects their particular needs and circumstances as well as their communities' willingness to pay for public safety grade mobile broadband services. Given their varying circumstances, it is unlikely to be efficient for each jurisdiction to pursue the same PSMB capability at the same time. This highlights the importance of identifying a flexible pathway and framework for the delivery of a PSMB capability.

A key consideration for all jurisdictions is how the capability should be delivered. Different approaches give rise to potentially different costs, benefits and risks. These need to be evaluated and weighed up to determine the best way forward.

How should a PSMB capability be delivered?

There are many possible delivery options

There are myriad combinations of technologies and infrastructure that could feasibly be used to deliver a PSMB capability.

There is widespread agreement — both internationally and among study participants — that PSMB should be delivered using 4G Long Term Evolution (LTE) technology, regardless of the deployment approach chosen. It has advantages over previous mobile technologies (such as increased peak data rates, higher spectral efficiency, and the ability to automatically detect and rectify faults) and will continue to evolve and improve. Moreover, LTE is based on open international standards and is widely used around the world.

However, there are varied and strong views about whether, and to what extent, the infrastructure embodied in a PSMB capability (such as core networks, base stations, transmission equipment, backhaul capacity and radiofrequency spectrum) should be dedicated to PSA users or shared with other users. While it is technically feasible to deliver a PSMB capability under a dedicated, commercial or hybrid approach, the costs and risks can vary significantly.

A number of options have been evaluated

The Commission has evaluated four specific options (and variants thereof) for delivering a PSMB capability in areas of Australia where there is existing commercial mobile coverage (table 1). It has also considered how mobile broadband might be provided to PSAs in areas of Australia where there is currently no commercial mobile coverage (box 4).

Table 1 **Overview of PSMB delivery options evaluated**
Areas within commercial carrier coverage footprint

	Dedicated	*Full coverage hybrid*	*Targeted coverage hybrid*	*Commercial*
Dedicated spectrum for PSAs	Yes (national)	Yes (national)	Yes (inner metro areas only)	No
Networks relied on in inner metro areas	Dedicated	Dedicated and commercial	Dedicated and commercial	Commercial
Networks relied on in other areas	Dedicated	Dedicated and commercial	Commercial	Commercial
Estimated population coverage of dedicated network element	99%	99%	50%	0%
Core network infrastructure	Dedicated core (shared by all jurisdictions)	Use carrier core	Use carrier core	Use carrier core
Number of mobile carrier networks PSAs use	0	1	1	1

Box 4 **Deploying a PSMB capability outside the commercial footprint would be very expensive**

Some areas of Australia do not have commercial mobile coverage at present, but are covered by land mobile radio networks. Because there is limited scope to reuse existing infrastructure in these areas, the cost of rolling out a permanent mobile broadband network would be very high. It would require substantial investment in new base station sites and backhaul capacity. The cost of building a new base station site is in the order of three times more expensive (according to some estimates) than deploying new equipment to an existing base station. There would need to be very large benefits of a permanent mobile network in these areas to justify the costs. That said, it is possible that targeted network extensions may be warranted in some cases. There are already policy programs in place which subsidise the extension of commercial mobile carrier networks into otherwise 'non-commercial' areas.

There are lower-cost options (such as transportable base station equipment and satellite broadband) that can be pursued to provide a level of mobile broadband coverage and capacity in these areas, albeit not to a public safety standard. Commercial mobile carriers and land mobile radio network operators already use these techniques in areas without permanent mobile broadband coverage.

A dedicated PSMB capability

A dedicated PSMB capability would mean that PSAs have access to (and control over) their own PSMB network, using their own parcel of spectrum (for the purposes of quantitative evaluation, 10 MHz of spectrum in in the 800 MHz band has been assumed). While it is assumed that existing sites and backhaul would be used as part of this solution, significant new investment would be required. This includes new base stations, base station equipment, backhaul capacity and core networks (control centres).

Under this option, PSAs would not be able to 'overflow' onto commercial networks and receive public safety grade mobile broadband services. However, they would still be able to purchase standard commercial mobile services, as they do today.

A commercial approach

A commercial approach would mean that PSAs obtain PSMB services from a commercial mobile carrier through a contract for service. The carrier would determine how best to meet PSA requirements using its own mobile network and spectrum holdings.

This option would require that the carrier invest in its network to improve network reliability and deliver the services that PSAs require. This could include installing additional battery backup, upgrading physical sites and building new backhaul links. Adding PSA traffic to a carrier network would also be expected to bring forward investments in sites, spectrum and backhaul.

A commercial approach could also be delivered using multiple mobile carriers. This option has also been evaluated.

A full coverage hybrid approach

A full coverage hybrid approach would provide PSAs with a dedicated network that covers the entire commercial mobile footprint (as per the dedicated approach) and their own parcel of spectrum. This would be sufficient to meet some — but not all — of PSAs' capacity needs (about 80 per cent). PSAs would rely on a commercial carrier network to access additional public safety grade network capacity on a preferential basis.

PSAs would rely on the core network of the mobile carrier under this option (that is, the core network is shared). However, the parcel of spectrum set aside for PSAs would *not* be shared, meaning PSAs would have access to their own dedicated 'channel'.

An alternative way to implement this option is to have a separate core network built for PSMB, which would interface with the carrier network. This may be more amenable to PSAs (or an agent on their behalf) directly controlling the configuration of the PSMB capability (including upgrades) or the security arrangements.

This alternative has been considered as part of the Commission's analysis, as has the option of relying on multiple mobile carriers to deliver the commercial component of the full coverage hybrid approach.

A targeted coverage hybrid approach

A targeted coverage hybrid approach would provide PSAs with a dedicated network and spectrum that covers inner metropolitan areas only (defined as dense urban and urban areas, which contain around 50 per cent of the population).

PSAs would rely on a mobile carrier network (and carrier spectrum) for about 20 per cent of their capacity needs in inner metropolitan areas (once they exhaust their own dedicated capacity). Outside of these areas, PSAs would rely on a commercial carrier for both coverage and capacity.

As with the full coverage hybrid, PSAs would rely on the core network of the mobile carrier. However, the implications of establishing a separate core network have also been considered as part of the Commission's analysis.

Costs have been assessed using a network costing approach

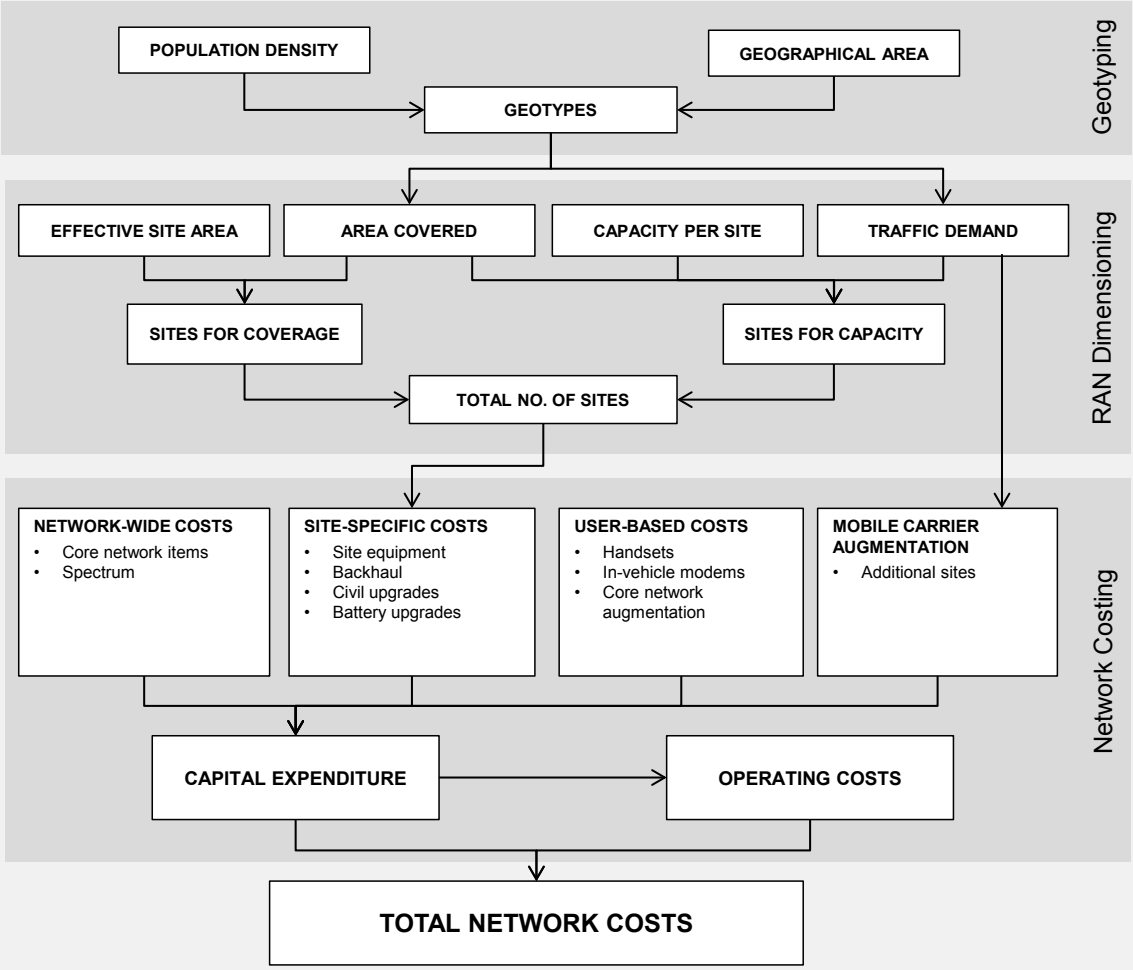
The Commission has assessed network costs in a quantitative way, using a fit-for-purpose, bottom-up approach (box 5). The framework and methodology draws on that used in other analyses but has been adapted to the specific nature of this study.

Box 5 A fit-for-purpose framework for evaluating network costs

The bottom-up cost framework involves three key steps, as illustrated below.

- Geotyping — using census data to assign different geographical areas of Australia to particular geotypes (dense urban, urban, suburban, rural or remote).
- Radio access network dimensioning — estimating the number of mobile sites required to meet coverage and capacity requirements, as defined by the Commission's PSMB scenarios.
- Network costing — applying benchmark cost values (such as the costs of mobile base station equipment) to calculate total capital and operating costs.

The key output from the quantitative evaluation is a net present value for each option, assuming a 20-year time horizon (over the period 2018 to 2037).



The primary objective of the quantitative analysis is to identify indicative cost differences between options for delivering a PSMB capability, and the key drivers of those cost differences. It is not designed to:

- produce precise estimates of the total costs of individual options or individual cost components

- describe what the architecture of a PSMB network would look like in practice
- calculate the optimal mix of inputs for delivering a PSMB capability.

The cost analysis focuses on estimating the opportunity costs associated with each PSMB delivery option — that is, the value of the best alternative use of these resources. The focus is not on the distribution of costs or the prices for PSMB communication services that might be charged in practice. Moreover, the analysis only considers the costs entailed by each option that are incremental to investments that have already been made.

To compare costs on an even keel, it is assumed that each option would deliver the same level of PSMB network capacity, as defined by the Commission's capacity assumptions (discussed above). Dealing with the quality dimension of a PSMB capability is more difficult. Nevertheless, certain levels of service quality are implied by the assumptions made in the quantitative analysis, and are common to all options. Specifically, under each option:

- the capability has been designed to provide geographical coverage equal to existing commercial networks, which equates to a population coverage in excess of 99 per cent
- some capital investment is made to the core network to provide priority services to PSAs
- a proportion of network sites is subject to some form of hardening, which is assumed to improve network resilience and reliability.

Finally, for ease of exposition, the options have been costed on a national basis — that is, by assuming each jurisdiction proceeds with rolling out PSMB at the same time, using the same delivery method.

The costs and risks of delivery options vary markedly

A commercial approach minimises costs

The Commission's quantitative analysis found that deploying a dedicated PSMB capability is nearly three times more expensive than relying on commercial networks. Specifically, the estimated net present cost of the dedicated option over 20 years is about $6.2 billion, compared with about $2.2 billion for a commercial option (table 2).

The cost difference between the commercial and hybrid options narrows as the geographic region covered by the dedicated network component decreases.

However, even the lowest-cost hybrid option considered by the Commission (the targeted coverage hybrid) was estimated to be 32 per cent more expensive than a commercial option ($2.9 billion compared to $2.2 billion).

There are two main reasons why the cost of delivering a PSMB capability is estimated to be lower under a commercial option, relative to a dedicated or hybrid option.

- The dedicated option (and to a lesser extent, the hybrid options) requires significantly more new investment. This includes new sites, base station equipment (to operationalise the dedicated spectrum), a core network and backhaul.
- Commercial carriers have a wider portfolio of spectrum resources, providing them with greater flexibility to meet customer requirements at least cost.

Table 2 **Composition of PSMB delivery costs**

Cost item	*Dedicated*	*Full coverage hybrid*	*Targeted coverage hybrid*	*Commercial*
	$m	$m	$m	$m
Capital costs	**2 241**	**2 093**	**1 321**	**984**
New site build	110	100	23	0
New radio access network equipment	1 035	943	220	0
Site hardening	174	159	121	117
Core network and add-ons	143	45	45	45
Mobile carrier network augmentation	0	35	146	171
Spectrum	264	295	250	135
User equipment	516	516	516	516
Operating costs	**3 910**	**3 040**	**1 583**	**1 217**
Site leasing costs	1 412	1 266	344	0
Site backhaul leasing costs	1 776	1 141	975	1 068
Network operating costs	722	633	263	150
Total cost	**6 152**	**5 133**	**2 904**	**2 201**

Further, commercial carriers are expected to be able to minimise PSMB operating costs by spreading certain costs (such as the costs associated with maintaining base station equipment) over a larger number of users. It has not been possible to quantitatively evaluate these efficiencies due to data limitations. However, the input assumptions used in the quantitative analysis have been adjusted so that network operating costs are lower under a commercial option.

Sensitivity analysis has been used to understand how changes to assumptions about the amount and value of specific network inputs (particularly those where there is a high degree of uncertainty) affect overall costs.

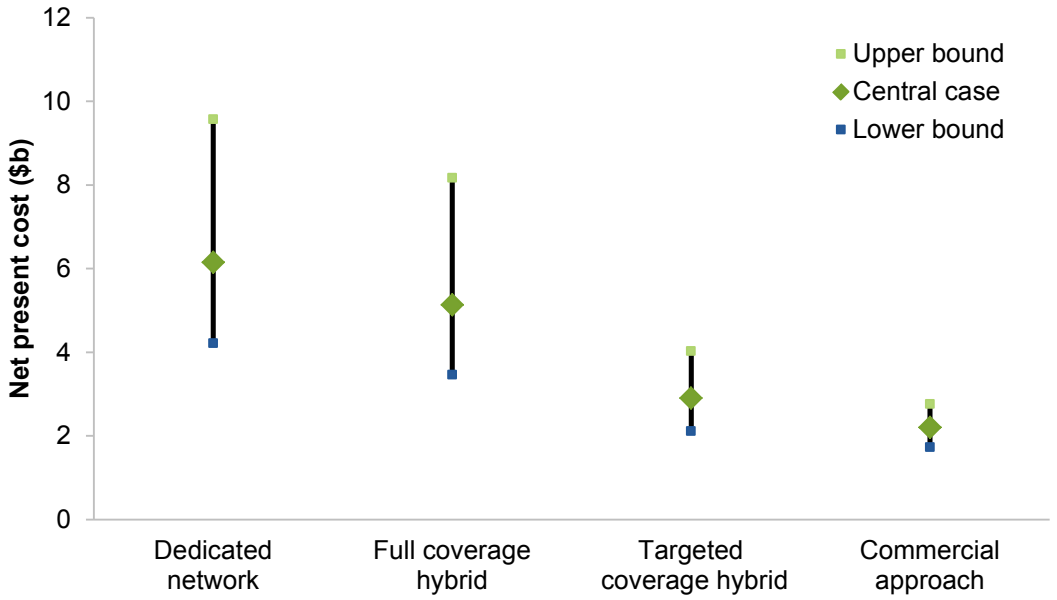
The results are most sensitive to assumptions about site backhaul leasing costs, the cost of radio access network equipment and site leasing costs. Other parameters (such as the cost of building new sites and the proportion of sites hardened for ‘civil upgrades’) have less bearing on the cost estimates.

Importantly, varying key assumptions and input values simultaneously to explore 'best case' and 'worst case' scenarios does not change the rankings of the different options — the commercial option remains the lowest cost option under all of the scenarios evaluated (figure 5). For example, a dedicated network is estimated to be between about 2.5 and 3.5 times more expensive than a commercial option, depending on the assumptions used.

The estimated range of costs for the commercial option is small compared to the other options. This is because some input values that are only relevant to the dedicated and hybrid options are highly uncertain (such as site leasing and base station equipment costs), and so a wide range of values for these inputs has been considered in the sensitivity analysis.

Figure 5 **PSMB delivery costs**

Best case and worst case sensitivity analysis



Finally, the quantitative evaluation is based on a specific set of assumptions about the design of the PSMB options. These assumptions have been varied to explore the effects on absolute and relative costs.

- Separate core networks may provide PSAs with more control over the design and delivery of PSMB services (relative to sharing a core network with a carrier, or with each other), but come at a cost. For example, were each jurisdiction to deploy its own core network, the cost of the dedicated network option would increase by more than 20 per cent.
- Relying on multiple carrier networks under a hybrid or commercial option (instead of a single carrier) is likely to reduce the amount of network hardening required to deliver a

given reliability standard. However, there would also be costs associated with each carrier upgrading its core network and systems to deliver priority services to PSAs, and to facilitate roaming with another network (if required). The Commission's analysis suggests that multi-carrier options are somewhat more expensive than single-carrier options, though limited data made it difficult to be definitive about the net cost impacts.

Applying alternative network design assumptions does not change the cost ranking of the delivery options — in all cases, the commercial option remains the most cost effective by a significant margin.

Other factors to consider

There are factors other than cost to consider when deciding which delivery option to adopt. Specifically, the risks associated with delivering PSMB can vary depending on the deployment approach, and so may bear on the relative merits of respective options. Deployment timeframes, the flexibility that options afford to governments and PSAs, and the potential impacts of PSMB on other mobile customers are also relevant.

There is uncertainty about the precise standards that could or would be achieved for priority services

Whether PSAs should be provided with a parcel of dedicated spectrum (for their exclusive use) was a contentious issue in this study. Some participants considered that network access and user prioritisation would be at risk if services were delivered using shared spectrum as part of a commercial solution, and favoured a dedicated or hybrid approach on this basis. However, evidence to underpin these arguments is sparse.

By contrast, several study participants and mobile communications experts indicated that features of LTE technology mean it is technically feasible to provide priority access and capacity to PSAs without dedicated spectrum. Moreover, some elements of prioritisation technology have been demonstrated on a pilot basis (for example, access technology in Telstra's LANES product).

This notwithstanding, there is some uncertainty as to the precise levels of network accessibility that could or would be delivered under a commercial approach. However, this is not justification for using dedicated spectrum to deliver PSMB. Uncertainty about network accessibility and other service standards is a feature of *all* delivery approaches. Pilots (discussed later) would provide an opportunity to resolve uncertainty about the service levels that mobile carriers can deliver and the costs of doing so.

Moreover, dedicated spectrum does not guarantee that PSAs will always be able to gain network access. Existing LMR networks used only by PSAs can and do become congested during large incidents. Congestion — and the consequences this has for network access — is a risk under all PSMB delivery approaches, not just those where PSAs share network

infrastructure with other users. Prioritisation techniques will be critical to ensure that network capacity is allocated to those users who value it most.

Competitive procurement may be more challenging under some options

Many study participants expressed concerns about the degree of competition in the market for mobile broadband, and noted Telstra's dominance in many areas (in mobile services and backhaul) and the relatively small number of equipment vendors. This could make it challenging for governments to obtain value for money in procurement by leveraging competition.

These challenges are likely to be greater under the commercial and hybrid options than for a dedicated network, due to the greater reliance on (and investment in) carriers' existing networks under the commercial and hybrid options. However, there are strategies that governments can use to make procurement more contestable under any delivery option (discussed later).

Commercial and hybrid options are more susceptible to supplier lock-in

Supplier lock-in occurs when a customer is dependent on a supplier for a service and is unable to change supplier without incurring significant switching costs.

Supplier lock-in can stem from a supplier using non-standardised technology (for example, when there is only one supplier of proprietary equipment). This risk is common to all PSMB delivery options and can usually be managed through contracting and procurement processes.

Lock-in can also arise as a result of significant and unrecoverable investments being made by a single supplier, making it difficult — and potentially very costly — for customers to switch suppliers in the future. This, in turn, can influence the pricing behaviour of the incumbent supplier. This risk is most pronounced under the commercial and hybrid options, where it is assumed that a commercial carrier would undertake significant investment.

A multiple-carrier option would be complex

Options which use multiple mobile carriers for service delivery can potentially spread investments over several networks. This may lower the risk of lock-in by reducing the amount of investment sunk into any one network, improving contestability for future PSMB contracts and upgrades. The use of multiple networks can also create a level of redundancy (or overlap between networks) which could mean less investment in hardening is necessary to meet reliability requirements.

In practice, however, implementing a multiple-carrier option would be complex. Roaming arrangements would likely be required — especially where two or more carrier networks are used to service the same area — to ensure public safety users can easily move between networks. Establishing such arrangements would have costs, particularly if a 'seamless' roaming experience is sought. Moreover, such agreements are relatively rare in Australia, reflecting the commercial difficulties involved. There is also a risk that technology upgrades would be delayed under a multi-carrier solution, given the need to coordinate such upgrades across multiple network operators.

A dedicated option provides little flexibility to scale up capacity in the short term

A dedicated option provides almost no scope, at least in the short term, to accommodate an increase in demand beyond what the network is initially provisioned to meet (except by way of transportable mobile cells, which take time to deploy once an incident is underway). While network capacity can be rationed to prioritise the most urgent communications, some important users or applications may inevitably need to be dropped.

In most parts of Australia, commercial networks have large amounts of capacity that could accommodate spikes in PSA communications during large-scale events. A commercial or hybrid approach therefore provides much more flexibility than a dedicated network — PSAs could agree to purchase a base-level of capacity with the option to exceed this amount should the situation require it.

Rollout timeframes and delay risks vary

A dedicated network is expected to take longer to deliver (and therefore longer for the associated benefits to be realised) than a hybrid or commercial approach because of the significant amount of capital investment required upfront.

A separate issue is the risk of delay to a rollout timetable once it has been set in place. Any delay in PSMB availability could reduce its benefits, as these will also be delayed. All options could face delays due to contract negotiation. However, the risk of delay is expected to be higher under a dedicated or hybrid approach as:

- there is limited spectrum suitable for mobile broadband currently available, and further spectrum may not be available for jurisdictions to purchase until ACMA clears it of other uses
- deploying new infrastructure and equipment takes time, and lengthy complex projects are more likely to overrun their expected delivery dates.

Technology upgrades might prove less economic under a dedicated approach

Commercial mobile networks are continually upgraded as mobile carriers make new investments to keep up with evolving technology and competitor offerings. Some of these upgrades have high fixed costs that are largely invariant to the number of users on the network.

The relatively small number of users on a dedicated PSMB network would mean that implementing future upgrades to technology (such as emerging 5G technologies) would come at a high cost per user. By contrast, mobile carriers have large user bases over which to recover these costs. This could mean that new technologies are incorporated more slowly under a dedicated option (and to a lesser extent under the hybrid options) relative to the commercial option. As a result, parts of the PSMB network could become incompatible with new applications and devices developed for consumer markets.

It is unclear whether (or how) non-PSA users would be affected under a commercial or hybrid option

Some study participants suggested that delivering a PSMB capability could have consequences for the quality of service experienced by other mobile users (where network infrastructure and spectrum is shared, such as under a commercial or hybrid approach).

On the one hand, enhancements to carrier networks to ensure that mobile services are delivered to a public safety standard could improve the quality of service experienced by non-PSA users (a positive spillover). On the other hand, providing PSAs with priority access to networks and capacity may mean displacing commercial customers or degrading their quality of service at certain points in time (a negative spillover).

It is impossible to know with any certainty how carrier involvement in a PSMB solution might affect the quality of service experienced by non-PSA users overall. How these spillover effects would vary across the commercial and hybrid delivery options is also uncertain. In any case, these effects would likely be reflected in the prices charged by carriers (to both PSA and non-PSA users).

The way forward

A commercial approach offers the best way forward

On first principles, the most efficient, effective and economical way of delivering a PSMB capability to PSAs is by relying on commercial mobile networks, including carrier spectrum, services and expertise. Relative to a hybrid or dedicated approach, a commercial approach:

- imposes a considerably lower cost on the community

- is expected to deliver a PSMB capability sooner, and carries a lower risk of delay
- provides PSAs with the flexibility to scale up demand in the short term, where it is efficient to do so
- lowers the per-user cost of adopting technology upgrades, increasing the likelihood that these upgrades are undertaken in a timely way.

A commercial approach does create greater challenges for governments in pursuing competitive procurement outcomes, and it does carry a higher risk of supplier lock-in. However, there are procurement strategies that can help to address these challenges (discussed later). Moreover, while lock-in risks would be lower under a dedicated approach, it is highly unlikely that the estimated $4 billion cost difference between these approaches is justified based on lock-in risk alone. Hybrid options with a small dedicated component are closer in cost to the commercial approach; however, these options do not significantly reduce the lock-in risk (given their heavy reliance on commercial networks).

Pilots would provide an opportunity to develop confidence in a commercial approach

As noted earlier, there is sufficient evidence to suggest that it is technically feasible for commercial carriers to deliver priority network access for PSAs without dedicated spectrum. Given the additional costs involved, the Commission considers that the case for using dedicated spectrum to deliver PSMB (that is, through a dedicated or hybrid approach) is weak.

However, to the extent governments or PSAs have residual reservations about the capability or willingness of commercial carriers to deliver a public safety grade service using shared spectrum, this can be managed through small-scale trials or pilot programs that prove the technology (for example, on short-term contracts and in targeted areas). These pilots should focus on the most uncertain or contentious aspects of a commercial PSMB capability, and should be professionally and publicly evaluated. LMR voice networks are expected to be available for at least the next 5–10 years in all jurisdictions, creating a relatively low-risk environment for experimentation with new technology.

Undertaking pilots has other benefits, and may be advantageous even if jurisdictions are confident that the carriers can deliver PSMB without dedicated spectrum. Pilots would help jurisdictions to better gauge the costs, benefits and risks of PSMB, and to identify risk mitigation strategies. Moreover, the outcomes and lessons from pilots could be used to build a business case to expand the capability more widely.

Indeed, starting small is likely to be beneficial for all jurisdictions, given the significant uncertainty about PSA demand for mobile broadband services and technological developments. There is also scope for jurisdictions to share their experiences with one another and to learn from ongoing developments with PSMB elsewhere in the world.

In the event a pilot is deemed unsuccessful, the first step should be to clearly identify the problem (or cause of failure) and investigate potential solutions. Only if the problem is intractable — or the costs of addressing it exceed the costs of alternative deployment approaches — should jurisdictions consider proceeding with piloting or rolling out a hybrid or dedicated PSMB capability. Investing in dedicated spectrum in anticipation of commercial carriers failing to deliver the requisite services would represent a highly risk-averse and costly strategy.

Spectrum should be priced at its opportunity cost

All mobile broadband networks require access to spectrum.

- Under a commercial approach to delivering PSMB, the spectrum holdings of commercial carriers would be used. A carrier might rely exclusively on its existing spectrum assets or purchase some new spectrum to accommodate PSA traffic.
- Under a dedicated or hybrid approach, PSAs would need exclusive access to a suitable band of spectrum. Jurisdictions or PSAs could purchase and own this spectrum themselves, or pay to access a dedicated spectrum channel on a carrier's network.

Regardless of how and to whom spectrum is made available, it should be priced at its opportunity cost — the value of the next best use for the spectrum. This would give purchasers a strong incentive to use spectrum in an efficient way, including potentially leasing or selling spectrum access rights to a third party when it is not needed.

Australian Government intervention in spectrum allocation is not necessary to facilitate PSMB

In 2012, ACMA made an in-principle decision to set aside 10 MHz of spectrum within the 800 MHz band to support the deployment of a PSMB capability. This would be done as part of a broader rearrangement of spectrum, under which 30 MHz is to made available for mobile broadband generally. ACMA has stated that it would await direction from the Australian Government before deciding how to allocate this spectrum, following the Government's response to the Commission's final report.

However, any jurisdiction or PSA that wishes to access spectrum for PSMB is not dependent on the Australian Government directing ACMA to allocate spectrum for this purpose. It could pursue access to spectrum in a similar manner to other users, such as by applying for an apparatus licence or obtaining a spectrum licence at auction.

Indeed, the Commission has not been presented with evidence that state and territory governments face unnecessary regulatory impediments to accessing spectrum, or that government agencies are on an unequal footing with other potential buyers. Accordingly, the Commission does not consider that Australian Government intervention in spectrum allocation processes is necessary to facilitate a PSMB capability or for state and territory

governments to access spectrum. Intervention in these processes to improve certain users' access to spectrum would have costs that would need to be weighed against the benefits.

Cost-reflective pricing would encourage efficient use of PSMB

Jurisdictions can facilitate the efficient use of PSMB (and efficient investment in it over time) by adopting cost-reflective pricing models. These would encourage agencies to consider the costs and benefits of using PSMB (against other inputs, such as vehicles and equipment) and give PSAs an incentive to manage their demand efficiently when networks are congested.

Where governments choose to assist PSAs with meeting the costs of using PSMB, this should be done in the form of an increased budget allocation. This would preserve the incentives PSAs have to use PSMB efficiently, relative to alternative funding models (such as directly subsidising the provision of PSMB or key inputs).

A jurisdiction-wide implementation entity could help

Regardless of how jurisdictions proceed, implementing a PSMB capability will involve a number of technical and commercial tasks, such as developing the technical specifications that a PSMB capability would need to meet, or directly procuring services.

There would be benefits in entrusting a dedicated agency in each jurisdiction to undertake such tasks. Some jurisdictions have already established agencies to manage PSA communications and invest in LMR networks at the state level (such as the NSW Telco Authority) and could potentially task these agencies with the implementation of a PSMB capability.

History suggests that a coordinated approach is likely to be more effective than letting each PSA independently make procurement decisions. The latter approach has led to duplication of investments in LMR networks and significant constraints on technical interoperability across agencies in many jurisdictions. By contrast, a jurisdiction-wide approach could:

- minimise duplication of equipment and procurement
- lead to economies of scale (for example, where purchasing a larger number of handsets would reduce the unit cost)
- offer opportunities to coordinate PSMB investments with those in LMR networks or other state government programs (such as mobile black spot initiatives).

It is ultimately up to each jurisdiction to decide what level of coordination to pursue and the corresponding governance arrangements.

Good procurement practices can deliver value for money

Good procurement is difficult. Governments do not have complete information about companies' cost structures, technical capabilities or intentions. Moreover, the challenges of designing a good tender process can be amplified by the state of competition in markets for mobile broadband services and equipment.

However, governments are not powerless in dealing with mobile carriers and technology providers. They have several tools at their disposal to strengthen their bargaining position and/or facilitate competition in tender processes to deliver better value for money for taxpayers.

- Governments can split tenders (by technology or service, and/or on a regional basis) to allow more companies to participate, provided the competitive benefits outweigh the additional tendering and coordination costs. This approach has been used successfully in other government contracts, such as for rail infrastructure.
- Benchmarking bids against other cost data can help governments to assess bids that are submitted through a tender process. Transparency measures (such as 'open book accounting' provisions) might also provide a useful way to gauge the reasonableness of costs after a contract is signed.
- Negotiating collectively can exert countervailing power. One option for state and territory governments is to negotiate with potential suppliers on behalf of their PSAs to secure a better deal. State-owned infrastructure and spectrum holdings can also be used to reduce costs and give governments leverage in the negotiation process.

There are also strategies available to governments to reduce lock-in risks. For example, keeping customisation of equipment to a minimum, and insisting on the use of technology that complies with open international standards, can give governments the option to switch suppliers in the future. Governments can also seek to retain ownership of some assets, for example, through 'build, own, operate and transfer' contracts. Moreover, aligning the length of contracts with the economic life of assets provides a way to avoid being locked in to a provider for longer than necessary. However, these are partial strategies, and it is unlikely that lock-in risks can be completely eliminated through contract design.

Finally, some study participants suggested that the PSMB procurement process should be designed with a view to promoting competition in the broader telecommunications market. PSMB procurement is unlikely to be the least-cost way of targeting competition objectives relative to alternative policy options (such as legislation governing competition and infrastructure access in telecommunications markets). Value for money should be the primary consideration for governments — attempting to target additional objectives through the PSMB procurement process could lead to unnecessary delays and costs.

Interoperability requires technical and institutional change

PSMB presents an opportunity for PSAs to interoperate within and across jurisdictions using a common communications platform, with potentially significant benefits.

A nationally agreed set of technical protocols is needed to facilitate interoperability between PSAs, both within and across jurisdictions. The protocols could cover technical matters such as network and handset technologies and a common suite of applications. These protocols should be agreed by Commonwealth, state and territory ministers before jurisdictions embark on procuring PSMB, so as to reduce the risk of 'early movers' locking in technologies that preclude future interoperability with other jurisdictions.

Protocols should be minimal in nature but need not preclude two or more jurisdictions working together more extensively to realise efficiencies in other areas (for example, by sharing parts of, or jointly procuring, a PSMB capability).

Institutional barriers to interoperability at the agency level, including an entrenched stubbornness to share information with other agencies, must also be overcome. Each agency will need to amend its processes and protocols for sharing and storing information, both with other agencies in the same jurisdiction and with their interstate counterparts. State and territory ministers can facilitate more effective cross-agency collaboration within their jurisdictions by setting clear expectations and deadlines.

Finally, where a jurisdiction chooses to rely on two or more mobile carriers for PSMB services, roaming agreements may be required (or at least desirable) to enhance interoperability. This would be a matter for individual governments to consider as part of the procurement process. Cross-border roaming arrangements might also be desirable where jurisdictions engage different mobile carriers for PSMB services. There would be value in jurisdictions working together bilaterally to consider whether and how to pursue cross-border roaming before they embark on procurement.

Capacity sharing arrangements are efficient, but won't be easy

Many PSAs are used to having their own communications networks, or their own dedicated channels on a shared network (that is, a 'partitioned' network). However, this model would be an inefficient way to provide a PSMB capability, as it could constrain an agency's ability to scale up its data use during an emergency.

Sharing a PSMB capability would require PSAs within each jurisdiction to reach agreement on how users and applications are to be prioritised in specific operational situations. This will be challenging and contentious in some jurisdictions. There is a role for ministers to lead efforts to develop inter-agency protocols within their jurisdictions by setting clear expectations and deadlines for when these protocols need to be put in place.

Summing up

Taken as a whole, the Commission's analysis and findings represent a set of guiding principles to help governments in implementing a PSMB capability (box 6). Key features of an efficient implementation strategy are to promote efficient service provision, deliver the best value for money for the community, and be evidence based, transparent and accountable.

Box 6 Guiding principles for government action on PSMB

Promote efficient provision

- Price spectrum at its opportunity cost, regardless of how it is distributed or to whom.
- Ensure PSAs face the cost of delivering (and investing in) PSMB.

Deliver the best value for the community

- Base decisions about the capacity and quality of PSMB on the associated costs, benefits and risks — a uniform capability is unlikely to be efficient across jurisdictions.
- Rely on LTE technology and maximise the use of existing infrastructure, where it is technically and economically feasible to do so.
- Adopt procurement practices that facilitate competition in tender processes, strengthen the purchaser's bargaining position and reduce lock-in risks.
- Develop common protocols that support technical interoperability across jurisdictions.
- Develop protocols and procedures at the agency level regarding the sharing of information and network capacity (where relevant).

Be evidence based, transparent and accountable

- Undertake pilots to build confidence in a commercial approach; to gauge the costs, benefits and risks of PSMB; and to gather evidence for a larger-scale rollout.

Recommendations and findings

Mobile broadband offers significant potential benefits

FINDING 2.1

The land mobile radio networks used by PSAs are reliable and have extensive geographic coverage (for voice only). However, they only support low-speed data applications, and they lack technical interoperability. This can prevent PSAs from communicating with one another, and means that radio equipment does not work upon crossing jurisdictional borders.

FINDING 3.1

PSA use of mobile broadband applications has the potential to improve the quality of public safety services, the operational efficiency of PSAs and the safety of officers.

FINDING 3.2

PSAs' uptake of mobile broadband applications is limited at present due to concerns about the quality of commercial mobile services. Critical issues include the ability of PSAs to get access to and sufficient capacity on commercial mobile networks during times of congestion, and the reliability of commercial networks relative to land mobile radio networks.

A PSMB capability must support mission critical situations

FINDING 4.1

The communications needs of PSAs are characterised by high and non-predictable peak periods. PSAs can (and do) employ strategies to reduce their demands on communications networks during peak periods without any significant loss of benefits. Provisioning a mobile broadband network to meet relatively infrequent peak events would be prohibitively expensive.

FINDING 4.3

PSAs expect a PSMB capability to deliver a standard of service that would allow them to use mobile broadband voice and data applications in 'mission critical' situations (for example, where there is a material risk of loss of life or severe injury).

However, there is no single set of service quality standards implied by this. Individual PSAs and jurisdictions will ultimately need to decide on the quality standards that a PSMB capability should deliver, taking into account the benefits, costs and risks to the community as a whole. There would be benefit in governments being transparent about how these tradeoffs are made.

FINDING 4.2

PSAs' use of mobile broadband services and applications would likely increase significantly if a PSMB capability was available. However, the level of network capacity that PSAs would use is highly uncertain, as are the benefits of that use.

Options for delivering a PSMB capability

FINDING 5.1

The costs of delivering PSMB under any option can be reduced by:

- maximising use of existing infrastructure
- sharing network capacity among PSAs in real time (that is, a non-partitioned network)
- allowing for flexible use of spectrum across users.

FINDING 5.2

Providing a permanent PSMB capability in areas not currently covered by commercial mobile networks would be very costly. There are lower-cost options that can be pursued to provide a level of mobile broadband coverage and capacity (such as transportable equipment or satellite broadband), albeit not to a 'public safety' standard.

Targeted extensions of mobile broadband networks may be warranted on a case-by-case basis, for example, where strategic assets are located in areas susceptible to emergency incidents.

FINDING 5.3

The technical standards for delivering mission critical voice services over Long Term Evolution networks are still in development. All Australian jurisdictions plan to continue operating their land mobile radio networks for mission critical voice until at least 2020 (and much longer in some cases).

PSMB networks should be designed with a view to incorporating mission critical voice services in the future.

FINDING 5.4

It is technically feasible to deliver a PSMB capability — including priority network access — under a dedicated, commercial or hybrid approach. However, there is uncertainty as to the precise service standards that could be achieved under alternative PSMB delivery approaches.

FINDING 6.1

A commercial approach is the most cost-effective way of delivering a PSMB capability to PSAs.

The Commission's analysis indicates that a dedicated network is nearly three times more expensive than a commercial option. The cost difference between a hybrid and commercial option is lower and narrows as the size of the dedicated network component decreases.

FINDING 6.2

The nature and magnitude of risk varies across PSMB delivery options. For example, the risk of governments becoming locked in to using a single supplier is most pronounced under a commercial approach, while a dedicated network is most susceptible to delays and technological obsolescence. However, risk and uncertainty are common to all PSMB delivery options and no option is clearly preferred on the basis of risk factors alone.

Good implementation is essential to get the most out of PSMB

RECOMMENDATION 7.5

Governments and PSAs that decide to deploy a PSMB capability should take a phased approach to implementation by first undertaking pilots of a commercial PSMB capability on a small scale. Pilots would provide an opportunity to:

- demonstrate the technical and commercial feasibility of a commercial approach
- evaluate the costs, benefits and risks of PSMB
- develop protocols and procedures for information and capacity sharing by PSAs
- develop the business case and resolve uncertainties ahead of a wider-scale rollout.

Individual pilots could be funded by one or more jurisdictions working collaboratively, with the outcomes shared among them. Commercial partners in pilots should be selected through competitive tendering. The outcomes of pilots should be professionally and independently evaluated, and published.

FINDING 7.1

Prices that reflect the cost of providing a PSMB capability would encourage PSAs to use it efficiently.

RECOMMENDATION 7.1

If individual governments decide to facilitate the deployment of a PSMB capability, police and emergency services ministers should set clear expectations and deadlines for PSAs under their jurisdiction to develop inter-agency protocols for sharing information over mobile broadband. These protocols should aim to achieve effective cross-agency collaboration and should include security procedures to safeguard sensitive information.

In jurisdictions where two or more PSAs share the same PSMB capability, ministers should also set expectations and deadlines for PSAs to develop protocols for prioritising specific agencies, users, devices and applications.

RECOMMENDATION 7.2

PSMB presents an opportunity for PSAs to interoperate within and across jurisdictions using a common communications platform, which would deliver significant benefits. To facilitate this, the Australian, state and territory governments should task police and emergency services ministers with agreeing to a set of minimum interoperability protocols within one year. These protocols should have the objective of facilitating national network, device and application interoperability.

RECOMMENDATION 7.3

If the Australian Communications and Media Authority licences spectrum for PSMB, it should be priced at its opportunity cost.

FINDING 7.2

Using procurement processes for PSMB to target policy objectives other than value for money — such as promoting competition in parts of the broader mobile broadband market or meeting equity objectives — would be a blunt, costly and non-transparent way to meet those objectives. Other policy instruments are likely to provide more effective alternatives for achieving additional objectives.

RECOMMENDATION 7.4

Governments and PSAs that decide to deploy a PSMB capability should maximise value for money in procurement by using competitive procurement processes. In doing so, they should adopt strategies to increase the number of potential bidders and reduce the risk of becoming locked in to a single supplier.

Strategies include:

- benchmarking bids against other cost data and making tender processes transparent
- splitting up tenders by service and/or region
- governments negotiating on behalf of their PSAs
- leveraging infrastructure and spectrum holdings in negotiations
- using short-term contracts that require adherence to open international standards.

1 Introduction

1.1 Background to the study

For emergency services, reliable communications can be the difference between life and death, both for their personnel and members of the public. At present, public safety agencies (PSAs) — the police, fire, ambulance and emergency services — primarily rely on narrowband radio networks that offer voice communications and some low-speed data services (including text messaging and database queries). These networks are built to a high standard and can be relied on in 'mission critical' situations.

PSAs are also making increased use of more advanced communications technologies. Some are using commercial mobile broadband services to send and receive images, text, video and voice messages. However, uptake of commercial mobile broadband services and applications by PSAs has been modest and limited to non-mission critical situations. This is because the services currently available on the commercial market do not meet the quality of service standards that PSAs require. It is unlikely that PSAs will fulfil their responsibilities efficiently if they continue to rely predominantly on narrowband technology.

Mobile broadband holds significant potential for PSAs and the communities they serve, in terms of cost savings and improved public safety outcomes (such as lives saved or injury and property damage avoided). The prospective benefits are manifold. Mobile broadband could allow police officers to collect and transmit key evidence when out in the field. Live video streaming between a fire crew and central command could improve situational awareness, ensure equipment and officers are deployed safely and efficiently, and expedite the evacuation of residents. And the ability for ambulance officers to remotely access medical records or send images to the hospital could speed up treatment and save lives.

Whether or not these benefits are realised largely depends on the availability of a 'public safety grade' mobile broadband capability that meets high service standards for reliability, coverage and other characteristics. The consensus is that PSAs are unlikely to make significant investments in, or widespread use of, mobile broadband until such a public safety grade service is available. There is a risk that this will not happen within the next few years — or in a way that allows for interoperability across agencies and jurisdictions — without some kind of government intervention.

Delivering a mobile broadband capability that meets PSA requirements will be challenging. There are myriad possible approaches — including deploying a dedicated network, using commercial networks or some combination of these — and each leads to different technical challenges, costs and risks. Moreover, the benefits of such a capability

are highly uncertain, and contingent on operational and cultural change at the agency level to incorporate mobile broadband into activities and procedures and share information with other agencies.

A further complication is that no single implementation model is likely to fit the different needs of each state or territory. Some jurisdictions already manage and invest in public safety communications on a statewide basis, and have recently upgraded their narrowband networks. Others have taken a more decentralised approach. The roles, responsibilities and operational requirements of individual PSAs differ across the country, and so one size will not fit all.

1.2 What has the Commission been asked to do?

The Commission has been asked to undertake a 'first principles' analysis of the most efficient, effective and economical way of delivering a public safety mobile broadband (PSMB) capability to PSAs by 2020. This is to include an assessment of the relative costs, benefits and risks of deploying a dedicated PSMB network, relying on commercial networks, and a combination of these.

The terms of reference set out several characteristics of a PSMB capability that the Commission must have regard to. These include the ability for the capability to be nationally interoperable, operate in both metropolitan and regional Australia, be resilient, and ensure accessibility, priority and sufficient capacity for PSAs. In addition, regard must be given to relevant domestic and international experiences, and work that has been undertaken to date.

The Commission was not asked to evaluate whether a PSMB capability should exist at all. Rather, this study is about identifying how best to deliver a PSMB capability, giving consideration to the specific needs of PSAs, the relative merits of alternative deployment approaches, and the likely costs and benefits to the community. The impacts of alternative approaches were weighed up to come to a view on the best way forward for delivering PSMB, including the appropriate roles for governments, PSAs and commercial carriers.

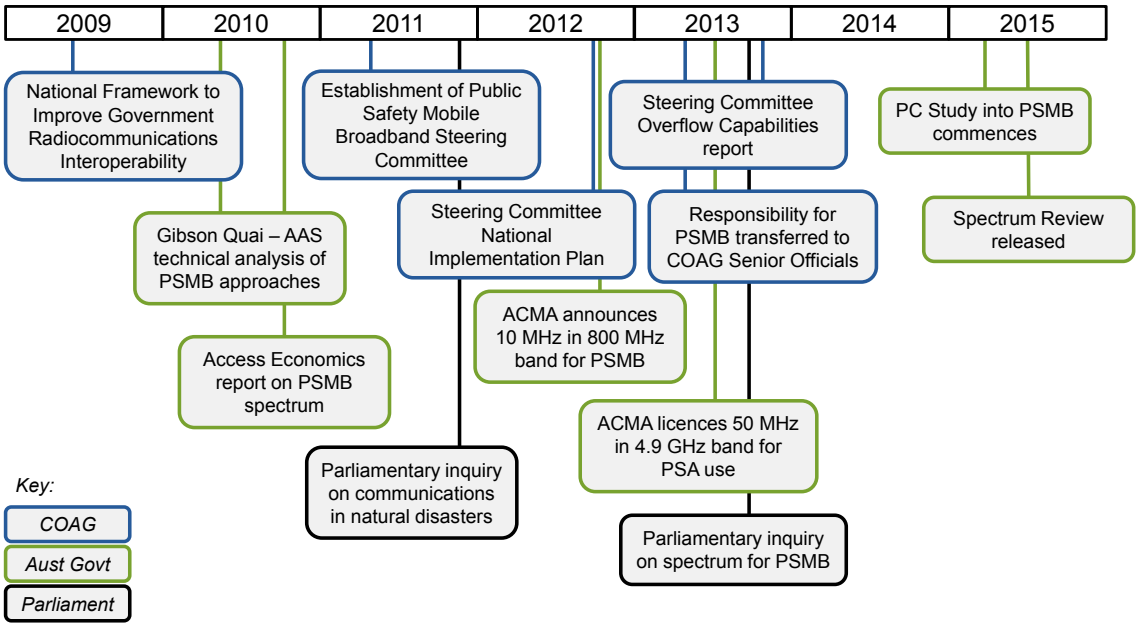
1.3 Domestic and international experiences

This study is being undertaken in the context of earlier work relating to PSMB, as well as parallel developments in Australia and overseas that are of relevance. Further detail is provided in appendix B.

Previous Australian reviews of PSMB

PSMB has been the subject of several reports and policy developments over the past six years (figure 1.1). This includes work by state and territory governments, as well as the Australian Government, under the auspices of the Council of Australian Governments (COAG).

Figure 1.1 **Previous developments relating to PSMB**



In particular, a detailed technical analysis was commissioned by the Australian Government in 2010 and released, in part, the following year. This work modelled the costs of delivering PSMB under several specific options, including a dedicated network, the use of commercially provided services, and various combinations of these (GQ-AAS 2010). It also involved building up a detailed picture of PSA requirements for mobile broadband, in consultation with PSAs across Australia. However, only limited parts of the report were made public.

In 2011, the Australian Government established a Public Safety Mobile Broadband Steering Committee, comprising senior officials representing government agencies, PSA peak bodies and the COAG Standing Council for Police and Emergency Management

(Attorney-General's Department 2011). This committee was tasked with reporting on the most effective and efficient way to deliver a PSMB capability. It produced a detailed National Implementation Plan (in 2012) and an Overflow Capabilities report (in 2013), neither of which was released publicly. In April 2013, COAG transferred responsibility for PSMB to a group of senior officials (COAG 2013).

More broadly, jurisdictions have cooperated to improve the ability of public safety officers to 'interoperate' across narrowband communications networks. This culminated in the *National Framework to Improve Government Radiocommunications Interoperability 2010–2020*, which was endorsed by COAG in 2009 (COAG 2009).

Work on PSMB has also been undertaken in other forums. Much of this work has focused on the allocation of radiofrequency spectrum, since access to specific frequencies of spectrum is required to wirelessly transmit and receive information in any radio network. In particular, two parliamentary inquiries have investigated the communications (and spectrum) needs of PSAs (ECRC 2011; PJCLE 2013). Both recommended that the Australian Government allocate spectrum specifically for the purposes of constructing a PSMB capability.

Spectrum policy and licensing is the responsibility of the Australian Communications and Media Authority (ACMA). In October 2012, ACMA made an in-principle decision to set aside 10 megahertz (MHz) of spectrum within the 800 MHz band to support the deployment of a PSMB capability. It also announced that 50 MHz of spectrum in the 4.9 GHz band would be set aside for exclusive use by PSAs, and formally licensed this in June 2013. However, spectrum in the 800 MHz band is yet to be formally allocated for PSMB and ACMA has indicated that it will take into account the Commission's study in reviewing the future use of this band (ACMA, sub. 14).

In addition, Australia's spectrum policy and management framework has been subject to a recent review (Department of Communications 2015b). Among other things, this review proposed replacing the current legislative framework with outcomes-focused legislation that facilitates more timely allocations of spectrum and greater flexibility of use, as well as allowing public sector bodies to lease, sell or share spectrum for their own benefit. The Australian Government announced that it would implement the main recommendations of this review from 2016 (Turnbull and Fletcher 2015).

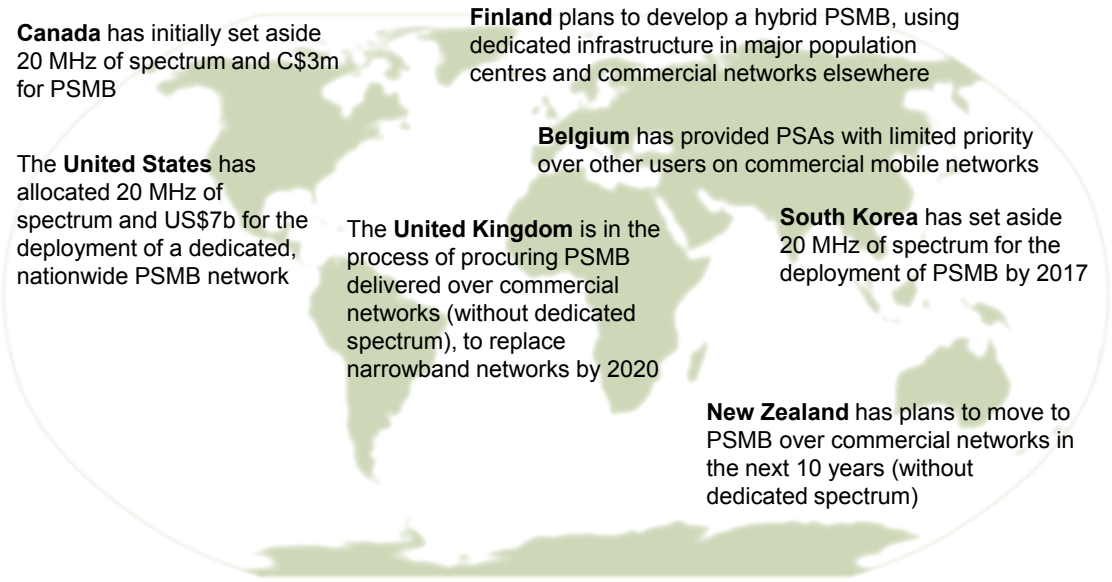
Other countries are also pursuing PSMB

Several other countries are investigating, planning or implementing a PSMB capability. The specific approach taken differs across countries, with some closer to a dedicated approach and others more reliant on commercial networks (figure 1.2).

The United States, Canada and South Korea have all announced that they have set aside 20 MHz of spectrum in the 700 MHz band for public safety use, and all three intend to construct networks dedicated to delivering PSMB (appendix B). By contrast, the United

Kingdom and Belgium have sought to have mobile broadband delivered to their PSAs mainly over commercial networks by way of contracts that set specific service standards.

Figure 1.2 **International approaches**



Progress varies across countries. Only Belgium has a fully operational service, but it mainly consists of a standard 3G mobile service with limited priority given to PSAs over commercial networks. New Zealand's PSAs also rely on standard mobile services, and there does not appear to be any kind of preferential treatment for PSAs. However, the NZ Government has indicated that it intends to implement PSMB over commercial networks in the next 10 years. The United States, United Kingdom, South Korea and Finland are in advanced stages of planning for PSMB capabilities that meet high standards of reliability, priority, security and other requirements. By contrast, in Canada, many key decisions related to governance and service standards are yet to be made.

Alongside these developments, work has been underway in multilateral forums to harmonise technologies and spectrum use across countries. The 3rd Generation Partnership Project, which develops international technical standards for mobile broadband, has started to integrate specific public safety requirements into the standards. In addition, the International Telecommunications Union has suggested specific spectrum bands that can be used for public protection and disaster relief, including within the 800 MHz band in the Asia–Pacific region (encompassing Australia).

1.4 Stakeholder perspectives on PSMB

State and territory governments have primary responsibility for public safety, including by setting policy and funding PSAs. The Australian Government is also directly responsible for some PSAs, such as the Australian Federal Police. Governments are therefore ultimately accountable for the activities of PSAs and the outcomes they achieve for the community.

PSAs use a range of inputs to fulfil their duties, including communications technology. While there is nothing to prevent PSAs purchasing commercial mobile broadband services — and many are already doing so — governments may wish to intervene on behalf of their PSAs to secure a public safety grade service. This could be done to meet policy objectives that governments have set, including:

- national interoperability across agencies and jurisdictions
- delivery of PSMB by 2020
- broader public safety objectives.

Government involvement may also offer opportunities to achieve greater cooperation among PSAs and value for money in securing a suitable mobile broadband service.

PSAs' requirements are diverse

PSAs' communication needs have several aspects that distinguish them from the needs of other mobile broadband users. Communications tend to increase significantly during emergency incidents — which are often unpredictable — to many times the level during 'business as usual' periods. PSAs also need to rely on their communications systems in mission critical situations where lives are at risk, even where communications infrastructure has been damaged or mobile phone networks are congested.

These aspects have implications for the type of mobile broadband capability that PSAs require. PSA engagement in this study, as well as in past policy processes, has revealed several desired features of a PSMB capability. In broad terms, these can be categorised as quantity (the amount of data capacity on a network) and quality (the type of service).

Specific characteristics of a PSMB capability (reflected in the terms of reference) include:

- sufficient data capacity to support a range of applications, including text messaging, database access, location tracking and video streaming
- a wide coverage footprint, including in metropolitan and regional areas
- high levels of reliability, such that the network is always operational
- the ability to 'interoperate' across different agencies and jurisdictions

- the ability for public safety officers to establish a connection to their communications network and receive priority over non-PSA users, even during periods of congestion
- the ability to integrate voice communications
- a high degree of security.

There is broad agreement that a PSMB capability should be of a sufficient quality standard to support the use of mobile broadband voice and data applications in mission critical situations. But there is less agreement on the specific service levels that would be required to meet this standard, and little work has been done to articulate these. In particular, estimates of the data capacity required to meet PSA needs vary considerably, with little consensus on the most appropriate level that should be delivered.

Individual states have progressed with PSMB

All jurisdictions have recognised the potential benefits of PSMB, and some have undertaken their own studies on how to deliver it (separate to activities conducted at the national level). In particular, both New South Wales and Victoria have investigated ways to establish a PSMB capability within their respective jurisdictions.

The NSW Telco Authority is currently undertaking an assessment of the costs and benefits of a PSMB capability in New South Wales (NSW Telco Authority, sub. 30). This has included a detailed assessment of the costs of specific delivery options, a bottom-up forecast of agency data requirements for mobile applications, and an evaluation of ways to maximise competition and efficiency in the delivery of PSMB. The work to date has not been made public.

The Victorian Government has commissioned studies on the benefits and costs of a national broadband capacity for emergency services (in 2011) and on international experience with public safety broadband (in 2013) (Victorian Government, sub. 28). Only the latter document has been made publicly available (Deloitte 2013).

Private-sector solutions are starting to emerge

Technology companies, network operators and other private-sector entities have been active participants in policy processes relating to PSMB. Indeed, in Australia and other countries, the private sector has begun to develop and trial mobile broadband solutions (including network equipment, handsets and service provision) targeted to meet public safety requirements. A prominent example of this is Telstra's LANES capability, a hybrid approach to PSMB that has undergone several trials (box 1.1).

Box 1.1 **Telstra LANES**

Telstra LANES is a hybrid approach to public safety mobile broadband. It consists of a dedicated spectrum channel that can only be accessed by users from public safety agencies (PSAs). When PSA data requirements exceed the capacity of this channel, users can seamlessly move onto Telstra's broader commercial network, where they receive priority over other network users. This allows the network capacity available to PSAs to be scaled up instantly.

The capability involves integrating a dedicated channel of spectrum into Telstra's network and using a single core network to manage traffic from both public safety officers and non-PSA users. It is based on Long Term Evolution technology (also known as 4G) and draws on dynamic prioritisation techniques and public safety applications developed by Motorola Solutions.

Telstra LANES has been trialled in Queensland and Western Australia in 2013, for the G20 Leaders' Summit in Brisbane in November 2014, and during the Australian Football League Grand Final in Melbourne in October 2015 (in all cases, using spectrum licensed to Telstra for the dedicated network component). Telstra (sub. DR41, p. 4) has claimed that the latter trial:

> … demonstrated the ability of a commercial mobile carrier to provide PSAs with a standards based solution for priority access to the network as well as preferential and uninterrupted broadband performance during a network congestion event.

Sources: Telstra (subs. 19, DR41; 2014a).

1.5 The Commission's approach

The Commission is focusing on the most efficient way to implement a PSMB capability by 2020. Specifically, it is assessing the relative costs and benefits of a range of different approaches from the perspective of the community as a whole. This is guided by the *Productivity Commission Act 1998* (Cwlth), which requires the Commission to have regard to achieving higher living standards for all members of the Australian community.

The Commission has approached this task using cost–benefit analysis. This allows for a rigorous and consistent assessment of the costs and benefits (including those that are non-monetary) of a range of options for meeting a policy objective. This assessment is undertaken both quantitatively and qualitatively. Specifically, the Commission has:

- identified a range of 'scenarios' that describe the quantity and quality of mobile broadband services that a PSMB capability could deliver — these scenarios do not represent the Commission's view as to what quantity or quality of service should be actually delivered
- explored the technical and cost implications of using different inputs and deployment approaches to provide a PSMB capability
- evaluated the costs, benefits and risks associated with a set of specific delivery options
- quantitatively analysed the costs associated with each delivery option

- examined the institutional, governance and procurement aspects of implementing a PSMB capability.

In line with its standard practice, the Commission has sought to draw on publicly available information to the greatest extent possible. This is to provide transparency in the sources used to develop findings and recommendations, and to allow interested parties to replicate the quantitative component of the study. Some information was received on a commercial in confidence basis. This information has been considered by the Commission. Where robust information or empirical data were not available to cite publicly, the Commission has made judgements. These are clearly indicated in the report.

1.6 Conduct of the study

The terms of reference for this study were received on 25 March 2015. To assist interested parties to prepare submissions, the Commission released an issues paper on 20 April 2015. The Commission received 31 initial submissions in response to the issues paper from PSAs and their representative associations, Australian Government agencies, state and territory governments, mobile network carriers and equipment providers.

A draft report was released for public comment on 23 September 2015. Subsequent to this, a further 15 submissions were received.

The Commission met with a range of organisations, individuals, industry bodies and government agencies during the course of this study. Technical workshops were held in Melbourne and Sydney in June 2015 to discuss the approach to the quantitative component of this study. In addition, the Commission engaged the company UXC Consulting to provide technical input and expert advice, and Network Strategies Limited to review the quantitative analysis. The Network Strategies referee report is provided in appendix D.

The Productivity Commission thanks all study participants for meeting with the Commissioner and staff, participating in technical workshops and making submissions to the study.

1.7 Structure of this report

The remainder of this report is structured as follows.

- The next chapter reviews the current state of public safety communications and the associated shortcomings.
- Chapter 3 identifies the opportunities that mobile broadband offers PSAs and factors that may be limiting uptake to date.
- Chapter 4 assesses PSA requirements for mobile broadband and develops a set of scenarios to guide quantitative analysis of delivery options.

- Chapter 5 investigates the technical feasibility of, and cost drivers associated with, different approaches for deploying PSMB.
- Chapter 6 evaluates the costs, benefits and risks of a set of specific delivery options for PSMB, using both quantitative and qualitative analysis.
- Chapter 7 discusses the broader institutional, governance, regulatory and procurement aspects of implementing a PSMB capability.

Appendixes support the analysis in the main body of the report. Appendix A lists the individuals and organisations that participated in the study. Appendix B reviews past work undertaken in Australia and relevant international experiences with delivering a PSMB capability. Appendix C provides the full technical details regarding the quantitative analysis undertaken by the Commission, and appendix D provides the referee report for the analysis. Computer files used in this analysis have been posted on the Commission's website (http://www.pc.gov.au/inquiries/completed/public-safety-mobile-broadband).

2 Public safety agency communications

Key points

- Public safety agencies (PSAs) have traditionally communicated using voice radio, but increasingly some information and communications are being digitised and carried over data services.
- PSA demand for communication services is not constant and varies in both a predictable (for example, on Friday/Saturday nights, and during major planned events) and unpredictable (for example, during emergencies) way, resulting in peaks and troughs in demand for capacity.
- The 'mission critical' nature of the work PSAs undertake distinguishes the communication requirements of PSAs from other users. While exact functional requirements will differ between PSAs, all agencies require their communication services to have high availability, security and reliability.
- Data capabilities are provided through both dedicated land mobile radio (LMR) data networks and through commercial 3G/4G mobile networks.
- LMR voice networks form the backbone of PSA communications. These networks have extensive coverage and have proven to be reliable over decades of operation.
- Population coverage of LMR voice networks and commercial 3G/4G mobile networks is similar across states and territories, although there are differences in geographic coverage.
- There are some issues with LMR voice networks.
  - The use of standalone networks based on different standards, frequencies and end-user devices has resulted in a lack of technical interoperability.
  - There are examples of some LMR voice networks becoming congested during weekly peak periods and during emergencies.
  - Several analog LMR networks (mostly in regional areas) are yet to be encrypted, potentially compromising confidentiality and PSA operations.
- LMR data networks are typically more reliable than commercial mobile networks, but are limited in coverage (only available in some metropolitan regions) and can only carry low volumes of data. Commercial mobile networks have a much larger coverage area and achieve higher data throughput, but reliability concerns limit usage by PSAs to mostly non-mission critical situations.

2.1 Who are the public safety agencies?

Public safety agencies (PSAs) undertake a range of community safety and incident response activities, often in close collaboration with each other. The terms of reference state that PSAs include police, fire, ambulance and emergency services. For this study, emergency services include all agencies for whom emergency management is their core business, such as the State Emergency Service (SES), as well as marine search and rescue services provided by the Australian Maritime Safety Authority (SCRGSP 2015).

- *Police agencies* pursue the achievement of a safe and secure environment for the community, including through investigation of criminal offences, response to life threatening situations, and provision of road safety and traffic management. Police agencies also assist the judicial process by providing custody services.
- *Fire service organisations* work to minimise the impact of fires, which include structural fires, grassfires and bushfires, and vehicle and other mobile property fires. Fire services are also involved in search, rescue and recovery operations, fire prevention activities, and building community resilience.
- *Ambulance service organisations* prepare for, provide and enhance: pre-hospital and out-of-hospital patient care and transport; inter-hospital patient transport; specialised rescue services; ambulance services to multi-casualty events; and capacity building for emergencies.
- *SES* help communities prepare for, respond to, and recover from unexpected events, such as road accidents, floods, earthquakes, cyclones, and search and rescue.
- *Marine rescue and coast guard organisations* provide marine rescue, boating safety and communications services.

Other agencies such as Surf Life Saving Australia, Sheriffs' departments, Air Services Australia, local councils and utility companies could arguably be considered in scope (CDMPS et al., sub. 7; LGAQ, sub. DR32). However, while they all serve a public safety function or provide an important input to PSAs' activities, emergency management is not the core activity of these agencies. It is important to note that this will not preclude these agencies from accessing any future public safety mobile broadband (PSMB) capability. Indeed, any system developed to meet the requirements of the identified PSAs is likely to overlap with the requirements of other users.

As state and territory governments have primary responsibility for delivering emergency services, most PSAs are administered at the state or territory level. Generally, PSAs are run as public agencies by government departments. A small number of PSAs are administered at the Commonwealth level, including the Australian Federal Police and the Australian Maritime Safety Authority (SCRGSP 2015).

While there are commonalities between PSAs, no two agencies are the same. The scope of operational activities undertaken will vary with many factors, including the time of day, the day of the week (weekday or weekend), the time of year (summer or winter), and the

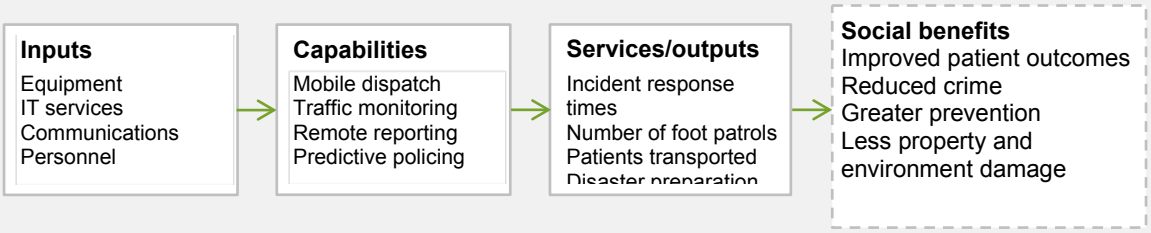
area of operation (city, metropolitan or rural). While all PSAs require communication services to fulfil their responsibilities, with these differences in operations come different demands and requirements for communication services.

2.2 PSA demand for communication services

PSAs have a wide variety of resources at their disposal (box 2.1). For example, state-of-the-art helicopters capable of providing life-saving blood transfusions mid-flight, police scanners that automatically scan number plates to check vehicles against registration databases, and remote monitoring of a building's fire warning system.

Box 2.1 Value chain of PSA services

PSAs rely on multiple inputs to complete their missions, of which the ability to communicate is just one. Inputs include personnel (frontline officers, dispatchers, office staff, central command decision-makers), equipment (helicopters and vehicles to footwear and knee-pads), training, information technology systems and communication infrastructure.



Inputs equip PSAs with the capabilities necessary to deliver the services and outputs required of them. For example, the capability to dispatch jobs directly to emergency vehicles allows PSAs to provide timely assistance in life-threatening situations, and the ability to remotely lodge incident reports allows police officers to spend more time on patrol. Some of these outputs, such as incident response times, are measurable, although there are issues with the interpretation (for example, how response times impact on outcomes) and comparability (for example, differing calculation methodologies between jurisdictions) of such measures. Others are harder to quantify but nonetheless yield benefits for the community.

The work of PSAs is often time critical, and to effectively respond to an incident PSAs need information. The efficacy of PSAs is enhanced if they can deliver the right resources, at the right time, to the right location. An ability to automatically scan number plates is of little use if further information about the vehicle, persons and their history cannot be obtained.

Communication capabilities enable this exchange of information. These capabilities are not an end in themselves – rather, they form an essential input for PSAs to provide their services.

The quality of communications affects PSA outcomes by increasing the efficiency of resource use, leading to either:

- a reduction in the cost of providing a given level of service
- an improvement in the service provided, for a given cost.

By reducing costs and enabling PSAs to provide more effective services, communities are the ultimate beneficiaries of PSA communication capabilities.

PSAs communicate using voice and data services

The information that PSAs send and receive comes in many forms including voice, text, image and video. Not all communication services can transmit these different forms of information equally (box 2.2). The communication services used to share and exchange this information fall into two broad categories: voice and data.

Box 2.2 The difference between communication services and applications

A communication *service* is a system of physical assets, operating software and technical standards that together provide a communication capability. For example, a 4G commercial mobile service is a combination of physical assets (such as transmission towers, backhaul links), operating software (core network architecture) and technical standards that in conjunction provide end users with the ability to communicate data.

An *application* is the means through which a service is put into use in pursuit of a certain function, task or activity. Applications can involve both software programs that run over a communication service and the peripheral devices that interface with the service. For example, Skype (an application) could use the National Broadband Network (a data service) to provide video conferencing (a function). Ambulance Victoria uses the Mobile Data Network to run Computer Aided Dispatch software and devices to assist them with rapid response to emergencies.

Generally, digital services permit a variety of applications, whereas due to technological limitations, analog services permit only voice applications.

Source:(VDTF 2015b).

Voice services

Voice services allow real-time communication between PSA units, command centres and other resources. Historically, voice has comprised the bulk of PSA communications – if a PSA unit wished to determine the status of another unit, or to receive a dispatch from central command, voice communication has been the primary, if not only, means to communicate this information. Voice is still regarded as the paramount communications requirement for PSAs (P3 Communications and TCCA 2015).

Voice services are provided to PSAs using fixed, mobile and satellite technologies (section 2.5). Fixed-line voice services include all wired communication connections to a

premise, such as copper and fibre networks. They typically provide better voice quality, reliability and security than mobile and satellite voice services, however with an obvious lack of mobility.

Many jurisdictions are in the process of upgrading their voice services from analog to digital — in metropolitan areas in particular. This comes with significant benefits, including improved audio quality and the ability to integrate low-speed data services, enabling applications such as man-down alarms, GPS tracking, and encryption.

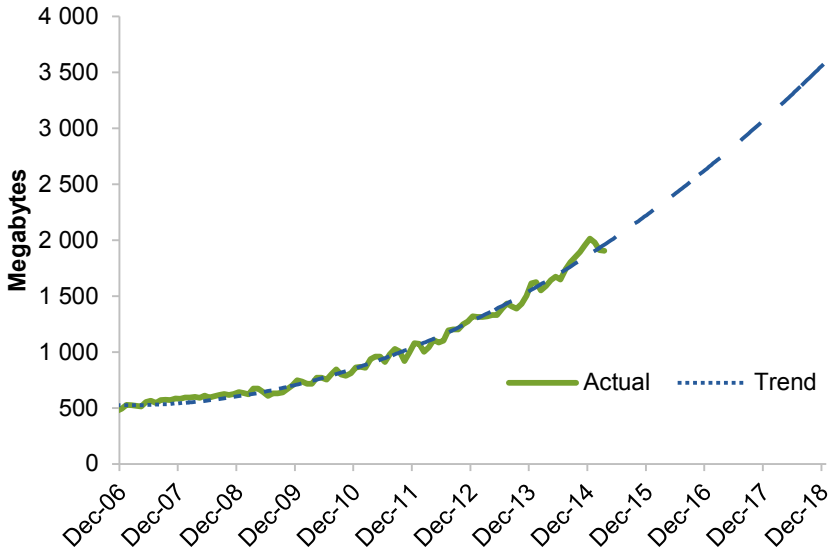
Data services

Information that is stored in digital form, such as text, images and video, can only be transmitted over a data service. This information is a series of on/off codes or 'ones and zeros' transmitted over either a wired network or the radiofrequency spectrum to a receiving terminal, which converts the signal back into a useful form (text, image, video or sound).

Data services have the advantage of being able to transmit information accurately, often without input or interaction by the receiving party and, with newer technology, can transmit a large quantum of information very quickly.

Figure 2.1 **Mobile data use in Victoria is increasing**

Mobile Data Network actual and projected usage, by month



Sources: Motorola, pers. comm. 17 November 2015; Weiss .

Increasingly, information that was communicated via voice is being digitised and carried over data services. For example, ambulance services previously used voice communications to dispatch paramedics and relay job information. This could include information such as incident priority, the best route to a given location, and special access information such as the location of house keys (Metropolitan Ambulance Service 2004). The advent of mobile data terminals (MDTs) means that this information can now be transmitted directly to the vehicle via text, helping ensure that human errors are minimised and freeing up paramedics' time for other uses.

Figure 2.1 shows how PSAs' use of the Mobile Data Network in Victoria has grown since 2006, with further growth projected in the coming years. PSA use of mobile broadband data services (currently and in the future) is discussed further in chapter 4.

To date, PSAs' use of mobile data services on their own land mobile radio (LMR) networks has typically been limited to text-based applications. PSAs are starting to use mobile applications with higher bandwidth requirements, such as images and video. They are largely reliant on commercial mobile networks to provide these services.

2.3 How are PSAs communicating?

Both PSAs and the community hold information that is relevant for the provision of public safety and emergency services. PSAs generate, store and share a wealth of information, from personal information and criminal records stored in a police database, to the simulated movement of a fire front. Community members provide vital information to PSAs about the location and nature of emergency incidents, both when they occur and as they unfold.

Agency-to-agency communication

PSAs rely on communication systems for internal information sharing (with colleagues in the field or command) and to communicate with other PSAs and support agencies. The hierarchal structure of PSAs, with a chain-of-command and centralised decision making, results in a need for information to be ferried from frontline officers to their superiors and vice versa. This drives a two-way communication flow that is as demanding on sending information as it is on receiving, whether it be via voice or data. Depending on the information being sent, communication between public safety officers can be either one-to-one or one-to-many.

One-to-one communications

One-to-one communication refers to correspondence that is exclusively between two individual users on a network. PSAs use one-to-one communication both for voice and

data. For example, officers responding to an incident will often have a need to communicate directly between one another within the incident site.

One-to-many communications

A key factor of PSA communications is heavy reliance on one-to-many communication, where many users can receive the voice or data transmitted by a single user. One-to-many communication is utilised when the information may be of value to multiple recipients, for example, weather forecasts and traffic updates. One-to-many communication also allows any user to monitor the actions and status of other users, so while the majority of people tuned-in to a given channel may not be the intended recipients of a message, all users can benefit via increased situational awareness (Minehane, Molloy and Burgan 2014).

Communication between the community and PSAs

An increasingly important aspect of PSA communication is the two-way flow of information between the community and PSAs. All PSAs have avenues through which the community can contact the agency to request assistance or to communicate information. These communications take the form of emergency calls for assistance (box 2.3), non-emergency calls for assistance (for example, patient transport requests), information on potential incidents (for example, reports of smoke or suspicious behaviour), requests for information (for example, burning-off procedures) and other routine calls.

Box 2.3 Triple Zero services

For emergency incidents, communication occurs primarily through the national Triple Zero service and the corresponding state- or territory-level emergency service organisation call centres. The Triple Zero service currently answers about nine million calls each year.

Mobile phones have become the primary device through which the Triple Zero service is accessed, with 67 per cent of calls placed by a mobile phone in 2012-13. This has created some problems for PSAs as, unlike landlines, the exact location of the caller is not provided automatically.

Triple Zero is a voice only service. However, it is envisioned that the Next-Gen Triple Zero service will incorporate greater functionality, such as text messaging, video capability and an enhanced ability to determine a caller's location.

Source: Department of Communications (2014b).

Receiving accurate information from the community during an emergency is critical to PSAs achieving situational awareness. The higher the quality of information PSAs receive about an event, the better placed they are to prioritise incidents and manage their assets. Currently, PSAs rely heavily on voice communications for this information, sometimes leading to issues with accuracy.

Part of PSAs' mission is to provide timely and accurate information to the community so that they can prepare for or evacuate in the event of a disaster. Multiple avenues are used by PSAs to distribute information to communities, including:

- press releases and media events, which are carried by news organisations or published online
- warnings and emergency information broadcast on television and radio
- emergency details on PSAs' or other government websites
- Facebook, Twitter and other social media platforms
- community engagement for preparation and prevention activities.

In times of emergency the volume of these communications can be substantial. For example, during the four days of the 2013 Tasmanian bushfires, the Tasmanian Fire Service issued five bushfire advices, forty-six Watch and Act messages, thirty-nine bushfire emergency warnings, nineteen Emergency Alert messages (box 2.4), as well as advice through news outlets, ABC local radio, and online, and physical door-knocking (Department of Communications 2014b).

Box 2.4 **Emergency Alert**

Emergency Alert is the national telephone warning system used by emergency services to send voice messages to landline phones, and text messages to mobile phones located in declared warning areas. Negotiations, contracting and procurement for the system has been led by the Victorian Government on behalf of all states and territories.

To determine if a person is located in a warning area, Emergency Alert relies on the registered service address for fixed-line phones and the last known location and registered address of a mobile handset. For mobiles, this information is provided to Emergency Alert by the three mobile carriers, Telstra, Optus and Vodafone. Due to differences in how carriers collect these data, the ability for Emergency Alert to successfully determine a mobile handset's location varies between carriers.

Sources: Emergency Alert (nd); Victorian Government Solicitor's Office (2015).

2.4 Operational and functional requirements of PSAs' communication services

Communication services are critical to PSA operations

A key distinction between the communication needs of PSAs and those of the broader community is the mission critical nature of the work PSAs undertake. Because PSAs are often engaged in operations where the threat to lives or property is significant, they tend to have higher requirements for communication services with respect to availability, security

and interoperability (chapter 4). Applications and communication services that meet these requirements are often described as mission critical, for example, push-to-talk voice, man-down alarms and Computer Aided Dispatch.

The nature of PSA work results in peaks and troughs in demand

PSA demand for communication services is not constant. It varies temporally and spatially. This is both predictable (Friday and Saturday night, major planned events) and unpredictable (emergencies). These periods can broadly be classified into four categories (Cornick and Gathercole 2012; VHA, sub. 11).

- Business as usual — such as undertaking activities that are everyday and routine, such as traffic management or transporting patients, as well as responding to minor, non-life-threatening emergencies. During these periods, demand for communication services is expected to be relatively stable and predictable.
- Planned events — such as major sporting events, music festivals or G20 leaders' meetings, which require a larger than usual PSA presence. During these events, demand for communication services is likely to be relatively high, but predictable.
- Localised, large-scale emergency incidents — such as fires in major buildings, bomb threats or other infrequent incidents which require a large and sustained cross-agency response. These events will likely entail high peak demand in localised areas. There is uncertainty about the timing and location of such incidents.
- Wide-area, large-scale emergency incidents — includes bushfires, major floods, cyclones and other emergency incidents that impact a wide geographic area. Typically, these occur in regional areas, although they can occur in major cities (for example, the 2003 Canberra bushfires). These incidents will likely entail high and sustained demand for communication services over a wide area. There is uncertainty about the timing and location of such incidents, although certain areas are historically more prone to such emergencies, which facilitates forward planning.

Each of these incident types places different demand requirements on communication systems. Moreover, one incident type can shift to another as an incident unfolds.

PSAs have unique communication requirements

The operational and functional requirements PSAs seek from their communication services varies by agency, activity and location. For example, firefighting is conducted in harsh, physically demanding environments, and often across broad areas and remote locations. The needs of a firefighter and the demands she places on her communication system will differ from those of a police officer attending a localised emergency incident in an urban setting, or patrolling a music festival. For example, firefighters will typically require customised communication equipment to protect against risks of ignition and explosion that might otherwise be caused by the radio itself (MFB, sub. 6), a risk that is less pertinent

to other PSAs. On the other hand, access to encrypted communication channels is of lower priority for firefighters than the police services, where unencrypted communications can have a severe impact on their operations (SCF Associates 2014).

Despite these differences, there are operational and functional characteristics of PSA communications that are shared across the PSAs (box 2.5).

Box 2.5 Characteristics of public safety agency communications

High Availability — PSAs are unable to effectively provide their services in the absence of an ability to communicate. Networks should either have very high availability or have sufficient built-in redundancy options.

Extensive coverage — reflecting the geographic scope of PSAs, network coverage needs to be extensive. For some PSAs, this will include basements, stairwells, tunnels and so on.

Relay capabilities — public safety officers need to maintain communication with the command centre and other units both from within their vehicles and when using handheld devices.

Voice

Voice clarity — voice communications must be clear and free from interference to ensure that information is relayed accurately and efficiently.

Push-to-talk — the ability, at the press of a button, to switch a communications device instantaneously from receive mode to transmit mode.

Dynamic talkgroups — the ability to group users onto their own virtual channel based upon a common communication need.

Direct mode operation — the ability for end-user devices to communicate directly with one another independently of the radio network.

Security and encryption — for safety and confidentiality purposes, PSA communications should be capable of only being heard by the intended recipient.

Data

Short data messaging and paging — send short messages to personnel without the need to use voice channels.

Computer Aided Dispatch (CAD) — used to dispatch resources to an incident, often in conjunction with a mobile data terminal. CAD applications have varying degrees of functionality ranging from simple job tasking and location tracking through to detailed incident information.

Automatic Vehicle Location — remote GPS tracking of vehicle location to aid in asset management and CAD.

Database access — mobile access to records, registries and other databases.

Man-down alarm — an alerting device that can be quickly and easily activated when the wearer is in distress and in need of urgent assistance.

Sources: CDMPS et al. (sub. 7); Minehane, Molloy and Burgan (2014); SCF Associates (2014).

Firefighting communication requirements

Firefighters operate in physically demanding conditions that place extreme stresses upon both the communications equipment and the operator. Devices that are not shock, heat, and water resistant may fail in the harsh operating environment (MFB, sub. 6; SCF Associates 2014). Firefighters wear bulky and often cumbersome safety equipment, such as thick gloves and breathing apparatuses, for which communication equipment must be compatible.

Voice communication is widely considered the most important and, in some cases the only, tool for coordinating resources at the fire front (SCF Associates 2014). Network coverage is a key consideration, with firefighters operating deep inside buildings, stairwells, basements, tunnels and remote bushland in regional areas. Hand-held radios must be high-powered to allow signals to be transmitted from these locations (MFB, sub. 6).

It follows that voice clarity and speech intelligibility are key concerns for firefighters. Operation in noisy environments, compounded by the use, where necessary, of self-contained breathing apparatuses, can overwhelm a voice transmission to the point of inaudibility. Such situations require re-transmission, wasting valuable time, or may result in a complete breakdown of communication between firefighters and between firefighters and central control (SCF Associates 2014).

In regional areas, fire services rely heavily upon volunteer fire fighters. These volunteers are usually alerted to an emergency and the need to report to their stations via an emergency paging system. Accordingly, a reliable, wide-area paging system is essential to the operation of many fire brigades (Country Fire Authority 2013).

Ambulance communication requirements

Ambulance services rely heavily upon data applications for communication, and are large users of commercial mobile networks. An entire job, including dispatch, patient information, mapping, vehicle location, and job status, can be handled without a single voice communication (Queensland Ambulance Service, pers. comm., 26 August 2015).

This is not to say that voice is unimportant. Radio links to patient delivery destinations (such as hospitals) are still necessary for streamlining patient transfer (Queensland Ambulance Service, pers. comm., 26 August 2015). Medical emergencies that are specialised in nature or where the responding paramedic has limited experience may also require radio communication to off-site sources of medical expertise (SCF Associates 2014). Voice networks and procedures are also needed for redundancy, should there be issues with Computer Aided Dispatch or other data applications.

Ambulance services need communication security primarily for patient confidentiality purposes, since patient health information and medical records may be transmitted to responding units.

Police communication requirements

Compared to other PSAs, the police spend a greater proportion of time deployed in the field, typically on patrol or on duty in public places (SCF Associates 2014). Deployment in the field coupled with the mobile nature of police activities results in a large quantum of both voice and data communications. Among the PSAs, the police are the heaviest users of voice and data services.

Security of voice communications is of critical importance to police services. The nature of police work means that police officers are more likely to be the target of malicious actions by individuals or groups in the community than other PSAs. The ability for such people to intercept police communications, which may include details such as officer location, can put officers at risk. Further, police work can involve the need for secret tactical planning and the element of surprise, both of which are compromised when communications can be intercepted (SCF Associates 2014).

Police routinely query databases for information concerning persons or properties of interest. Mobile access to these databases varies by jurisdiction but typically includes access to personal details, outstanding warrants, and vehicle and firearm registries. The frequency and importance of these queries to modern police work results in a strong reliance on data services.

2.5 Network infrastructure used to meet PSA communication needs

A combination of physical assets, operating software and technical standards is required to provide PSAs with a communication capability. This combination of inputs is generally arranged as a network, that is, a series of connections (whether wired or wireless) that allow two or more users to communicate data and/or voice.

To meet their communication needs, PSAs use a disparate set of networks owned by both commercial carriers and the PSAs themselves (box 2.6), including: land mobile radio, commercial 3G/4G services, fixed-line services, satellite services.

Box 2.6 PSAs use both commercial and dedicated networks

Both commercial and dedicated networks are used to deliver communication services to PSAs. A dedicated network is a network that has been built for the exclusive use of PSAs (or a limited number of government agencies) and is specifically designed to meet PSA needs. In some cases, these networks will be owned and operated by PSAs or the corresponding government agency. However, PSAs do not always own these networks themselves. For example, the Government Wireless Network in Queensland is owned, operated and managed by Telstra. The network has been designed specifically to meet the requirements of Queensland PSAs, and only the PSAs and select government agencies are permitted to use the network.

When using commercial services the PSAs are essentially like any other customer – they buy services on the open market that are provided on a 'best efforts' basis, that is, without any special arrangements concerning availability, priority or reliability. For this reason, commercial services are mostly used for operational and administrative purposes (chapters 3 and 4). Ongoing developments in the technical standards that underpin the delivery of mobile technology — and in particular 4G technology — are providing scope for PSAs to be offered better service levels using commercial networks (chapter 5).

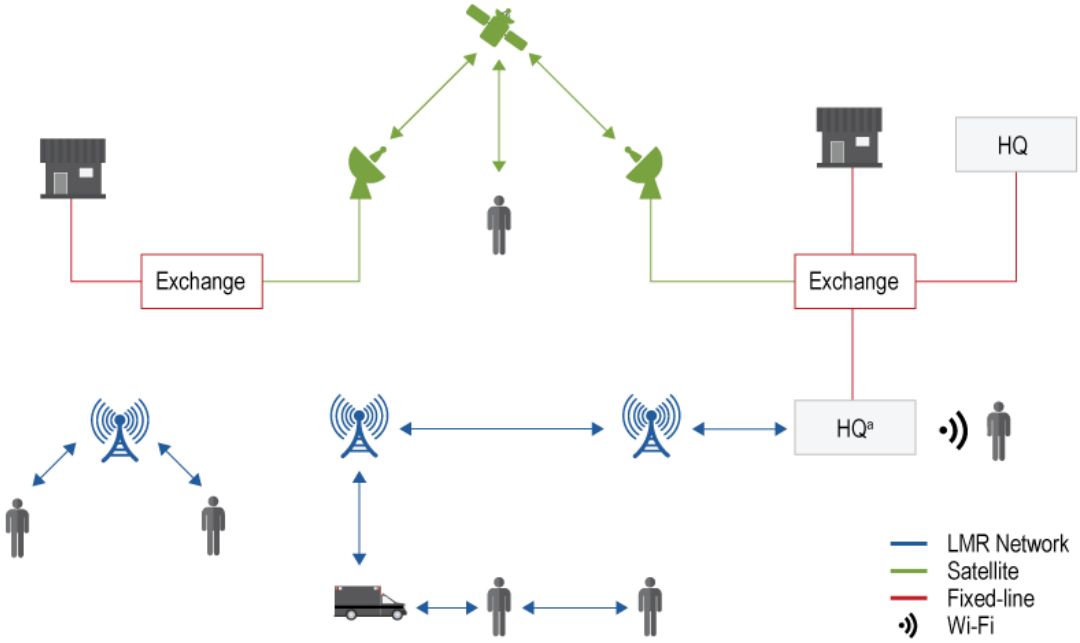
Key elements of communication networks

Although conceptually useful to think of communication networks as standalone, networks that are interlinked (through the use of 'gateway devices') can share common pieces of infrastructure (BAI, sub. 1). For example, in figure 2.2, when person A calls headquarters, both the satellite network and the fixed-line network are used to complete the call. Likewise, should person B wish to send an email to house A, the Wi-Fi, fixed-line, and satellite networks are used.

This 'any-to-any' connectivity is a standard feature of most communication networks, in particular those used by the public. For example, making a call between the Optus and Vodafone mobile networks is seamless. However, PSA networks are typically less interlinked than public networks due to differing (often proprietary) standards used on each network, because the gateway devices that link the networks are prohibitively expensive, or because the networks are truly standalone, that is, they are not physically connected to any other network.

Figure 2.2 **Communication networks**

Any-to-any connectivity of communication networks



[a] HQ stands for headquarters

Further, while commercial networks are often national or international in scope, dedicated PSA networks are typically delineated by jurisdictional boundaries. As responsibility for emergency management principally vests with state and territory governments, PSA networks are typically geographically dimensioned with only the state- or territory-level jurisdiction in mind. This has resulted in a clear demarcation of PSA networks at the jurisdictional boundary, which can lead to interoperability issues with cross-jurisdictional operations, particularly during large disasters (section 2.7).

Spectrum is an essential input into wireless networks

All radio networks, whether they carry voice or data, utilise radiofrequency spectrum when transmitting signals. To minimise interference and to ensure spectrum is allocated to its highest value use, some parts of the radiofrequency spectrum are subject to detailed planning (box 2.7).

Box 2.7 The need to plan spectrum

The range of available spectrum is theoretically infinite, however parts of the spectrum are more suited for a given use than others.

Lower-frequency signals are less affected by objects in their path, such as foliage and buildings, whereas high frequency signals can carry more data (where more bandwidth is available) but are limited to line-of-sight communication. This tradeoff leads to some parts of the spectrum being considered 'water-front property' for many uses, where an ability to propagate through built-up urban environments is balanced against the capacity to carry large amounts of information. Spectrum in this range (around 400 MHz to 900 MHz) is ideal for mobile telephony, television broadcasting and some types of radio communications.

It is not possible for everyone to transmit using the same frequency. In general, radio antennae cannot distinguish between multiple signals of similar strength on the same frequency, leading to interference between users. This rivalrous nature of spectrum necessitates regulation and planning of its use, which is achieved by:

- restricting who can transmit on a given frequency
- ensuring that there is sufficient separation between frequencies used to transmit a signal
- specifying the maximum transmission power of devices and, hence, the geographical area in which that frequency is used.

In addition to preventing interference, planning allows countries to harmonise their use of spectrum. This involves designating certain frequency bands to be used for specific purposes, which allows both continuity of critical services between countries and the exploitation of economies of scale by industry. For example, the planning of transmission frequencies helps coordinate services that are international in nature, such as emergency and distress communication, maritime services, and aeronautical services. Businesses also benefit from technical standards that allow them to make devices that are compatible for use in multiple markets, leading to economies of scale.

Sources: ACMA (2013b); Carney, King and Maddock (2015).

Wireless communication networks used by PSAs commonly use spectrum located in either the High Frequency (HF), Very High Frequency (VHF) or Ultra High Frequency (UHF) bands. As the choice of spectrum frequency comes with tradeoffs concerning coverage, building penetration, data-capacity and interference, the spectrum band deployed will in part depend on the performance requirements expected of the service (table 2.1). However, in general, long-range low data rate services such as paging are confined to frequencies in the VHF band (148–172 MHz); voice services are located in the lower parts of the UHF band (403–520 MHz and 820–870 MHz); and services that require a very high data rate or for which a direct line of sight can be reliably established, such as network backhaul, Wi-Fi or satellite communication, are located in the upper portions of the UHF band.

Table 2.1 **Propagation characteristics and uses of different frequencies used by PSAs**

Illustrative examples

	Frequency	*Propagation distance*[a]	*Foliage penetration*	*Typical use in radio communications*
HF	3 to 30 MHz	50 to 1 000+ km	Highest	Long-range communication
VHF high-band	148 MHz to 172 MHz	5 to 120 km	High	Rural voice, paging services
UHF low-band	403 MHz to 520 MHz	1 km to 50 km	Low	Metropolitan voice and data
UHF mid-band	820 MHz to 870 MHz	0.5 to 25 km	Low	Dense urban voice and data
UHF high-band	Up to 2.5 GHz	line-of-sight	Lowest	Communications backhaul, Wi-Fi, satellite

[a] Propagation distance is also a function of output power. Values are for typical power outputs.

Sources: ACMA (2009); Victorian Department of Justice (2010).

PSAs use multiple standalone, single-application networks. The technical characteristics of spectrum combined with the limitations of analog and early digital technologies have resulted in each application (or, where data services are concerned, a loose grouping of applications based on bandwidth) being provisioned over its own dedicated network. Further, lack of coordination between PSAs has in some areas led to a duplication of networks that both provide a similar capability but operate completely independently of each other. As a result, PSAs' communication needs are typically met through an abundance of standalone, single-application networks, often with each network operating on a different frequency and with different standards (figure 2.3). In some jurisdictions (such as Victoria), these networks are shared between PSAs. However, in others, individual PSAs operate their own independent networks.

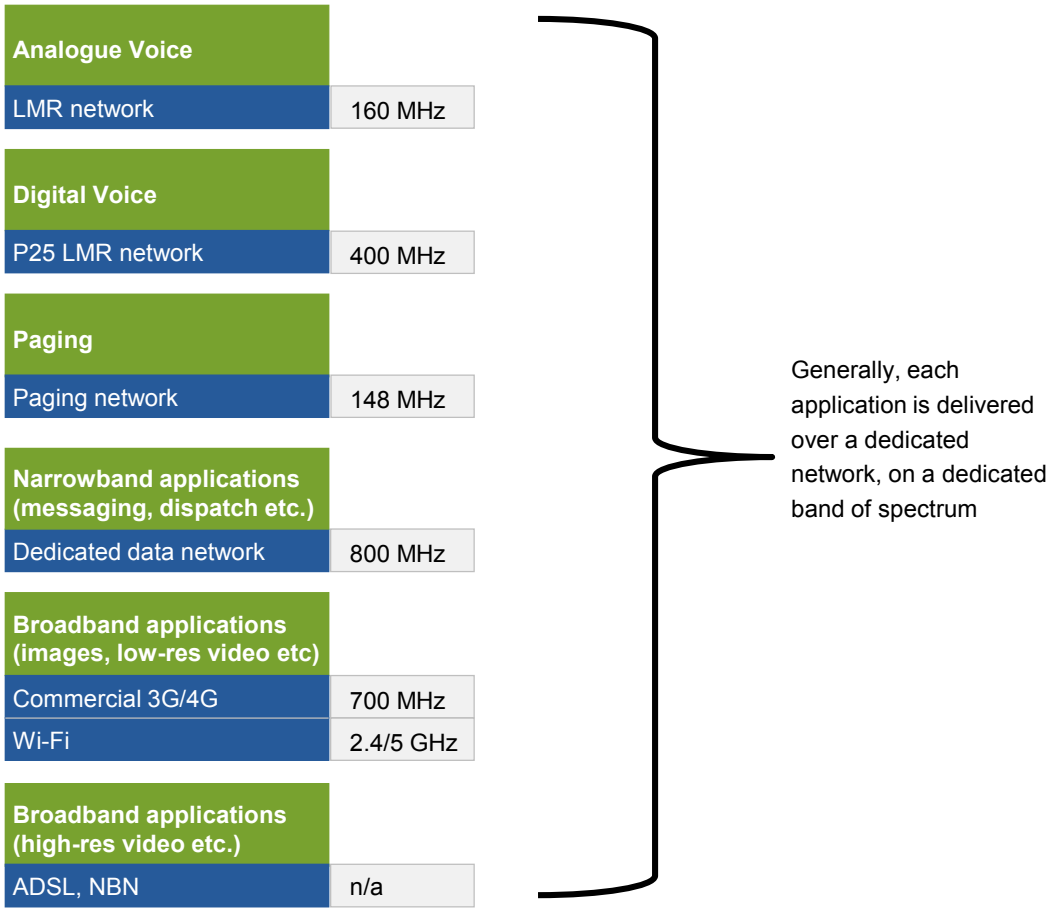
The first four applications of figure 2.3 (analog and digital voice, paging, and narrowband applications) are supported by different types of dedicated LMR networks. With the recent development of commercial mobile broadband services (circa mid-2000s) and the wide availability of broadband internet, broadband applications such as imaging and video are available to PSAs in some areas.

Land mobile radio networks

LMR networks enable wireless communication between land stations (typically towers, but may include aircraft or maritime stations), mobile stations and end-user devices such as handsets and MDTs (ACMA 2014e).

Figure 2.3 **A disparate set of networks is used to deliver a suite of applications**

Based on Victorian PSA communication infrastructure



Sources: ACMA (2012); Victorian Department of Justice (2010).

LMR networks can be grouped into three types, based on the applications that the networks support, including:

- voice networks (colloquially known as 'two-way radio' networks), which can be either:
  - analog — capable of transmitting analog voice. These networks have extremely limited data capabilities
  - digital — capable of transmitting both digital voice and low-speed data
- dedicated data networks — networks used exclusively for data transfer. These may have been considered high speed upon deployment, but are generally seen as low-speed by today's standards
- paging networks — simple alerting and text messaging.

Different types of LMR networks can be both complementary or substitutable for each other. For example, data networks are complementary to voice networks – they introduce

new capabilities to PSAs, such as the ability to access databases, but cannot completely replicate the push-to-talk functionality of a voice network. This is also true of paging systems, as the ability to send out an alert to personnel is an integral, but distinct, part of PSA communications. Accordingly, in a given jurisdiction these networks are typically run in parallel with one another.

Analog and digital voice networks are substitutable, but in practice PSAs often continue to run analog networks where digital voice is available. This is a byproduct of the piecemeal approach to upgrading analog voice networks to digital, where only parts of a network are upgraded at one time.

LMR voice networks

LMR voice networks form the backbone of PSA mobile communications. Trunked analog networks (box 2.8) constitute the largest radio communication networks used by PSAs across Australia, although digital networks are used in all capital cities.

Box 2.8 **Trunked radio and Talkgroups**

Radio communications occur over 'channels' — a slice of spectrum centred on a given frequency. In analog networks each channel can only carry one voice transmission at a given time; if someone else is transmitting on that channel, then no one else will be able to transmit until the channel is clear.

One way to organise networks is to group users by either functional need or geographic location and assign them a specific frequency to use for radio communications. This approach raises two issues.

- There are only so many channels available, limiting the number of 'groupings' that can be made.
- These channels will often be left idle, representing an inefficient use of resources.

Trunked radio is a computer controlled system that allows sharing of radio channels. Instead of reserving a physical channel for exclusive use by one user group, users are grouped into virtual channels called 'talkgroups'. When a member of a talkgroup wishes to communicate, the computer finds an unused channel and automatically moves all members of the talkgroup to the new channel. Unless the network is congested, this all occurs automatically and in a fraction of a second, such that the switch in channels is unnoticeable to the user.

Trunked radio systems either enable communication to take place with fewer designated channels or, for a given number of radio channels, a greater number of user groupings. Either way, the end result is a more efficient use of spectrum resources.

Source: RadioReference (2015).

Analog LMR networks possess many of the operational and functional requirements sought by PSAs, including:

- push-to-talk

- direct mode operation
- the ability to set up talkgroups
- high availability
- relay capabilities
- one-to-many communications.

Digital LMR networks meet the same operational and functional requirements of the analog networks, but with the addition of clearer voice, greater capacity, and additional functionally, such as man-down alarms, GPS tracking and encryption (box 2.9).

Box 2.9 **PSA use of data networks**

How data networks are used by PSAs varies between jurisdictions. The following examples are illustrative of major metropolitan regions around Australia.

Victoria Police

- Computer Aided Dispatch link to the Emergency Services Telecommunications Authority
- Access to the Law Enforcement Assistance Program, a fully relational database that stores details of all crimes brought to the notice of police as well as family incidents and missing persons
- Access to firearms and vehicle registries
- Shift reporting and remote submission of patrol duty running sheets
- Support for BlueNet Automatic Number Plate Recognition program

Victoria Ambulance

- Computer Aided Dispatch link to the Emergency Services Telecommunications Authority
- Event information, remarks and real-time updates
- Relay resource status and availability back to dispatch
- Ability to log and submit employee information

Sources: Victoria Police (2015); Victorian Auditor-General (2014); Victorian Department of Justice (2010).

LMR paging networks

All states and territories have a dedicated LMR network for paging purposes. Paging is used primarily as an alert tool, notifying personnel of a need to either contact an operator for further information or to report to their stations, where further information will be provided. Paging networks are a one-way broadcast, with generally no means for the recipient of the message to use the network to communicate back to the controller. As the data requirements of a page are low, often consisting of only a few lines of text, and coverage is of paramount importance, paging networks typically operate at lower frequencies.

Paging networks are known to suffer from reliability issues, especially throughout periods of congestion. During emergencies it is not uncommon for messages to be significantly delayed or fail to be delivered to their intended recipients. For example, during the 2009 Victorian bushfires, the transmission speed of the paging system was reduced to expand reception coverage, leading to serious delays in all but the most urgent messaging (VBRC 2010). Compounding the issue is an inability for PSAs to see if their message has been delivered, with corresponding uncertainty as to whether alternative communication channels should be mobilised. In some cases PSAs are using text messages as a form of redundancy to the paging network.

LMR data networks

For the purposes of this study, the term 'LMR data network' will be limited to standalone networks deployed for the specific purpose of supporting applications that rely on data. Under this definition, digital LMR voice networks would not be considered data networks. While the digital LMR voice networks currently used in Australia all have some ability to send data, the networks are generally very slow (for example, P25 phase 2 networks — a commonly used standard — achieve maximum speeds around 20 per cent of a dial-up modem) and the vast majority of their capacity is used for voice communications.

Information sent over a LMR data network is typically displayed to the user via a MDT. These are in-vehicle computerised devices consisting of a screen, keypad, periphery devices and associated software. The applications available to PSAs will depend on the technical specifications of both their MDTs and the LMR data network, as well as the software and database architecture of PSAs' information technology systems. Applications that run on hand-held devices, such as iPads, are typically provided over commercial networks, not LMR data networks.

Commercial mobile voice and 3G/4G networks

PSAs use commercial mobile networks for voice and data communication both officially, that is, through contracts and arrangements with the commercial carriers, and unofficially, at the initiative of individual members (including volunteers).

Commercial mobile networks are used extensively to meet PSAs' back-office and administrative communication needs, including voice services for non-frontline staff and management, remote access to email, and general mobile web-browsing. The relatively non time-critical nature of these applications means that occasional service unavailability, while undesired, can be tolerated. More recently, some PSAs have begun utilising commercial mobile networks to assist with everyday activities and provision of services (box 2.10).

Box 2.10 Applications of commercial broadband services

Many PSAs are starting to integrate mobile devices running over commercial networks into their operations (chapter 3).

- Most states' and territories' police forces are in the process of distributing tablets and other mobile devices to their members. For example:
  - as of April 2015, the Queensland Police Service (QPS) had distributed 2000 iPads to field officers. Amongst other functions the QLiTE application, built by QPS' internal information technology team, enables remote access to state and federal databases, and supports a streamlined infringement issuing process.
  - in early 2015, NSW police commenced a trial of 500 Samsung tablets, allowing police to access databases, issue infringements and record intelligence while on patrol.
  - the Northern Territory Police Force is undertaking a similar iPad roll-out to all of its 1300 frontline officers.
- The Queensland Ambulance Service is rolling out an iPad application that allows paramedics to report patient cases while on the road. Paramedics can now receive the details of a job directly from central dispatch and enter patient information into the system while on the move.
- South Australian Ambulance Service vehicles have been fitted with mobile data terminals. Since late 2012, paramedics responding to an emergency are given on-the-road updates about the patient and the incident via a real-time feed from the ambulance dispatcher in Adelaide.

Sources: Cowan (2014); Coyne (2015); Francis (2015); Moran (2013).

Commercial services are being used 'unofficially' by public safety officers

It is difficult to determine the extent to which public safety officers use their own devices on commercial mobile networks while at work. However, anecdotal evidence suggests this use is not insignificant. Use appears to be more common in volunteer organisations such as the SES and volunteer fire brigades, often for coordination purposes. For example, upon receiving a paging message, SES volunteers may liaise outside of official channels to coordinate their response (although this is not endorsed or encouraged by organisational practice or policy) (Victorian SES, pers. comm., 6 August 2015).

PSAs operating in rural areas have also been known to use commercial mobile networks and Citizen Band radio when encountering blackspots in LMR voice network coverage (Victorian SES, pers. comm., 6 August 2015). However, while unofficial use of personal devices on commercial networks may have tacit approval in some circumstances, the Commission has heard that some PSAs have banned these devices outright out of safety and confidentiality concerns.

Fixed-line networks

PSAs use fixed-line networks to obtain broadband internet, voice telephony, teleconferencing, video conferencing, and fax services. These services are almost wholly supplied by the commercial sector. Fixed line services are also used to support other communication services, such as Triple Zero calls (box 2.3) and the Emergency Alert system (box 2.4).

Wi-Fi networks

Wi-Fi is a wireless network technology standard. The term Wi-Fi has become synonymous with enabling devices to access a fixed-line home or office broadband connection through a wireless access point. Wi-Fi uses spectrum located in the internationally recognised 2.4 GHz and 5 GHz bands, but power restrictions typically limit public Wi-Fi equipment to ranges measured in the tens of metres (ACMA 2014g).

As Wi-Fi is essentially an extension of a fixed-line broadband connection, the technology supports all data applications that can be used over the internet and 3G/4G networks. Wi-Fi is ideally suited for short-range, high capacity networks either temporarily deployed in support of an incident (such as mesh networks), or permanently fixed in areas with high expected use or throughput requirements (such as video surveillance links, or in command centres) (ACMA, sub. 14). PSAs are yet to fully integrate deployable Wi-Fi networks into their regular operations, so on a practical level the use of Wi-Fi is currently restricted to either office and business applications or non-real-time applications, such as 'store-and-forward' or 'data off-load', where information is stored on a device until it comes within range of an appropriate connection.

Satellite networks

Satellite is used primarily for communication in areas of Australia where there is no LMR or commercial network coverage. This includes large parts of Western Australia, Queensland, South Australia, the Northern Territory, western New South Wales and mountainous regions of Victoria and Tasmania. Satellite also acts as a redundancy measure should primary communication networks fail.

Although satellite networks possess a vast coverage footprint, the technology is no panacea. Satellite communication can be impacted by weather events such as storms, heavy rain or smoke and ash clouds, limiting availability. This is problematic for PSAs as many of their peak communication needs occur during events characterised by these weather phenomena. Further, satellite coverage is not universal, with regions of reduced reception or complete black spots.

Capacity of data networks

All networks have a different capacity to carry data. The speeds achieved by the user depend on many factors, such as the number of people accessing the network, the location of the user (near the tower or at the cell edge, proximity to an exchange), or whether they are inside or outdoors (chapter 5), making precise comparisons difficult. However, as each network typically represents a several-fold or even an order of magnitude difference on other technologies, precision is not needed to compare the capabilities of different networks. Table 2.2 compares the range of typical speeds a user could expect on networks employed by PSAs.

Table 2.2 **Speed and coverage comparison of data networks**

Technology	*Typical data rate (kbps) (approximate)*	*Current coverage area*
Fixed-line broadband	50 000	na
Wi-Fi coupled with fibre connection	50 000	30m (indoors, public licence)
Wi-Fi coupled with ADSL 2+ connection	10 000	30m (indoors, public licence)
4G	14 000	Approx. 3% of landmass[a]
3G	3 500	Approx. 30% of landmass
Satellite	2 600	National
LMR data network[b]	96[c]	Most capital cities
P25 digital network	9.6[c]	Metropolitan and some regional areas

[a] Based on 94 per cent population coverage (Telstra, sub. 19) and an assumption that these networks cover the most densely populated regions. [b] Based on Victoria's Mobile Data Network. [c] Maximum data rate. **na** Not available.

Sources: iiNet (2015); Motorola Solutions (2011); NBNCo (2014); OpenSignal (2015); Simpson (2014); Sydney Morning Herald (2014).

Coverage footprints of voice and data networks

To perform their duties effectively, PSAs require access to a suite of communications tools which work irrespective of geographic location or population density. Depending on the incident, PSAs might need to operate in remote areas, deep inside buildings, or below ground.

Two metrics are used to measure the coverage of communication networks: geographical coverage, that is, the proportion of the total landmass covered; and population coverage, that is, the proportion of population covered by the network based on residential address. Geographical coverage is important to PSAs as, for some, their operational jurisdiction extends statewide, with an obligation to respond to an emergency regardless of location. However, as the majority of PSAs' activities are undertaken within or close to the

community, coverage must include as large a proportion of the population as reasonably possible.

All states and territories achieve high population coverage, but geographic coverage varies

The topography and population distribution of Australia means that the population coverage of communication networks is much higher than geographical coverage. Most of Australia's population is concentrated in the south-eastern and eastern coastal regions, and the south-west corner of Western Australia (figure 2.4). Within these regions the population is further concentrated in urban centres, particularly the capital cities. This means that it is possible to dimension a network to cover only a relatively small proportion of a state or territory's landmass yet still cover a large majority of its population. In this way, geographical coverage of the different communication networks (paging, LMR and commercial 3G/4G) varies greatly between jurisdictions, but population coverage of these networks remains close to uniform.

Some PSA networks — such as StateNet in Victoria and the Tasmanian Ambulance Service LMR network — provide extensive geographic coverage of their jurisdictions, at around 95 per cent (Victorian Department of Justice 2010). Geographic coverage in other jurisdictions is lower, reflecting either their topography or population distribution. The combined coverage of the LMR networks used by PSAs is difficult to ascertain as networks often overlap, methodologies for calculating coverage can be different (for example, in-car or handheld), or the combined coverage area is unclear due to differences in how jurisdictions report coverage levels. Anecdotal evidence suggests that combined LMR voice networks have a larger geographic footprint than any other communication network operating in Australia, except satellite. However, this may overstate the coverage available to any one PSA, as rarely do PSAs have end-user devices that can access networks in other jurisdictions or even equipment to access the networks of other PSAs in their state or territory.

PSAs also supplement their permanent LMR networks with temporary transportable coverage. Transportables can be used to provide greater:

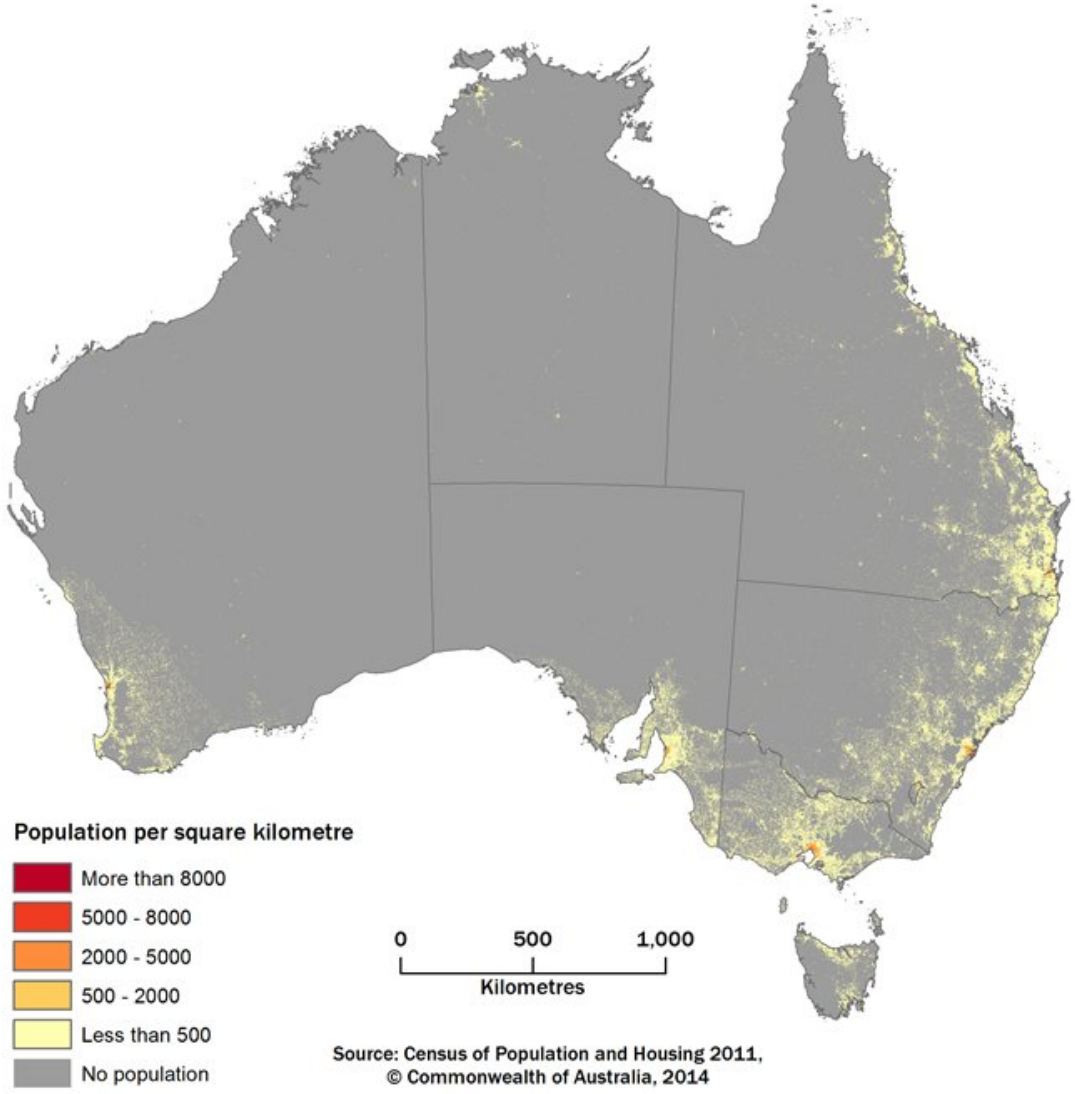
- *coverage* in areas where there is currently no or very poor reception
- *capacity* in areas where there is coverage but when it is overwhelmed during an incident.

In many jurisdictions, individual PSAs have deployed their own standalone LMR voice networks. Often this has been for security reasons, such as a need to limit the audience of police communications, but it is also a byproduct of communication responsibility historically falling within the remit of individual PSAs rather than a coordinating state- or territory-level body. This is the case in:

- Tasmania, where Tasmania Police operate a separate network to the joint Tasmanian Fire Service and Ambulance Tasmania networks (Tasmanian Auditor-General 2014)
- Queensland, where in some regional areas the Queensland Police Service, Queensland Fire and Rescue Service and Queensland Ambulance Service all operate on separate networks
- Western Australia, where St Johns Ambulance operates a dedicated statewide system.

These networks are dimensioned in a way that reflects the needs and operational reach of each agency, which may be overlapping but will not be identical (MFB, sub. 6).

Figure 2.4 **Australian population density, 2011**



Source: ABS (2014).

Coverage of LMR data networks is limited to metropolitan areas

Some Australian capital cities (such as Perth, Sydney and Melbourne) have deployed an LMR data network.

Increasingly, coverage footprints of LMR data networks are being augmented with coverage from commercial mobile networks. This is enabling PSAs in some regional areas to access data-based applications, while also providing a redundancy measure for blackspots and outages experienced within the original LMR data network. For example, the second generation of MDTs used by Victoria Police allowed roaming onto Optus' 2G/3G commercial network outside the coverage of the Mobile Data Network. A third generation of terminals currently being trialled will enable roaming onto Telstra's 3G/4G network on a 'best efforts' basis, effectively achieving whole-of-state population coverage.

2.6 Institutions, governance and regulatory arrangements

Primary responsibility for emergency management rests with state and territory governments — they have discretion to set their own emergency management agenda along with the accompanying appropriation decisions, including how much funding will be available and how it will be distributed between agencies. The Australian Government's role is largely limited to leadership on issues that require coordination, such as spectrum allocation, and supporting states and territories to develop their capacity for dealing with emergencies and disasters. This may involve physical and financial assistance to states or territories when they cannot reasonably cope during an emergency (PC 2014a).

Arrangements in states and territories

Emergency services constitute a ministerial portfolio in all states and territories, with the minister holding wide-ranging responsibilities relating to appropriation, policy development and crisis management. Precise administrative arrangements differ between the states and territories, although generally the various fire and SES agencies are administered together, with police administered separately (in most cases under the same minister). Ambulance services are also administered separately, either under the department of health or fully privatised.

All jurisdictions procure communications services independently of each other. In some jurisdictions (for example, Victoria, New South Wales and Queensland), major procurements of communications services are handled through a central agency. The role of these agencies is to provide a centralised resource for coordination and expertise, which allows PSAs and other government departments to focus on their core missions, and to realise scale efficiencies (NSW Telco Authority 2015; PSBA 2015). In cases where a

central communications agency does not exist, PSAs are responsible for procuring their own communications services.

For commercial services, individual PSAs are responsible for their own procurement and contracts.

Coordination across jurisdictions is improving

To date, national emergency planning across the states and territories has been piecemeal and lacked coordination. Following the 2009 Victorian bushfires and other natural disasters in the mid-to-late 2000s, governments at all levels recognised the need for a more cooperative and collaborative approach (COAG 2015).

At the intergovernmental level, the Council of Australian Governments (COAG) is the principal forum through which state and territory cooperation is advanced. In 2009, COAG tasked the National Emergency Management Committee to drive and coordinate the development of the National Strategy for Disaster Resilience, a whole-of-nation approach to disaster management (Australian Emergency Management Institute 2011). Through the Standing Council on Police and Emergency Management, COAG continues to work on improving disaster relief and recovery arrangements, including the *National Framework to Improve Government Radiocommunications Interoperability 2010–2020* (box 2.11).

Box 2.11 National Framework to Improve Government Radiocommunications Interoperability

In 2009, the Council of Australian Governments endorsed the *National Framework to Improve Government Radiocommunications Interoperability 2010–2020*, developed in collaboration with the National Coordinating Committee for Government Radiocommunications.

Noting that agencies responding to emergencies are often hampered by low levels of radio communication interoperability, the National Framework provides guiding principles and key areas of work for jurisdictions to enable transition towards interoperability. The Framework aims for all Australian governments to transition their domestic radio communications equipment to interoperable systems, modes and frequencies by 2020.

Source: COAG (2009).

States and territories are at different stages of the LMR network procurement cycle

Each state and territory government makes investments into LMR infrastructure based on its own budgetary priorities and PSA requirements. As a result, not all jurisdictions are at the same stage in the procurement cycle (table 2.3).

Table 2.3 **Recent procurements**

	Cost ($m)	*Install date*	*Expected life*
NSW Government Radio Network (NSW)	250–450	1993	Rolling upgrades
Melbourne Metropolitan Radio Network	261	2004	9 years
Mobile Data Network (Vic)	140	2006	9 years
Government Wireless Network (Qld)	457	2014	15 years
South Australian Government Radio Network (upgrade)	175	2017	12 years
Police Metro Radio Network (Perth)	58	2007	na
NT Digital radio	13	2010	na

na Not available.

Sources: CDMPS et al. (sub. 7); Critical Comms (2015); NSW Telco Authority (2015); The Drum (2010); VDTF (2015a, 2015b).

Some states, such as Queensland and South Australia, have made significant recent investments into digital radio for their PSAs. These investments are expected to have a life of between 12 and 15 years, with contracts for service extended as far as 2029. Other jurisdictions have either made these upgrades earlier (such as Victoria) with the assets currently 'midlife', or are expected to upgrade their digital radio networks in the near future.

Arrangements at the Australian Government level

The Australian Government acts as the coordinating body for issues of national interest. This includes administration and funding of the Australian Federal Police and Australian Maritime Safety Authority, spectrum planning, and broader legislative and enforcement responsibility relating to competition and infrastructure access.

The Australian Government has responsibility for spectrum planning

As a rivalrous, non-excludable resource, spectrum requires management and coordination to maximise the value of its use. In Australia, spectrum is managed by the Australian Communications and Media Authority (ACMA), an independent statutory authority whose objectives, responsibilities and powers in relation to spectrum management are detailed in the *Radiocommunications Act 1992* (Cwlth) and other related legislation (box 2.12).

Spectrum planning is carried out in concordance with an overarching international framework. Under the auspices of the United Nations, the International Telecommunication Union (ITU) issues the *Radio Regulations*, a supranational technical document that allows for coordination on radio communication issues such as spectrum allocation and harmonisation. As a signatory to the ITU, Australia has obligations under international law regarding compliance with these regulations (appendix B).

In carrying out its duties, ACMA prepares a spectrum plan which divides available spectrum into frequency bands. The *Australian Radiofrequency Spectrum Plan 2013* is the broad level technical map that allocates certain sections of the radiofrequency spectrum to various types of services. While the majority of the Spectrum Plan is consistent with the ITU *Radio Regulations,* there are some national variations (ACMA, sub. DR35).

Box 2.12 The Australian Communications and Media Authority

The Australian Communications and Media Authority (ACMA) is the independent statutory authority responsible for regulation of most elements of Australia's media and communications landscape. Through regulations, derived standards and codes of practice, ACMA seeks to ensure that Australia's media and communications sectors operate effectively and efficiently, and in the public interest.

ACMA is a 'converged' regulator, created to bring together the regulation of the main channels of communications: telecommunications, broadcasting, radio communications and the internet. ACMA has responsibilities under four principal acts: the *Radiocommunications Act 1992* (Cwlth), the *Telecommunications Act 1997* (Cwlth), the *Telecommunications (Consumer Protection and Service Standards) Act 1999* (Cwlth) and the *Broadcasting Services Act 1992* (Cwlth). ACMA also has responsibilities under other Acts, such as maintenance and monitoring of the Do Not Call Register.

ACMA manages spectrum in accordance with the Radiocommunications Act. This Act gives ACMA powers related to the planning of radiofrequency spectrum for specific uses, the licensing of radiocommunication spectrum and equipment, and powers to issue standards and other technical regulations.

Source: ACMA (2014d).

For some of these bands, in particular those which are congested, ACMA will issue a 'band plan' instrument (ACMA, sub. DR35). These plans are used to provide a more detailed description of spectrum allocation applicable to different services, often down to individual channel assignment. The spectrum bands that PSAs use to operate their radio communication equipment are mostly subject to these detailed band plans.

Some PSA radio communications are migrating to the 400 MHz band

In 2008, ACMA conducted an extensive examination of PSA communication needs through a wide-ranging review of the 400 MHz band. As part of a holistic strategy to facilitate national interoperability (in accordance with the COAG framework), ACMA decided to migrate some government radio communications to the 400 MHz band (ACMA 2012). This 'harmonised government segment' is primarily for government agencies providing security, law enforcement and emergency services. However, not all government radiocommunications services will operate in the 400 MHz band, with some services continuing to operate in VHF bands (ACMA, sub. DR35).

Harmonising government services into a single band is a necessary step to achieving national interoperability between PSAs and other emergency services agencies (ACMA 2014a). ACMA commenced this migration in 2012, with key milestones set for government agencies to transition to the harmonised band (ACMA 2015d).

- 31 December 2015 — relocation of government services in high- and medium-density areas into the harmonised government band.
- 31 December 2018 — relocation of government services in low-density and remote areas into the harmonised government band.

As of June 2015, 54.5 per cent of total apparatus licences in these bands had transitioned ahead of the milestone (ACMA 2015e).

2.7 Limitations of current PSA communication capabilities

The communication capabilities of PSAs are different between each state and territory, and between each PSA. Considering there are eight states and territories in Australia and three major PSAs in each state or territory, it is not practical for the Commission to assess the suitability of current arrangements for all 24 individual cases. However, there are some common themes.

LMR voice networks are resilient and have extensive coverage

The LMR networks used by PSAs have proven to be reliable in a range of strenuous circumstances, over several decades of operation. While not infallible, LMR networks are often the only communications network that continues to operate during disasters, such as the 2011 Queensland floods and 2015 Hunter Valley floods. New digital LMR networks are being built to a 'five nines' (99.999 per cent) service standard, or the equivalent of a maximum of 5.26 minutes of down time per year.

The geographic coverage of LMR networks is extensive. In most states and territories, no other network offers the same geographic coverage of the combined LMR voice networks, although there are some caveats. LMR networks are adept at covering large areas and penetrating foliage, but lack in-building coverage in some areas. Blackspots are also present, most often in remote regions (VBRC 2010).

LMR voice networks lack interoperability

The use of standalone LMR voice networks based on different standards, frequencies and using different end-user devices results in a lack of technical interoperability, that is, an

inability for one set of equipment to communicate with another set on a technical level. This results in several issues for PSAs.

- PSA radio equipment may not work in other states or territories. This is a particular problem when PSAs are deployed interstate during large-scale emergencies.
- PSAs within the same state or territory using separate networks will not be able to communicate directly with each other without expensive network bridging equipment.
- PSAs will be limited to the coverage footprint of a single network.

Some PSAs have arrangements in place to work around interoperability issues. For example, Victorian Country Fire Authority radios are installed in all Melbourne Fire Brigade appliances, and the Department of Environment and Primary Industries maintains a cache of radios to provide to other agencies (VBRC 2010). However, these arrangements are expensive and are not scalable in a way that provides universal technical interoperability.

In jurisdictions where technical interoperability is possible, procedural and operational barriers to interoperability remain. All PSAs use a command hierarchy to some extent, whether to ensure proper accounting and efficient use of resources or as a means by which superiors can maintain situational awareness. Such a structure cools enthusiasm for allowing public safety officers to communicate directly with one another. Terminology can also vary between agencies. Chapter 7 discusses steps governments and PSAs can take to improve operational interoperability.

LMR voice capacity is insufficient in some areas

LMR networks are at different stages of their asset lifecycles. For some, this means that dimensioned capacity is in excess of what PSAs currently use. For example, the Government Wireless Network in Brisbane had ample spare capacity during the G20 Leaders' Summit, which is likely to be the largest operation that the area will see for the operational life of the network.

There are examples of LMR networks becoming congested during weekly peak periods and during emergencies. Congestion has proven to be a problem during emergencies (such as the 2009 Victorian bushfires and the 2011 Queensland floods), particularly in rural and remote areas. Some networks (such as the Metropolitan Mobile Radio network in Melbourne) suffer from congestion each evening as additional protective service officers start their shifts (Victorian Auditor-General 2014).

Analog LMR networks lack security

Historically, voice transmitted over an analog LMR network has been unencrypted. This exposes PSA communications to interception by members of the public who own the

appropriate equipment, such as police scanners. More recently, PSA radio communications have been available for streaming from dedicated websites or via mobile phone apps.

Upgrades to digital radio systems in many states and territories have improved the security and integrity of these systems. However, several analog LMR networks (mostly in regional areas) are yet to be encrypted, meaning that anybody with an internet connection can listen in to these radio communications, potentially compromising confidentiality and PSA operations.

LMR data networks are slow and have limited coverage

The dedicated LMR data networks deployed in some metropolitan areas are slow when compared to commercial offerings (section 2.5). This limits the type of applications that can be used over the network to those with very low throughput requirements (such as text-based queries and photos). Coverage of these networks is typically limited to metropolitan regions, with extensions throughout the state or territory (where offered) via roaming agreements with commercial mobile carriers. These roaming agreements are on a 'best efforts' basis and do not guarantee PSAs the same level of service as on the dedicated LMR data networks.

Commercial networks are used to support operational — rather than 'mission critical' — activities

Commercial mobile broadband services provided on a 'best efforts' basis have proven to be highly beneficial in supporting public safety operational activities, however agencies are reluctant to rely on these services for mission critical activities due to concerns about service quality (chapter 4). In particular, PSAs have suggested that there have been instances where the coverage and capacity of the commercial networks has not met users' expectations (MFB, sub. 6; Victoria Police, sub. 17).

At present, the reliability of commercial networks does not match that of LMR voice networks. While rare, events do occur in which commercial networks are unavailable for an extended period of time, such as during the 2015 Hunter Valley floods or the 2014 Warrnambool exchange fire. In both these incidents, LMR networks continued to operate.

FINDING 2.1

The land mobile radio networks used by PSAs are reliable and have extensive geographic coverage (for voice only). However, they only support low-speed data applications, and they lack technical interoperability. This can prevent PSAs from communicating with one another, and means that radio equipment does not work upon crossing jurisdictional borders.

3 Framework for analysis

Key points

- Public safety agency (PSA) use of mobile broadband applications has the potential to improve the quality of public safety services, the operational efficiency of PSAs and the safety of officers.
- Take up of mobile broadband applications by PSAs has been limited due to concerns about the quality of commercial mobile broadband services. Key issues include the ability of PSAs to get priority access to — and sufficient capacity on — commercial mobile networks during times of congestion, and the reliability of commercial networks relative to land mobile radio networks.
- The Commission has undertaken a first principles analysis to determine the best way to deliver a public safety mobile broadband (PSMB) capability to PSAs. (The Commission has not been asked to assess whether there should be a PSMB capability.) The analysis has involved:
  - understanding the mobile broadband requirements of PSAs, in terms of network capacity and quality of service
  - identifying options that could feasibly meet these requirements, including a dedicated PSMB network, an approach reliant on commercial networks, and a hybrid approach
  - evaluating the costs, benefits and risks of each option from the perspective of the community as a whole.
- Data limitations and uncertainties mean that not all costs, benefits or risks can be quantified. In particular, a lack of suitable information has meant that the benefits and risks of each option cannot be quantified in monetary terms.
  - As the options under evaluation have been designed to deliver a similar level of PSMB capability, the impact of each option on public safety outcomes (and thus, its benefits) is not expected to vary markedly.
- The Commission has also examined broader considerations that will need to guide policy decisions, including governance models, procurement processes and the practicality of implementation.

This chapter explores the opportunities that mobile broadband offers public safety agencies (PSAs) and the factors that may be limiting uptake to date. It also describes the Commission's first principles approach to analysing the best way to deliver a mobile broadband capability to PSAs.

3.1 Mobile broadband can enhance public safety

Mobile broadband (and the applications it supports) is dramatically changing the way people communicate and share information. However, PSAs' uptake of mobile broadband has been modest to date due to concerns about the quality of service offered over commercial mobile networks and the inability of land mobile radio (LMR) networks to support data-rich applications. Greater use of mobile broadband could be achieved (and the associated benefits realised) if PSAs had access to a capability that was better aligned with their needs.

Mobile broadband is changing the way people share information

Mobile broadband refers to the wireless delivery of an internet service over a mobile network, including through phones, tablets and portable modems. The underlying technologies used to deliver mobile broadband have undergone significant advances — from the 2G (second generation) networks that have carried voice calls and text messages since the 1990s, to the 4G (fourth generation) networks that allow real-time video streaming today (box 3.1).

Mobile broadband technologies are still evolving: new features are being added to 4G networks (and the underlying technical standards) each year (chapter 5). Some companies have even started referring to, and have sought to develop, fifth generation high-speed mobile broadband technology (Analysys Mason 2015).

The use of mobile broadband by consumers and businesses has grown rapidly (figure 3.1).

- The number of mobile broadband subscriptions globally has increased twelve-fold since 2007, and these now outnumber fixed-line internet connections (ITU 2015).
- In Australia, total mobile broadband data use increased tenfold in the three years to 2014 (ACCC 2015b), and has been projected to increase by 38 per cent each year between 2013 and 2017, with traffic over 4G networks in particular increasing at 76 per cent annually (CIE 2014).
- Data downloaded in Australia as at June 2015 equated to 1.1 gigabytes per subscriber in that month (ABS 2015).

Mobile broadband has had a substantial impact on the Australian economy. For example, a recent survey of businesses attributed an average saving of 1.4 per cent in overall operating costs to mobile broadband (CIE 2014). It can also increase business productivity by facilitating more productive use of time (allowing internet access from anywhere) and faster decision making. Businesses use mobile broadband in a range of ways, including through corporate applications and online data storage, and to engage with customers.

Box 3.1 Evolution of mobile broadband

Several technologies have been used to provide mobile data services in Australia. The three major commercial carriers (Telstra, Optus and Vodafone) operate overlapping networks, using different technologies, and most user handsets can access more than one type of mobile network.

- 2G (second generation) networks were launched in Australia in 1993. These provide digital voice communications as well as low-speed data, including text messages, multimedia messages and caller identification.
- 3G (third generation) networks were introduced in Australia in 2005 and deliver significantly faster data rates than 2G networks. Services on these networks have enabled mobile internet browsing, and audio and video streaming.
- 4G (fourth generation) networks were launched in Australia in 2011. These enable even faster data speeds, with lower latency (delays) and reduced network congestion. 4G networks can provide peak download speeds of up to 100 megabits per second, rivalling the speeds offered by some fixed-line networks.

Ongoing investment in 3G and 4G networks means that 2G networks may be shut down in the near future. For example, Telstra has announced that it will close its 2G network by the end of 2016.

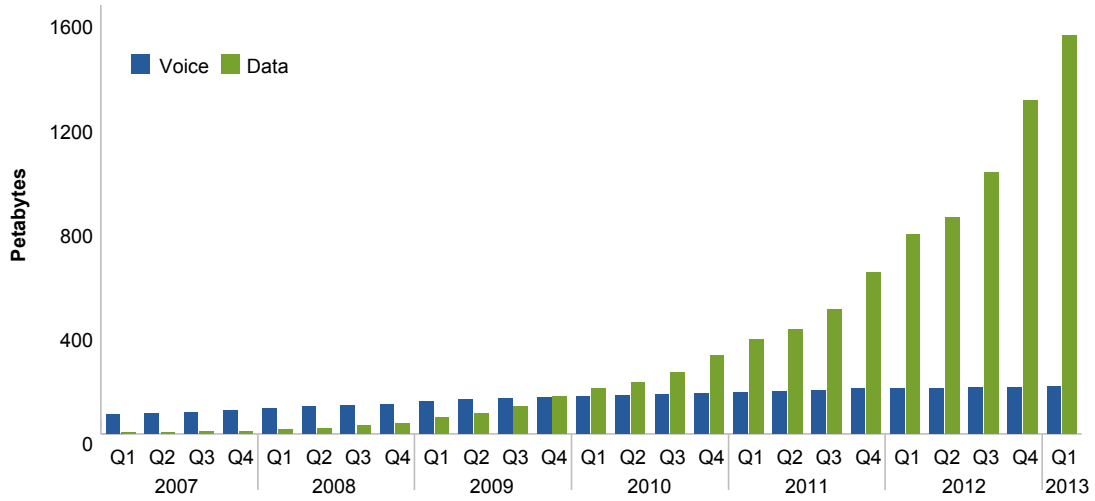
At present, the three commercial carriers are continuing to expand their 4G networks to meet a similar level of population coverage as their 3G networks. Data transfer happens over both 4G and 3G networks (depending on a user's handset and location, and network congestion).

Voice calls and text messages are predominantly transferred over 3G and 2G networks. However, Telstra has begun providing voice services over 4G networks, and Vodafone plans to follow suit in 2015.

5G (fifth generation) mobile networks offer higher data speeds and capacity compared to earlier technologies. 5G is not expected to become commercially available in Australia until around 2020, as further work needs to be done on technical standards before network infrastructure and handsets can start being rolled out.

Sources: 3GPP (2014); ACCC (2015b); ACMA (2014c); Kidman (2015); Telco Antennas (2014); Wright (2015).

Figure 3.1 **Global data traffic in mobile networks**



Source: Ericsson (2013a).

Mobile broadband presents a significant opportunity for public safety

Public safety operations are becoming increasingly information driven. Mobile broadband applications (such as location tracking, biometrics, live video streaming, image transfer and dispatch messaging) offer significant potential to improve the efficiency and effectiveness of public safety services, fundamentally changing the way these services are delivered.

For example, mobile broadband applications can allow:

- police officers to access databases when out in the field, to use facial recognition technology or electronic fingerprint matching (biometrics) and to collect and transmit key evidence
- ambulance officers to remotely access medical records and expert assistance (remote diagnostics), or send images or other data (such as electrocardiogram readings) to the hospital while in transit
- fire officers to remotely access maps, building plans and locations of hazardous materials to locate incidents more quickly and identify how best to respond; or to stream video of a fire front from an aerial vehicle (for example, a drone or helicopter) to a control centre.

The community is the ultimate beneficiary of these applications, through reduced property damage and crime, fewer injuries and deaths, and better quality health care.

Mobile broadband also provides a way to more effectively share information between the community and PSAs. Members of the public are increasingly providing agencies with valuable information — such as photos of unfolding crimes and live video of floods and bushfires. The potential benefits of this information were widely recognised by study participants (for example, ATF, sub. 4; MFB, sub. 6; Victoria Police, sub. 17). However, the ability to share these data with officers in the field is limited at present (chapter 2).

PSAs are already using some mobile broadband applications (over commercial mobile networks) to establish and maintain a common operational picture between field officers and command, and between individual officers (box 3.2). PSAs are predominantly relying on commercial mobile services to support these applications. These are provided on a 'best efforts' basis — that is, PSAs are treated more or less equally with other customers over the commercial networks.

FINDING 3.1

PSA use of mobile broadband applications has the potential to improve the quality of public safety services, the operational efficiency of PSAs and the safety of officers.

There is a widely held view among study participants that PSA use of mobile broadband has been modest and piecemeal to date, and that PSAs are not fully realising the opportunities that mobile broadband presents. Participants suggested various ways that PSAs (and the broader community) could benefit from using mobile broadband more expansively (box 3.3).

The main reason for low uptake of mobile broadband by PSAs is concerns about the quality of service offered over commercial mobile networks. Study participants pointed to the fact that PSAs are not offered priority access to commercial networks during times of network congestion. They also expressed concern about the coverage of commercial networks (relative to LMR networks), and the susceptibility of commercial networks to outages during natural disasters and other kinds of interruption (MFB, sub. 6; PFA, sub. 8).

As a result, PSAs tend to limit their use of mobile broadband applications to low-risk situations, and are reluctant to use commercial mobile broadband services during 'mission critical' operations (chapter 4). PSAs have suggested that until a public safety grade service is available, they are unlikely to make widespread use of mobile broadband or undertake significant investments in mobile devices, upgrades to systems or protocols, or personnel training (ACT Emergency Services Agency, sub. 25).

Box 3.2 How are PSAs using mobile broadband applications?

Ambulance

The NSW Ambulance Service uses mobile broadband to check and update electronic patient records in transit, reducing the time spent on administrative tasks and enhancing the quality of services delivered to patients. There has also been some use of high-bandwidth video to provide early remote diagnosis and treatment of stroke victims. The NSW Telco Authority has identified this as an important source of benefits from PSMB.

Fire and rescue

NSW Fire and Rescue is using mobile broadband for:

- automatic vehicle location services, which can facilitate faster vehicle dispatch
- a first responder in-vehicle tablet application that provides officers with information and remote access to operating guidelines and databases
- in-vehicle applications for voice and video communications and inventory checks.

In Victoria, the Metropolitan Fire Brigade uses unmanned aerial vehicles to capture photos and videos of areas that are difficult or dangerous to reach, thus saving time, protecting officers and enhancing situational awareness.

Police

Victoria Police use a mobile application to simplify processes for family violence reporting. It allows officers to pre-populate reporting forms with information already captured and stored in databases. As information is entered into the application, it is instantaneously updated in the database entry. Reporting changes are estimated to have released an extra 72 000 police hours for patrol and proactive duties, at an equivalent value of $3.8 million.

Victoria Police also uses commercial mobile broadband in its traffic enforcement vehicles, which are equipped with in-vehicle video, automated number plate recognition systems (to alert officers of stolen vehicles, unregistered vehicles, or other offences linked to a number plate) and mobile terminals that provide remote database access.

Tasmania Police recently deployed over 1000 tablet devices, providing frontline police officers with remote access to secure databases and other applications. Officers can now write up statements from witnesses and victims of crime, as well as accident and crime reports, in the field, resulting in more time spent out in the community. Time savings over a six week trial were estimated at one day per tablet used.

The Commission understands that police in other Australian jurisdictions are also using mobile broadband for database checks, administrative tasks and other purposes.

New Zealand Police began a roll-out of smart phone and tablet devices in 2013, with 7000 iPhones and 4100 iPads issued to frontline officers. Significant benefits were achieved, including an estimated time saving of 30 minutes per officer per shift, mostly due to mobile broadband applications that allow officers to respond to situations more effectively and move from one job to the next without returning to the station.

Sources: Acer Computer (2014); Fire & Rescue NSW (pers. comm., 14 July 2015); MFB (2013); New Zealand Police (2014); NSW Telco Authority (sub. 30); Telstra (2015b); Victoria Police (2014); Victorian Government (sub. 28).

Box 3.3 PSAs could make greater use of mobile broadband applications: participant views

Study participants strongly supported providing PSAs with a public safety grade mobile broadband capability.

> [I]t is our firm view that police and ambulance officers, firefighters, paramedics, and other public safety agency frontline personnel have demonstrated a clear need for a dedicated nationwide wireless broadband network to support their operational needs. (BAI, sub. 1, p. ii)

> [H]aving 21st Century mobile broadband communications is also vital to police officer work health and safety, particularly officers working on the front-line. Police officers need the best in intelligence about offenders they are pursuing, up-to-date situational awareness, and data, video and other forms of critical information to operate most effectively and safely in the interests of the community and their own welfare. (PFA, sub. 8, p. 2)

> Reliable broadband data capabilities will support the exchange of timely and accurate information in the field. Integrating agency networks enables better coordination and improved service delivery outcomes for the community. (Victorian Government, sub. 28, p. 6)

Video-based applications are seen as offering significant benefits to PSAs. These applications can improve the situational awareness and preparedness of PSA officers, and facilitate the provision of remote medical support.

> Sharing live video feed among PSA officers in the field and backend command control centre is becoming very important for these entire PSMB operational scenarios. (NEC, sub. 5, p. 5)

Participants also considered that a PSMB capability could be used to enhance PSA communication with the public.

> With regard to communications between the PSA's and the community, it is critical in times of disaster, both for the PSA's to advise community safety aspects, but even more importantly as part of the information gathering systems as in many cases it is data on 'social media' that provides an additional information to incident commanders on how to respond. (ATF, sub. 4, p. 11)

> Communications between PSAs and the community is a growing area of focus within Victoria. Traditional means of communications, such as radio and television are now augmented by a range of new media including mobile apps, social media, web pages, Emergency Alert, Next Generation Triple Zero etc. Broadband communications infrastructure to reliably inform the community of vital emergency information is already regarded as a mandatory requirement … (Victorian Government, sub. 28, p. 15)

The implication is that greater benefits could be realised if PSAs increased their use of mobile broadband. Participants argued that concerted action by governments and others is needed to provide a public safety grade service that PSAs can rely on (PFA, sub 8; CAA, sub. DR36).

FINDING 3.2

PSAs' uptake of mobile broadband applications is limited at present due to concerns about the quality of commercial mobile services. Critical issues include the ability of PSAs to get access to and sufficient capacity on commercial mobile networks during times of congestion, and the reliability of commercial networks relative to land mobile radio networks.

Governments can facilitate PSMB

PSAs represent only a small fraction of potential demand relative to the wider consumer market. In practice, the services currently on offer from commercial mobile carriers fall short of what PSAs require for mission critical situations. Although the quality of services offered by mobile carriers is likely to continue to improve in line with general market developments, the risk is that these services do not improve to the extent that PSAs require (at least in the near term), or do not evolve in a way that facilitates PSA interoperability.

There is a general presumption that governments will need to intervene on behalf of their PSAs to facilitate greater adoption and take up of mobile broadband. This view was expressed by study participants and reflects actions being taken by governments in other countries to deliver mobile broadband to PSAs (appendix B).

Governments could become actively involved in facilitating PSMB in a number of ways. For example, they could:

- directly fund, own and/or operate a dedicated PSMB network
- pay one or more of the commercial mobile carriers to deliver a PSMB service
- provide additional funding or other inputs (such as spectrum) to PSAs that would help them to build or purchase a mobile broadband service
- collaborate with other jurisdictions and coordinate efforts to develop technical protocols and platforms for interoperability.

All these options would have benefits and costs for the community, including the costs that arise from directing resources away from alternative uses (opportunity costs). This study weighs up these benefits and costs, and considers how governments could best facilitate PSMB and the roles that PSAs will need to play in making use of it.

3.2 The Commission's first principles approach

The Commission has been asked to undertake a 'first principles' analysis to determine the most efficient, effective and economical way of delivering a PSMB capability to PSAs by 2020, giving consideration to:

- the need for the capability to be reliable and secure, be nationally interoperable across jurisdictions and agencies, provide PSAs with priority access, and operate in both metropolitan and regional Australia
- the relative costs, benefits and risks of alternative approaches for deploying a PSMB capability — including deploying a dedicated PSMB network, an approach that is reliant on commercial networks, or some combination of the two
- relevant domestic and international reports and experiences.

Analytical approach

The Commission has approached this task through the method of cost–benefit analysis (box 3.4). Cost–benefit analysis is a tool that can be used to rigorously and consistently assess a range of options for meeting a policy objective, and in a way that encourages decision makers to take into consideration all costs and benefits of a project (PC 2014b).

Box 3.4 Cost–benefit analysis

Cost–benefit analysis (CBA) is a method that can be used to evaluate whether an investment project or a policy makes the community better off overall compared to the status quo. It involves aggregating impacts on all members of the community and appropriately taking account of risks.

In CBA, benefits are valued according to the willingness of individuals to pay for them, which is often more than they would actually pay. For example, mobile broadband could improve the services that fire agencies provide to the community, thereby reducing risks to life and property.

Similarly, costs are valued according to the willingness of an alternative purchaser to pay for the resources involved (this is called 'opportunity cost'). In other words, the inputs needed to deliver a project are measured according to the value that is forgone by not using them in other economic activities. For example, funds spent on building mobile network infrastructure would not be able to be spent on other things that the community values, such as transport or education.

Importantly, CBA takes into account the value of the service to consumers beyond the price paid, and the cost beyond what is paid to the factors of production. CBA can also take into account any externalities — other costs and benefits — that fall on people outside those involved in the transaction.

The costs and benefits of projects and policies often accrue over a considerable length of time. To reflect this, the analysis is typically conducted over a long time period, such as 20 or 30 years. To take account of people's preference to receive benefits now rather than later, future values are discounted to a present value.

In general, projects with positive net benefits should be accepted. However, where there are mutually exclusive projects, the one with the highest net benefits should be preferred.

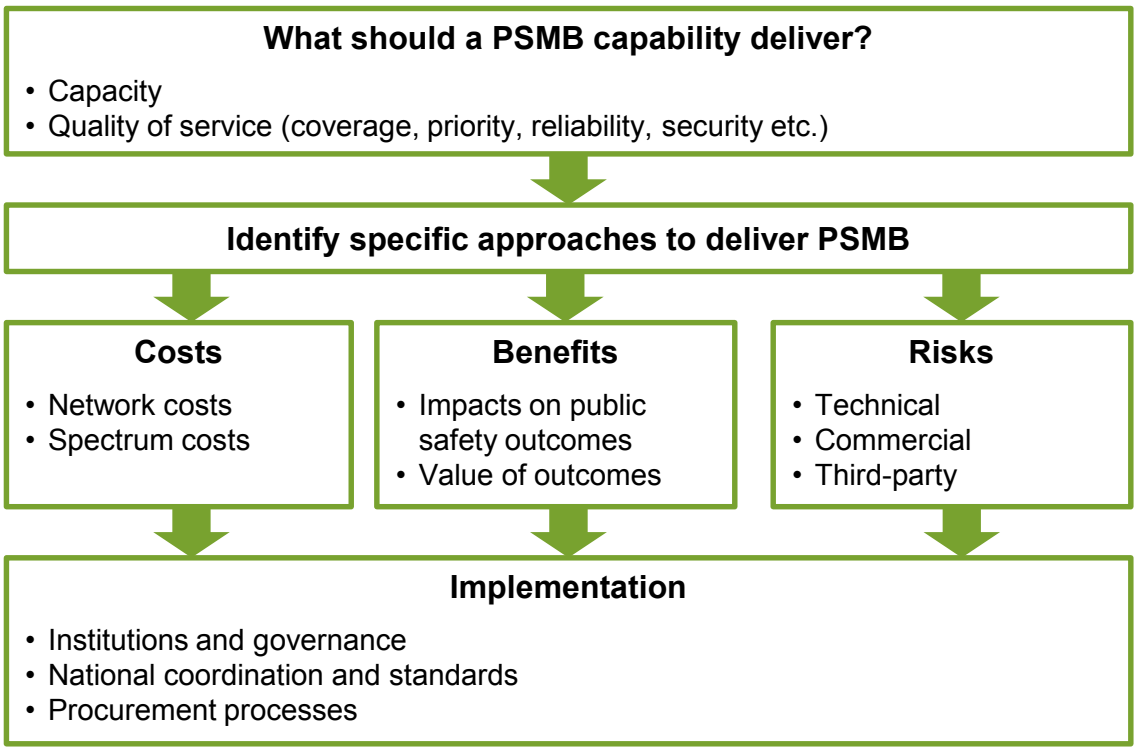
Sources: Baker and Ruting (2014); Department of Finance and Administration (2006); PC (2014b).

In undertaking this analysis, the Commission has sought to quantify as many elements as possible. However, it is not always feasible to express non-monetary benefits and costs in dollar terms. Particularly in regard to the benefits and risks of rolling out a PSMB capability, the Commission has described likely impacts qualitatively due to lack of data.

The process used by the Commission to apply cost–benefit analysis is summarised in figure 3.2. The first stage is to develop an understanding of PSAs' mobile broadband requirements into the future, taking into account the mission critical nature of public safety work and the associated service quality requirements (chapter 4). Drawing on these insights and other evidence, the Commission has sought to identify a range of PSMB scenarios that describe the level of network capacity that a PSMB capability could deliver.

A number of assumptions have been made about the quality of mobile broadband services delivered under these scenarios. These assumptions have been made to facilitate the quantitative analysis; they should not be read as a proposed or ideal standard for a mission critical PSMB network.

Figure 3.2 **The Commission's analytical approach**



The next step is to consider the various ways that a PSMB capability could be delivered. Specifically, the Commission has explored — in a qualitative way — some of the technical and cost implications of relying on different inputs and deployment approaches (chapter 5). This analysis is used to highlight some of the key drivers of costs and the tradeoffs between different deployment approaches.

There are many ways that PSMB could be delivered, and it is not practical to undertake a detailed evaluation of every possible approach. However, important insights can be gleaned from examining a discrete set of options. To this end, the Commission has specified and evaluated a number of specific PSMB delivery options that are realistic, technically feasible and sufficiently differentiated (chapter 6). This analysis illustrates — quantitatively where possible — the costs, benefits and risks associated with each option. It also examines the implications of using different types and quantities of inputs to deliver PSMB.

There is a range of implementation issues associated with PSMB that are difficult to assess quantitatively, or to capture through a cost–benefit analysis. While some of these

implementation challenges will arise regardless of how PSMB is delivered, others will vary by deployment approach. For example, the institutional and governance arrangements that underpin delivery of PSMB can affect the efficiency (or otherwise) of investment in, and operation of, PSMB networks. Implementation can also pose risks and challenges for governments, PSAs, the community and commercial providers. The Commission has examined these aspects of implementation and potential strategies that can be used to manage risk (chapter 7).

Evaluating PSMB options

The Commission has sought to evaluate the costs, benefits and risks of various PSMB delivery options over a 20-year time horizon.

Where possible, the costs of alternative options are evaluated in a quantitative way to show the relative importance of particular cost drivers or the magnitude of certain tradeoffs (box 3.5). The quantitative analysis is illustrative only and should be considered in the context of its limitations (discussed below and further in chapter 6). Chapter 6 and appendix C provide a fuller exposition of the approach taken to the quantitative component of the evaluation.

Box 3.5 A 'fit for purpose' quantitative analysis

This study undertakes a bottom-up quantitative analysis, involving three key steps:

- geotyping — using ABS data to assign different geographical areas of Australia to particular geotypes (dense urban, urban, suburban, rural or remote)
- radio access network dimensioning — estimating the number of mobile sites required to meet coverage and capacity requirements
- network costing — applying benchmark cost values (such as the costs of mobile base station equipment) to calculate total capital and operating costs.

The key output from the quantitative evaluation is a net present value of the cost of each option, assuming a 20-year time horizon (2018–2037). Importantly, the exercise is **not** designed to:

- produce precise estimates of the total costs of individual options, or individual cost components; rather, the focus is on relativities
- describe what the architecture of a PSMB network would look like in practice
- identify (in an exact way) the optimal mix of inputs for delivering a PSMB capability.

Costs

There are two main sources of costs to consider: the direct network costs of delivering a PSMB capability, and the potential indirect costs imposed on non-PSA users. Indirect costs are considered qualitatively due to data limitations (chapter 6).

The Commission has focused on two main components in quantitatively assessing the direct costs of PSMB:

- network-related costs (capital and operating expenditures) (box 3.6)
- spectrum costs.

Consistent with the principles of cost–benefit analysis, each of the above components is assessed in terms of its opportunity cost (the value of the next best alternative use). It is also measured incrementally — that is, the cost of delivering a PSMB capability relative to the status quo.

Box 3.6 Network-related costs

A number of network-related costs have been examined in this study. Many of these differ depending on the deployment approach being analysed.

Capital costs

- Radio access network sites and equipment (including towers, antennas and power equipment)
- Site hardening costs (including installing back-up batteries and upgrading civil features of the site to improve resilience and security)
- Core network and add-ons (including core network deployment, upgrades to provide priority services, gateways to link with land mobile radio networks and new operation and billing support systems)
- End user devices (including handheld devices and in-vehicle terminals)

Operating costs

- Network-level costs (including maintenance of mobile sites and other infrastructure components, and network management)
- Site leasing costs (including the costs of deploying new equipment)
- Backhaul leasing costs (including the costs of purchasing backhaul capacity)

End-user service prices are of limited use in the analysis, because the prices actually paid in markets do not always reflect the underlying costs. For example, market prices currently charged for end-user services may reflect the cost of *past* investment — or imperfections in the market — rather than the underlying cost of inputs needed to deliver a PSMB capability in *future*. The Commission's analysis is focused on these underlying input costs,

regardless of who owns existing infrastructure or finances the deployment of PSMB (these matters are dealt with separately).

Some cost components can be interdependent. For example, the quantum of spectrum used may have a bearing on the magnitude of network costs needed to provide a given level of capability to PSAs (chapter 5). Similarly, the choice of spectrum band may influence network and end user equipment costs, since only some spectrum bands are supported by existing network equipment and end-user devices. Where non-supported spectrum bands are used, there would be a need for customised (and therefore more costly) end-user devices.

For the purpose of the quantitative analysis, network-related costs are calculated based on publicly available data and a number of assumptions. The opportunity cost of spectrum is estimated with reference to market transactions of spectrum in the same or comparable frequency bands. Sensitivity analysis is used to assess how these assumptions and data inputs affect the quantitative cost estimates, and to provide an indication of the likely range of costs where there are uncertainties (chapter 6, appendix C).

Benefits

A mobile broadband capability does not generate benefits in its own right. Rather, it facilitates the use of various mobile applications, which in turn can improve the efficiency and effectiveness of public safety services, leading to outcomes or improvements that the community values. The benefits of PSMB therefore hinge on how PSAs actually use the capability to deliver public safety services.

Two types of benefits are relevant for the evaluation exercise — the value of improved public safety outcomes (such as lives saved or property damage avoided), and cost savings (or productivity gains) in the delivery of public safety.

To quantify these benefits, it is necessary to:

- identify how PSAs would use a PSMB capability to change their activities, operations and procedures
- identify how these changes would impact public safety outcomes, including productivity improvements
- express the outcomes in monetary terms (a consistent unit of measurement that allows benefits to be compared with costs).

While potentially large benefits could flow from a PSMB capability, the task that has been assigned to the Commission is not to measure the benefits of PSMB per se. Rather, the relevant issue is whether the benefits are likely to vary between alternative PSMB deployment approaches and, if so, the nature and magnitude of those differences.

There are multiple challenges involved in quantitatively estimating benefits. First, it is very difficult to assess how PSMB is likely to impact on public safety outcomes. This is because these outcomes depend on a wide range of factors, including other tools that PSAs use (such as vehicles and LMR networks) as well as external influences (such as individuals' actions, the weather and crime reduction policies). Complicating this is wide variation across PSAs in the activities they undertake, where they operate, and how they will adapt their operations to make use of PSMB.

A lack of suitable data on all these factors makes measurement extremely challenging. While study participants commented that there were significant benefits to be gained from PSMB, few of them were able to follow up with documentation of those benefits. Moreover, very few publicly available studies have attempted to quantitatively estimate the benefits of PSMB, and there do not appear to be any studies that have quantitatively estimated the benefits of alternative PSMB deployment approaches.

Second, it is challenging to estimate the value the community places on different public safety outcomes, due to limited information. While it is sometimes possible to draw on existing published estimates (such as of the costs of crime or value of a 'statistical life'), few estimates are available and applying these to a different context can be fraught with error (Baker and Ruting 2014).

Third, the extent to which benefits can be confidently estimated is limited by the significant uncertainty surrounding how mobile broadband will be used by PSAs over time and how technologies will evolve. For example, there is a wide range of applications that PSAs could potentially use, some of which may not have been developed yet. This is further complicated by the coexistence of other communications technologies, such as LMR networks and satellite phones. As the NSW Telco Authority (sub. 30, p. 63) has observed:

> The lack of maturity in a PSMB both here in Australia and internationally makes undertaking a quantifiable assessment of the benefits difficult, as a result there is little material in the public domain. Unlike costs, benefits will only be realised into the future once PSMB is available and so are difficult to quantify now.

Given these practical difficulties, the Commission has assessed the differences in benefits between deployment approaches in a qualitative way. In effect, the Commission has undertaken a cost-effectiveness analysis and supplemented this where feasible with a qualitative analysis of any differences in benefits between different delivery options. That said, because the options under evaluation have been designed to deliver a similar level of capability to PSAs, the impact of each option on public safety outcomes (and thus, its benefits) is not expected to vary markedly.

Risks

One of the main challenges in identifying and quantifying the costs and benefits of different options for delivering a PSMB capability is the high level of uncertainty surrounding the magnitude, nature and timing of the costs and benefits. There may also be risks associated with the procurement, construction and operation of a PSMB capability (chapter 6).

The Commission's evaluation focuses on risks that are likely to differ across delivery options. These can be grouped into three main categories:

- technical risks — for example, risks relating to construction cost overruns and delays, whether the capability meets PSA service requirements, and integrating technology over time
- commercial risks — for example, risks associated with being locked in to a specific supplier, differences in handset costs across options, or suppliers not participating in tendering
- third-party risks — for example, the risk of adverse impacts on consumers (or other groups) arising from disruption in the quality of service they receive over mobile networks, or due to reduced competition in the market.

These risks are diverse, and do not always lend themselves to quantification. The Commission has assessed these risks qualitatively, with a focus on how they might differ across delivery options (other risks may be common across options, such as delays in governments making decisions). In doing so, the ability to partly or fully mitigate risks under each option has been taken into account.

Challenges and limitations with quantitative evaluation

The limitations with any quantitative analysis and its interpretation have long been recognised. Albert Einstein is noted for saying that 'not everything that can be counted counts, and not everything that counts can be counted'. It is a case in point for assessing the costs and benefits of PSMB.

There are several challenges with quantitatively evaluating PSMB delivery options:

- the design (or 'dimensioning') of mobile broadband networks is technically complex, and involves a wide range of considerations and inputs
- a significant amount of data would be required to quantitatively analyse all the costs and benefits of a specific PSMB option, and these data do not always exist
- even where data inputs are available, there are critical gaps, such as where information is commercially sensitive and thus cannot be publicly reported.

While the Commission is not an expert in mobile network design, it has drawn on publicly available research and analytical exercises undertaken by others. It has also sought feedback on specific elements of its analysis through technical workshops and the draft report process, and from consultants, industry experts and commercial mobile carriers. Where commercial-in-confidence data have been received from study participants, these data have not been directly used in the quantitative analysis for reasons of transparency — doing so would make it difficult (or impossible) for the Commission's estimates to be reproduced and scrutinised. Nevertheless, these data have been helpful in forming views on specific benchmarks for various network cost components.

Finally, rather than attempting to identify a single best way forward for implementing PSMB, the Commission has sought to provide advice and guidance on key elements of PSMB deployment approaches and their implementation — including institutions, governance and procurement. This guidance is robust to a range of possible circumstances. This is essential given the differing circumstances of individual jurisdictions (and PSAs), and the impracticality of a one-size-fits-all solution.

4 What is a public safety mobile broadband capability?

Key points

- A mobile broadband capability can be described in terms of the network capacity available to end users and the quality of services delivered.
  - Network capacity refers to the amount of traffic that can be transmitted on the network at any given time and is often measured in bits per second.
  - Service quality has several dimensions, including coverage, reliability, security and interoperability.
- There is no single definition of a 'public safety grade' mobile broadband (PSMB) capability; a range of capacity levels and service quality standards could feasibly apply.
  - Public safety agency (PSA) demand for communications services increases significantly during emergency incidents (peak periods) relative to 'business as usual' periods. It is unlikely to be economic to provision a mobile network to cater for relatively infrequent peak demand periods.
  - Not all PSA demand needs to be met in real time. Demand management by PSAs is crucial to ensuring the net benefits of a PSMB capability are maximised.
  - The 'mission critical' nature of public safety activities means PSAs require a higher quality of service relative to other mobile customers.
- PSAs' future demand for mobile broadband network capacity is highly uncertain, as are the benefits of that use. Demand will depend on a complex range of factors, including the prices that PSAs face, the availability of alternative communications systems and technological developments. Attempts to generate a quantitative, 'bottom up' estimate or projection of demand would be extremely data intensive and unlikely to yield robust results.
- There is broad agreement that a PSMB capability should be of sufficient quality to support the use of mobile broadband data applications in mission critical situations. However, there is no single set of PSMB quality standards implied by this. A range of service quality characteristics and performance metrics could be relevant.
- The level of network capacity and service quality made available to PSAs should reflect the particular circumstances of individual jurisdictions: there is no 'one size fits all' solution.
  - Some jurisdictions may want to use PSMB networks to deliver mission critical voice services, once the appropriate standards are in place and there is a business case for retiring land mobile radio networks. Additional and/or stronger service standards may be required to support this.
- PSMB scenarios have been developed to facilitate the quantitative analysis. These scenarios allow delivery options to be assessed on an even keel and the cost implications of provisioning for different levels of network capacity to be illustrated.

A mobile broadband capability has two important dimensions — the quantity of mobile broadband services (or network capacity) available to end users and the quality of those services (section 4.1).

The key task for this study is to identify the best way to deliver a 'public safety grade' mobile broadband capability. What this means in practice is somewhat subjective; definitions vary and study participants presented a range of views. However, given the task at hand, it is useful to consider — at least in a broad way — what the capacity and quality dimensions of a public safety mobile broadband (PSMB) capability might look like.

A useful starting point is to consider the unique responsibilities and activities of public safety agencies (PSAs), and the role of mobile broadband communications in delivering public safety services (section 4.2). Detailed information about what PSAs are seeking from a mobile broadband service, including their willingness to pay (or demand), would also be useful. However, publicly available information is sparse, and there is significant uncertainty (section 4.3).

This notwithstanding, PSMB scenarios can be used to highlight the relative merits of different deployment approaches (dedicated, commercial or hybrid, section 4.4). Scenario analysis can also illustrate the cost implications of provisioning for different levels of network capacity. Ultimately, however, jurisdictions will need to decide what level of network capacity and service quality is in their best interests, taking into account the costs and benefits to the community as a whole.

4.1 Key dimensions of a mobile broadband capability

Network capacity

The 'quantity' of services that a mobile broadband capability provides is often described in terms of network capacity, though a number of other terms are also relevant (box 4.1). Capacity refers to the speed and volume of data that can be transmitted through a mobile network and is dependent on a range of factors. It can be measured in terms of bits per second (bps) available to end users at a given time and location (a speed or 'flow' measure), or in terms of the amount of data that can be transmitted over a given period of time (a volume or 'stock' measure). Capacity is of prime importance to mobile users because it determines the type and amount of mobile applications that can be used.

Many study participants have pointed to the importance of a PSMB capability providing sufficient capacity to public safety officers, particularly during periods of peak demand when networks become congested. However, as discussed in section 4.3, evidence on what this means for the level of network capacity required as part of a PSMB capability is sparse.

Box 4.1 Measuring the quantity of mobile broadband services

The capacity or throughput of a mobile network refers to the speed and volume of data that can be transmitted on the network at any given time.

Network capacity is dependent on a range of factors, including the technology used, and the type and amount of spectrum available (Ernst & Young 2011). The amount of capacity that an individual user can access at any point in time is affected by additional factors, including their distance from the nearest mobile tower or base station, environmental and topographical factors, and the type of device they are using (chapter 5).

Network capacity can be measured as a 'flow' (or speed), for example:

- kilobits per second (kbps): 1 kbps = 1000 bps
- megabits per second (Mbps): 1 Mbps = 1000 kbps
- gigabits per second (Gbps): 1 Gbps = 1000 Mbps
- terabits per second (Tbps): 1 Tbps = 1000 Gbps.

Stock measurements of mobile broadband networks are also used, such as the total volume of data used over a given period of time (for example, gigabytes or terabytes per year).

Mobile network capacity has two elements: uplink capacity and downlink capacity. The uplink capacity determines how much data end users can send (for PSAs, this could be field officers sending information about a scene or victims to other field officers or to central command). The downlink capacity determines how much data end users can receive (such as patient medical records or maps). PSAs are likely to have a high demand for uplink capacity, and exhibit a higher uplink–downlink ratio, relative to other mobile customers. This reflects the need for officers to transmit information and evidence from incident scenes back to central command (Alcatel-Lucent, sub. 15).

Quality of service

A number of characteristics of mobile broadband service quality are important to PSAs. The terms of reference specify that the Commission is to give explicit consideration to these characteristics in identifying the best way to deliver a PSMB capability.

Accessibility

Accessibility (in the context of PSMB) refers to the ability of PSAs to get on to (or connect to) a mobile network (box 4.2). Network accessibility can be measured in several ways, such as the portion of PSA access attempts that are successful in a given period (the access success rate (Telstra, sub. 19)), or the probability that a voice or data connection can be set up within a specified timeframe (NSW Telco Authority, sub. 30). Many study participants considered that PSAs need 'guaranteed' access to PSMB networks at all times (NSW Telco Authority, sub. 30; PFA, sub. DR40), though precise accessibility standards were not proposed.

Accessibility can be affected by congestion on mobile networks (there is a limit to how many users a network can support at a given time), and the reliability or availability of the underlying network infrastructure (no users will be able to obtain access if the network is unavailable).

Responses to this study suggest that PSAs are most concerned about network accessibility when they rely on commercial networks for mobile broadband services. Some participants pointed to occasions where they have had difficulty connecting to commercial mobile networks (as part of a 'best efforts' service offering) due to high demand from the general public (MFB, sub. 6; Victoria Police, sub. 17).

There are strategies that can be used by network operators to provide certain users — such as PSAs — with 'guaranteed' (or a very high probability of) network access, such as:

- setting aside a portion of spectrum that can only be accessed by authorised users
- providing authorised users with preferential access to mobile broadband networks, by making use of user prioritisation systems (discussed below).

These strategies could potentially be used by commercial carriers to deliver PSMB services to PSAs, as discussed in chapter 5. (Improvements to the capacity and robustness of underlying networks could also improve PSA accessibility rates, all else equal.) That said, implementing these changes would have costs. These costs would need to be weighed against the benefits of improving accessibility levels.

Some participants suggested that PSAs would experience higher levels of network accessibility under a dedicated (or standalone) network approach. However, a dedicated network is not immune from accessibility issues; indeed, over-subscription occasionally arises on land mobile radio (LMR) networks. Moreover, a dedicated network approach is unlikely to represent the most cost-effective way of providing public safety officers with a given level of network access, and provides little flexibility to scale-up demand in the short-term (chapter 6).

User prioritisation

User prioritisation refers to systems that prioritise some or all PSA officers, devices or applications over other traffic on a mobile broadband network (box 4.2). User prioritisation systems provide one way for network operators to improve the accessibility levels of PSA users (by prioritising their access attempts over those of others). Moreover, once PSAs obtain access to a network, prioritisation systems can be used to give precedence to PSAs' demand for network capacity (relative to other users' demand).

Motorola (sub. 12, p. 23) pointed to the importance of user prioritisation for PSAs being achieved in real time.

> There is a need for PSMB to support the ability for PSAs to not just statically prioritise but to dynamically prioritise users and applications, and even to 'pre-empt' other users by removing

them from the network when capacity is limited. … This dynamic prioritisation should not be simply limited to a user but rather, based on application type, user roles, agencies, incident types, mutual aid, quick action, and jurisdiction.

Box 4.2 What does it mean to guarantee accessibility and priority for PSA users?

Most public safety agencies (PSAs) are seeking a mobile broadband service that delivers 'guaranteed' network access and prioritises PSA traffic over other traffic. There are various ways that these requirements could be operationalised.

Static or dynamic accessibility and prioritisation

Static (or 'default') access and priority arrangements are determined based on the long-term needs of PSAs (that is, considering business as usual activities and possible emergency activities). For example, each PSA user might be allocated a particular profile or status, which determines how access and network capacity are allocated.

Dynamic access and priority are where the default arrangements are able to be changed in real time, potentially facilitating a more efficient response to unfolding emergency incidents (for example, if the nature and location of an incident render the default settings sub-optimal). A dynamic change could be triggered by various means, such as end-users pressing an emergency button on their device or turning on vehicle lights and sirens.

Access and priority on the basis of agency, user, device or application

Access and priority could be determined on the basis of the agency, the public safety officer, the device or the application. For example, mission critical voice applications could be given precedence over data applications and low priority voice, or location services and dispatch messaging could take precedence over video and file transfers. Assigning priority on the basis of device might also be desirable, such as for PSA workforces that are highly volunteer dependent or subject to churn. This approach might also suit in-vehicle devices, which have multiple users.

How should accessibility and prioritisation mechanisms be controlled?

A contentious issue is who is made responsible for administering access and priority mechanisms, and who has the authority to initiate or implement dynamic changes. As noted above, it may sometimes be desirable for public safety officers themselves to have the ability to trigger access and priority changes. In other cases, it may be more practical for an authorised administrator, dispatcher or incident commander to be the sole custodian of dynamic changes.

Can access and priority be 'guaranteed'?

In practice, it is not feasible to guarantee that a particular service standard will be met 100 per cent of the time. For this reason, service level commitments are typically defined in terms of an acceptable performance standard (for example, that a network is available 99.9 per cent of the time), or an acceptable risk of failure (less than 0.1 per cent). The same is expected to be true of access and priority mechanisms, meaning some acceptable level of failure would need to be specified.

Source: NPSTC (2012).

Other participants (such as the Police Federation of Australia (sub. DR40)) emphasised the importance of PSAs having direct 'control' over their priority status.

From a network operation perspective, user prioritisation can be achieved in different ways, including by reducing the amount of capacity available to other users (slowing down network access) or by 'load shedding' (or 'pre-emption' — that is, dropping some users off the network during high-traffic periods on a priority basis). In some cases, PSAs may be able to initiate changes to their priority status directly, provided they have the appropriate end-user devices and authorisations (box 4.2). User prioritisation is not just an issue where PSAs share a network with other users: it may also be desirable in a dedicated network approach to ensure that available network access and capacity are assigned to the most important PSA traffic.

At present, PSAs using commercial mobile broadband services are typically afforded only the same priority as other users (that is, they receive a 'best efforts' service). However, user prioritisation systems could be implemented under a commercial, hybrid or dedicated approach to delivering PSMB (chapter 5).

While a carrier would be responsible for network operation under a commercial approach to delivering PSMB, this would not preclude PSAs retaining control over the priority status of their officers, devices and applications. For example, contractual arrangements could set out how prioritisation is to be implemented (chapter 5). Moreover, dedicated and hybrid approaches to delivering PSMB would not necessarily give individual agencies or officers greater control over priority settings. It would still be necessary for PSAs to reach agreement ex ante on how access and capacity are to be allocated on a priority basis, the circumstances in which priority settings can be changed, and how.

Coverage

The coverage of mobile broadband networks is important to PSAs because it determines where in Australia they are able to access mobile broadband.

PSAs are responsible for protecting people, property (such as buildings, power stations and gas pipelines) and land (such as state forests and national parks). This means PSAs operate across a vast geographic area, including major population centres, rural, regional and remote communities, unpopulated areas and at sea. The ability of PSAs to use communications systems in these areas is dependent on the coverage of the underlying networks.

Network coverage can be measured in two ways: by estimating the percentage of the population that resides in the coverage area, or by estimating the land area or road distance covered by a network.[1] Both of these coverage measures are important to PSAs, and many

[1] Each of these calculations can be done in multiple ways, giving rise to potentially different coverage levels for the same network.

study participants considered that a PSMB capability should have the same network and geographic coverage as LMR networks (discussed below). The ability for public safety officers to access mobile broadband services indoors and underground has also been raised as an issue (Telstra, sub. 19).

Reliability (or resilience)

In broad terms, network reliability (or resilience) refers to the ability of the network to provide and maintain an acceptable level of service in the face of various faults and challenges to normal operation (ENISA 2011; NPSTC 2014). Network reliability is often measured in terms of:

- availability — the minimum percentage of time the network is functioning (or the maximum number of hours per year it is unavailable due to faults or unplanned outages)
- network recovery time — the time it takes to rectify faults and outages (such as mean down time, or mean time to repair, measured in hours).

For example, Telstra reports monthly against two measures of network reliability — the percentage of services that were fault-free, and the percentage of time on average that services were operational (Telstra 2015a). Reliability is measured nationally and across 44 metropolitan and regional areas.

Network availability is important to all network operators (and users), including the commercial carriers. Indeed, commercial network outages can lead to revenue loss, reputation risk and loss of customers.

However, a number of study participants considered that the reliability levels of commercial networks are too low to support public safety services, and do not match those of LMR networks. The Australian Radio Communications Industry Association noted that:

> Anecdotal evidence from major incidents, both within Australia and internationally, is that often the narrow-band systems continue to operate long after other communications systems fail. (ARCIA, sub. 2, p. 13)

As noted in chapter 2, during the 2015 Hunter Valley floods and the 2012 Warrnambool exchange fire (box 4.3), LMR networks continued to operate despite one or more of the commercial networks being unavailable.

Box 4.3 Warrnambool Telstra exchange fire

In November 2012, the Telstra telephone exchange at Warrnambool, in south-west Victoria, caught on fire due to an electrical malfunction. The exchange acts as a transmission hub for telecommunications, connecting about 100 000 people over a 15 000 square kilometre area. The exchange is an example of an 'infrastructure single point of failure':

> The trade-off between improved network resilience and the practicalities of network design and operation often leads to compromises that may result in the strategic acceptance of single points of failure existing within a network. (Gregory et al. 2014)

The fire caused significant damage to essential telecommunication equipment and had an immediate impact on the Telstra mobile network. Telephone, internet, mobile broadband, business services (for example, banking) and emergency services (including 000) were disrupted. Optus' 2G mobile network was also affected; however, its 3G network remained fully operational.

Sources: ACCAN (2014); Gregory et al. (2014); Optus (sub. 18).

Security

The data and information generated, stored and exchanged by PSAs is often highly sensitive and confidential. Protecting this information from disruption, interception and misuse is critical to the integrity of PSAs' operations and the privacy of individuals. For these reasons, PSAs typically require a more secure communication service than most commercial users.

The security of the *physical* network infrastructure is also important to PSAs. This means that network infrastructure is protected from malicious intent or natural events that could disrupt operation. An example of how the physical security of telecommunications infrastructure can be compromised is provided in box 4.3. Motorola (sub. 12, p. 20) noted that:

> As governments and PSAs consolidate and share communications solutions, these solutions become greater targets for attack and as such, measures must be taken to protect against the risk of both physical security and cyber security (firewalls, intrusion detection, antivirus, etc.).

The security of communications services and physical network infrastructure is typically described in terms of the techniques, strategies and infrastructure that are in place to uphold security. For example, communications security can be achieved through end-to-end encryption of voice and data communications (chapter 5).

Interoperability

PSAs and policymakers regard mobile broadband communications interoperability as crucial to achieving coordinated and efficient public safety services. In broad terms, mobile broadband interoperability implies that PSAs are able to continuously share data communications with other agencies — within and across jurisdictions — during

multi-agency and/or widespread incidents. Interoperability can be achieved at different levels of a PSMB capability — the network level, the device level, the application level and the agency level (chapter 5).

Network interoperability means that users on separate networks can communicate with each other. Device interoperability means that end-user devices can operate on other networks. Commercial mobile networks in Australia exhibit network and device interoperability — for example, Optus customers are able to call customers on the Telstra and Vodafone networks, and end-user devices (such as iPhones) are technically capable of operating on each of the carriers' networks. When a device is interoperable across networks it may be possible to enable 'roaming' — technical and commercial agreements between network operators that allow a device to automatically switch from one network to another as required.

Historically, one of the main limitations of LMR networks has been a lack of interoperability between different agencies and jurisdictions (chapter 2). Inquiries following the Victorian bushfires in 2009 and the Queensland floods in 2011 highlighted that the interoperability of LMR networks and devices is often poor and can limit the effectiveness and efficiency of PSA activities.

This issue is being addressed through the *National Framework to Improve Government Radiocommunications Interoperability*, endorsed by COAG in 2009. The objective of the framework is to transition all PSA narrowband (LMR) radiocommunications equipment to interoperable systems, modes and frequencies in the 400 MHz spectrum band by 2020 (COAG 2009).

In practice, achieving interoperability is about more than the technology solution. This is particularly the case for application and agency interoperability, which mean — respectively — that agencies are able to communicate using common applications, and share intelligence and other information where appropriate. For example, Victoria Police (sub. 17, p. 11) highlighted that interoperability depends on 'governance, training, and standard operating procedures', and cautioned that:

> … without a National Governance Structure the opportunity will be lost to truly operate nationally in a joined up manner, and deliver such broadband capabilities within and across borders in an unfettered secure and resilient manner.

Institutional barriers to interoperability are discussed in chapter 7.

Device compatibility

A key issue for many PSAs is the ability of officers to access mobile broadband using a wide range of field equipment, including 'off-the-shelf' devices (smart phones, tablets and laptops), customised devices and other equipment that supports mobile broadband applications (for example, communication devices in ambulances or police cars).

Participants stressed that such flexibility is important for containing the device costs faced by PSAs, accommodating the sizable volunteer base within the emergency management sector, and facilitating PSAs' uptake of mobile broadband applications (and the benefits that flow from this). Indeed, Rivada Networks (sub. 9, p. 16) considered that PSAs 'cannot evolve efficiently if they are burdened with paying a premium for specialised devices that are not offered with the benefits of commercial economies of scale'.

Voice integration

Voice (delivered over LMR networks) is the principal way that PSAs communicate. A range of voice services and applications are relied upon heavily by PSAs, including push to talk, one-to-many communications (group calls and talk groups), dispatch and emergency alerting (chapter 2).

In the future, it is likely that PSAs will want to consolidate voice and high speed data traffic onto a single network (NSW Telco Authority, sub. DR46). However, when and whether this happens will depend on a range of factors, including the ability of mobile broadband networks to integrate (and deliver) the voice services that PSAs rely upon to an equivalent or better quality (relative to LMR) and the lifecycles of existing LMR infrastructure and systems.

Various characteristics of voice service quality are important to PSAs, especially during mission critical situations, including:

- latency, that is, the time taken to initiate communications (such as how quickly a user can talk on the system after pushing a button), and how soon others receive the transmission. In narrowband LMR systems, any talk group member can initiate a group call by pressing a single button and the call is established in less than half a second (TETRA MoU Association 2004)
- the quality and integrity of the audio that is transmitted. For example, in mission critical situations, the listener must be able to understand without repetition, identify the speaker, detect stress in a speaker's voice, hear background sounds and so on
- the ability to operate push to talk one-handed. Some applications developed for smartphones require users to hold the phone in one hand and push a button on the touch screen. This may not be acceptable for certain roles and circumstances affecting public safety officers.

The latency of data services (such as real-time video) delivered over PSMB is also important to PSAs. In this context, latency refers to the time it takes for a packet of data to be delivered to its destination and is usually measured in milliseconds. In practice, data packets can be held up in long queues, or take a less direct route to avoid congestion, increasing latency.

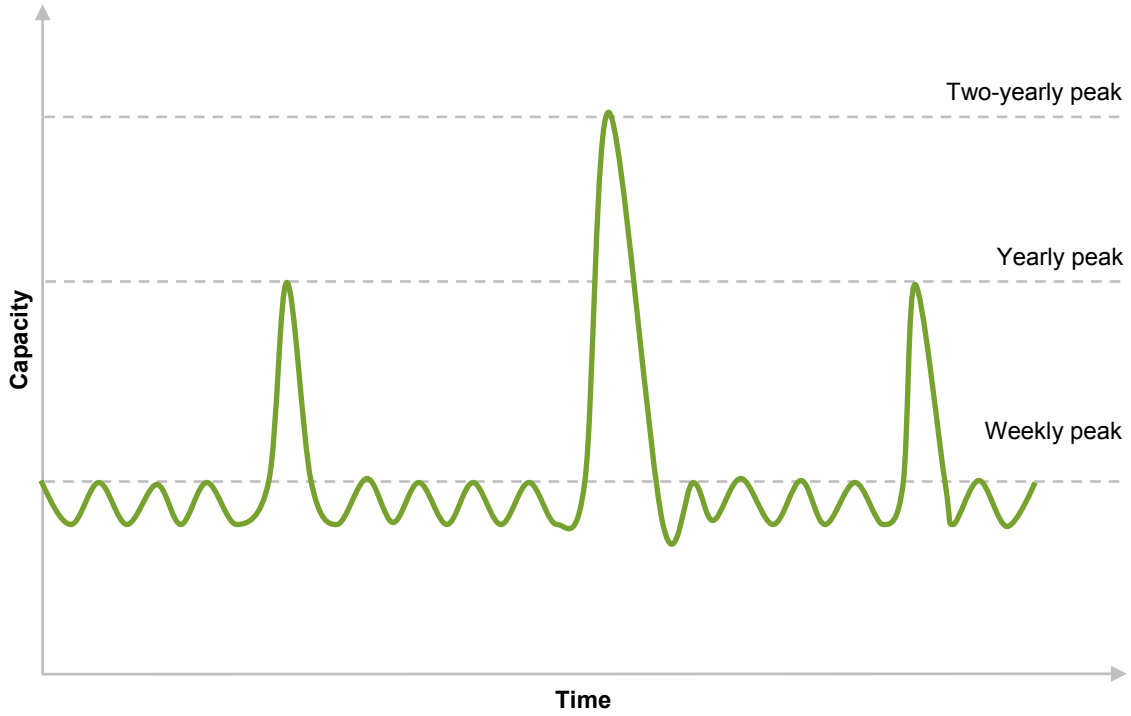
4.2 How are PSAs different to other mobile broadband customers?

The distinct nature of PSAs' activities and their demand for mobile broadband services (and communications services more generally) is important for considering the amount of network capacity, and the quality of service, that a PSMB capability should deliver. ('Demand', as it is described here, does *not* refer to how PSAs' network usage relates to price or 'willingness to pay'; it is therefore not a true measure of demand, as economists usually define it.)

PSA demand for mobile broadband is 'peaky'

The network capacity that any PSA requires will vary over the course of a day, month or year. Broadly speaking, PSAs' activities (and their corresponding communications needs) can be classified into 'business as usual' (BAU) periods and peak periods (figure 4.1).

Figure 4.1 **Stylised PSA demand profile**



BAU periods are those where PSAs undertake routine tasks, such as transporting patients between hospitals or conducting roadside breath testing. Peak periods refer to times where PSAs are responding to emergency incidents or large planned events, in addition to BAU. Peak periods can include relatively minor emergencies (a traffic accident or house fire),

major or wide-scale emergencies (a natural disaster or hostage situation) and large planned events (AFL Grand Final Day or the Darwin Cup).

The capacity requirements of PSAs are expected to remain fairly stable and predictable during BAU periods, but surge suddenly and (potentially) significantly when PSA activities peak. That said, the unique features of particular agencies mean that no two PSAs share the same demand profile — for example, police tend to have higher BAU demand relative to fire agencies, given the large volume of non-emergency activity (proactive patrols, community policing and so on) that police undertake (NSW Telco Authority, sub. 30; SCF Associates 2014).

Participants also pointed out that PSAs' use of mobile broadband services during BAU periods is growing rapidly, as agencies gain experience with mobile broadband technology and embed mobile devices and applications in their day-to-day operations (MFB, sub. 6). PSAs' future mobile broadband needs are discussed in section 4.3.

Peaks are large (relative to 'business as usual') and unpredictable

General (non-PSA) mobile traffic also comprises BAU and peak periods. However, the traffic profile of PSAs can be distinguished from general mobile broadband traffic in two respects.

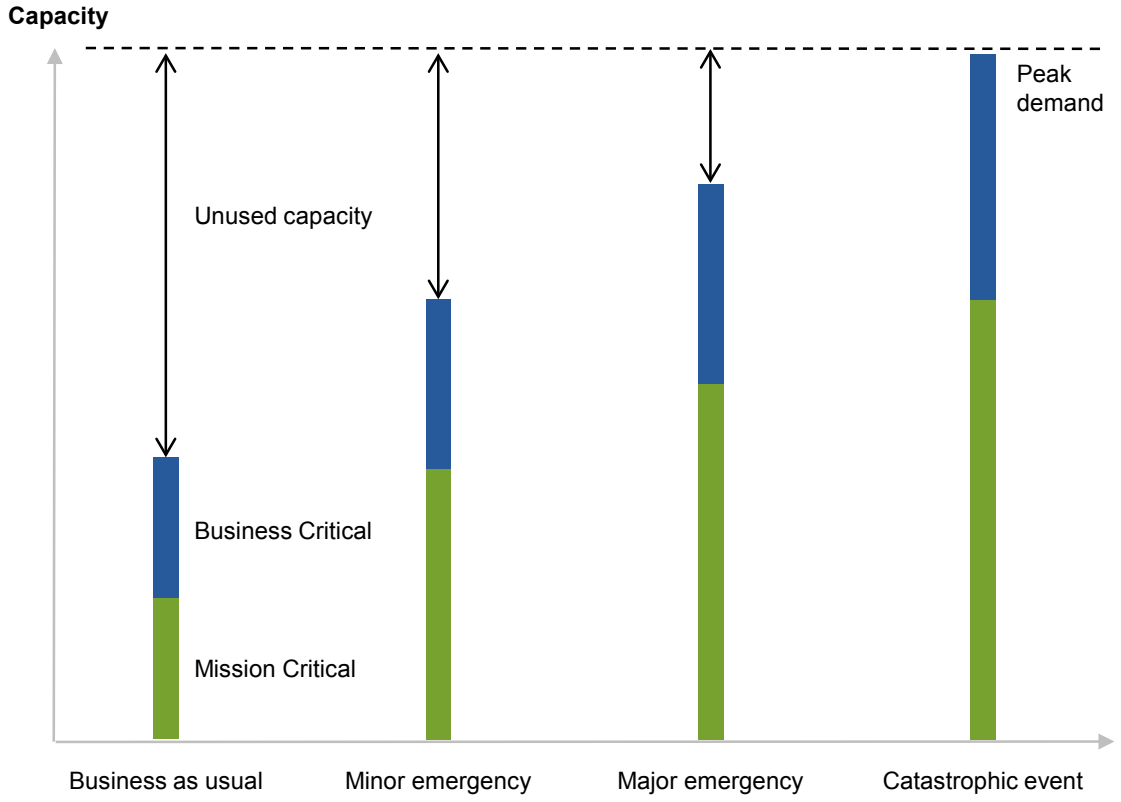
First, the difference between demand during BAU periods and peak periods is large relative to other mobile broadband customers. For example, Alcatel-Lucent (sub. 15, p. 4) observed that:

> PSA communications networks will typically demonstrate a significantly greater discrepancy between average everyday demand and peak demand than in a commercial network. In Alcatel-Lucent's experience, current peak PSA communications traffic in times of crisis and emergency is typically 10-to-20 times larger than average demand as PSAs focus their attention on a particular location and/or event.

Second, many peak demand periods for PSAs are unpredictable in timing, location, severity and incidence (as is the nature of crisis and emergency). Usage patterns of commercial mobile customers are relatively easier to predict by comparison, drawing on historical experience for when key surges in demand take place (for example, Friday and Saturday nights, New Year's Eve and during major sporting events).

These features have implications for the development of PSMB options, and the planning and design of PSMB networks (often referred to as 'network dimensioning', chapter 5). In particular, deploying a (permanent) PSMB network to meet demand during relatively infrequent and unpredictable peak events would lead to very low levels of capacity utilisation (figure 4.2) and high marginal costs per megabyte of data transmitted, likely making it uneconomic. Indeed, commercial mobile networks are typically designed to deliver some estimate of 'busy hour' traffic over a typical week or month (box 4.4), not demand during infrequent peak events.

Figure 4.2 **Meeting peak demand implies significant network capacity**



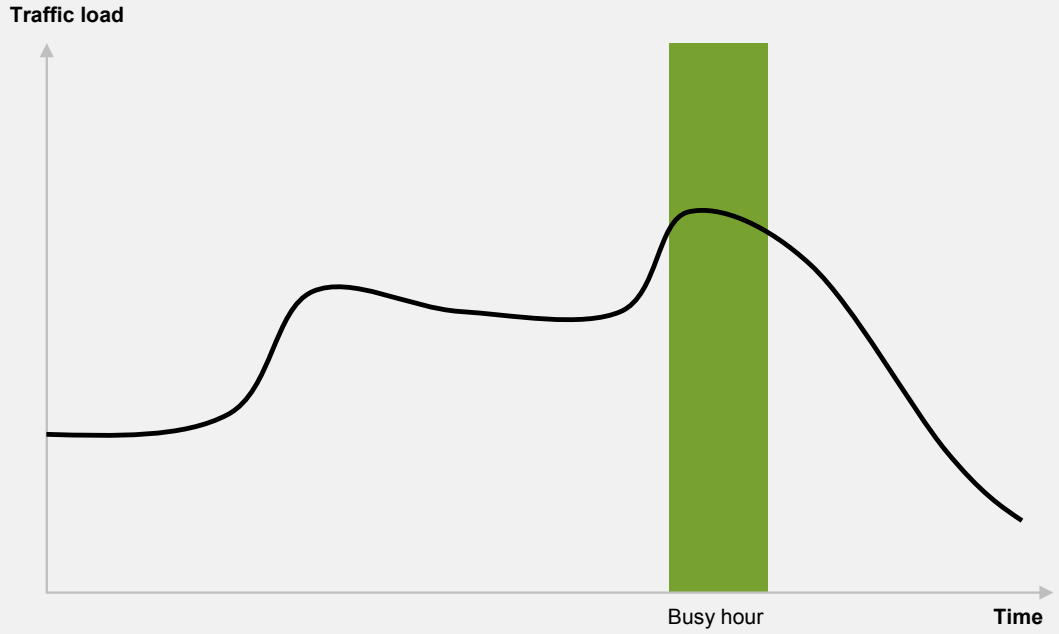
Dimensioning a mobile network to meet lower levels of demand does not necessarily mean that PSMB networks would be severely congested during peak periods, or that important demand would go unmet. There are strategies that can be used to provide PSAs with temporary coverage and capacity (such as cells on wheels, chapter 5) and techniques are available to PSAs to manage their demands on a network during peak periods.

In particular, some PSA communications during peak periods are not necessarily high priority, and may be able to be shifted to other time periods without any significant loss. This is true of some voice communications currently delivered over LMR networks, and the same is expected to be true for mobile broadband communications. Strategies can also be employed to reduce PSAs' demand for mobile broadband capacity during peak periods, such as 'store and forward' or 'compression and broadcast' of video-based applications, or offloading traffic to alternative networks (fixed or Wi-Fi). Appropriate pricing frameworks can ensure that PSAs are encouraged to pursue these options where it is more efficient than using network capacity (chapter 7).

Box 4.4 **What is the 'busy hour'?**

In mobile networks, the 'busy hour' is the 60-minute period during which mobile network usage is at its highest in a given period (a day or a week, for example). The busy hour might well occur at different times in different regions of Australia. A single user can potentially contribute to two or more busy hours — in their home location (where the busy hour might occur in the evening) and in the place they commute to for work or education (where the busy hour might occur in the daytime).

Commercial mobile networks are typically dimensioned to meet a carrier's assessment of average or normal 'busy hour' traffic. This might be calculated by averaging the busy hours for each day over a week, month or year.



FINDING 4.1

The communications needs of PSAs are characterised by high and non-predictable peak periods. PSAs can (and do) employ strategies to reduce their demands on communications networks during peak periods without any significant loss of benefits. Provisioning a mobile broadband network to meet relatively infrequent peak events would be prohibitively expensive.

The mission critical nature of PSA work drives high quality of service requirements

PSAs rely on communications systems for most (if not all) of their activities, some of which are regarded as mission critical.

What is mission critical?

The term 'mission critical' has many meanings. A mission critical situation, for example, could refer to PSA activities or operations where reliable communications are necessary to avoid loss of life, serious injury or significant damage to valuable or strategic assets (NSW Telco Authority, sub. 30). Mission critical is also used to describe certain properties of communications systems (such as resilience, priority and security) that make them appropriate for use in PSA operations.

What is meant by a mission critical LMR voice network is relatively well accepted (although not necessarily universally defined). For example, Motorola (sub. 12) suggested that a mobile radio communications system must fulfil four key requirements in order to be considered mission critical:

- the infrastructure must be resilient, redundant and highly available
- communication must be reliable
- communication must be secure
- point-to-multipoint communication must be supported.

What is implied by a mission critical mobile broadband data network is less clear. Some consider that a mission critical mobile network is one that — should it fail — would 'place public order or public safety and security at immediate risk', and could potentially cause loss of life (TCCA 2013a, p. 7). Others define mission critical mobile networks as those which are 'durable, resilient and effective in all situations and conditions', thereby allowing frontline officers to successfully respond to emergencies (ARCIA sub. 2, p. 4).

For this study, the Commission has used 'mission critical' to refer to PSA activities or situations where lives are on the line (that is, where there is a material risk of loss of life or severe injury), which could occur during BAU or peak periods.

Implications for service quality

The mission critical nature of some public safety operations means that the quality of mobile broadband services (and indeed, the quality of all communications services that agencies rely upon) is paramount. In particular, it means that PSAs require a higher level of service — across most, if not all quality characteristics — than other mobile customers. This reflects the high benefits of reliable communications during mission critical events and the potentially dire consequences of communications systems failing.

While not all PSA activity is mission critical (such as routine or administrative tasks that may be considered operational, informational or business critical), it is not practical to offer PSAs a 'two-tiered service'. Mission critical situations are difficult to predict in advance and situations can escalate to mission critical as circumstances change. For these

reasons, PSAs require that their communications systems have the capacity to be used in mission critical situations as a matter of course.

However, there is no single set of quality standards implied by a mission critical mobile broadband capability, as discussed in sections 4.3 and 4.4.

4.3 What do PSAs want from a PSMB capability?

If jurisdictions choose to facilitate the delivery of a PSMB capability, decisions will need to be made about the level of network capacity and standard of service that the capability should deliver.

One way to begin this task is to consider what PSAs are seeking from a mobile broadband capability. In practice, this information is imperfect, and does not necessarily reflect PSAs' (or the community's) willingness to pay for PSMB. However, it does shed light on some of the priority issues for PSAs, and the importance of taking a flexible and incremental approach to implementing a PSMB capability.

There are limited data about PSAs' future use of mobile broadband services and applications

There is widespread agreement among study participants and other stakeholders that PSAs' use of mobile broadband would increase significantly if a public safety grade service were available — particularly in terms of uplink, and largely driven by video-based applications.

For example, the Victorian Government (sub. 28, p. 20) observed that PSAs' data consumption has increased rapidly in recent years, and considered that demand would grow further with a PSMB capability.

> With the rapidly changing technological landscape, data consumption has grown significantly … [However] PSA responders are unable to leverage broadband data capabilities that are widely available in the community to improve service delivery (and reduce the risk of impacts from emergency events) … With greater availability of mobile broadband networks, content-rich information can be shared, including real-time video, enhanced location tracking, interactive maps and two-way messaging.

However, detailed information about how PSAs would use this service (including the type, composition and volume of mobile applications) is limited, as is information about the benefits of that use. Some estimates that have been brought to the Commission's attention are not publicly available, or are from international sources that cannot be easily translated to the Australian context. Moreover, the rapidly evolving nature of mobile broadband technology means that existing work tends to 'age' fairly quickly.

Submissions provide some insights

A report by Gibson Quai — AAS Consulting (now UXC Consulting) in 2011 to the Public Safety Mobile Broadband Steering Committee of COAG used a 'bottom up' approach to estimate how Australian PSAs might use mobile broadband in the future, using a number of hypothetical incident scenarios (GQ-AAS 2011b).

Almost all figures and calculations have been redacted in the publicly available version of this report. However, the Victorian Government, in its submission to this study (sub. 28), cited some demand estimates from a Public Safety Mobile Broadband Steering Committee report that draws on the Gibson Quai — AAS work (box 4.5). This gives a sense of the potential size of PSAs' mobile broadband needs during particular incidents. However, it is difficult to interrogate these estimates (as the underlying analysis is not available), or to understand how demand might evolve in different incidents or regions. Moreover, this report found that PSAs' future mobile broadband requirements were highly uncertain, given their use of mobile broadband was only in its infancy. This suggests that these figures — now four years old — should be treated with some caution.

Estimates of PSA demand for mobile data during certain types of incidents were also provided by agencies in Western Australia (box 4.5). Two types of estimates were developed — a 'reasonable use' estimate (defined as the level of network capacity that agencies consider reasonable given existing and known emerging data applications), and a 'minimum use' estimate (the level of capacity that agencies regard as operationally acceptable in the event that reasonable use demand exceeds capacity) (WA Department of the Premier and Cabinet, sub. DR 45).

Finally, the NSW Telco Authority (sub. 30) is currently examining the costs and benefits of a PSMB capability for that state. As part of this work, the Authority has made some assumptions about the required levels of network capacity, including that:

- a minimum cell edge data rate of 256 kilobits per second (kbps) should be provided. The cell edge data rate refers to the amount of capacity that a user located at the edge of the cell (the furthest point from a mobile tower) could expect to experience (chapter 5)
- higher levels of capacity should be available towards the centre of the cell (up to 10 megabits per second (Mbps)).

These assumptions have been taken into account in the development of the Commission's PSMB scenarios, as discussed in section 4.4.

Box 4.5 Estimates of PSA demand for mobile broadband

Victoria

The Victorian Government submission to this study cites demand estimates from a 2011 report of the Public Safety Mobile Broadband Steering Committee. The estimates refer to anticipated PSA demand for uplink capacity in high-usage areas (such as inner Sydney) by 2020. Three estimates are provided:

- business as usual demand of 40 megabits per second (Mbps) over 180 km^2, assuming 3600 mobile units in operation
- planned event demand of 67 Mbps over 180 km^2, assuming 4000 mobile units in operation
- large scale incident demand in excess of 200 Mbps over 50 km^2, assuming 870 mobile units in operation, and 30 per cent of units transmitting video during the peak periods of the incident.

As discussed in section 4.4, the Commission's quantitative analysis focuses on PSAs' network requirements on a per square kilometre basis. It is useful, therefore, to convert the estimates cited by the Victorian Government to a Mbps/km^2 metric. The Commission estimates that the Public Safety Mobile Broadband Steering Committee figures are approximately equivalent to an average (over the relevant network area) of:

- business as usual demand of 0.22 Mbps/km^2 uplink
- planned event demand of 0.37 Mbps/km^2 uplink
- large scale incident demand of 4.00 Mbps/km^2 uplink.

Western Australia

'Reasonable use' demand estimates developed by PSAs in Western Australia are based on three types of public safety incidents. In each case, the focus of the analysis is on the peak usage period.

- A fire at a primary school was estimated to result in 58 PSA resources being deployed, requiring network capacity of approximately 16 Mbps uplink and 17 Mbps downlink.
- A hostage situation in a public park was estimated to result in uplink demand of 25 Mbps and downlink demand of 55 Mbps. The number of PSA resources deployed was not disclosed.
- A large-scale bushfire involving 228 PSA personnel was estimated to result in uplink demand of 19 Mbps and downlink demand of over 42 Mbps.

Estimates of the area over which these operations would occur (in km^2) were not provided.

Sources: Victorian Government (sub. 28); WA Department of Premier and Cabinet (sub. DR 45).

Many other countries are at a similar point to Australia

Some work on PSMB has been completed in other countries. However, many countries are at a broadly similar point to Australia — that is, contemplating, planning and in some cases beginning to implement a mobile broadband capability for PSAs (appendix B). To the Commission's knowledge, there is currently no example of a 'public safety grade' mobile

broadband capability in operation anywhere in the world (and accordingly, no data on how PSAs use such a capability). Moreover, attempts by foreign governments to robustly estimate PSAs' future demand for PSMB confront many of the same challenges experienced in Australia (discussed below).

That said, there is some limited information available from the United States and Canada regarding PSAs' expected network capacity requirements. This information may be relevant for considering how a PSMB capability could be defined in the Australian context (section 4.4).

The US Government is planning to build and operate a nationwide 4G network for PSAs, but with scope to lease out capacity to non-PSA users when the network is underutilised. A government authority (FirstNet) has been established to manage the delivery and operation of the dedicated network (appendix B). The Statement of Objectives suggests that the FirstNet project is to provide network capacity of between 0.1 and 3.0 Mbps per square mile (equivalent to about 0.04 to 1.16 Mbps per square kilometre), depending on the population density of the area and other characteristics (FirstNet 2015e). This network is yet to be deployed, meaning actual capacity levels could vary.

The Canadian Government is also looking to establish a PSMB capability (appendix B). Work undertaken by the Centre for Security Science (part of Defence Research and Development Canada) in 2011 included some estimates of PSA demand for mobile broadband network capacity, based on illustrative scenarios (box 4.6).

The UK Government is in the process of procuring a PSMB capability (the Emergency Services Network) from commercial mobile carriers (appendix B). However, little information is publicly available regarding the network capacity, or standard of mobile service, to be provided to PSAs. The UK Government expected to complete the tender process by the end of 2015.

It has proven difficult to obtain data on PSAs current use of mobile broadband services

PSAs are already using a range of mobile data services, including low-bandwidth services provided over LMR networks (predominantly messaging and paging), and some commercial broadband services provided over commercial networks (for example, Queensland Police's QLite application over the Telstra network, and Victoria Police's ability to roam between the (dedicated) Mobile Data Network and commercial networks).

Information on the quantity and quality of data services currently being used by PSAs could be a useful starting point for defining a PSMB capability — specifically, it could put a 'floor' or minimum on the level of mobile broadband capability that is required.

Box 4.6 PSMB demand estimates for Canada

In 2011, the Centre for Security Science (part of Defence Research and Development Canada) conducted a technical assessment of the 700 MHz spectrum requirements for mobile broadband data communications. In consultation with PSAs and other stakeholders, it developed three incident scenarios to assess data throughput and application requirements:

- a severe multi-vehicle accident
- a chemical plant explosion and fire
- a sports event riot.

The report does not provide disaggregated data. However, demand profiles are presented which suggest that in the first year, total uplink demand (across all PSAs) would be about:

- 5 Mbps during a multivehicle accident
- 7.5 Mbps during a chemical plant explosion
- 10 Mbps during a sports event riot.

These estimates include PSA demand for mobile data communications for day-to-day operations (such as for the issuing of traffic notices, patrols and incident reporting).

By making some assumptions about the geographic area over which these incidents take place, it is possible to convert these estimates to Mbps/km^2 (the metric used by the Commission in this study, section 4.4). Specifically, assuming that the public safety activities associated with a multi-vehicle accident are contained within a 1 km^2 area, while the chemical plant explosion and sports event riot affect a 2 km^2 area, the respective equivalent demand estimates are 5 Mbps/km^2, 3.75 Mbps/km^2 and 5 Mbps/km^2.

Source: CSS (2011).

However, this information has not been provided to the Commission through submissions, and is generally not available publicly. One exception is some information published by Victoria's Emergency Services Telecommunications Authority on data consumption over the Mobile Data Network (which is predominantly used for dispatch, database checks and automatic vehicle location) (ESTA 2014b). This shows that Victorian PSAs are currently consuming about 1.5 Gigabytes (GB) of data per month over this network. However, this is projected to grow exponentially in the next five years, to nearly 3.5 GB per month by 2018 — a 15 to 20 per cent growth rate per year (Weiss 2015).

A request for information regarding PSAs' current use of mobile data (and other matters) was circulated to state and territory governments in May 2015. Responses were limited, though information provided by Tasmania suggests that some PSAs are consuming relatively significant amounts of data over commercial mobile broadband networks.

In 2013-14, Tasmania Police deployed over 1000 tablet devices to its frontline police officers, replacing police desktop computers and in-car mobile data terminals (Acer Computer 2014). The Tasmanian Government has indicated that traffic over these tablets is currently about 1 GB per month per device, which is expected to increase with additional

in-field video demands (Tasmanian Department of Premier and Cabinet, pers. comm., 7 September 2015).

Some agencies have expressed a reluctance to disclose information on current usage because it does not capture PSAs' 'latent' demand for mobile broadband services. In other words, because usage is constrained by the capacity of LMR data networks and quality concerns associated with commercial networks, data usage is low and not indicative of how demand would evolve if a PSMB capability were available. Indeed, the Victorian figure described above (1.5 GB per month) is equivalent to about 4.5 kbps or 0.3 bps/km^2, which implies only very low bandwidth applications (such as vehicle tracking) are being used. (This conversion is based on certain assumptions, including that the Mobile Data Network land area is approximately 17 000 km^2 (GQ-AAS 2011a).) In practice, the majority of traffic probably occurs in a small portion of the network and at certain times of the day. However, even then, levels of data use per square kilometre would be very low.

FINDING 4.2

PSAs' use of mobile broadband services and applications would likely increase significantly if a PSMB capability was available. However, the level of network capacity that PSAs would use is highly uncertain, as are the benefits of that use.

A detailed, 'bottom up' estimate of PSA demand for network capacity is not feasible

In practice, no two PSAs are the same — their capacity requirements are likely to vary across locations and incidents, and grow and evolve in different ways and at different rates. For this reason, a rigorous, bottom-up approach to estimating demand would need to consider the particular needs of every individual agency.

This would involve categorising each agency's activities into different types of incidents, and then — for each type of incident — collecting data on:

- the number of end-user devices expected to be used at the incident (including handheld, vehicle-mounted and so on)
- the mobile broadband applications that would be used on each device (such as voice calls, database access or real-time video feeds)
- the upload and download requirements of each application
- how many applications would be used simultaneously.

The results could then be aggregated into a weighted sum of annual traffic requirements across all types of PSA activities and across all PSAs (assuming information is available on the size, frequency and coincidence of different types of PSA activities).

However, the Commission has not attempted to quantitatively estimate or project PSAs' future mobile broadband requirements. Such an exercise is unlikely to yield robust results given extensive data requirements and the many unknown factors that will bear on demand, including:

- the availability of other communications systems (including LMR, Wi-Fi and satellite)
- the pricing model and prices that PSAs face for mobile broadband services
- adjustments to PSA operational and communication procedures and protocols
- developments in mobile broadband technology (and applications), and the expansion of long term evolution (LTE) networks.

Moreover, estimating PSAs' future demand for mobile network capacity was not considered feasible or worthwhile by the majority of study participants (box 4.7).

In any case, estimating PSAs' future demand for network capacity is not a critical requirement for this study. The Commission's has focused on identifying the best way to deliver PSMB, irrespective of the level of capacity that the capability provides or how it changes over time.

Box 4.7 Participant views on estimating demand

The accurate prediction of future data capacity requirements has proven to be extremely difficult and unreliable, both in the public safety and consumer mobile broadband environment. (Victorian Government, sub. 28, p. 29)

PSA's are still not experienced enough with the potential usage of mobile data to be able to accurately forecast their ultimate demands. (ARCIA, sub. 2, p. 3, 12)

It will be difficult to predict future demand requirements with a high degree of precision in this fast-moving environment. (Victoria Police, sub. 17, p. 13)

In general, it has proved extremely difficult to estimate what the upper limits of peak demands might be, given that the scale of events varies so greatly … It is likely that once PSMB becomes a reality, there will be latent demand emerging across the emergency services sector which cannot be predicted to any degree of accuracy at this stage. (MFB, sub. 6, p. 15)

Estimating PSA demand for mobile broadband is difficult for two reasons. First, there is uncertainty about how and for what applications PSA use of mobile broadband will develop over time. Second the unpredictable nature and location of events that PSAs are required to deal with. (Telstra, sub. 19, p. 31)

Actual demand for mobile broadband traffic often exceeds demand forecasts due to the introduction of new applications and services that were simply not anticipated by operators. (Ericsson, sub. 10, p. 15)

PSAs are seeking a standard of service that would support data use in mission critical situations

The evidence submitted throughout this study suggests that the defining feature of a PSMB capability (relative to commercial mobile carrier offerings) is that it enables PSAs to use and rely on mobile broadband data services in mission critical situations. However, study

participants presented imprecise and often inconsistent views about the specific levels of service that are sought, or the way in which some of the quality characteristics important to PSAs (such as security or 'guaranteed' network access) should be met.

As discussed in chapter 5, there are technical barriers to delivering mission critical voice services over LTE at the present time. However, given many jurisdictions are likely to want to integrate voice and data networks in the future, it is important that PSMB networks are designed and implemented with a view to supporting this. In particular, PSMB networks should be flexible enough to meet any additional quality of service requirements associated with delivering mission critical voice services.

Participant views on a mission critical data network

Coverage

A number of study participants considered that a PSMB capability should provide the same geographic and population coverage as LMR voice networks. For example, the Victorian Government (sub. DR44, p. 5) noted that:

> Victorian PSAs will not regress in their communications capability. Victoria expects a PSMB capability to be of an equivalent coverage footprint to its existing networks. Today, Victoria's LMR networks cover greater than 99 per cent of Victoria's population (95 per cent of geographic coverage — 15 per cent more landmass coverage than the nearest commercial network).

Similarly, Motorola (sub. 12, p. 16) considered that:

> For PSMB to be fully Mission Critical it will require similar network coverage levels to narrowband networks. … Currently, PSA narrowband voice systems typically require 95-98% area coverage and often include in-building coverage.

The Metropolitan Fire Brigade (MFB) (sub. 6, p. 11) pointed to the importance of 'in building' and rural coverage in particular.

> For the MFB, this includes in-building coverage, additional coverage in buildings via distributed antenna systems, so that portable hand held devices can be used throughout the coverage areas. Since the 2009 Black Saturday fires the MFB is increasingly responding to rural areas across Victoria, and responses interstate. In these circumstances we respond under the management of other agencies. In these cases we would expect to get the coverage those services get and interconnect with the services we are responding with.

Reliability (or resilience)

Participants generally considered that a PSMB capability should exhibit a higher level of reliability than commercial mobile networks currently provide — by way of example, Telstra reported that its network was available 99.9 per cent of the time on average for the month of September 2015 (Telstra 2015a).

Specifically, some study participants considered that a PSMB capability should provide a comparable or better level of reliability to LMR networks, particularly if PSMB is to be the primary communications network for PSAs (VHA, sub. 11).

LMR voice networks are typically designed to deliver very high levels of network availability (a common measure of reliability). For example, the ACT Government (sub. 25, p. 4) noted that:

> Mission critical systems within the ACT Emergency Services typically operate on 99.999 per cent uptime. This very high availability level is indicative of the trust and requirement that is placed upon these systems.

The Victorian Government highlighted that the Mobile Data Network in that state has reported levels of availability 'well in excess of 99.99 per cent over the last nine years' (sub. DR44, p. 7). Similarly, the NSW Telco Authority (sub. 30, p. 9) noted that:

> In an operational context, public safety agencies currently have mission critical communications services (both voice and narrowband data) that are generally available 99.99% of the time. Effort to improve availability to the optimal level of 99.999% is continuing.

However, the MFB (sub. 6) suggested that the different nature of LTE and LMR networks makes it difficult to directly compare reliability levels.

Interoperability, security and priority

There was strong support among study participants for a PSMB capability that facilitates inter-agency and inter-jurisdiction interoperability, user prioritisation and secure communication services. For example, the NSW Telco Authority (sub. 30, p. 47) considered that:

> Communications concerning criminal investigations, covert surveillance and national security operations must be secure. Security in this context does not just mean that communications cannot be intercepted and interfered with, but also that other information such as the location of handsets and devices is not available to non-authorised personnel, nor the meta data generated by and from these devices.

That said, participants provided little guidance as to how these outcomes should be achieved, or what meeting these objectives would mean for the PSMB deployment approach. Moreover, participants appear to place different levels of importance on the achievement of these characteristics. For example, Motorola (sub. 12, p. 21) submitted that end-to-end encryption of communications, with no opportunity for interception in between, is fundamental to achieving security objectives.

> PSAs need the ability to control the encryption of devices and workgroups in a dynamic manner, with the ability to regularly change the encryption key.

However, encryption (and security more generally) was not considered to be a high priority for all PSAs. Victoria Police (sub. 17, p. 14) observed that:

> The end-to-end information security requirements will differ amongst the PSAs because of the different missions of each PSA. For example, the CFA [Country Fire Authority] does not require its voice communications to be encrypted because it encourages its volunteers and interested community members to access its communications via scanners and web pages.

Other evidence on what constitutes a mission critical data network

As noted earlier, a number of other countries are contemplating or implementing a PSMB capability. Preparatory work undertaken in these countries reveals some insights about the service quality standards being pursued.

For example, the Statement of Objectives for the FirstNet project in the United States details that the PSMB capability should:

- achieve annual end-to-end availability of 99.9 per cent (up to nine hours down time per year)
- support the static and dynamic prioritisation of public safety officers based on predefined user profiles (including the ability to change user profiles in real time in response to incidents) (FirstNet 2015f).

While information about the quality of service to be delivered over the UK Emergency Services Network is not publicly available, official sources suggest that the new network needs to provide end-to-end security (Shipley 2015) and a high level of coverage (98 per cent by population on an in-building basis and 90 per cent geographic coverage) (UK Home Office 2015a).

A 2010 report for the TETRA Association proposed a number of operational requirements that it considered essential to public safety communications in the United Kingdom, namely:

- annual end-to-end availability of 99.98 per cent (up to two hours down time per year)
- 80-bit end-to-end encryption of communications
- network coverage consistent with the typical organisational boundaries of PSAs, specifically, population coverage of 99.5 per cent for outdoor, 65 per cent for indoor, and 99.9 per cent for air to ground (Analysys Mason 2010).

Many of these proposals were supported by a more recent report prepared for the European Commission (SCF Associates 2014). This report considered that a public safety network should have the same or greater resilience as the Airwave network (the narrowband data network in the United Kingdom), the provision of public safety features for data and voice (such as group call, push-to-talk and direct-mode communications), and priority of emergency services officers over commercial customers on the network.

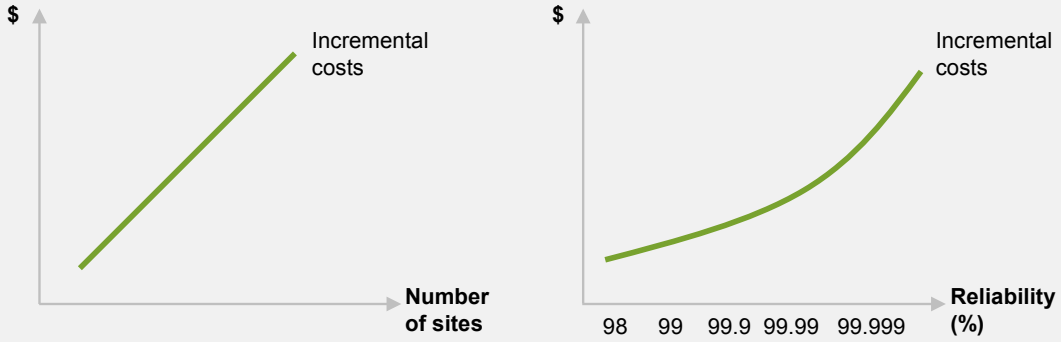
There is no 'one size fits all' PSMB capability

In practice, the capacity and quality of a PSMB capability could take a range of values. However, delivering a PSMB capability has costs, and many of these costs (met by governments and ultimately taxpayers) are likely to increase exponentially with capacity and service standards (box 4.8).

Box 4.8 Greater reliability comes at an increasing cost

Evidence presented to this study suggests that a PSMB capability would need to deliver very high levels of network reliability — measured as the proportion of time the network is available — to support the use of mobile data applications in mission critical situations. Reliability levels in the order of 99.9 to 99.999 per cent have been canvassed (equivalent to annual down time of about nine hours or five minutes respectively).

However, achieving high levels of network reliability has costs, and greater levels of reliability tend to come at an increasing cost (see figure). Reliability is a function of the number of mobile sites that need to be hardened and the extent of hardening required at each site. As reliability levels increase (say from 98 per cent to 99 per cent), proportionally more hardening (investment) is required to deliver the same unit increase in reliability standards. This reflects the increasing severity of risks that need to be mitigated to reach higher levels of reliability.



It is in the best interests of the community for individual jurisdictions to pursue a capability that reflects their particular needs and circumstances and their communities' willingness to pay for public safety grade mobile broadband services. A uniform capability across all jurisdictions is unlikely to be efficient. Dramatic differences in population densities (and the likelihood and materiality of emergencies) across different regions means that a variable capability *within* jurisdictions is also likely to be warranted, especially with regard to network capacity.

That said, the considerable uncertainty about how PSAs will use mobile broadband applications, and about the benefits of that use, is a reality for all jurisdictions. It is prudent, therefore, for all jurisdictions to 'start small' in rolling out a PSMB capability, irrespective of the deployment model chosen. This could mean commencing with a modest level of network capacity and service quality, but with scope to scale up capacity and quality standards over time, as PSAs gain experience with mobile applications, the business case develops, and jurisdictions transition mission critical voice services to

PSMB. This approach would also ensure that PSAs have sufficient time to make the operational changes necessary to get the most out of PSMB. These issues are discussed further in chapter 7.

4.4 PSMB scenarios for analytical purposes

The Commission has undertaken a quantitative analysis to better understand how the costs of delivering a PSMB capability vary depending on the delivery option (chapter 6). A necessary part of this analysis is to require that broadly the same level of PSMB capability is delivered under each option, such that they are evaluated on an even keel.

To this end, the Commission has specified a number of PSMB 'scenarios' that define a specific level of capacity to be delivered over the planning horizon. Importantly, these scenarios are not suggestive of the type of capability jurisdictions should adopt, or of PSA demand for mobile broadband. Using these scenarios in the quantitative cost analysis has enabled the Commission to:

- examine how the costs of delivering a given PSMB capability vary across delivery options
- consider whether (and, if so, how) the relative cost effectiveness of alternative delivery options changes depending on the amount of capacity that is delivered.

Capacity

The capacity metric used in the Commission's quantitative analysis is the total amount of capacity available to PSA users at a given location and time (that is, Mbps/km^2). This approach was supported by a number of study participants — for example, the Victorian Government (sub. 28, p. 30) considered that 'the best metric to define and/or measure service capacity is uplink bits per second (bps) within a specific area (km^2)'.

Three levels of network capacity have been considered

In the central (or base) case, it is assumed that the PSMB capability would provide end users in metropolitan areas (dense urban, urban and suburban areas) with network capacity of 1.5 Mbps/km^2 (uplink and downlink). This compares to capacity levels of about 10-100 kbps for LMR data networks (chapter 2).

In practice, PSAs' demand for uplink capacity may exceed downlink demand (section 4.1). However, even though preferences for uplink and downlink capacity may be asymmetric, the nature of mobile networks is such that they are typically dimensioned to meet the greater of the two.

Network capacity of 1.5 Mbps/km^2 would be sufficient to support the simultaneous use of two to three mobile devices running real-time video-based applications at any given time, in every square kilometre (assuming each video requires capacity of 500 to 1000 kbps (Adobe nd)). Other mobile applications have far lower capacity requirements — accordingly, 1.5 Mbps/km^2 would also support the simultaneous use of one mobile device running a video application and at least 20 devices conducting database checks, sending emails and tracking the location of vehicles (assuming each device would require about 50 kbps (CSS 2011)) .

A higher and lower level of capacity have also been considered to understand the sensitivity of the quantitative results to different levels of demand (chapter 6).

- The upper-bound estimate of 4.0 Mbps/km^2 would support the simultaneous use of at least four and as many as eight video-based applications in every square kilometre of metropolitan areas.
- The lower-bound estimate of 1.0 Mbps/km^2 would be sufficient for about one to two videos, or 20 devices accessing lower-capacity applications, in every square kilometre of metropolitan areas.

In each case, a lower amount of network capacity is provided in less densely populated regions, as described in table 4.1.

Table 4.1 **PSMB scenarios**

	Central case	*Lower bound*	*Upper bound*
Dense urban, urban and suburban areas			
PSMB capacity	1.5 Mbps/km^2	1 Mbps/km^2	4 Mbps/km^2
Growth rate	5% pa	2% pa	10% pa
Rural and remote areas			
PSMB capacity	500 kbps/km^2	200 kbps/km^2	800 kbps/km^2
Growth rate	5% pa	2% pa	10% pa

In developing these scenarios, the Commission has considered:

- the demand figures cited by the Victorian Government and the estimates developed by PSAs in Western Australia (box 4.5)
- the network capacity levels associated with the FirstNet project in the United States, and the incident scenario work undertaken in Canada in 2011 (section 4.3)
- confidential information provided to the Commission on PSAs' current data usage over commercial carrier networks.

The Commission has also had regard to the network capacity assumptions detailed by the NSW Telco Authority (sub. 30). The Authority suggested that a PSMB capability should

provide a theoretical maximum data speed of 10 Mbps. The Commission's scenarios are described in terms of *average* data speeds (such as 1.5 Mbps/km^2 in the central case). However, a user standing right next to a mobile tower would receive much higher speeds than average (possibly up to 10 Mbps). The Commission's quantitative analysis is based on the same cell edge data rate cited by the NSW Telco Authority (256 kbps).

Growth rates

The Commission's quantitative cost analysis covers a 20-year horizon and is based on meeting PSA capacity requirements (as defined by the above scenarios) each year.

To project capacity levels over this period, the Commission has applied a growth rate of 5 per cent per annum in the central case. Sensitivity testing has been conducted to consider the implications of lower and higher growth rates (2 and 10 per cent per annum respectively).

As discussed in chapter 3, mobile broadband usage in Australia (by the general public) is growing at a rapid rate and this is projected to continue. For example, some estimates suggest that mobile broadband data traffic in Australia is expected to increase by 38 per cent each year between 2013 and 2017 (CIE 2014).

In this context, the growth rates built into the Commission's PSMB scenarios may appear modest. However, it is important to understand that commonly reported mobile broadband growth rates tend to focus on *stock* rather than *flow* measures (box 4.1). Stock measures capture how the total volume of data consumed in a given period (such as GB per year) changes over time. These measures tend to exhibit much higher rates of growth than measures focused on data usage (or demand) at a given point in time (such as Mbps). This reflects the fact that a lot of the growth in mobile broadband traffic volumes is due to people using their mobile devices more frequently and more customers taking up mobile devices.

Applying aggressive growth rates to the network capacity metric used here (Mbps/km^2) risks overstating the amount of capacity that PSAs would need (or could feasibly use) at a given location and point in time. For example, a 38 per cent annual growth rate applied to the central case would mean that PSAs have access to over 900 Mbps/km^2 in year 20 — it is highly unlikely that such extensive mobile device usage would be efficient during most plausible emergency incidents. By contrast, under the central case assumptions (1.5 Mbps/km^2 in year one, increasing at 5 per cent per annum) the PSMB capability would provide PSAs with 4.0 Mbps/km^2 in year 20 (or 27 Mbps/km^2 using the upper bound assumptions of 4.0 Mbps/km^2 in year one and increasing at 10 per cent per annum).

Service quality

The key distinguishing feature of PSMB — from a service quality perspective — is that it can be relied upon in mission critical situations. However, there is no single set of PSMB quality standards implied by this (not least because there are multiple ways to characterise 'mission critical'). A range of service quality characteristics (reliability, priority, security and so on) and performance metrics could potentially be relevant.

From an efficiency perspective, the community as a whole will be best off where PSMB quality standards reflect the relative benefits and costs. This is likely to give rise to different PSMB quality standards across PSAs and jurisdictions, reflecting their individual circumstances. The divergent views of study participants on this topic — and the lack of consensus among international PSMB experts — attests to this.

It is also likely that PSA quality of service requirements will change over time, especially if mission critical voice services are to be delivered over PSMB networks at some point in the future.

In this context, the Commission has not attempted to define or prescribe the quality standards that a PSMB capability should deliver. However, for the purposes of the quantitative analysis contained in this report, the Commission has made a number of assumptions about the quality of mobile broadband service delivered to PSAs under each option. Specifically:

- the network has been designed to provide geographical *coverage* equal to existing commercial networks, which equates to a population coverage in excess of 99 per cent
- some capital investment is made to provide preferential or *priority* services to PSAs
- a proportion of network sites are subject to some form of hardening — including the installation of additional battery backup and civil upgrades — which implies some improvement to network *resilience* and *reliability*.

These assumptions have been made to ensure that, as far as possible, the delivery options are evaluated on an even keel — they should not be read as a proposed or ideal standard for a mission critical data network. More work needs to be done by jurisdictions and PSAs to articulate in detail the network standards they need, through a transparent process of weighing up benefits and costs. The Commission's approach to the quantitative analysis is discussed further in appendix C.

FINDING 4.3

PSAs expect a PSMB capability to deliver a standard of service that would allow them to use mobile broadband voice and data applications in ‘mission critical’ situations (for example, where there is a material risk of loss of life or severe injury).

However, there is no single set of service quality standards implied by this. Individual PSAs and jurisdictions will ultimately need to decide on the quality standards that a PSMB capability should deliver, taking into account the benefits, costs and risks to the community as a whole. There would be benefit in governments being transparent about how these tradeoffs are made.

5 How can a PSMB capability be delivered?

Key points

- Meeting public safety agencies' (PSAs) requirements for a public safety grade mobile broadband (PSMB) capability poses technical, economic and commercial challenges. However, it is technically feasible to deliver this capability — including priority network access — under a dedicated, commercial or hybrid approach.
- There is broad consensus that a PSMB capability should be delivered using Long Term Evolution (LTE) technology. It has various enhancements over previous mobile technologies, and will continue to evolve and improve.
- Key drivers of the cost of delivering a PSMB capability are the network coverage and capacity requirements, which are met using a mix of infrastructure and spectrum.
  - Infrastructure requirements include mobile sites and equipment, transmission backhaul and central network systems.
  - Spectrum has opportunity costs — the foregone alternative uses of that spectrum — that need to be considered alongside the costs of other inputs.
- Commercial mobile carriers have existing networks which cover most of the population, and hold large parcels of spectrum.
- Commercial approaches to PSMB (and to a lesser extent, hybrid approaches) avoid many of the upfront infrastructure costs required under a dedicated approach, and can take greater advantage of operating efficiencies.
- While some elements of a PSMB capability have been demonstrated, there is uncertainty as to the precise service standards that could or would be achieved under alternative delivery approaches.
- Irrespective of the approach to delivering PSMB, costs can be minimised by leveraging existing infrastructure where feasible, sharing network capacity among PSAs on an efficient basis and allowing for flexible use of spectrum across users.
- PSMB networks should be designed with a view to incorporating 'mission critical' voice services once the relevant technical standards are in place and there is a business case to do so.
- Extending a permanent PSMB network beyond the footprint of commercial networks would be costly under any approach. Deployable mobile cells or alternative technologies, such as satellite broadband, offer a more cost-effective option in some parts of Australia.
- Relying on common technical protocols and taking a flexible approach to implementation will help to minimise costs and deliver a sustainable PSMB capability.

The key requirements of a public safety mobile broadband (PSMB) capability (chapter 4) could be met in several ways. This chapter looks at the technical considerations and cost drivers on the supply side. It steps through considerations relating to network capacity and coverage, priority access, network reliability, the integration of voice services, interoperability and security, multi-carrier approaches and roaming, and timing and sustainability. The focus is on how these factors might vary depending on the delivery approach, setting the scene for the evaluation of costs, benefits and risks of specific options in chapter 6. Issues relating to implementation — including institutional arrangements and contracting — are discussed in chapter 7.

5.1 Delivery approaches for PSMB

The terms of reference refer to three high-level approaches for delivering PSMB: a dedicated approach, an approach fully reliant on commercial networks, or a combination of the two (hybrid approach). Study participants offered views on what these approaches might look like (box 5.1). The essential elements of each are described below.

A dedicated approach

At the most basic level, a dedicated approach to delivering PSMB would mean public safety agencies (PSAs) have access to (and control over) their own mobile broadband network which is constructed and operated to a given set of standards. To minimise capital deployment costs, a dedicated approach would likely involve leveraging existing network infrastructure (such as mobile sites and backhaul transmission) owned by PSAs, governments and commercial mobile carriers. Importantly, a dedicated network for PSMB would require its own dedicated radiofrequency spectrum.

A commercial approach

A commercial approach would mean that PSAs obtain PSMB services from one or more mobile carriers through a contract for service. Mobile carriers would determine how best to meet PSA requirements using their own mobile networks and spectrum holdings. This approach would not involve any dedicated spectrum for PSAs, but would require mobile carriers to adapt their networks to meet the higher quality requirements implicit in a PSMB capability.

Hybrid approaches

A hybrid approach would involve elements of both the dedicated and commercial approaches.

There are various forms a hybrid could take. For example:

- constructing and operating a dedicated network for a targeted coverage area (with dedicated spectrum), and using mobile carrier networks and other options (such as deployable cells) elsewhere
- integrating dedicated spectrum into an existing mobile carrier's network, such that PSAs have a 'dedicated lane' on the network, and the ability to overflow to a mobile carrier (or carriers') network as required.

Depending on the specific design, a hybrid approach could fall closer to a dedicated network or a commercial approach. Several hybrids are evaluated in chapter 6.

Box 5.1 Study participant definitions of PSMB delivery approaches

Dedicated approach

Telstra understands a dedicated network relates to either: A fully private network with no carrier elements utilised in the delivery of the PSMB capability; or A privately built network that does not utilise a commercial network service provider mobile broadband core but does uses [sic] other commercial network facilities, infrastructure and/or backhaul services via commercial arrangements, as is the case currently in certain jurisdictions for the provision of LMR [land mobile radio]. (Telstra, sub. 19, p. 7)

Capacity of a dedicated network will be guaranteed and provide user control of network access and priority but capacity and coverage will be limited to the dedicated PPDR [Public Protection and Disaster Relief] spectrum allocated and actually deployed by the customer. (Motorola, sub. 12, p. 24)

Commercial (or carrier) approach

A carrier model is similar to a carrier hybrid model except no dedicated capacity (including spectrum) is made available. The PSMB data is prioritised and carried on the shared carrier's network capacity. (Telstra, sub. 19, p. 7)

Hybrid approach

Where commercial carrier coverage exists, it is proposed that their capacity be virtualised, hardened and partitioned and that a PSMB be virtually delivered by collocating and sharing existing sites, power, towers and backhaul. (BAI, sub. 1, p. 5)

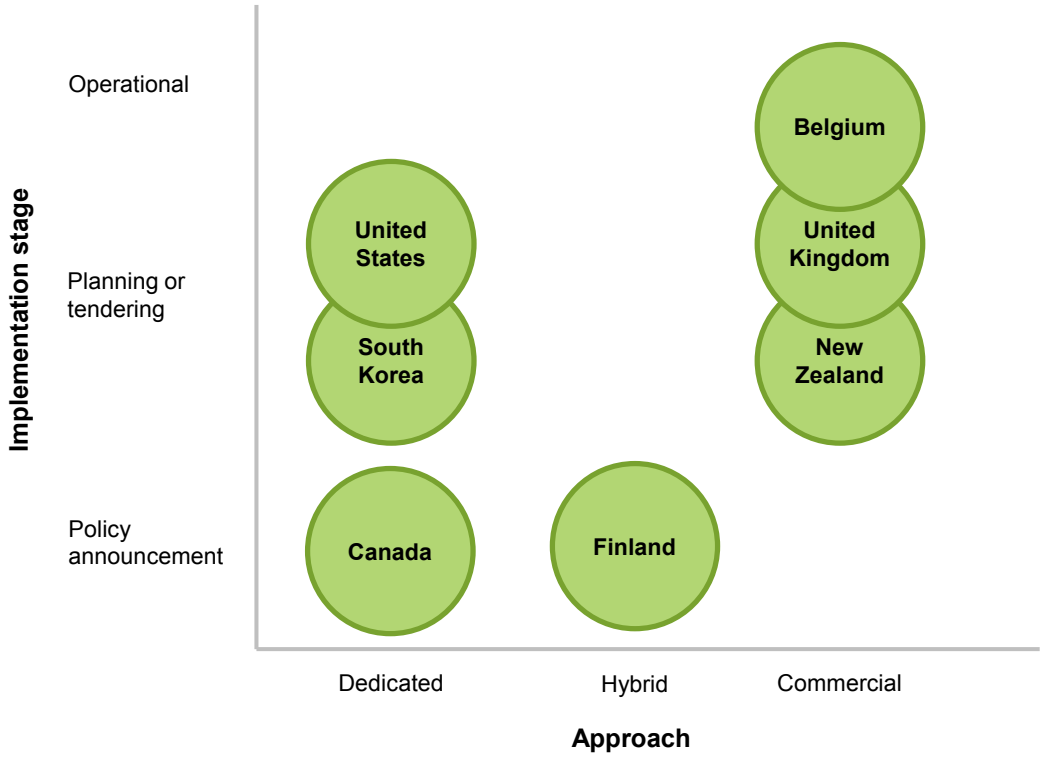
Telstra considers there are two hybrid variations that are relevant for consideration: A private dedicated PSMB capability that can roam onto a public carrier network. [And] Carrier provision of some dedicated PSMB capacity and seamless overflow to the carrier's public network (e.g. Telstra LANES™ model) where the PSMB traffic is given priority. (Telstra, sub. 19, p. 7)

An alternative, less infrastructure dependent approach to delivering a PSMB services (sic) is for PSAs to pursue a service provider model underpinned by agreements with multiple MNOs [Mobile Network Operators] on a "pay-per-use" basis. This solution could be implemented via agreements with two or three MNOs. (VHA, sub. 11, p. 7)

… [T]here are numerous variations for a hybrid model. It is likely that a hybrid model will ultimately be deployed in Australia, gaining the best aspects of existing MNO and public safety agency infrastructure, and balancing the needs of higher population densities in the cities and larger town centres against the low density population and lower demand anticipated in rural and remote areas. (NSW Telco Authority, sub. 30, p. 27)

There are various approaches to PSMB being investigated, planned or implemented in other countries which lie somewhere on the continuum between a dedicated and a commercial approach. Some countries are more advanced than others (figure 5.1). Appendix B provides further information on international developments.

Figure 5.1 **Diverse international approaches to PSMB**



5.2 Understanding mobile networks

Delivering a PSMB capability involves designing a mobile broadband network to meet specific network capacity and quality of service requirements (chapter 4). Doing so requires a series of decisions about which inputs to use, and the extent to which existing infrastructure and other resources can be leveraged (or shared) to deliver it cost effectively.

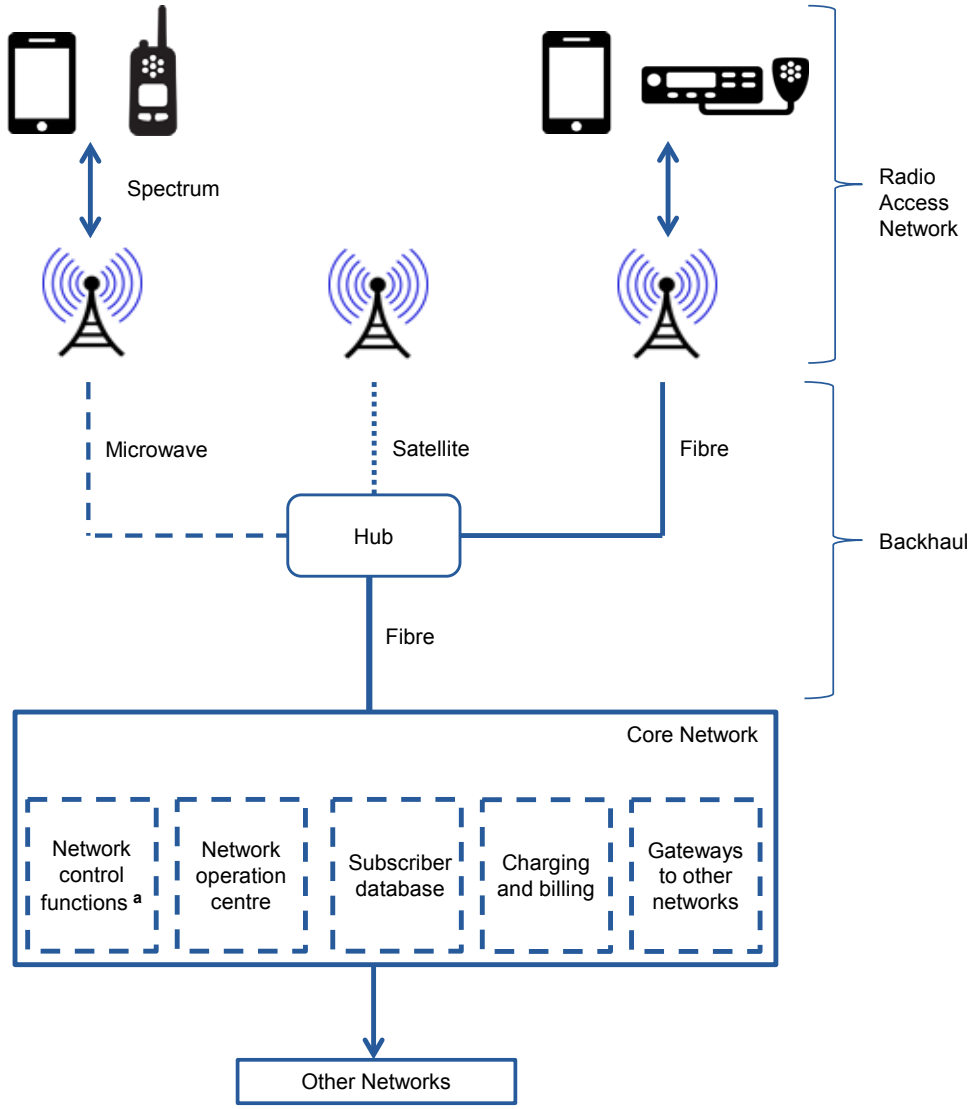
A mobile network has four key elements

Broadly, a mobile network consists of four elements (figure 5.2).

- Radio access network — a large number of mobile base station sites containing equipment such as radio antennas, a transmission tower, hardware and software. Each site can transmit and receive information over a limited range.

- Backhaul transmission — the high capacity links which carry large volumes of data from sites back to the core network — either underground (using optical fibre links) or in the air (using microwave or satellite technology).
- Core network — the collection of elements that together control and manage the network (the 'brains of the network). Typically, a mobile network would have one core network with redundancy to avoid a single point of failure.
- Spectrum — a natural resource that can be used in the transmission of information via electromagnetic waves at different frequencies.

Figure 5.2 **Key elements of a mobile network**



a 'Network control functions' are functions that different elements of the core undertake when managing a call or data session on a mobile network, such as user authentication, assigning resources, traffic management, and cell handover.

Sources: Alcatel-Lucent (2009, 2010); Gras (2015).

All of the inputs above involve costs. Some inputs, such as radio access network equipment, have clear financial implications. Other inputs, particularly spectrum, are less tangible but still involve opportunity costs (box 5.2).

Box 5.2 Spectrum has opportunity costs

Spectrum is a limited resource. To minimise interference with other users and ensure spectrum allocation meets various policy objectives, the Australian Communications and Media Authority regulates the use of spectrum. The main objectives of Australia's regulatory framework are to allocate spectrum to its most efficient use and to make adequate provision for public and community services (chapter 7).

An essential consideration in allocating spectrum is its opportunity cost — the value of the next best alternative use that is forgone when spectrum is allocated to a particular use or user.

Several factors influence the potential uses of spectrum, and hence its opportunity cost:

- the frequency — spectrum in lower bands has greater propagation (coverage), whereas higher bands offer greater throughput due to the increased bandwidths available
- international harmonisation — bands are typically of greater value to mobile carriers when supported by international manufacturers of network equipment and end-user devices
- the bandwidth — the amount of spectrum available
- location — demand for mobile broadband spectrum is likely to be higher in metropolitan areas where there are more people (and more need to add to capacity), and lower in regional areas where traffic demand is lower.

The opportunity cost of spectrum is likely to increase as consumers make greater use of smartphones, tablets and other data-intensive devices into the future. Demand from commercial carriers is a key driver of the opportunity cost of spectrum.

Sources: Department of Communications (2015b); OECD (2014).

Mobile carrier networks contain a mixture of different cell types, from larger coverage area (macro) cells to smaller coverage area but higher capacity (small) cells. Different types of cells can use different spectrum bands (3GPP nd).

Spectrum is a key input for mobile broadband networks

The type and amount of spectrum used in a mobile network has an important bearing on how networks are designed — principally because it influences how many sites are needed to deliver a given level of capacity.

Different types of spectrum have different technical properties. Generally speaking, lower frequencies provide a wider coverage range (and better penetration of buildings), whereas larger bandwidths are available at higher frequencies, thereby allowing higher capacity to be provided within a cell. Spectrum frequencies under 1 gigahertz (GHz) are considered highly desirable for mobile broadband, although mobile operators typically have a mix of spectrum types for different purposes and geographic areas (table 5.1). The cellular nature

of mobile networks means spectrum is re-used in adjacent cells, thereby allowing a large geographic area to be covered with only a limited set of frequencies.

Table 5.1 **Australian mobile carrier spectrum holdings**

Band	*Optus*	*Telstra*	*Vodafone Hutchison Australia*
700 MHz	2 x 10 MHz national	2 x 20 MHz national	..
800 MHz	..	2 x 10 MHz national 2 x 5 MHz outside five largest cities	2 x 10 MHz five largest cities 2 x 5 MHz in Canberra, Darwin, and Hobart
900 MHz	2 x 8.4 MHz national	2 x 8.4 MHz national	2 x 8.2 MHz national
1800 MHz	2 x 15 MHz in largest five cities Small number of regional licences	2 x 20 MHz in Adelaide, Brisbane and Perth 2 x 15 MHz in Melbourne and Sydney 2 x 10 MHz in Canberra, Cairns and Hobart 2 x 12.5 MHz to 2 x 15 MHz regional areas	2 x 30 MHz in Melbourne and Sydney 2 x 25 MHz in Adelaide, Brisbane and Perth 2 x 5 MHz in Canberra, Darwin and Hobart
2 GHz	2 x 20 MHz metro 2 x 15 MHz regional 2 x 10 MHz remote	*2 x* 15 MHz metro 2 x 20 MHz regional 2 x 10 MHz remote	2 x 25 MHz in Melbourne and Sydney 2 x 20 MHz in Adelaide, Brisbane and Perth 2 x 10 MHz in Canberra and Darwin 2 x 5 MHz in regional areas
2.3 GHz	98 MHz in Adelaide, Brisbane and Perth 91 MHz in Melbourne and Sydney 70 MHz in Canberra	..	..
2.5 GHz	2 x 20 MHz national	2 x 40 MHz national	..

.. Not applicable.

Sources: ACMA (2015g); Analysys Mason (2015); CIE (2014).

End users communicate over a mobile network using different types of portable devices to send and receive information — such as smartphones, tablets and vehicle-mounted terminals. To access the network, a device must have computer chips and software compatible with the spectrum band(s) being used on the network. Many widely available devices are compatible with multiple (but not infinite) parcels of the spectrum (NSW Telco Authority, sub. DR46). For example, the Apple iPhone 6s/6s plus models available in Australia are configured to support 22 different spectrum bands used for Long Term Evolution (LTE) in various countries, including bands used by Telstra, Optus and Vodafone Hutchison Australia (Vodafone) (Apple nd).

International spectrum harmonisation for PSMB is progressing

Work is underway at the international level to harmonise the spectrum bands used for the delivery of PSMB at a regional level. Under the current international framework administered by the International Telecommunication Union (ITU), spectrum harmonisation for PSMB occurs in three separate regions, with Australia aligned with the Asia-Pacific region (Region 3). Appendix B contains further information about international spectrum harmonisation.

Infrastructure sharing is common in the mobile sector

As a means of minimising capital and operating costs, mobile carriers often share (or co-locate) radio access network infrastructure through commercial negotiation. Typically, this involves carriers sharing passive infrastructure, such as physical sites, towers and power supplies. Carriers also have regulatory obligations to provide access to this infrastructure to third parties under certain circumstances (chapter 7).

More extensive forms of infrastructure sharing involve mobile carriers sharing equipment, such as spectrum and base station equipment (Alcatel-Lucent 2010; GSMA 2012; Mahindra et al. 2013; NEC 2013). This type of sharing is supported by recent LTE technical standards (ATF, sub. 4, attachment 5). Active radio access network sharing is less prevalent in Australia than in some international markets (Coleago Consulting 2015), although there are some roaming arrangements in place — for example, between Optus and Vodafone in selected regional areas.

LTE differs from previous generation mobile technologies

Mobile technology continues to evolve. The latest generation technology is LTE, a fourth generation (4G) technology. LTE technology is based on open international standards set by the 3rd Generation Partnership Project (3GPP) and updated on a 18–24 month cycle (ATF, sub. 4, attachment 3). LTE has various enhancements compared with previous generation mobile technologies (box 5.3). Technical standards for 'mission critical' voice applications on LTE are currently in development (section 5.6).

LTE is the accepted technology for PSMB

There is widespread agreement — both internationally and amongst study participants — that PSMB should be delivered using LTE technology regardless of the delivery approach. The 3GPP LTE standard has been endorsed nationally and internationally as the preferred technology standard to support commercial and mobile broadband networks for Public Protection and Disaster Relief (appendix B).

Box 5.3 LTE enhancements over previous mobile technologies

LTE has various enhancements over previous generation mobile technologies, including:

- higher peak data rates and more efficient use of spectrum
- the ability to make greater use of 'small cells' (for example, femtocells) to target additional capacity in dense areas or indoors
- more effective sharing of traffic at the edge of a cell by multiple adjacent cells, which takes the pressure off any one cell
- the ability to apply differentiated Quality of Service, priority and pre-emption mechanisms for different users and applications
- the ability to use 'carrier aggregation', which enables carriers to mix and match (non-contiguous) combinations of spectrum into a virtual single block in order to scale-up capacity for a specific group of users or applications in an individual area when needed
- the ability for automatic detection and removal of failures, and automatic configuration of networks
- the ability to use device-to-device communications to enable direct-mode communication between proximate users even when the network is unavailable.

Sources: 3GPP (2015a, 2015d); 4G Americas (2013); ACMA (sub. 14; 2013d); Ericsson (sub. 10); Rumney (2013).

Mobile broadband technology will continue to evolve and improve. This will have implications for what is technically possible in the future, and continue to change the expectations for PSMB. Study participants noted the potential for new PSA applications based on the emerging market for the Internet of Things, including machine-to-machine applications (Alcatel-Lucent, sub. 15; CDMPS et al., sub. 7) (box 5.4).

Box 5.4 Machine-to-machine applications and the 'Internet of Things'

Machine-to-machine (M2M) communication refers to technology that allows two or more devices to communicate with each other without the manual assistance of humans. Such communications are part of the broader 'Internet of Things' (IoT) — a system of electronics, recorders, sensors and the like, embedded into physical objects and spaces and networked together through the internet.

M2M communication and the IoT allow monitoring, data collection and automated action by machines that increase the information available to human decision makers and free up resources for other uses. In some areas, PSAs already make extensive use of M2M communication. For example, many buildings have smoke and heat sensors that automatically alert local fire brigades in the event of fire. However, the expansion of mobile broadband greatly increases the scope of M2M technologies. In development are devices to be worn by officers to monitor their health during an incident, as well as devices that allow PSAs to link in to on-site sensors, such as alarms, monitoring equipment and video cameras. As the set of devices which are part of the IoT increases, further opportunities for PSAs may arise — for example, traffic lights that can communicate with ambulances to provide a clear path to an emergency.

Sources: Department of Homeland Security (2015); Nokia (2015).

5.3 Coverage and capacity requirements

The design or 'dimensioning' of a mobile network is driven largely by the desired levels of coverage and capacity. These considerations are interrelated (Motorola, sub. 12). Typically, the dimensioning of a mobile network first involves establishing a coverage layer (coverage sites), then adding additional sites in specific areas to meet expected demand (capacity sites). The higher the defined level of 'quality' attached to the coverage layer (indoor, in-tunnel, outdoor handheld or in-vehicle) the more capacity is provided to users as a minimum standard (Telstra, sub. 19).

Coverage and capacity are key drivers of network costs

A very high proportion of the capital and operating costs of mobile networks is associated with deploying and maintaining the coverage layer. A modelling exercise commissioned by the Australian Communications and Media Authority (ACMA) indicated that coverage is a more significant driver of the number of LTE sites in a network than capacity (Analysys Mason 2015).

There are technological limitations to how far mobile base station equipment can transmit over a geographic area. But other factors can also affect coverage. Coverage (and capacity) can differ depending on the end-user device — for example, vehicle-mounted antennas can pick up a signal further from a cell site than handsets can. It can also vary depending on whether a user is outdoors, indoors or underground. The quality of coverage required influences the density of the network, and the types of sites and spectrum used (chapter 6).

Adding capacity to a mobile network is also an important driver of costs. As such, in delivering a PSMB capability it is important to ensure that capacity is utilised as efficiently as possible. This means sharing capacity amongst PSAs on a flexible basis, rather than allocating a fixed amount to each individual agency (a 'partitioned network').

Mobile carrier networks have extensive population coverage

Coverage of mobile carrier networks in Australia is typically presented as a proportion of the population. Combined, commercial 3G and 4G networks cover about 98 to 99 per cent of the population, but significantly less in terms of Australia's landmass (in the order of 30 per cent). That said, population and geographic coverage can vary considerably across jurisdictions (for example, Western Australia compared to Victoria) and mobile carriers (box 5.5). The coverage of mobile carrier networks is often different to that of land mobile radio (LMR) networks, although the nature and extent of this difference varies (chapter 2).

Box 5.5 Mobile network coverage in Australia

All three mobile carriers have 3G networks with extensive population coverage.

- Telstra's 3G mobile network covers 99.3 per cent of the population, equivalent to 2.36 million square kilometres (km^2) on land (about 31 per cent of Australia's landmass).
- Optus' 3G network covers 98.5 per cent of the population, equivalent to 1 million km^2 (about 13 per cent of Australia's landmass).
- Vodafone's 3G network covers 95.4 per cent of the population, equivalent to about 350 000 km^2 (about 5 per cent of Australia's landmass), although Vodafone customers can roam on Optus' network in selected regional areas under a commercial agreement.

Each mobile carrier continues to expand its 4G network coverage, but at this stage it trails 3G coverage. For example, Telstra's 4G (LTE) coverage was expected to reach 94 per cent of the population by mid-2015, and it intends to extend its 4G footprint to 99 per cent of the population (2.5 million km^2) by 2017. Optus' 4G coverage is currently at 86 per cent of the population.

Sources: Analysys Mason (2015); Optus (sub. 18; 2012); Penn (2015); Telstra (sub. 19).

There are different ways to deliver network capacity

Three main factors determine the capacity that can be provided by a mobile network.

- Spectrum — a larger amount of spectrum can deliver greater capacity.
- Sites — a larger number of sites can deliver greater capacity.
- Technology — some technologies can carry a greater amount of data per megahertz (MHz) of spectrum (or have a higher spectral efficiency) than others (ACMA, sub. 14).

There is a tradeoff between spectrum and infrastructure, assuming technology of a given spectral efficiency (ACMA, sub. 14). This means that, in some cases, it is possible to deliver the same level of capacity over less spectrum by building more sites, or vice versa. This tradeoff is most relevant in areas where mobile networks are dense (such as metropolitan areas) — it does not work as well in less densely populated rural and remote areas because of technical and regulatory constraints on increasing cell size beyond a certain distance (ACMA, sub. 14).

The spectral efficiency of technology influences the extent of the tradeoff between spectrum and sites. The shift to LTE technology has improved the level of capacity that can be provided by a given set of spectrum and infrastructure inputs (box 5.3).

Prioritisation mechanisms will be required under all approaches

A key requirement of a PSMB capability is that it provides PSAs with 'sufficient' network capacity in a timely way and on a consistent basis (chapter 4).

Some study participants have suggested that this would be difficult to achieve under a commercial approach to delivering PSMB because of the high likelihood of network congestion (Motorola, sub. 12; NSW Telco Authority, sub. 30; Victorian Government, subs. 28, DR44). Instances of congestion were anticipated to be less frequent under a dedicated or hybrid approach (NSW Telco Authority, sub. 30; Victorian Government, sub. DR44).

However, network congestion — and the potential this has to prevent users from accessing network capacity when they need it — is a risk under all PSMB delivery approaches, not just those where PSAs would share network infrastructure with other users. Indeed, congestion will arise whenever demands on the network approach or exceed its capacity — the source of demand (that is, whether it stems from a PSA user or a member of the public) is irrelevant.

The prospect of network congestion highlights the importance of using prioritisation techniques — that ensure capacity is allocated to those users who value it most — as part of any PSMB delivery approach (section 5.4).

The costs of providing coverage and capacity differ across approaches

The costs of meeting PSMB coverage and capacity requirements will vary depending on whether a dedicated, commercial or hybrid deployment approach is pursued.

Existing carrier infrastructure is more readily leveraged in a commercial approach

There was broad consensus across study participants that leveraging the use of existing infrastructure would significantly lower the costs of delivering a PSMB capability (BAI, sub. 1; Optus, subs. 18, DR37; Telstra, sub. 19; Victorian Government, sub. 28). The Australian Mobile Telecommunications Association considered that (sub. 21, p. 2):

> Unnecessary duplication of infrastructure should be avoided. Industry members have well-established policies and processes in place to enable the sharing of physical infrastructure via the Mobile Carriers Forum (MCF) and similar commercial sharing arrangements should be considered in the design of any PSMB capability.

The potential to use or share existing infrastructure arises in various ways.

- Sharing existing mobile carrier cell sites — approximately 15 000 unique mobile carrier sites have already been deployed across Australia (ACMA 2015g).
- Leasing commercial backhaul capacity — there is a well-developed market for the provision of backhaul transmission capacity (particularly in metropolitan areas and major regional centres), over optical fibre, microwave and satellite technology (and existing carrier sites already have backhaul in place for commercial operations).

- Leveraging publicly owned infrastructure — for example, the use of existing sites and backhaul capacity already deployed for operation of LMR networks, or sites and other infrastructure resources in the transportation, maritime or defence sectors (Government of South Australia, sub. 29; Victorian Government, sub. 28). (While governments may pay a lower price for using their own sites than if mobile carrier sites were used, this still has opportunity costs which would need to be considered in an evaluation of economic costs.)
- Leveraging other complementary telecommunications network infrastructure — for example, seeking to access fibre, wireless or satellite capability deployed (or that will be deployed) as part of the National Broadband Network rollout.

In principle, it would be possible to leverage mobile carrier network infrastructure for PSMB to the same extent under all delivery approaches. That is, even under a dedicated approach, space could be sought on existing mobile carrier sites, or backhaul capacity could be leased from the commercial market, thereby considerably reducing infrastructure deployment costs compared to a 'greenfields' build. At face value, the large number of existing mobile sites appears far in excess of what would be needed to deliver a PSMB capability (in areas where commercial carriers have coverage), suggesting relatively few new physical sites would be needed.

However, leveraging existing commercial infrastructure on a large scale is not without challenges. While numerous, carrier sites will not necessarily have spare capacity that could easily accommodate new dedicated equipment for PSMB (particularly where carriers reserve sufficient space for their future needs). Using carrier sites for PSMB would also require adhering to relevant property restrictions, and ensuring that sites remain within tolerance levels for electromagnetic energy emissions.

These challenges notwithstanding, it is likely that existing carrier infrastructure would be more readily leveraged under a commercial approach to delivering PSMB, relative to other approaches. Indeed, sharing mobile carrier infrastructure would be implicit in a commercial approach, and mobile carriers would have a strong incentive to do this in the most efficient way possible to minimise their total network costs. By contrast, in a dedicated approach (and some hybrid approaches), separate commercial arrangements would need to be negotiated with mobile carriers to gain access to existing infrastructure, such as sites.

There is also scope to use government-owned infrastructure (including LMR sites and backhaul capacity) to facilitate the delivery of PSMB. This might be desirable where it is not feasible to access commercial carrier sites, or to take advantage of the 'hardened' nature of LMR sites (in terms of power supply backup and civil construction standards). That said, due to differences in network architecture, LMR networks typically have many fewer sites than mobile carrier networks (for example, in Victoria there are approximately 200 unique sites across the StateNet and Rural Mobile Radio networks, compared to over 3800 unique mobile carrier sites) (ACMA 2015g; Nally 2014). This suggests that, where it

is not possible to use mobile carrier sites for delivering PSMB, a significant number of greenfield sites would be required.

Dedicated and hybrid approaches require installing new equipment upfront

A dedicated or hybrid approach to PSMB would involve deploying a coverage layer across the dedicated network component. Even where an existing site can be leveraged to avoid a greenfields build (discussed above), significant costs would be incurred, including:

- the deployment of new mobile base station equipment in each cell (to operationalise the dedicated spectrum band where it is not already supported at the site)
- purchasing (or where not possible, deploying new) backhaul capacity to service each site (unless an LMR site already had sufficient backhaul capacity)
- ongoing maintenance of sites and equipment (and capital refresh over time).

Some of this new investment would comprise fixed costs. That is, the investment will need to be incurred irrespective of the amount of traffic that is expected to be carried on the network — for example, new mobile base station equipment. The same scale of investment would not be required under a commercial approach because mobile carriers have already incurred these fixed costs (Optus, sub. 18).

A commercial operator could likely exploit greater operating efficiencies

There are significant costs associated with operating mobile networks, including the operation, maintenance and periodic upgrade of sites and equipment, transmission networks, and core network systems. There are also significant organisational-level costs, including for administration, service and labour force management, and accommodation (Optus, sub. 18; Telstra sub. 19; Victorian Government, sub. 28).

Many of these operating costs will be largely invariant to PSA traffic (fixed costs) — for example, costs associated with maintaining site equipment, core network elements and billing platforms (Motorola, sub. 12). Accordingly, by exploiting economies of scale and scope, mobile carriers are expected to be able to minimise PSMB operating costs relative to a dedicated network operator (who would need to incur the aforementioned fixed costs and spread them over a much smaller subscriber base).

That said, it may be feasible to achieve scale efficiencies under a dedicated network approach by contracting out operation and maintenance activities to commercial partners.

The spectrum inputs available to a dedicated network operator would likely be more constrained

Network operators would rely on a combination of sites and spectrum to provide sufficient capacity to PSAs as part of a PSMB capability.

The large amount and mix of spectrum, cell types and technologies held by mobile carriers (section 5.2) affords them considerable flexibility in terms of how they meet demand for network capacity. For example, mobile carriers will often deploy a lower spectrum band (such as below 1 GHz) at a given site to provide network coverage to a broad area, and then have the ability to add spectrum from other bands (such as above 1 GHz) to the same site (at a lower cost than building a new site) to boost localised capacity. Further, because higher-band spectrum is typically allocated in wider bands (table 5.1), this allows mobile carriers to provide greater levels of capacity per site in a local area compared to if they could only use their narrower sub-1 GHz spectrum bands.

There is no technical reason why an 'optimal' mix of infrastructure and spectrum could not be used to deliver PSMB services under a dedicated network approach. However, it could be more difficult to achieve if suitable spectrum is not readily available or able to be acquired. Indeed, spectrum is a limited resource. Much spectrum in bands suitable for LTE has already been licenced, and a signification portion is held by mobile carriers. This, in turn, means that a dedicated network operator may not be able to add capacity as cost effectively as a mobile carrier. The Commission's quantitative analysis examines how the costs of adding capacity may differ across PSMB delivery options (chapter 6, appendix C).

Irrespective of the delivery approach to PSMB, the valuable and scarce nature of spectrum heightens the need to use it as efficiently as possible, such as through flexible arrangements that allow it to be shared. Under any delivery approach for PSMB, efficient pricing and licensing frameworks can facilitate the sharing of spectrum resources with other potential users to reduce the risk of it sitting idle (chapter 7).

FINDING 5.1

The costs of delivering PSMB under any option can be reduced by:

- maximising use of existing infrastructure
- sharing network capacity among PSAs in real time (that is, a non-partitioned network)
- allowing for flexible use of spectrum across users.

Extending mobile coverage will be costly under any approach

Some study participants suggested that a PSMB capability should provide equivalent geographic coverage to LMR networks (for example, Victorian Government, sub. DR44). This would mean rolling out a PSMB network in areas of Australia where there is currently no commercial mobile coverage (but there is LMR coverage).

This could be achieved by taking a dedicated, commercial or hybrid approach to the delivery of PSMB.

- A dedicated approach would involve building a new LTE network for PSAs, with dedicated spectrum.
- A commercial approach would involve paying a mobile carrier to extend its network to deliver 'public safety grade' mobile broadband services.
- A hybrid approach could take many forms — for example, a mobile carrier could be paid to deliver PSMB using a combination of dedicated and carrier spectrum.

The Commission has not undertaken a quantitative evaluation of the costs of these PSMB delivery options for two reasons. First, while some use of existing infrastructure (such as LMR sites) in areas outside the mobile carrier footprint may be possible, no option provides significant scope to share or reuse existing infrastructure — a substantial greenfields network build would be required, meaning the resource costs associated with each option are likely to be broadly comparable. Second, insufficient publicly available data means it has not been possible to establish the nature and size of the 'coverage gap' in each state and territory (areas that have LMR coverage but not commercial mobile broadband coverage) (chapter 2).

That said, the Commission was able to develop a 'back of the envelope' estimate of the cost of deploying an LTE network in areas of Victoria that are not covered by a mobile carrier network but are covered by LMR networks (box 5.6). This analysis does not provide insights as to the most cost-effective delivery approach to pursue (as noted above, the resource costs are unlikely to vary significantly across delivery approaches). However, it does highlight that deploying an LTE network in this region would be very expensive, and would significantly increase the total cost of delivering a PSMB capability to PSAs.

Moreover, while the Commission has focused on Victoria — primarily for reasons of data availability — it is likely that matching the LMR footprint would be a far more costly exercise in other jurisdictions where the geographic coverage of carrier networks is considerably less than LMR networks. For example, the Victorian Government (sub. DR44) indicated that the coverage gap between LTE and LMR networks in New South Wales is about eight times larger (on a square kilometre basis) than that in Victoria.

Box 5.6 Extending mobile coverage in Victoria

The Victorian Government (sub. DR44) submitted that public safety LMR networks cover about 95 per cent of Victoria's landmass, while mobile carrier network coverage extends to about 80 per cent — a difference of about 35 000 km^2.

Using this information and other inputs (chapter 6 and appendix C), the Commission estimates that the cost of providing a mobile broadband capability in this 'coverage gap' would be in the order of 1.2 to 1.8 times the cost of deploying a PSMB capability in areas of Victoria within the mobile carrier footprint (a 190 000 km^2 area).

These estimates are highly illustrative. They depend heavily on assumptions about the nature of the geographic areas covered, network design, and the costs of acquiring sites, equipment and backhaul.

Sources: Productivity Commission estimates; Victorian Government (sub. DR44).

Key drivers of the costs of extending PSMB coverage outside the existing mobile carrier footprint in each state and territory would include:

- the capital costs of installing new base station equipment and backhaul links
- the ongoing costs of operating sites and equipment
- the capital costs of constructing or acquiring new sites.

The costs of building new mobile sites are significant. For example, according to some estimates, the costs of building a new base station site is in the order of three times more expensive than deploying new equipment to an existing base station (Bell Labs 2011). Information provided confidentially to the Commission during this study suggests the differential is even higher.

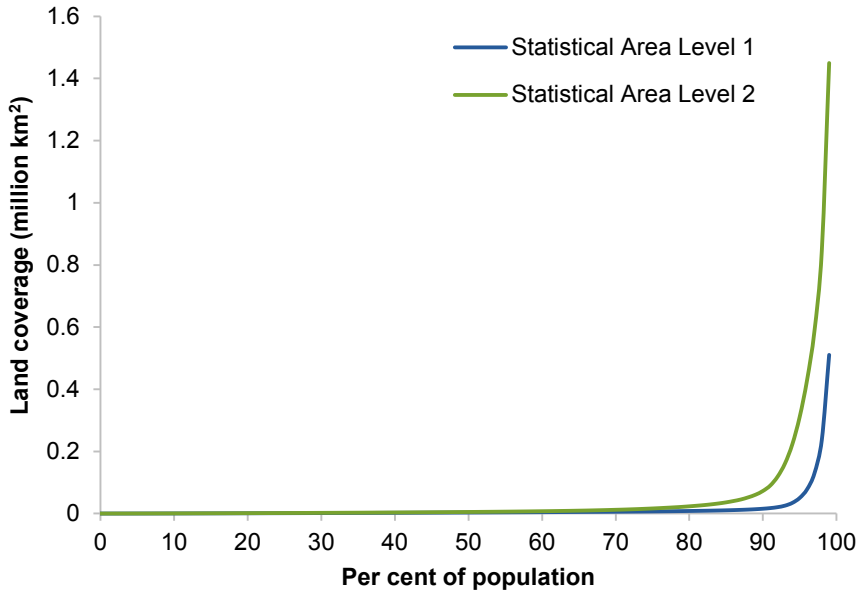
Further, the cost of achieving a unit increase in population coverage (say from 99.3 per cent to 99.4 per cent) would be expected to increase exponentially as a proportionally larger increase in geographic coverage is required (figure 5.3).

It is highly unlikely that the benefits of a PSMB capability in regions outside of the mobile carrier footprint would be sufficient to justify the costs, at least in the short-term. This reflects the fact that existing LMR networks are expected to continue operating in all Australian jurisdictions for at least the next five years (and in some cases, for considerably longer), and that there are other technologies capable of providing a level of mobile broadband coverage when and where it is needed at a lower cost. Indeed, BAI (sub. 1, p. 2) submitted that:

> In the less densely populated areas of Australia it is not, and never will be, viable to establish a high speed communications coverage network using PSMB, VHF, UHF or cellular terrestrial options.

Figure 5.3 **Land coverage for percentage of population covered[a]**

Illustrative example



[a] Statistical Area Level 1 and Statistical Area Level 2 are spatial units in the Australian Statistical Geography Standard.

Data sources: ABS (*Australian Statistical Geography Standard (ASGS): Volume 1 – Main Structure and Greater Capital City Statistical Areas*, *July 2011*, Cat. no. 1270.0.55.001; *Socio-economic Indexes for Areas (SEIFA), Data Cube only, 2011*, Cat. no. 2033.0.55.001).

Alternative technologies can provide some level of capability in remote regions

There are ways to deliver a level of broadband capability in areas outside the mobile carrier coverage footprint (albeit not to a public safety grade standard) without extending LTE networks. For example, transportable equipment — known as 'Cells on Wheels' (COWs) — provides temporary mobile broadband coverage in specific regions when it is needed. Mobile carriers and LMR network operators already rely on transportable equipment to extend the coverage and capacity of their networks on an as-needs basis (chapter 2). To deliver mobile broadband when and where it is needed, PSAs could use their own COWs and spectrum to provide temporary coverage and capacity, or they could engage this capability through mobile carriers.

Because of the inherent flexibility in when and where COWs are deployed, they provide a relatively low-cost way of providing network coverage and capacity in localised areas. They are particularly suitable for large planned events (such as music festivals), and may also be useful for dealing with medium to long-term emergency situations (such as a flood and recovery scenario). On the other hand, the time taken to deploy COWs to areas where coverage is required will limit their effectiveness in some emergency scenarios.

Another alternative is satellite broadband. Satellite networks are used by commercial carriers to provide mobile voice and data services, and commercial investment in this platform is ongoing (Optus, sub. 18). Satellite technology has also been used by mobile carriers in emergency situations to provide voice and data services as a back-up while terrestrial services were being restored (Optus, sub. 18), and satellite voice services are already used by PSAs outside LMR coverage areas.

Relying on satellite broadband could be more economical than using transportable equipment. Moreover, satellite services can be accessed in any geographic area relatively quickly, where commercial arrangements are already in place. However, there are quality issues that need to be considered. For example, time-sensitive applications may not perform as well on satellite networks, and performance can be affected by weather conditions or the presence of smoke. That said, the next generation of satellites — such as those currently being deployed by NBN Co — will provide greater capability than current generation satellites (Department of Communications 2015a; NBN Co 2015b).

The case for extending mobile coverage is not static

While the costs of providing PSMB in areas without existing mobile carrier coverage are expected to be significant, it is likely that mobile carriers will extend their networks over time for commercial reasons. This would significantly improve the business case for providing a PSMB capability in these regions, all else equal.

A number of factors will bear on the coverage decisions of mobile carriers, including population movements, the pricing of complementary inputs (such as backhaul) and technological developments. For example, the development of technologies to extend the coverage footprint of LTE cells — known as Extended Range Communications — is currently being researched and tested in the United States (Redding and Gentile 2014; Sokol 2015).

Technological development may also allow governments to use spectrum currently used for LMR networks to deliver mobile services over LTE. This could reduce the costs of extending PSMB networks, given the superior coverage properties of the spectrum bands used by LMR networks (such as those in the 400 MHz spectrum band) (RF Technology, sub. 3; VHA, sub. 11). Moreover, if LMR networks are retired at some point in the future, this would likely increase the benefits (and case for) more extensive PSMB network coverage.

In the meantime, the roll out of PSMB services in areas where there is mobile carrier coverage would provide an opportunity for governments to build a business case for extending coverage over time.

Policies are already in place for targeted mobile coverage extensions

There may be a case for targeted extensions of mobile networks to deliver PSMB services, especially if the footprint of carrier networks does not map to areas of significant public safety risk. For example, the Victorian Government (sub. 28, p. 25) noted that:

> The business requirement for coverage (both voice and data) is for 100% geographic coverage of the State, in addition to 30km out to sea, overlapping coverage into neighbouring States, and in-building and tunnel coverage. It is recognised that fully meeting this requirement will never be feasible, so a risk-based analysis must be undertaken to direct coverage augmentation investments appropriately.

The NSW Telco Authority (sub. 30, p. 45) noted that:

> From an operational perspective, the provision of PSMB capability in regional and remote areas is necessary in order for public safety agencies to respond appropriately to an incident and to operate effectively. It is important to note that extending coverage to these areas does not necessarily mean providing blanket coverage across an entire state. A prudent financial management approach requires that coverage extension be determined based on business needs and a risk analysis to ensure that vital resources are not wasted.

There are policy programs in place which subsidise the extension of commercial mobile carrier networks into otherwise 'non-commercial' areas (box 5.7).

Box 5.7 Policies to extend commercial mobile coverage

Various government policies have subsidised the extension of commercial mobile networks, largely focusing on improved coverage in regional areas.

- In Western Australia, the state government contributed $39 million in 2012 to expand mobile coverage along highways and in remote towns as part of the state's Regional Mobile Communications Project. Telstra won the contract and has deployed 113 new base stations, which were expected to increase its coverage footprint in Western Australia by 31 per cent. While Telstra owns the infrastructure, it is required to allow PSAs in the state to co-locate their own radio communications equipment on each site.
- The Australian Government announced $100 million in funding in 2015 for 499 new mobile base stations to be installed in regional areas by the end of 2018 as part of its Mobile Black Spot Program. This is supplemented by funding from mobile carriers and state and territory governments. An additional $60 million of Australian Government funding has been allocated for a second round of the program. Winning bidders in the program are required to give other mobile carriers the opportunity to co-locate equipment on the new sites (including through sharing access to power and backhaul).

Sources: Department of Communications (2014a); Turnbull (2015); WA Department of Commerce (2014).

Where it is considered efficient to do so, governments could choose to tailor any future mobile coverage extension programs to focus more explicitly on matters and outcomes important for PSAs. For example, by prioritising locations considered particularly susceptible to emergency incidents (such as fire-prone areas with limited permanent

population), or which are critical to the transmission of emergency personnel in an emergency incident (such as key rural roads or community meeting points).

FINDING 5.2

Providing a permanent PSMB capability in areas not currently covered by commercial mobile networks would be very costly. There are lower-cost options that can be pursued to provide a level of mobile broadband coverage and capacity (such as transportable equipment or satellite broadband), albeit not to a 'public safety' standard.

Targeted extensions of mobile broadband networks may be warranted on a case-by-case basis, for example, where strategic assets are located in areas susceptible to emergency incidents.

5.4 Delivering priority services

Study participants have indicated that a key aspect of a PSMB capability is the ability to treat PSAs preferentially — or with priority — relative to other network users, and to be able to prioritise between different types of PSA users and applications. Two issues are particularly important to PSAs:

- priority access to the network — meaning the network operator is able to identify and prioritise the access attempts of PSAs (or certain PSAs) over those of other users. This can increase the likelihood that high-priority users will gain network access in a timely manner, even if the network is congested
- priority access to network capacity — having gained access to the network, identified PSA users and their applications would be prioritised over the applications being used by others. This can increase the likelihood that high-priority users will have access to sufficient capacity to carry out their duties regardless of the demands placed on the network.

Views differ as to whether commercial networks can provide priority network access

Some state governments and PSAs questioned whether it is technically feasible for mobile carriers to provide priority network access to PSAs without dedicated spectrum, particularly when their networks are experiencing congestion (ACT Emergency Services Agency, sub. 25; CAA, sub. DR36; MFB, sub. 6; NSW Telco Authority, sub. 30).

Specifically, study participants submitted that there is a limit to the types of priority services that can be offered on LTE networks without dedicated spectrum. For example, the NSW Telco Authority (sub. 30) suggested that LTE networks may not be able to:

- handle multiple simultaneous access requests beyond a certain threshold
- grant network access (such as for call set up) in a timely manner
- deliver priority network access for PSAs alongside other commitments, such as the prioritisation of Triple Zero voice calls.

Other participants pointed to limited evidence in the public domain of mobile carriers being able to identify and prioritise the access attempts of some users over others on an LTE network (NSW Telco Authority, sub. 30; Victorian Government, sub. 28).

Given these concerns, several study participants submitted that PSMB should be delivered using dedicated spectrum — either through a dedicated or hybrid approach — on the basis that it will mitigate the risks of PSAs being unable to access a mobile carrier's network when it is congested (CAA, sub. DR36; MFB, sub. 6; Motorola, sub. DR43; NSW Telco Authority, sub. 30). For example, the Metropolitan Fire and Emergency Services Board (sub. 6, p. 3) indicated that:

> MFB would support dedicated spectrum … because relying on private carriers to have available the required spectrum in wide-ranging emergency events would not be feasible. MFB is keen to avoid a scenario where, once the maximum dedicated spectrum is used, PSAs could not be given priority (on the mobile network, if you haven't connected, the system doesn't know you're trying to achieve access) …

Other participants and studies indicate that dedicated spectrum should be targeted to those areas most at risk of network congestion, such as highly dense urban areas (Motorola, sub. DR43; Peltola and Hammainen 2015; Telstra, sub. DR41). Other participants and studies indicate that dedicated spectrum should be targeted to those areas most at risk of network congestion, such as highly dense urban areas (Motorola, sub. DR43; Peltola and Hammainen 2015; Telstra, sub. DR41).

However, several study participants and mobile communications experts have indicated that it *is* technically possible to provide priority network access for PSAs on commercial LTE networks without dedicated spectrum (Borkar, Robertson and Zdunek 2011; Ericsson, sub. 10; Ferrus and Sallent 2015). For example, Ferrus and Sallent (2015, p. 218) noted:

> 3GPP networks in general and LTE in particular support two mechanisms that allow an operator to impose cell reservations or access restrictions … [These access controls] allow the network operator to prevent overload of the access channel under critical conditions, though it is not intended that access control be used under normal operating conditions.

Ericsson (sub. 26, p. 3) submitted:

> [T]hese technologies [for prioritising and pre-empting access to congested LTE networks] exist and Ericsson's Public Safety LTE offers Dynamic Prioritization and Pre-emption. Public Safety LTE systems immediately prioritize those users most critical to serving an incident, de-prioritize nonessential users and, when necessary, pre-empt. 3GPP support for this capability has been available for several years …

Several methods for delivering a priority network access capability to PSAs on an LTE network have been identified:

- 'access control' and 'access class barring' functions. These allow the network operator to restrict or prevent access attempts made by lower-priority users — in turn maximising the probability that PSAs can gain access to a congested network (Ericsson, sub. 26; Ferrus and Sallent 2015; McElvaney 2015; Motorola, sub. 31; Nokia Networks 2014)
- forms of 'pre-emption', such as the network operator shifting lower-priority users into other spectrum bands (load management), determining whether a connection can be dropped to free up resources for a higher priority user (box 5.8), or more extreme forms where commercial access classes are shut down based on pre-agreed triggers to make room for other users (Ferrus and Sallent 2015; McElvaney 2015; Nokia Networks 2014; NPSTC 2015a; Rivada Networks, sub. 9).

These mechanisms rely on the fact that different users on an LTE network are allocated to different access classes, and that users assigned to certain classes can be provided a superior priority and quality of service to other users (box 5.8).

A priority data service for PSAs (referred to as LANES, box 5.9) has been trialled by Telstra, most recently during the Australian Football League Grand Final in Melbourne. Telstra claims that this trial successfully demonstrated that priority access for PSAs can be provided on a public mobile broadband network (Telstra, pers comm., 30 November 2015).

Trials of priority network access on LTE networks for PSAs have also been conducted, and results presented, in conjunction with the rollout of the FirstNet network in the United States (FirstNet 2014; McElvaney 2015). While FirstNet will be a type of dedicated PSMB network, the planned business model is to lease out network capacity (and in effect, spectrum) when it is not being utilised by PSAs (appendix B).

Priority network access is technically possible but service levels are uncertain

In the Commission's view, there is sufficient evidence to be confident that priority network access for certain users can be delivered without dedicated spectrum, even when a mobile network is congested.

This notwithstanding, there is some uncertainty as to the precise levels of network accessibility that could or would be delivered under a commercial approach. However, this is not justification itself for using dedicated spectrum to deliver PSMB. Uncertainty about network accessibility (and other service standards) is a feature of *all* PSMB delivery approaches. Pilots would provide an opportunity to resolve uncertainty about the service levels that mobile carriers can deliver, and the costs of doing so, allowing governments and PSAs to make informed and efficient decisions regarding PSMB service levels (chapter 7).

Box 5.8 Access classes and priority services in Long Term Evolution (LTE) technology

Access classes in the 3rd Generation Partnership Project (3GPP) standards

The 3GPP standards allow for prioritisation of certain classes of users by allocating them to different access classes:

- classes 0–9 are randomly assigned to the entire mobile population
- class 10 is reserved for 000/112 calls
- class 11 is reserved for network administrative purposes (carrier staff)
- class 12 is reserved for security services
- class 13 is reserved for public utilities (for example, water or gas suppliers)
- class 14 is reserved for emergency services
- class 15 is reserved for carrier staff.

How prioritisation works in LTE

A 'bearer' is the term used to describe a 'virtual' channel established between the endpoints of an LTE network (from the end-user device to the core network). Once users are allocated an access class, their bearer is the means by which the network operator can differentiate one user's traffic from another's (such as between a PSA and commercial user) and one application's traffic from another's (such as a video stream compared to a web browsing session). There are two types of bearer in LTE.

- Default bearer: Every end user has at least one default bearer that is established when the end-user device first attaches to the network and remains available for the duration of the connection. An end-user device can have anywhere from zero to several dedicated bearers established at any given time and each is set up and taken down on an as-needed basis.
- Dedicated bearer: This is used when the quality of service requirements for some traffic are different than the provisions provided by the default bearer.

Each bearer (whether dedicated or default) is associated with two parameters.

- Quality Class Identifier: This parameter dictates the packet-level preferential treatment a bearer receives.
- Allocation and Retention Priority (ARP): This parameter dictates the preferential treatment an individual bearer receives when it is being established. During periods of congestion, the network may need to make decisions regarding which bearer requests should be accepted and which should be rejected, and may also choose to drop bearers of low priority to free up required resources. The primary role of the ARP parameter is to facilitate this decision-making process — it ensures that the request of the bearer with the higher priority level is given preference over lower-priority bearers.

Sources: Borkar, Robertson and Zdunek (2011); Ferrus and Sallent (2015); Hallahan and Peha (2013).

Moreover, dedicated spectrum does not guarantee that PSAs will always be able to gain network access. Existing LMR networks used only by PSAs can and do become congested during large incidents. Congestion — and the consequences this has for network access — is a risk under all PSMB delivery approaches, not just those where PSAs share network

infrastructure with other users. Prioritisation techniques will be critical to ensure that network capacity is allocated to those users who value it most.

Prioritisation of PSA users and applications is technically possible

A less contentious issue in this study is the ability to categorise and prioritise PSA users (and their applications) once those users have gained access to the LTE network. Several study participants argued that this is achievable within existing LTE technology (Alcatel-Lucent, sub. 15; Ericsson, sub. 10; Motorola, sub. 12) (box 5.8).

Some prioritisation on commercial networks already occurs

Mobile carriers already prioritise some types of traffic and applications. For example, it has been standard practice (at least on 2G and 3G mobile networks) for voice traffic to take priority over data traffic, primarily because of the risks that latency presents to the quality of a voice call. For the PSA sector, Triple Zero calls and the Wireless Priority System Service already receive priority over data services on carrier networks (Telstra, sub. 19).

Study participants indicated that a number of large organisations — including in the transport, defence and mining sectors — are already acquiring better than 'best effort' standard mobile data services, through either installing their own private LTE networks or under commercial arrangements with carriers (Alcatel-Lucent, sub. 15; ARCIA, sub. 2; ATF, sub. 4; Telstra, sub. 19). However, the precise service levels offered (including for prioritisation) are unclear. A priority data service for PSAs was trialled by Telstra at the G20 Leader's Summit in Brisbane in 2014, and most recently at the Australian Football League Grand Final in 2015. However, the Commission is not aware of any examples in the public domain of mobile carriers providing priority for PSAs on commercial LTE networks on a permanent basis, whether in Australia or other countries.

The commercial propositions for delivering prioritised PSMB over carrier networks drawn to the Commission's attention have been based on the presumption of some dedicated spectrum being allocated for PSMB in the first instance (box 5.9).

Priority arrangements can be changed under any approach

Broadly, two types of priority settings could apply to PSA users and their applications:

- static (or 'default') priority settings — specific pre-defined levels of priority that individual PSAs users and/or their applications receive on a network
- dynamic priority settings — priority levels for individual PSA users or applications that can be changed in real time (for example, during emergency incidents) (NPSTC 2015a).

Box 5.9 **Commercial technology for delivering priority services**

Telstra LANES

Telstra LANES involves integrating spectrum set aside for a PSMB capability into the architecture of the Telstra commercial carrier network so that it can form a seamless and reliable service for PSAs. This network could then be hardened through government investment to meet desired resilience requirements. Under the Telstra LANES model, spectrum set aside for PSMB is partitioned for PSA use only. PSA-only partitioned spectrum is then augmented with prioritised data on the carrier LTE spectrum in LTE coverage areas. Under a Memorandum of Understanding signed in 2014, Telstra's LANES capability will draw on technology developed by Motorola Solutions, which provides the capability for dynamic prioritisation.

Rivada Networks

Rivada Networks has put forward a model for delivering a PSMB capability using dedicated spectrum (30 MHz of spectrum in the 700 MHz band). Priority would be managed using 'ultra-priority access' and 'ruthless pre-emption technology' designed by Rivada. This includes the use of Rivada's spectrum sharing technology, which would make bandwidth available instantly to PSAs when they need it. At other times, network capacity would be leased to other parties (on a wholesale basis) when not in use by PSAs, in order to facilitate competition and allow for more efficient use of spectrum.

Sources: Rivada Networks (sub. 9); Telstra (subs. 19, DR41; 2014a).

Study participants submitted that PSMB should incorporate the capability to dynamically modify user and application priority settings (CDMPS et al., sub. 7; Ericsson, sub. 10; Motorola, sub. 12). The case for embedding this functionality within a PSMB capability was also made on economic grounds — namely that statically configured default priority settings for PSAs may not lead to the most efficient use of resources, as the priority a user needs will increase or decrease depending on their role or the incident they are attending (CDMPS et al., sub. 7; Ericsson 2014b; Motorola, sub. 12).

The capability for priority levels to be altered dynamically during incidents has been defined as a key objective by FirstNet in the United States (FirstNet 2015f). A recent report by the National Public Safety Telecommunications Council in the United States provides insights into how dynamic priority would be delivered.

> Dynamic priority attributes are designed to identify the NPSBN [Nationwide Public Safety Broadband Network] user's current activities and are measured in real time. Dynamic priority attributes temporarily override the user's default priority attributes. Typically, human intervention is required to trigger a dynamic priority change, such as pressing a device's emergency button or being assigned to an incident. (NPSTC 2015a, p. 34)

Current 3GPP standards provide the standard network and interface capabilities to enable a dynamic prioritisation capability to be built into an LTE network (Motorola, sub. DR43). However, Motorola (subs. 31, DR43) notes that these standards do not define the dynamic adjustment of priority levels for users and applications, and there is no planned 3GPP work to resolve this. As a result, Motorola notes systems that implement dynamic prioritisation

will be of a propriety nature since they will need to include elements that go beyond what is defined in the relevant standards. In this regard, there appear to be different commercial solutions for delivering dynamic prioritisation to PSAs (box 5.9 provides examples).

Nevertheless, the Commission understands that it is technically feasible to prioritise individual PSA users and applications statically and dynamically on LTE networks in a way that is consistent with 3GPP standards (Ericsson, sub. 26; Rivada Networks, sub. 27; Nokia Networks 2014), irrespective of the delivery approach.

How priority settings are changed could depend on the delivery approach

Changes to PSA priority settings could occur at two levels:

- end-user control — public safety officers being able to initiate changes to their priority settings in the field, which are immediately operationalised, such as by pressing a distress button
- central command control — PSAs' central command being able to implement changes to priority settings, such as upgrading or downgrading the priority levels of some public safety officers allocated to a local area.

Some study participants submitted that PSAs should have direct control over the priority settings for PSMB, including the ability to make changes in real time (Alcatel-Lucent, sub. 15; ATF, sub. 4; Motorola, sub. 12). Moreover, some participants considered that such control can only be achieved where PSAs (or a government on their behalf) own and control the network (PFA, sub. 8), including their own core network.

The Commission understands that it would be technically possible for PSA users to have direct (dynamic) control over their priority settings from the field under any PSMB delivery approach (subject to users having the appropriate devices and permissions). For example, certain applications (such as distress buttons) could be configured to instantly and automatically be prioritised over the network when they are activated.

The Commission also understands that it would be technically possible to make changes to PSA's priority settings as a result of instructions from PSA central command under any PSMB delivery approach — although the method by which changes are made may differ in practice. For example, under a dedicated approach, PSAs would direct their network operator to make changes to the priority settings. Under a commercial approach, protocols that govern how carriers change the priority settings of PSAs (either in response to requests made by a PSA's central command, or other pre-defined triggers) would be required, and may need to be written into a contract.

Irrespective of the deployment approach, changes to priority settings would require some kind of exchange between public safety officers requesting priority changes and the technicians that implement them.

5.5 Network reliability

The ability for mobile networks to continue to operate in adverse conditions, to a high level of certainty, is considered a core element of a PSMB capability (chapter 4). Reliability is largely a function of the resilience and robustness of the underlying infrastructure used to deliver mobile broadband services, how the network is managed and the effectiveness of fault restoration measures. The ability for PSA users to switch to alternative networks if the primary network fails can also be important.

Features of LMR networks which promote reliability

Network reliability is typically measured in terms of 'availability' (Ericsson, sub. 10; Motorola, sub. 12) — either in terms of individual network elements (such as individual sites) or end-to-end network availability (such as over a day, month or year).

LMR networks used by PSAs are designed to provide very high levels of availability (chapter 4). Study participants have indicated that LMR networks have various features which make them inherently more reliable than commercial mobile networks.

- LMR sites are often targeted for hardening to make them less susceptible to damage during fires, floods and other natural disasters (NSW Telco Authority, sub. 30).
- LMR sites typically have backup power supplies for 12–48 hours at each site, and up to 2–5 days for hard-to-access sites, compared to about 3–4 hours at a mobile carrier site (Alcatel-Lucent, sub. 15; Ericsson, sub. 10; Motorola, sub. 12; Victorian Government, sub. 28).
- LMR sites typically have multiple backhaul paths at each site (ATF, sub. 4; Motorola, sub. 15), which is not always the case for mobile carrier sites, particularly in low density areas (Alcatel-Lucent, sub. 15; Optus, sub. 18).
- LMR networks have highly proactive and reactive restoration measures in place, including undertaking repairs in a matter of hours, even in regional and remote areas (NSW Telco Authority, sub. 30).

While LMR networks are not considered perfect (Optus, sub. DR37), study participants pointed to Australian and international examples where LMR networks continued to operate during emergency incidents but mobile carrier networks did not (ATF, sub. 4; NSW Telco Authority, sub. 30; PFA, subs. 8, DR40).

Mobile carrier networks can be modified to improve reliability

There was broad consensus among study participants that mobile carrier networks would require a process of 'network hardening' to meet the requirements of a mission critical PSMB network. In practice, what this precisely entails, and how a particular set of

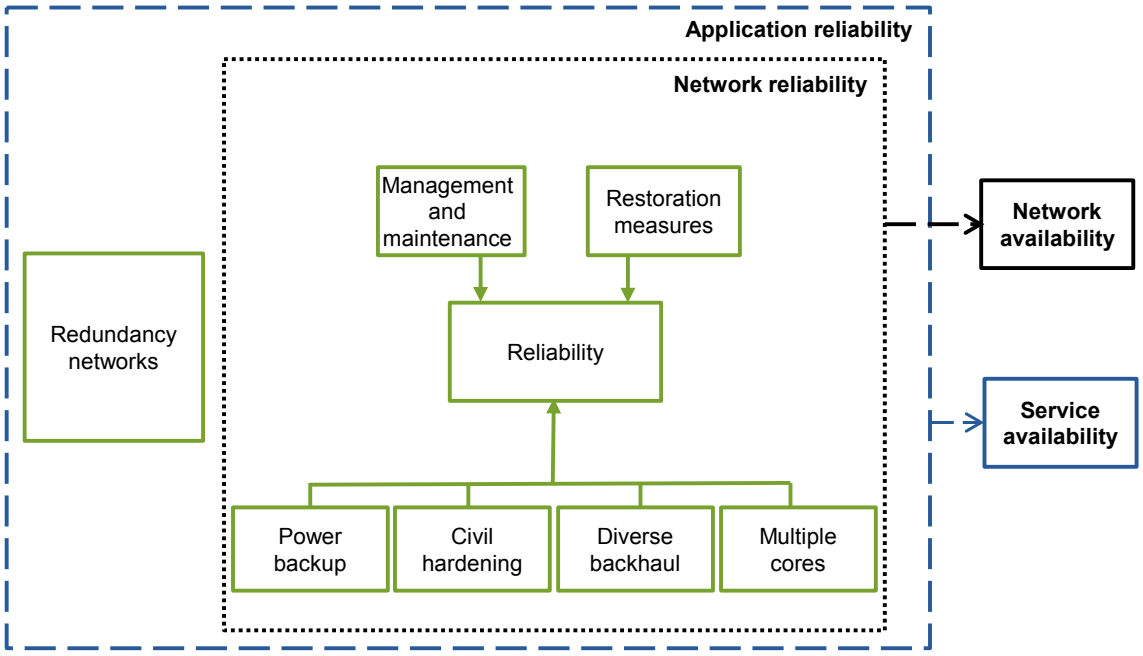
hardening arrangements would translate to specific reliability measures, is a more complex matter.

There are various ways to harden mobile carrier networks

There are various inputs which contribute to the overall level of network reliability and which fall under the category of 'network hardening', including (figure 5.4):

- adding extra power supply backup, particularly to mobile carrier sites which are harder to access in the event of a natural disaster or incident
- civil upgrades to make key sites more resistant to floods, fires and sabotage, such as the possible raising of equipment to avoid flood damage
- adding alternative path (redundant) backhaul links to sites which do not already have geographically diverse backhaul
- ensuring that there is adequate redundancy built into the core network.

Figure 5.4 **Achieving reliable services for PSAs**



The Government Wireless Network in Queensland provides an example of a network approach designed to meet the specific needs of PSAs, including levels of resilience, while using existing mobile carrier infrastructure (box 5.10).

Aside from individual network hardening, further redundancy can be offered by providing PSAs with access to alternative networks in the event of a network outage. For example, some study participants submitted that an approach which draws on the infrastructure of

multiple mobile carrier networks would minimise the risks of a single point of failure, and would potentially reduce the extent of investment needed in other network hardening (Coutts Communications, sub. 20; CSIRO, sub. 16; Optus, subs. 18, DR37; VHA, sub. 11) (section 5.8).

Box 5.10 The Queensland Government Wireless Network

The Government Wireless Network is a mission critical digital radio network that provides secure radio communications for Police, Fire and Ambulance services in Brisbane and South-East Queensland. The network is provided under a managed service arrangement with Telstra, which is responsible for the design, build, operation and maintenance of the network over a 15-year period from 2014. Much of the infrastructure used in the radio access network is co-located on commercial cellular infrastructure.

Sources: Queensland Treasury (2015); Telstra (sub. 19).

There is no technical limitation to mobile carriers hardening their networks to meet whatever service requirements are sought for PSMB (Ericsson, sub. 10). Telstra (sub. 19) argued that mobile carrier networks can be hardened to meet any resilience requirements, and far more readily than building a new dedicated network.

LTE networks offer greater reliability than earlier technologies

Several features of LTE networks indicate they are likely to be inherently more reliable than previous mobile broadband technologies such as 2G and 3G networks for delivering PSMB (3GPP 2015a; 4G Americas 2013; Ericsson 2014b; SCF Associates 2014). In particular, LTE networks:

- typically use a large number of small cells in a dense configuration in highly populated areas, giving them a greater degree of site redundancy
- have the capability to operate as 'self-organising networks' that can self-configure (new base stations can be inserted into an LTE network and will work immediately), self-optimise (a site will operate to best meet the needs of the overall network) and self-heal (the network will automatically re-configure to cope with problems)
- have lower power demands than earlier technologies, meaning that backup power supplies last longer or that batteries can be deployed at cell sites rather than generators.

Future international technical standards for LTE are expected to further improve the reliability of LTE networks (box 5.3).

The network hardening required to meet a given reliability standard could be influenced by several factors

The type and extent of network hardening required to meet a given reliability standard (and therefore overall hardening costs) could be influenced by several factors. For example:

- use of commercial networks — taking advantage of the high coverage (site) density of commercial networks in metropolitan areas (including in buildings and tunnels) would lower hardening requirements and costs, all else equal (Telstra, sub. 19)
- use of LMR sites — a greater proportion of publicly owned LMR sites in the network design would lower the number of sites that need civil site upgrades because they have already been built to deliver mission critical services (NSW Telco Authority, sub. 30)
- number of carrier networks — fewer sites would need to be hardened in any approach that relies on multiple carriers' networks rather than a single carrier's network (Optus, subs. 18, DR37; VHA, sub. 11).

In practice, the amount of hardening required to meet a given PSMB reliability standard could vary across delivery approaches (for example, due to differences in the mix of sites used). However, it has not been possible to quantify hardening requirements and costs in a precise way, due to a lack of information about the reliability of existing networks, and the mix of sites that would be used to deliver PSMB. Instead, the Commission's quantitative analysis (chapter 6) assumes that all PSMB delivery options would utilise a broadly similar mix of sites, and would therefore require an equivalent level of network hardening.

5.6 Migrating voice to LTE networks

The primary means of PSAs communicating in mission critical situations is, and is likely to remain, voice services (chapter 4). PSAs currently rely on LMR networks to deliver their mission critical voice capability (chapter 2). Ongoing technological advancements offer the prospect of migrating mission critical voice to LTE in the future. This, combined with potential cost savings from integrating voice and data on one network, means some governments are considering when and how this transition will occur.

Mission critical LTE voice applications are still in development

Mobile carriers in Australia continue to use their 2G and 3G networks to provide voice services, and are expected to progressively enable their LTE (4G) networks to provide voice to commercial users (Griffith 2015a, 2015b). Study participants indicated that a range of 'push to talk' (PTT) voice applications over 3G and LTE networks are already available in international markets today or have been trialled domestically. However, participants do not consider these to be at a mission critical standard, nor are they standardised across operators (ACMA 2015h; Ericsson, sub. 26; Motorola, subs. 12, 31).

It is highly unlikely that voice services (such PTT and group calling applications) will be able to be delivered to a mission critical standard over LTE networks in the short term. The technical standards for these applications are still in development, and equipment may not become commercially available until 2018 or later (box 5.11). The commercial development of equipment that embodies updated standards will take additional time, including to test equipment and functions before deployment (ARCIA, sub. 2; ATF, sub. 4; Motorola, sub. 12, NSW Telco Authority, sub. 30). Some experts do not expect any final standards to be reflected in manufactured equipment at least until 2020 (ATF, sub. 4; P3 Communications and TCCA 2015).

Box 5.11 LTE mission critical voice standards by 3GPP

Release 12

The last set of 3GPP standards to be finalised was Release 12 (March 2015). This release contained some initial features of relevance to the public safety market, including standards for device-to-device communications, proximity services and group communications. Future releases are intended to build on this work.

Within 3GPP, a working group is responsible for the development of standards to support mission critical applications over LTE, including for upcoming Release 13.

Release 13

This release is expected to (among other things) initiate technical standards to facilitate the delivery of mission critical voice applications over LTE, including:

- Mission Critical Push to Talk
- Group Communication System Enablers
- enhancements to Group Calling functionality
- enhancements to Proximity-based Services.

Release 13 is expected to be finalised in March 2016.

Release 14

This release is expected to include enhancements to mission critical voice standards introduced in Release 13. It may also initiate technical standards for mission critical video. Release 14 is expected to be finalised around mid-2018.

Availability of compatible equipment

Typically, there is a 18–24 month period between 3GPP standards being finalised and compatible equipment (such as for end-user devices) being available from the commercial market. This allows for terminal design, chip design, manufacturing and testing to take place.

Sources: ARCIA (sub. 2); ATF (sub. 4, attachment 1); Ferrus and Sallent (2015).

LMR networks will continue to be used

Some governments and PSAs are considering the potential benefits of using a PSMB capability for voice communications and, eventually, consolidating PSA voice and data on to an LTE network. Notwithstanding this, governments are taking a cautious approach and investment and reinvestment in LMR networks continues. All Australian jurisdictions plan to continue operating their LMR networks until at least 2020 (and in some cases, for much longer) (chapter 2).

As such, some study participants have indicated that the initial focus of implementing PSMB is to establish a *data* capability to supplement LMR networks. For example, Motorola (sub. DR43, p. 3) noted that:

> Public safety agencies around Australia have already made long term investments in LMR in the order of 7–15 years and that presently the primary focus of PSMB is for data communications.

Victoria Police (sub. 17) submitted that full convergence to a single PSMB platform would likely take a decade to implement, including because it is not yet clear whether such converged services would meet PSA operational requirements. The Victorian Government's Emergency Communications Plan envisages a transition away from LMR networks in the medium to long term, assuming that a PSMB capability can meet the necessary service standards (EMV 2014). The Council of Ambulance Authorities (sub. DR36, pp. 3–4) also recommended a cautious approach.

> … the Australian Federal Government [should] … Support the continuation of Government Radio Networks until the full extent of rich data services have been implemented, the current GRN [Government Radio] networks are reaching end of life and 4G / 5G Push to Talk technology is mainstream and reliable.

A longer-term transition to mission critical voice over LTE, including a period of co-existence between LTE and LMR networks, is consistent with the approach foreshadowed in international jurisdictions. For example, the FirstNet network in the United States will first deliver PSMB data services, with voice services being added progressively over time (FirstNet nd) — though no timeframe has been indicated for voice being carried exclusively over LTE networks in the United States, or for decommissioning LMR networks (which will be a decision at the state or local level).

Of the international jurisdictions reviewed in this study, only the United Kingdom is anticipating full reliance on PSMB for mission critical voice communications by 2020 (appendix B).

The timing of the transition will depend on individual circumstances

The transition of mission critical voice to LTE could generate benefits for individual jurisdictions, such as:

- cost savings realised by avoiding the need to operate and maintain multiple networks simultaneously
- scope to sell (or lease) existing tower infrastructure or real estate associated with LMR networks.

From an economy-wide perspective, decommissioning LMR networks may enable ACMA to consider the most valuable alternative use of the spectrum used in these networks — for example, spectrum in the 400 MHz band (currently used for LMR) could be re-purposed to deliver LTE mobile services, either for the commercial market or PSAs (VHA, sub. 11).

This transition of mission critical voice to LTE would also raise costs and risks that would need to be considered, such as:

- costs associated with matching the geographic coverage footprint of LMR networks, should jurisdictions choose to do this
- costs associated with the process of planning, testing and transitioning to the new network (CDMPS et al., sub. 7)
- a loss of network redundancy once jurisdictions transition from running LMR and PSMB networks simultaneously, to PSMB only (Government of South Australia, sub. 29).

Ultimately, the appropriate time to transition mission critical voice services to PSMB networks (if at all) will depend on the circumstances of individual jurisdictions. Some governments may choose to move more quickly than others, given the status of their LMR networks or other considerations. For example, the Australian Federal Police (an Australian Government PSA) expects to undertake some technology-based tests of LTE-enabled communications during 2016. These tests will involve a commercial network and are designed to provide practical insights into prioritisation and PTT applications (AFP, pers comm., 2 December 2015).

The NSW Telco Authority is trialling a PTT capability over commercial mobile broadband networks for its office staff, and anticipates the commencement of a PSMB voice capability from 2019. However:

> … with less critical voice services migrating first until confidence in the ability to provide mission critical voice services over LTE is established. Given these timeframes, it is expected that as part of the overall effort to rationalise assets and infrastructure, a partial refresh of existing networks and assets will be carried out in order to ensure that integration is successful. (NSW Telco Authority, sub. 30, p. 33)

Irrespective of whether or when jurisdictions choose to retire their LMR networks, it is important that the deployment of PSMB (under any delivery approach) does not impede or prohibit the delivery of mission critical voice at a later time.

FINDING 5.3

The technical standards for delivering mission critical voice services over Long Term Evolution networks are still in development. All Australian jurisdictions plan to continue operating their land mobile radio networks for mission critical voice until at least 2020 (and much longer in some cases).

PSMB networks should be designed with a view to incorporating mission critical voice services in the future.

5.7 Interoperability and security

Sharing the right information with the right people is central to how PSAs operate. Communications technologies need to be interoperable to enable information sharing, whether across PSAs within a jurisdiction or between PSAs in different jurisdictions. Communications also need to be secure from interception or disruption.

A lack of interoperability on LMR networks (chapter 2) is one of the driving motivations for delivering an interoperable PSMB capability.

Interoperability has multiple elements

The term interoperability is often used to mean different things. Interoperability in the context of PSMB has four key elements (Motorola, sub. 12).

- Network interoperability — the ability of different networks to allow for users on each to communicate with each other; for example, the ability for a mobile device to call a fixed phone, or users on separate mobile networks to exchange messages.
- Device interoperability — the ability of an end-user device to work on different networks as required (Push2Talk, sub. DR33). For example, an iPhone can work on the Telstra, Optus and Vodafone networks. As defined here, device interoperability does not necessarily mean that devices will always connect to (or roam onto) other networks automatically to a pre-agreed level of service quality — it means that the device is technically capable of operating on those networks. (Roaming arrangements across different mobile carrier networks are discussed in section 5.8.)
- Application interoperability — the ability of agencies to communicate and share information with each other through common applications, databases and other software (HVHF Sciences LLC, sub. DR34).

- Agency interoperability — operational procedures beyond technology that enable agencies to interoperate, such as protocols for sharing intelligence and other information (CDMPS, sub. DR42; CSIRO, sub. 16; Motorola, sub. 12; Push2Talk, sub. DR33).

LTE networks can support interoperability under all approaches

Network interoperability is achieved through use of LTE

Network interoperability is inherent within LTE networks. Specifically:

- LTE is backed by open-source international standards that are widely supported by the majority of manufacturers of network equipment and end-user devices (Alcatel-Lucent, sub. 15; Ericsson, sub. 10)
- LTE is based on internet protocol, the method of encoding and transferring data in 'packets' that underlies all internet-connected devices and networks (Ericsson, sub. 10).

This means that — provided LTE standards (set by 3GPP) are adhered to across PSAs and jurisdictions (chapter 7) — PSMB networks will be interoperable regardless of whether a dedicated, hybrid or commercial delivery approach is adopted. Several study participants pointed to the potential for LTE technology to support an interoperable PSMB capability — for example, Rivada Networks (sub. 9, p. 11) noted:

> By agreeing to adopt 3GPP-compliant LTE technology, a vast majority of the interoperability concerns can be put to rest. Leveraging LTE standards will also resolve the majority of integrity and security concerns.

That said, Alcatel-Lucent (sub. 15) warned that the introduction of proprietary features or technologies could compromise the interoperability of PSMB, reiterating the importance of adherence to common technical standards.

Device interoperability is technically feasible under all approaches

PSA end-user devices must be configured with radiofrequency chipsets to support whatever spectrum band(s) is used to deliver PSMB services (section 5.1). In this sense, achieving device interoperability is likely to be simplest where all Australian PSAs rely on the same network (and spectrum band) for PSMB services. Where multiple networks are used, end-user devices may need to be compatible with multiple spectrum bands to ensure devices are interoperable across agencies and jurisdictional borders.

End-user devices manufactured for use on LTE networks are typically configured to support multiple spectrum bands (section 5.1). Accordingly, device interoperability should be relatively straightforward to achieve where PSAs rely on devices produced for the broader commercial LTE market ('off the shelf' devices), supplemented with 'ruggedised' external hardware where necessary.

It could be more challenging and costly to achieve device interoperability under a dedicated or hybrid approach — relative to a commercial approach — if the dedicated spectrum used is in a band that is not compatible with off the shelf devices (meaning customised devices are required). However, the risk of this can be mitigated by using internationally harmonised LTE spectrum bands (appendix B). Moreover, the compatibility (or not) of different spectrum bands with devices is something that PSAs and jurisdictions would be able to consider when contemplating alternative PSMB inputs and delivery approaches.

In any case, while achieving device interoperability would be more costly and complex where customised devices designed specifically for PSAs are used — as they will need to be configured to be compatible with the relevant spectrum bands — it is still technically feasible.

Some of the additional challenges that would arise under a multi-carrier approach — such as establishing roaming agreements — are discussed in section 5.8.

Application and agency interoperability is up to PSAs

Achieving interoperability at the application or agency level goes beyond the technical design of a PSMB network. It requires changes to a wider range of arrangements, including operational and information sharing protocols, that would need to be made regardless of which delivery approach to PSMB is pursued. Interoperability protocols, and strategies for overcoming institutional barriers to interoperability, are discussed further in chapter 7.

Interoperability between LTE and LMR networks

Existing LMR networks are expected to remain in operation for some years to come (section 5.6). However, as agencies make greater use of mobile broadband, an important question is whether it will be possible for users to interoperate across LMR and LTE networks — either on an ongoing basis, or as part of a transition to full reliance on PSMB for voice communications.

There are (at least) two options — PSAs could switch between separate sets of equipment depending on the network being used, or adopt ‘dual-mode’ equipment that can operate on both networks. Study participants noted that end-user devices and network equipment (such as gateway and interface devices) that allow for interoperability across LTE and LMR networks are already being manufactured (Ericsson, sub. 10; Motorola, sub. 12; NEC, sub. 5; Push2Talk, sub. DR33). These include systems that provide PTT functions and those that give voice communications priority over other forms of data (such as the Group Radio Solution that enables interoperability between narrowband and 3G networks trialled by Telstra (2011)).

In principle, adopting dual-mode equipment could be a less costly option in the long term if it means that the total number of end-user devices can be reduced. This could also reduce the risk of user error in mission critical situations, since personnel would not need to operate two different sets of equipment. However, each individual device may be more expensive, especially if it needs to be customised to a specific type of existing narrowband network (or to multiple narrowband networks to facilitate interoperability across jurisdictions). The smaller global market for such equipment may also increase costs.

However, the ultimate arbiter will be what is technologically possible. There are technical challenges to the development of dual-mode equipment, and it may not be possible to link every type of LMR network with an LTE network. Indeed, interoperability between LMR and LTE networks has not yet been standardised by 3GPP (Motorola, sub. 31). Moreover, the dual-mode handsets thus far developed are based on proprietary technologies — and many are not compatible with one another — although future 3GPP standards releases may be able to accommodate some of these features (Ericsson, sub. 10; Motorola, subs. 12, 31).

In any case, the prospects for achieving interoperability between LMR and LTE networks — whether it be through dual mode equipment or other arrangements — are expected to be broadly similar regardless of whether PSMB is delivered using a dedicated, commercial or hybrid approach.

Communications can be secured in a range of ways

Establishing and maintaining the integrity and security of communications is challenging over any network with multiple users and devices. This is especially the case for mobile networks that involve a range of dispersed network infrastructure and end-user devices.

In essence, security refers to the prevention (and rectification) of two types of threat.

- Disruption — the risk that network functions or services are not available when they are needed, due to wilful or accidental causes (such as power outages, physical damage, equipment failure, network congestion, radiofrequency 'jamming' or cyber-attack).
- Interception — the risk of unauthorised personnel eavesdropping on sensitive communications, accessing databases (such as crime databases) or identifying the location of devices or network users.

Physical infrastructure is central to reducing the risks of disruption. This can involve, for example, restricting access to sites and other infrastructure to reduce the possibility for unlawful tampering. It could also involve installing equipment that can detect and compensate for radiofrequency jamming (Motorola, sub. 12), or actively monitoring for cyber-threats. Disruption can also be minimised by improving the reliability of networks (section 5.5) and through technologies that enhance the accessibility and priority of PSA communications (section 5.4).

Protecting communications from interception or the unauthorised retrieval of data generally involves a different set of measures. For example, while physical infrastructure can restrict physical access to network equipment, it is less useful in preventing unauthorised persons from intercepting communications sent over the radio 'air interface' or from remotely gaining access to network control systems or end-user devices. Some PSAs, such as police, are likely to have higher security requirements in utilising PSMB given the nature of their work and the information they transmit and store.

At a minimum, protecting against interception and 'hacking' requires data to be encrypted. The most comprehensive method is 'end-to-end' encryption, which involves encrypting data travelling over the air interface and between different network components (such as backhaul and network cores) such that it can only be decrypted by the intended recipient. Study participants emphasised the necessity of end-to-end encryption in a PSMB capability (for example, Motorola, subs. 12, DR43; Victoria Police, sub. 17), including over interoperable LMR networks (Motorola, sub. 31). In particular, Victoria Police (sub. 17) noted that a high level of security would be needed where commercial end-user devices are capable of operating in the same spectrum band as a PSMB network.

Encryption technologies are already used across many networks — of which LTE is one example — and are continually being improved. For example, many mobile carriers offer Virtual Private Network solutions to their corporate customers to provide a secure connection between mobile end users and a company's secure internal networks (for example, Telstra 2015c). Some study participants noted that existing technologies are likely to be sufficient for encrypting PSAs' communications (Ericsson, sub. 10), and that these are consistent with LTE standards (Rivada Networks, sub. 9).

Other techniques available to maintain the integrity and security of communications include:

- the use of authentication techniques to confirm the identity of devices (or their users), such that only authorised personnel can access public safety networks (MFB, sub. 6; Motorola, sub. 12)
- measures to secure data stored in the network core (including 'configuration' data relating to users' access and priority over the network) or in databases (whether in secure data centres or in the 'cloud'), such as isolating PSA data (Motorola, subs. 12, 31)
- limits on the linking of databases or networks, such as restricting access to secure internal networks and databases (thereby limiting scope for hacking).

Technologies to do these things are already widely available and have been deployed on commercial mobile broadband networks.

From a technological perspective, the security of communications is largely a matter of incorporating encryption technologies into end-user devices and some network core

equipment. As a consequence, security is unlikely to have a significant bearing on costs across different PSMB deployment approaches (Ericsson, sub. 10).

PSAs could have a higher degree of direct control over security systems under a dedicated approach than under a commercial arrangement (section 5.3). However, even under a commercial approach, PSAs can retain control of how their communications are encrypted — PSA traffic may travel over commercial infrastructure, but mobile carriers would not necessarily be able to decode or understand that traffic. Indeed, commercially built or operated networks are already used to carry sensitive traffic for defence, police and others (Telstra, sub. 19).

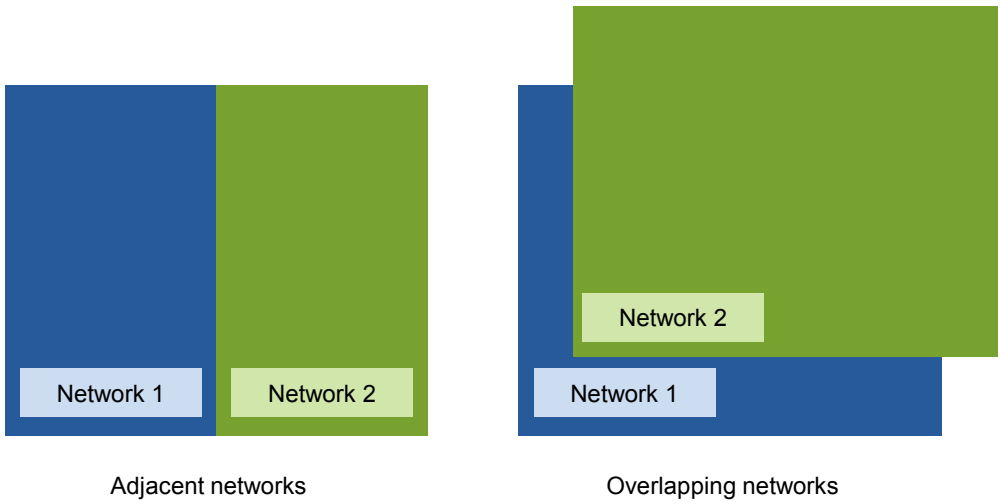
5.8 Multi-carrier approaches

More than one mobile carrier network can be used to deliver a PSMB capability (a 'multi-carrier' approach). This opens up several opportunities, including introducing an alternative way to improve network reliability, increasing the network capacity available to PSAs during an emergency, widening the PSMB network coverage area, and promoting competition at the procurement stage.

Broadly, a multi-carrier approach could be (figure 5.5):

- overlapping, promoting a level of redundancy and increasing the capacity available
- adjacent, where the overall PSMB network is broken into separate geographical areas to enable greater contestability of a procurement process and state-level flexibility.

Figure 5.5 **Multi-carrier deployment approaches**
Multiple networks can be either adjacent or overlapping



Benefits and challenges of multi-carrier approaches

Using multiple carrier networks offers potential benefits for delivering a PSMB capability compared to an approach which relies only on a single network (carrier or dedicated).

With overlapping networks the potential benefits include PSAs being able to access additional capacity (section 5.3), and greater network reliability because there are alternative networks in place if one is unavailable (CSIRO, sub. 16; Optus, subs. 18, DR37; VHA, sub. 11). By extension, the degree of network hardening required to achieve a given reliability standard would be lower, all else equal, resulting in cost savings (Optus, sub. 18; VHA, sub. 11). (A complicating factor is that, in some scenarios, access to multiple carrier networks in the same location might not improve reliability, such as when a flood or fire takes out both carrier's sites or they share a single physical site.) Study participants did not quantify the expected scale of these cost savings (chapter 6).

An adjacent network approach could allow a PSMB capability to be delivered by one mobile carrier in metropolitan areas, with rural areas covered by another. Alternatively, it could characterise a situation where each jurisdiction deploys its own PSMB capability independently and some use different mobile carriers. A potential benefit of this form of multi-carrier approach may be greater competition at the procurement stage, by separating out those markets that are contestable from those where there is only one supplier (chapter 7).

However, using multiple networks also introduces challenges. To move between networks public safety officers would require some form of 'roaming' agreement to be in place between separate network operators. Depending on the quality or type of roaming sought, this could be technically complex (and costly) to implement. There would also be commercial challenges where mobile carriers who are otherwise competitors are required to cooperate and coordinate. In general, as PSAs seek greater continuity of service and a more 'seamless' experience during handover from one network to another, the greater these technical and commercial challenges will be.

Roaming in a multi-carrier approach

Seamless roaming is technically achievable

Roaming technology allows customers of one mobile carrier to use the network of another, with systems keeping track of data usage and billing (Alcatel-Lucent, sub. 15; Ericsson, sub. 10; Rivada Networks, sub. 9). For example, in Australia, Vodafone has entered into commercial arrangements for its customers to roam on to the Optus network in some regional areas.

Some study participants have indicated that an approach which involves roaming between multiple carriers' networks introduces the risk that the PSMB capability provided to PSAs will not be 'seamless' where a call (or data session) has to be disconnected

and re-authenticated as network boundaries are crossed (Motorola, sub. DR43; NSW Telco Authority, subs. 30, DR46; Telstra, subs. 19, DR41). Some of these challenges are evident in arrangements for roaming between LMR and mobile networks today (box 5.12).

Box 5.12 Roaming between LMR and mobile carrier networks

There are examples of roaming arrangements established between LMR and mobile carrier networks. For example, devices connected to the Metropolitan Data Network in Melbourne will automatically switch to the Optus network (where available) when the connection with the network is lost. However, the application session will be interrupted as the new connection is established and authenticated, resulting in a break in data transmission. This is likely to be an issue for real-time applications, such as live video or voice communications, as the user experience might not be up to the standards that PSAs require.

Source: VDTF (2015b).

There are different types of roaming arrangements, with different quality standards attached (box 5.13). Put another way, roaming is not a 'seamless-or-nothing' proposition. There is a continuum of service levels and user experiences achievable. The Commission understands that establishing roaming arrangements between multiple networks is technically feasible, as is the implementation of measures to ensure that there is continuity of service when roaming across networks (Alcatel-Lucent, sub. 15; Ericsson, sub. 26; VHA, sub. 11).

A higher standard of roaming increases direct costs and commercial complexities

The use of multiple networks to deliver PSMB would introduce additional direct network costs. Each participating mobile carrier would need to ensure their network has the capability to recognise PSA users and, where relevant, the ability to provide them with preferential services. Telstra (sub. DR41) submitted that under a multi-carrier approach there is a risk that the capability would lead to a lower quality network experience.

Perhaps more significantly, there are questions as to whether mobile carriers would be willing to participate in a multi-carrier approach to PSMB. An approach which sought to achieve consistent service quality standards across networks would require closer integration between carrier networks than exists today, with some decisions concerning core infrastructure, network upgrades and general operation and maintenance needing to be standardised and coordinated.

An added complication is the difficulty of monitoring and enforcing contracts. Where multiple parties are partly responsible for service standards, it can become more difficult to assign liability in the event of breach of contract. This is likely to lead to contracts that are more complex and more costly to negotiate than when using a single network. These issues are likely to be more pronounced when networks are overlapping, as opposed to adjacent.

Other things equal, the higher the standard of roaming capability sought across carriers, the larger the costs and complexity which are likely to be involved (Telstra, sub. 19). Some of the cost tradeoffs involved in a multi-carrier option are considered in chapter 6.

Box 5.13 There are multiple ways to implement roaming

LTE standards allow for two types of roaming.

- International roaming — where users 'visit' a carrier's network when abroad, receiving similar levels of coverage and service as the network's domestic users.
- National roaming — where users on one mobile carrier's network can undergo 'handover' to another mobile carrier's network.

Each of these roaming arrangements could be used to deliver a PSMB capability, but with differing service levels.

International roaming allows users to connect to another network and receive an experience that is similar to that of the network's 'home' customers. Despite the name, a multiple-carrier PSMB network could use international roaming by providing PSAs with SIM cards that 'trick' the network into thinking they are international users (an approach used in Belgium's Blue Light Mobile network). However, switching between networks under international roaming is not seamless, requiring termination of the old network connection before searching, accessing, and re-authenticating on another network — a process that can take minutes.

National roaming offers scope for a more seamless handover of users between LTE networks, although precisely how seamless will depend on the level of integration between the two networks, and the type of applications to be supported. For basic applications (such as internet access), one possible method is to define the neighbouring cells of both networks in each mobile base station (eNodeB). In simple terms, this makes the base station aware of all the surrounding cells (of both networks) to which a handover can be made. Another is to enable Internet Protocol connectivity between the two networks, which allows for the Automatic Neighbour Relations feature of LTE to automatically find (and handover to) other cells in real time. More complex applications such as voice over LTE may also require support from the end-user device, chipset or the application vendor to fully implement roaming arrangements between multiple mobile networks.

Sources: Alcatel-Lucent (2010); Federal Communications Commission (2010b); Gras (2015); NMC Consulting (2013); NSW Telco Authority (sub. 30).

5.9 Timing and sustainability

Implementing a PSMB capability by or before 2020 (a consideration set out in the study's terms of reference) would be challenging. This reflects the complex and costly nature of the investment involved, the range of stakeholders affected, and broader domestic and international circumstances.

Key tasks required to implement a PSMB capability, which are common to all PSMB deployment approaches, include designing and running tender processes, negotiating contracts with commercial providers and establishing governance arrangements

(chapter 7). These tasks are likely to take years rather than months, and may pose significant challenges for jurisdictions operating on short timeframes.

The timeliness of PSMB deployment could also vary depending on the delivery approach. In particular, a dedicated network is expected to take longer to implement relative to other approaches, owing to the significant amount of new investment required and the acquisition of spectrum (chapter 6) (Motorola, sub. 12; Telstra, subs. 19, DR41).

A flexible approach is more sustainable

Ultimately, the sustainability of a PSMB capability will depend on whether it can meet the needs of PSAs over a long period of time as technology evolves, and whether it can do so at an acceptable economic cost (Department of Communications, sub. 23). Making this happen poses considerable challenges given the high levels of uncertainty involved.

Policymakers will need to be flexible. In other areas of infrastructure and policy, a flexible approach that allows changes to be made quickly when new information becomes available, or for investment to be delayed, can help to minimise costs over the long term (PC 2011, 2012). It can also lead to more sustainable solutions that provide services to the community in the face of unexpected events. This is often referred to as the 'real options' approach to investment.

Chapter 7 sets out how governments can incorporate flexibility into the implementation of a PSMB capability, including through the use of pilots and taking a phased approach to rollout.

5.10 Summing up

The Commission's analysis finds that it is technically feasible to deliver a PSMB capability under a dedicated, hybrid or commercial approach.

Some of the key tasks and technical challenges associated with delivering a PSMB capability — such as network hardening to improve reliability standards, the development of appropriate security arrangements, and adherence to open international standards to promote interoperability — are common to all deployment approaches. In other cases, the costs and complexity of delivering certain features of a PSMB capability (such as coverage) are likely to vary depending on the deployment approach.

The following chapter evaluates the costs, risks and benefits of PSMB deployment approaches through an illustrative set of delivery options.

FINDING 5.4

It is technically feasible to deliver a PSMB capability — including priority network access — under a dedicated, commercial or hybrid approach. However, there is uncertainty as to the precise service standards that could be achieved under alternative PSMB delivery approaches.

6 Evaluating PSMB options

Key points

- The Commission has evaluated the costs, benefits and risks of an illustrative set of delivery options for public safety mobile broadband (PSMB) to assess whether, how and why these might vary across options. Key costs have been evaluated quantitatively, whereas benefits and risks have been considered in a qualitative way due to a lack of robust data.
- Four delivery options have been evaluated for areas of Australia with commercial mobile coverage — a dedicated network, two hybrid options (with varying reliance on commercial networks), and a commercial option.
- A bottom-up approach was developed to evaluate the direct network costs of each delivery option over a 20-year period from 2018. Key insights from the analysis include that:
  - a commercial option is the most cost-effective way of delivering a PSMB capability to public safety agencies. The results indicate that a dedicated network is about 2.5 to 3.5 times more costly than a commercial option depending on the assumptions applied
  - the cost difference between a hybrid and commercial option is lower and narrows as the size of the dedicated network component decreases. However, even the lowest-cost hybrid option considered (with a dedicated network element in inner metropolitan areas only) is estimated to be about 32 per cent more costly than the commercial option.
- The cost differences between options are predominantly driven by more efficient use of existing infrastructure, including radio access network sites and backhaul transmission.
- The cost results are sensitive to the design of the options and a number of the input parameters and assumptions. However, the cost ranking of options is robust to the use of alternative design features, inputs and assumptions.
- Nevertheless, costs are not the whole story. The nature and magnitude of risk varies across PSMB delivery options. For example, the risk of governments becoming 'locked in' to using a single supplier is most pronounced under a commercial option, while a dedicated option is most susceptible to delays and technological obsolescence.
- While the benefits have not been quantified in this study, the options under evaluation have been designed to deliver a similar level of PSMB capability. As such, the impact of each option on public safety outcomes (and thus its benefits) is not expected to vary markedly.

This chapter evaluates the costs, benefits and risks of alternative ways of delivering a public safety mobile broadband (PSMB) capability — including quantitative evaluation of the costs of different options. The aim is to identify and understand key cost drivers, risks and tradeoffs between options.

Section 6.1 describes the options that have been evaluated. Section 6.2 summarises the approach to estimating the costs of these options, and section 6.3 sets out the results (with

further detail provided in appendix C). Section 6.4 evaluates the risks and section 6.5 the benefits of the options.

6.1 Options for evaluation

The terms of reference ask the Commission to consider three high-level deployment approaches — a dedicated PSMB network, a commercial approach and a combination of both. In practice, these three broad *deployment approaches* could be defined in myriad ways, giving rise to a large number of feasible PSMB *delivery options*. The diverse models adopted internationally attest to this (appendix B).

It is not practical to evaluate all feasible PSMB delivery options in detail. Instead, an illustrative set was selected based on considerations that the options:

- are capable, as far as possible, of providing a 'public safety grade' mobile broadband capability — that is, a level of network capacity and service quality suitable for 'mission critical' situations
- have regard to approaches being adopted in other countries
- have regard to approaches discussed in previous studies
- are able to be evaluated using publicly available information
- are technically feasible.

Some factors are common to all options

Based on the discussion in chapter 5 and consideration of study participants' views, a number of factors are taken as common across all options.

LTE technology

There is widespread agreement among study participants that a PSMB capability should be delivered using Long Term Evolution (LTE) technology, regardless of the delivery option chosen (chapter 5). Accordingly, LTE is a common feature of each option considered. The assumption made in this study is that LTE coverage in Australia will reach at least an equivalent level to 3G coverage in the future and that 4G networks will eventually be used to deliver mobile voice services (Penn 2015).

Traffic scenarios and growth rates

All options are dimensioned to meet the capacity scenarios and growth rates outlined in chapter 4 (table 4.1).

99 per cent population coverage

The quantitative analysis is based on the costs of delivering a PSMB capability to areas within the commercial mobile coverage footprint (for 3G mobile networks), or a target of approximately 99 per cent of the population.

This is not an indication that PSMB *could not* or *should not* be delivered in areas outside of mobile carriers' footprints (for example, in remote areas where there is already land mobile radio (LMR) coverage) (chapter 5). Rather, it reflects that:

- the cost of delivering PSMB in areas outside of the mobile carrier footprint is likely to be broadly similar regardless of the delivery option (as a substantial greenfields network build would be required in each case)
- a lack of publicly available data means it has not been possible to establish the nature and size of the 'coverage gap' between mobile carrier and LMR networks in each state and territory (chapters 2, 5)
- a rollout of PSMB to remote regions is unlikely to be something that jurisdictions consider in the short to medium term given the high costs involved and the ongoing operation of LMR networks. As such, given the potential for technological advances, cost estimates developed today risk becoming dated very quickly.

Quality of coverage

Any measure of coverage has an explicit or implicit quality dimension attached to it — such as the ability to receive an indoor signal on a handset (in-building coverage), an outdoor signal to a handset (handheld coverage), or outdoor signal to a specially constructed vehicle antenna (vehicle coverage). Different standards may be required in different areas, for example, in-building coverage is likely to be critical in central metropolitan areas, while outdoor coverage may be sufficient in rural areas (chapter 5).

To compare options on an even keel, it is assumed that each option achieves the same standard of coverage in each geographic region. That is, indoor handheld coverage in dense urban, urban and suburban areas, and outdoor vehicle coverage in rural and remote areas.

Sharing existing network infrastructure

Sharing existing infrastructure to the fullest extent possible avoids unnecessary duplication and reduces PSMB deployment costs, all else equal (chapter 5). In seeking to deliver a PSMB capability there are two key areas where 'network sharing' could lower capital costs and operating costs.

- Sharing radio access network infrastructure — this could include sharing 'passive' infrastructure at a site (such as space to put equipment, antennas/masts, power supplies

and backhaul capacity) or sharing 'active' equipment (such as spectrum, mobile base station equipment and existing backhaul capacity) (GSMA 2012; NEC 2013).

- Sharing core network infrastructure — this could involve, for example, a 'Gateway Core Network' approach where the Mobility Management Entity element is shared between different mobile carriers, or more extensive forms of sharing which involve spectrum for a PSMB capability being fully integrated into a carrier's core network (Alcatel-Lucent 2009; GSMA 2012; Telstra, sub. 19).

The sharing of radio access network passive infrastructure is relatively common in parts of the mobile sector in Australia and in other countries, and there are significant opportunities for this given that there are over 15 000 physical mobile sites across Australia. Accordingly, all options are based on a high degree of sharing of existing physical sites and the purchase of backhaul capacity from the commercial market.

Hardening network infrastructure

Investment to 'harden' mobile carrier networks to meet a higher level of reliability — through civil site upgrades, improved battery back-up and adding additional backhaul diversity — is common to all options (chapter 5). This is because all options involve sharing of commercial network infrastructure (including sites) to deliver PSMB.

Handset types and costs

The spectrum band used in delivering services to PSAs could be an important determinant of handset costs (chapter 5). Other things being equal, a spectrum band consistent with that used to provide commercial services would be expected to result in lower handset costs as PSAs could leverage off very large commercial markets for handsets. For custom made PSMB handsets and devices, there may be advantages in aligning the spectrum band used with that used in other countries for PSMB.

For the quantitative analysis, the mix of handsets (commercial handsets, ruggedised handsets and in-vehicle devices) and their unit costs are taken to be the same across options. However, some delivery options carry a higher risk that widely available (and cheaper) end-user devices are not able to be used (section 6.3).

PSMB capacity is used efficiently

Giving each PSA a fixed amount of network capacity over a PSMB capability (sometimes called a 'partitioned network') would likely mean that some capacity goes underutilised even where it may be of value to another agency. Sharing the available capacity among agencies in real time would be more flexible and reduce the total network capacity needed to meet each agency's requirements (chapter 5). Accordingly, it is assumed that within each option, efficient use is made by PSAs of available capacity.

Organisation-level operating costs

Delivering PSMB would involve organisation-level operating costs, such as:

- labour, administration and accommodation costs (Telstra, sub. 19)
- 'change management' costs from transitioning PSAs on to an LTE network for their mission critical communications, including education and training, changing operating procedures or changing organisational structure (CDMPS et al., sub. 7).

While the Commission recognises that these costs are likely to vary across PSMB delivery options, they were not included in the quantitative analysis due to data limitations.

Cost savings from retiring LMR networks

Some study participants considered that delivering data and voice services to PSAs over an LTE network could allow governments to retire LMR networks and realise cost savings (NSW Telco Authority, sub. DR46; Victorian Government, sub. DR44). Two sources of potential cost savings were identified. The first was the avoided costs of operating LMR networks, which the Victorian Government (sub. DR44) estimates would be between $590–$850 million over the 20 year planning period, assuming voice services transition to PSMB networks by 2025. The second was cost savings from leveraging LMR fixed infrastructure in the deployment of a PSMB capability, which the Victorian Government (sub. DR44) estimates would be in the order of 10 per cent of total build costs.

Jurisdictions may well decide to retire their LMR networks at some point in the future. However, it is very difficult to robustly estimate when this would occur in each state and territory, and the avoided costs it would give rise to, given the many factors that would bear on this decision and the associated savings. Moreover, it is unlikely that the realisation (or not) of any such cost savings would vary across PSMB delivery options. That is, to the extent there are cost savings from retiring LMR networks, they are expected to be largely independent of how PSMB services are delivered (appendix C). Accordingly, the Commission's quantitative analysis does not include these cost savings.

That said, the quantitative analysis does take account of the fact that existing infrastructure (including publicly-owned LMR sites) could be leveraged in the deployment of a PSMB capability. However, even where existing LMR sites are re-used, there is still an opportunity cost to account for (the foregone revenue that could have been earned by using the infrastructure for an alternative purpose).

Further details of the approach to the quantitative analysis are provided in appendix C.

Four central case options were evaluated

The Commission evaluated four central case options for delivering a PSMB capability in areas of Australia where there is existing commercial mobile coverage (table 6.1). Variations to the assumptions and inputs underpinning the central case options were also considered (section 6.3).

The Australian, state and territory governments are ultimately responsible for deciding whether, how and when to facilitate the delivery of a PSMB capability for their PSAs (chapter 7). In practice, it is likely that individual governments will take different PSMB policy decisions at different times. However, for ease of exposition, the options discussed in this chapter are outlined and costed on a national basis — that is, assuming each jurisdiction proceeds with rolling out PSMB using the same delivery method at the same time. This approach ensures that cost differences can be attributed to differences in the delivery method (the primary focus of this study), rather than other factors.

Table 6.1 **Overview of PSMB delivery options evaluated**
Areas within commercial carrier coverage footprint

	Option 1 – Dedicated	*Option 2 – Full coverage hybrid*	*Option 3 – Targeted coverage hybrid*	*Option 4 – Commercial*
Dedicated spectrum for PSAs	Yes (national)	Yes (national)	Yes (inner metro areas only)	No
Networks relied on in inner metro areas[a]	Dedicated	Dedicated and commercial	Dedicated and commercial	Commercial
Networks relied on in other areas[b]	Dedicated	Dedicated and commercial	Commercial	Commercial
Estimated population coverage of dedicated network element	99%	99%	50%	0%
Core network infrastructure	Dedicated core (shared by all jurisdictions)	Use carrier core	Use carrier core	Use carrier core
Number of mobile carrier networks PSAs use for PSMB	..	1	1	1

a Inner metro areas are defined as those covered by dense urban and urban geotypes (appendix C). **b** Other areas are defined as those covered by suburban, rural and remote geotypes (appendix C). **..** Not applicable.

Different types of contractual arrangements and operating models could be utilised to deliver a PSMB capability under each option. For example, a dedicated network could be owned and operated by a government-owned entity, or outsourced to a private operator. A commercial option could be delivered through a direct contract with a mobile carrier(s) or through the establishment of a separate entity that has contractual relationships with multiple carriers (akin to the approach already operating in Belgium) (appendix B).

In designing options for the quantitative analysis the Commission has not been prescriptive on the precise operating model that would be employed, including the nature of the contratual arrangements. (Moreover, as noted above, organisational-level costs have been excluded from the quantitative analysis.) Rather, the focus is on identifying options which allow the key drivers of incremental resource cost differences to be explored (which would be invariant to the precise operating model adopted). Chapter 7 discusses implementation issues in delivering a PSMB capability.

A dedicated PSMB capability (option 1)

A dedicated PSMB capability would mean that PSAs have access to (and control over) their own PSMB network, using their own parcel of spectrum set aside in the 800 megahertz (MHz) band on a national basis (box 6.1). While it is assumed that existing sites and backhaul transmission would be used as part of this option, significant new investment would be required. This includes sites, base station equipment, backhaul links and core network infrastructure.

PSAs would not be able to 'overflow' onto commercial networks for public safety grade mobile broadband services under this option. However, they would be able to purchase standard commercial mobile services, as they do today.

This option assumes a single core network is established for PSMB and is shared by all jurisdictions (to minimise costs). A variation to this assumption is considered in section 6.3.

Box 6.1 Spectrum band assumed for the quantitative analysis

There is ongoing debate about the relative merits of different bands of spectrum for a PSMB capability. Some study participants argued for an allocation of spectrum in the 700 MHz band, where 30 MHz remains unsold from the most recent auction in 2012.

Other participants argued that the spectrum lots in this band are not harmonized with the 700 MHz band spectrum for PSMB in countries such as the United States, and that it would be more appropriate to utilise spectrum in the 800 MHz band, which includes a band that has been identified by the International Telecommunication Union for 'public protection and disaster relief' use across the Asia-Pacific region (appendix B). It is in this part of the 800 MHz band that spectrum has been notionally set aside for PSAs by the Australian Communications and Media Authority, although spectrum in this band is also standardised for the provision of commercial LTE services (chapter 7). Spectrum allocation decisions are the responsibility of the Authority.

For the purposes of quantitative evaluation, the Commission has assumed that any spectrum allocated for a PSMB capability would be in the 800 MHz band. However, the Commission has not evaluated the relative merits of different spectrum bands and thus is not making any specific recommendation on the type or size of spectrum band.

Sources: PFA (subs. 8, DR40); Telstra (sub. DR41).

A commercial option (option 4)

A commercial option would mean that PSAs obtain PSMB services from a commercial mobile carrier through a contract. The carrier would determine how best to meet PSA requirements using its own mobile network and spectrum holdings.

This option would require that the mobile carrier invest in (or 'harden') its network to improve network reliability and deliver the services that PSAs require. This could include installing additional battery backup, upgrading physical sites and adding new backhaul links. Adding PSA traffic to a carrier network would require the carrier to utilise some of its spectrum resources (meaning alternative uses for that spectrum are potentially foregone), and would be expected to 'bring forward' investments in sites, spectrum and backhaul.

A commercial approach could also be delivered using multiple mobile carriers. This option has also been evaluated (section 6.3).

A full coverage hybrid option (option 2)

A full coverage hybrid option would provide PSAs with a dedicated network that covers the entire mobile carrier footprint (as per the dedicated option), using their own parcel of spectrum. The dedicated network component of this hybrid would be sufficient to meet some — but not all — of PSAs' capacity needs (about 80 per cent). PSAs would rely on a mobile carrier network to access additional public safety grade network capacity.

PSAs would rely on the core network of the mobile carrier under this option. However, the parcel of spectrum set aside for PSAs would *not* be shared, meaning PSAs would have access to their own dedicated 'channel'.

An alternative way to implement this option is to have a separate core network built for PSMB, which would interface with the mobile carrier network. This approach may be more amenable to PSAs (or an agent on their behalf) directly controlling the configuration of their PSMB capability (including upgrades) or their security arrangements. This alternative has been considered as part of the Commission's analysis, as has the option of relying on multiple mobile carriers to deliver the commercial component of the full coverage hybrid (section 6.3).

A targeted coverage hybrid option (option 3)

A targeted coverage hybrid option would provide PSAs with a dedicated network and their own spectrum for inner metropolitan areas only (defined as dense urban and urban areas, which contain around 50 per cent of the population).

PSAs would rely on a mobile carrier network for about 20 per cent of their capacity needs in inner metropolitan areas (once they exhaust their own dedicated capacity). Outside of these areas, PSAs would rely on a mobile carrier for both coverage and capacity.

As with the full coverage hybrid, PSAs would rely on the core network of the mobile carrier. However, the implications of establishing a separate core network have also been considered as part of the Commission's analysis.

6.2 Approach to the cost evaluation

The two main sources of costs considered in this study are the direct network costs of delivering a PSMB capability, and the potential indirect costs imposed on non-PSA users.

Direct network costs

Network-related costs can be grouped into four key elements — those associated with the radio access network, backhaul, core network and spectrum (box 6.2). Handset costs have also been included in the analysis (but are the same across options) (section 6.1).

Box 6.2 **Network cost elements: inputs and assumptions**

Capital costs

New site deployment — the cost of acquiring and provisioning new mobile cell sites (which applies to a small percentage of sites in the dedicated option only).

Radio access network equipment — the cost of deploying new radio network access equipment (eNodeB) at each site, including site works such as mast strengthening.

Site hardening — the cost of installing additional back-up batteries and upgrading civil features of the site to improve resilience and security.

The cost estimates for new site deployment, radio access network equipment and site hardening are averages, which take into account differences in individual sites and the amount of work required on each site.

Core network and add-ons — the cost of deploying new core network infrastructure, upgrades to provide priority services to PSAs, gateways to link with land mobile radio networks and new operation and billing support systems.

Spectrum — the cost of using spectrum to deliver PSMB. In the dedicated components of options 1, 2 and 3 it is assumed that 10 MHz of spectrum in the 800 MHz band is used, the cost of which is based on spectrum auction results. This cost has been scaled down for option 3, reflecting the smaller geographic footprint of the dedicated component. In the commercial components of options 2, 3 and 4, it is assumed that mobile carriers' spectrum is used, and the cost reflects the value that is foregone by not using that spectrum to serve other customers.

(Continued next page)

Box 6.2 (continued)

Mobile carrier network augmentation — the costs of deploying additional mobile carrier sites (including co-location costs), and the core network augmentation to meet PSA traffic.

End-user devices — the costs of a mix of off-the-shelf, ruggedised and in-vehicle devices.

Operating costs

Site leasing costs — the opportunity cost of deploying new base station equipment at an existing site, as the use of space precludes use for an alternative purpose.

Backhaul leasing costs — the annual cost of leasing backhaul capacity from a site back to a point of interconnection which connects to the core network. This is based on an average per-site cost (specified separately for regional and metropolitan sites) given that each site will be located at a different distance from the core network.

Direct network-level operating costs — the costs of operating and maintaining network elements directly related to providing PSMB, such as base station equipment and core network infrastructure. These have been estimated as a fixed proportion of the associated capital cost.

Source: Appendix C.

Network costs have been evaluated quantitatively using a fit-for-purpose, bottom-up approach (box 6.3). The analysis covers a 20-year period (from 2018 to 2037 inclusive) and is national in scope.

Box 6.3 **A 'fit-for-purpose' approach to evaluating network costs**

The objective of the quantitative evaluation is twofold — to identify key cost differences between options for delivering a PSMB capability, and to gain an understanding of key cost drivers. The choice of framework and methodology has been driven by its suitability for these purposes.

The bottom-up approach to estimating network costs involves three key steps:

- geotyping — using census data to assign different geographical areas of Australia to particular geotypes (dense urban, urban, suburban, rural or remote)
- radio access network dimensioning — estimating the number of mobile sites, and other additional network infrastructure, required to meet the coverage and capacity requirements embodied in the PSMB scenarios (chapter 4)
- network costing — applying benchmark cost values (such as the costs of mobile base station equipment) to calculate relevant capital and operating costs.

The key output from the quantitative evaluation is a net present cost value for each option, assuming a 20-year time horizon. Importantly, the analysis is not designed to necessarily:

- produce precise estimates of the total costs of individual options, or individual cost components (some cost items have been excluded from the quantitative analysis as explained in section C.9 of appendix C). Rather, the main focus is on relativities
- describe what the architecture of a PSMB network would look like in practice
- identify (in an exact way) the optimal mix of inputs for delivering a PSMB capability.

The cost analysis is premised on estimating the incremental (rather than total) costs of delivering a PSMB capability — that is, the costs associated with delivering PSMB relative to the status quo. These costs are intended to reflect opportunity (or economic) costs — that is, the value of the next best alternative use of the resources. This bottom-up costing approach is applied consistently across options, and can be contrasted with other approaches to cost analysis — such as Total Cost of Ownership or a financial business case — which focus on the financial costs to an individual entity (box 6.4).

Box 6.4 Features of a first principles costs analysis

The prices that governments or PSAs ultimately pay for PSMB services could differ from the incremental costs of supplying that capability (the focus of a bottom-up cost analysis). This situation could arise if above-normal profit margins are factored into PSMB prices (due to a lack of effective competition in the market, for example), or because PSMB prices reflect historical capital investment costs that are unrelated to the incremental costs of providing PSMB services.

On this basis — and given their understandable interest in end-user service prices — some study participants suggested that the Commission should take a 'top down' approach to its analysis of PSMB costs (PFA, sub. DR40; Victorian Government, sub. DR44). For example, by using current prices for 'business grade' mobile broadband services as a proxy, or estimating the prices at which PSMB would be supplied.

However, using end-user service prices as the basis for costing PSMB delivery options is not consistent with a first principles analysis — that is, identifying the most efficient outcome from the perspective of the community as a whole (chapter 3). Specifically, by including sunk costs and transfers between producers and consumers, such an approach risks overestimating the incremental resource costs associated with delivering a PSMB capability, and potentially misrepresenting the relative efficiency of alternative options. It would also be empirically challenging to implement, given significant uncertainty about the price 'mark-up' that mobile carriers would apply to public safety grade mobile broadband services.

Sources: Access Economics (2010); Boardman et al.(2011); PC (2014b).

Some costs are excluded

Certain costs are excluded from the quantitative analysis, either because there is insufficient information to assess their magnitude, or because they are unlikely to vary significantly across options. A full explanation is provided in appendix C (section C.9).

A common discount rate is applied across options

A real discount rate (7 per cent in the central case) has been applied consistently across all the options evaluated. Discounting future cost flows takes into account the fact that not all costs are incurred today, and so available funds can be invested in alternative projects — and earn a rate of return — before they need to be committed to PSMB. This rate of return is the discount rate, a measure of the opportunity cost of capital. The use of a common

discount rate across the options evaluated reflects the common opportunity cost of deployed funds (OBPR 2014b).

Indirect costs

Some study participants argued that where PSMB services are delivered using commercial networks, the quality of service experienced by non-PSA users could be adversely affected (a negative 'spillover' effect) (CDMPS et al., sub. 7; NSW Telco Authority, sub. 30). For example, the NSW Telco Authority (sub. 30, p. 59) submitted that:

> At the simplest level, the [non-PSA] user may experience a minor or major inconvenience (for example not being able to advise child care or family that they will be delayed). More profoundly, a person in distress or bystanders to an incident may not be able to contact emergency services or report an issue …

It is also possible that non-PSAs could experience an improvement in quality of service in this circumstance — for example, investments made to harden commercial networks could increase reliability for all users (a positive spillover).

A separate argument raised by study participants was that options which involve the delivery of PSMB via a single mobile carrier (as compared to multiple carriers) would adversely impact competition in the broader mobile market, with flow-on negative consequences for all mobile customers (VHA, sub. 11; Victorian Government, sub. 28). For example, VHA (sub. 11, p. 8) submitted that:

> … any cost-benefit analysis must consider the unintended flow-on impacts, the award of such a contract (and possibly additional spectrum) to a single MNO [Mobile Network Operator] will have on competition in the mobile services market. Moderate savings in the procurement of PSMB networks could be offset by the economic cost of a less competitive mobile services market that could ensue from the award of such contracts.

A high degree of uncertainty about the likely magnitude of these impacts — and a lack of publicly available information on which to base estimates — mean that the Commission was not able to quantify these effects, and has instead considered these issues qualitatively (section 6.4).

6.3 Cost evaluation results

This section highlights key insights that can be drawn from the Commission's quantitative analysis (appendix C sets out the results in more detail).

Central case

A commercial option minimises network costs

The Commission's quantitative analysis found that deploying a dedicated network is about 2.8 times more costly than relying on commercial networks. Specifically, the estimated net present cost of the dedicated option over 20 years is almost $6.2 billion, compared to about $2.2 billion for a commercial option (table 6.2).

Table 6.2 **Composition of PSMB delivery costs**
Central case options — net present value of costs[a]

Cost item	*Dedicated*	*Full coverage hybrid*	*Targeted coverage hybrid*	*Commercial*
	$m	$m	$m	$m
Capital costs	**2 241**	**2 093**	**1 321**	**984**
New site build	110	100	23	..
New radio access network equipment	1 035	943	220	..
Site hardening	174	158	121	117
Core network and add-ons	143	45	45	45
Mobile carrier network augmentation	..	35	146	171
Spectrum[b]	264	295	250	135
User equipment	516	516	516	516
Operating costs	**3 910**	**3 040**	**1 583**	**1 217**
Site leasing costs	1 412	1 266	344	..
Site backhaul leasing costs	1 776	1 141	975	1 068
Network operating costs	722	633	263	150
Total cost[b,c]	**6 152**	**5 133**	**2 904**	**2 201**

[a] The quantitative analysis is dependent on various assumptions and input values (appendix C). [b] This represents the sum of all costs considered in the quantitative evaluation. It should not be interpreted as the total costs that would be incurred in actually deploying a particular option. [c] Figures may not add due to rounding. **..** Not applicable. [b] Includes, where applicable, the cost of dedicated spectrum and an apportionment for use of mobile carrier spectrum holdings.

Source: Productivity Commission estimates.

The cost difference between the dedicated and commercial options is driven by two key factors.

First, greater *capital expenditure* (new investment) would be required in the dedicated option — on spectrum, mobile base station equipment to operationalise the dedicated spectrum, and a core network. This reflects the assumptions that:

- there are some costs that would not be reincurred under the commercial option where significant investments have already been made (such as to establish a network coverage layer or build a core network)
- mobile carrier networks contain significantly more sites than a dedicated network would, and as a result, less spectrum is required in a commercial network to produce the same increase in total network capacity, compared to a dedicated network
- mobile carriers already have a wide portfolio of spectrum resources (that is, holdings across multiple bands) which provides them with greater flexibility (relative to a dedicated network operator) to meet PSA customer requirements at least cost (chapter 5).

Second, greater *operating expenditure* would be incurred in the dedicated option, for both annual site leasing and backhaul costs, and network-related operating and maintenance expenditure (compared to a commercial option). This reflects the assumptions that:

- mobile carriers are in a stronger position to minimise PSMB operating costs by spreading them over a larger number of users compared to a dedicated option — for example, network site maintenance and billing costs will be largely invariant to the total number of users on the network
- mobile carriers will be able to avoid incurring new site leasing costs for PSMB when adding capacity to their networks because of their ability to deploy equipment at existing sites without incurring additional leasing costs.

Previous studies have also found that it would be more costly to deliver a PSMB capability via a dedicated network compared to other options (box 6.5).

There is a significant cost difference between the hybrid and commercial options

The costs of a hybrid option are lower the smaller the geographic region covered by the dedicated component. For example, the cost of the full coverage hybrid (option 2) is almost 1.8 times more expensive than the cost of the targeted coverage hybrid (option 3). This result is explained by the need to roll out dedicated equipment to a larger number of sites.

However, even the targeted coverage hybrid is estimated to be about 32 per cent more costly than the commercial option (figure 6.1). This cost difference is driven by two main factors:

- capital investment in site equipment compatible with dedicated PSMB spectrum at each site within the dedicated network footprint of the hybrid (table 6.2)
- additional site leasing costs that would be incurred for housing this equipment.

Box 6.5 Previous studies which compare PSMB network costs

Some previous studies which have compared the network costs of delivering a PSMB capability under different options have found that a dedicated PSMB network is more costly.

For example, a study by the Federal Communications Commission (2010a) in the United States found that a dedicated approach would require at least 2.5 times more capital investment than a shared network model. This study also found that use of a partnership model would reduce ongoing capital and operating costs by at least 10 per cent over a 10-year period.

A report by Access Economics publicly released in 2011 referred to the results of a separate study which compared the costs of different delivery options for PSMB (the report was by Gibson Quai-AAS). Access Economics (2010, p. 13) noted that:

> Over a 15 year license term, Gibson Quai-AAS's estimates indicate that, even under the most generous set of assumptions, a commercial arrangement with a carrier would be substantially cheaper than a private network …

A study by SCF Associates (2014) for the European Commission examined the costs of different options for deploying a mission critical high speed broadband network for public safety. While different methodologies were used to estimate the costs of each option, the results indicate that a dedicated network (using 700 MHz band spectrum) across the European Union would have capital expenditure around 40 per cent higher than a commercial option, and an annual operating expenditure that is nearly seven times greater.

Adding PSAs to mobile carrier networks is not costless

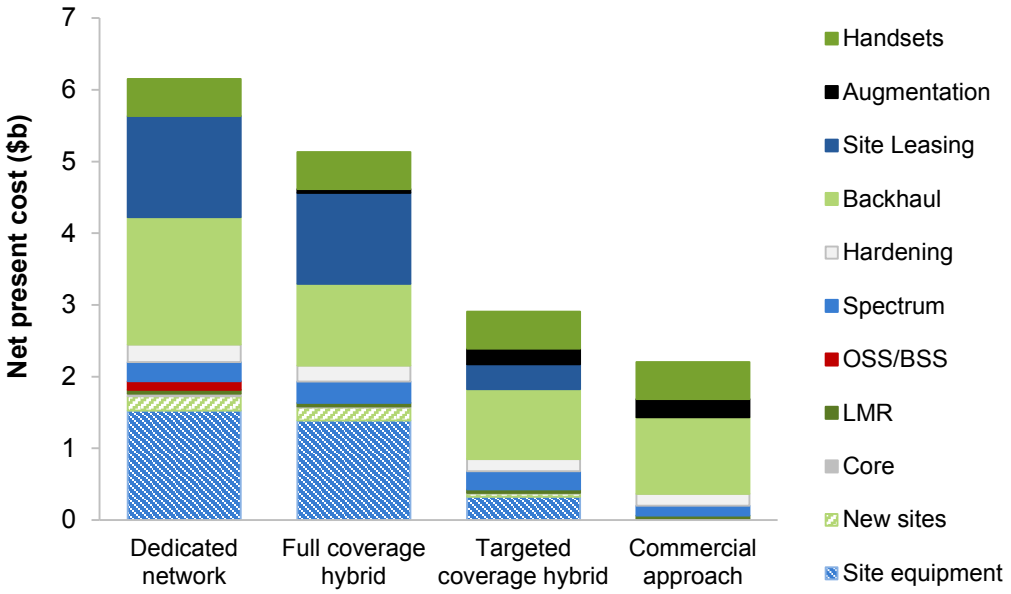
While PSAs represent a small proportion of a mobile carrier's total customer base, the addition of PSA traffic — where PSAs expect higher reliability standards and a higher priority status than other users — could be expected to impact the investment plans of carriers. Put another way, mobile carriers will incur costs in adding PSAs to their networks under commercial and hybrid options.

It is assumed that mobile carriers will incur two main types of capital expenditure costs in delivering a PSMB capability:

- upfront and ongoing investment to harden their mobile networks to provide a level of reliability consistent with delivering public safety grade mobile broadband
- ongoing investment to add capacity to their networks in order to meet the demands of their broader customer bases (PSAs and non-PSAs) compared to if they were not delivering PSMB on their networks (chapter 5).

Figure 6.1 **PSMB delivery costs**[a]

By option and cost item[b]



[a] This represents the sum of all costs considered in the quantitative evaluation. It should not be interpreted as the total costs that would be incurred in actually deploying a particular option. [b] OSS/BSS refers to Operations and Business Support Systems.

Source: Productivity Commission estimates.

In addition, it is assumed that where a mobile carrier delivers PSMB services over its own network, it would do so using its existing spectrum holdings. This has an opportunity cost — that is, foregone revenue from not using that spectrum to serve other customers — that is treated as a capital expenditure item in the quantitative analysis.

These incremental costs were reflected in the quantitative evaluation of commercial and hybrid options and increased the costs of these options. However, because option 4 involves 100 per cent of PSA traffic being carried on a single mobile carrier network, these costs are largest for this option (appendix C).

While the capital expenditure required to upgrade mobile carrier networks to deliver public safety grade mobile broadband services is material, this is outweighed by the ongoing operating costs that a mobile carrier(s) would incur. For example, capital expenditure is estimated to be 45 per cent of total costs over the 20-year period, compared to operating expenditure of 55 per cent of total costs. Operating expenditure includes costs associated with network maintenance and the leasing of backhaul.

Alternative option designs

The four central case options for delivering PSMB were based on a specific set of assumptions and inputs to facilitate the quantitative analysis. However, key design features and input assumptions can be varied to explore the effects on absolute and relative costs (table 6.3).

Table 6.3 **Variations to the central case options**
Alternative network design and input assumptions

Central case assumptions	*Alternative assumptions*			
	Dedicated	*Full coverage hybrid*	*Targeted coverage hybrid*	*Commercial*
Jurisdictions share a single core network for PSMB	Each jurisdiction establishes and uses a separate core for PSMB	..	..	..
Jurisdictions rely on a mobile carrier's core network	..	Jurisdictions establish and share a single dedicated core	Jurisdictions establish and share a single dedicated core	..
PSAs can access one mobile carrier network in a given location	..	Two overlapping carrier networks	Two overlapping carrier networks	Two overlapping carrier networks
10 MHz of dedicated spectrum	20 MHz (national)	20 MHz (national)	20 MHz (inner metro[a])	..
PSA traffic (metro areas[b]) of 1.5 Mbps/km^2	1 and 4 Mbps/km^2	1 and 4 Mbps/km^2	1 and 4 Mbps/km^2	1 and 4 Mbps/km^2
PSA traffic (other areas[c]) of 500 kbps/km^2	200 and 800 kbps/km^2	200 and 800 kbps/km^2	200 and 800 kbps/km^2	200 and 800 kbps/km^2
PSA traffic growth rate of 5% per annum	2 and 10% per annum	2 and 10% per annum	2 and 10% per annum	2 and 10% per annum
20% of PSA traffic overflows on to mobile carrier network	..	50% overflow on to carrier network	50% overflow on to carrier network	..

[a] Inner metro areas are those covered by dense urban and urban geotypes. [b] Metro areas are those covered by dense urban, urban and suburban geotypes. [c] Other areas are those covered by suburban, rural and remote geotypes. **..** Not applicable.

A key take away from applying these alternative network design assumptions is that they do not change the cost ranking of options — in all cases, the commercial option remains the most cost effective by a significant margin. However, use of these alternative assumptions has a material impact on the cost of particular options. A full exposition of the results of applying these alternative assumptions is provided in appendix C. Some of the key insights are discussed below.

Seeking more direct network control adds to costs

In the central case, the dedicated network option (option 1) involves all jurisdictions sharing a core network for PSMB. However, if jurisdictions wished, they could establish their own core networks, potentially affording individual governments and their PSAs more control over the design and delivery of PSMB services.

Similarly, in the central case, the hybrid options (options 2 and 3) involve PSMB services being delivered using a mobile carrier's core network. An alternative approach is to deploy a second, dedicated core network for PSMB services (shared by all jurisdictions).

Pursuing these alternative design features would increase the costs of these options owing to the additional network infrastructure required, and the costs of operating this infrastructure over the 20-year period. For example, were each jurisdiction to deploy its own core network, the total cost of option 1 would increase by more than 20 per cent.

Multi-carrier options involve a cost tradeoff

In the central case, the hybrid and commercial options involve PSAs having access to a single carrier's network in any given location.

An alternative approach is to rely on two, overlapping mobile carrier networks for the delivery of PSMB services. On the one hand, this is expected to put upward pressure on the costs of these options, as each carrier would need to upgrade its core network and systems to deliver priority services to PSAs, and to facilitate roaming with another network. On the other hand, a multi-carrier option could reduce the amount of network hardening required to deliver a given reliability standard (chapter 5).

It has not been possible to ascertain the relative importance of these effects due to a lack of information in the public domain. However, for the purposes of the quantitative evaluation, the Commission has made certain assumptions about the implications of pursuing a multi-carrier option to PSMB, namely:

- it would require greater investment in LMR gateways to facilitate interoperability between PSA narrowband networks and carrier networks
- it would require battery backup at fewer sites than in a single carrier option (75 per cent of sites compared to all sites).

On this basis, the costs of the hybrid and commercial options were estimated to increase marginally if PSAs were to rely on two mobile carrier networks for PSMB services rather than one. For example, the cost of pursuing a commercial option is estimated to increase by about 3 per cent when two carrier networks are involved. This could be regarded as a conservative estimate of the cost differential, given the costs associated with facilitating roaming across networks were not able to be quantified.

That said, owing to the dearth of publicly available information on the cost implications of multi-carrier approaches, these results should be considered illustrative only.

Changing the mix of inputs changes network costs

In delivering a given level of capacity over a mobile network, there is a tradeoff between using sites and spectrum, regardless of the PSMB deployment approach (chapter 5). However, since the Commission's quantitative analysis is built on a bottom-up costing approach (rather than an optimisation model), it is not possible to determine the combination of sites and spectrum that results in the lowest costs for each delivery option.

That said, for illustrative purposes, the Commission has explored how the costs of the dedicated and hybrid options change if 20 MHz of dedicated spectrum is used instead of 10 MHz. The results indicate that increasing the amount of dedicated spectrum (and thus decreasing the number of sites) reduces the costs of the dedicated option (by 15 per cent) and the full coverage hybrid (by 11 per cent).

On the other hand, doubling the allocation of dedicated spectrum increases the cost of the targeted coverage hybrid option by 5 per cent. This is because mobile sites in dense urban and urban areas are assumed to have relatively small coverage footprints, which means that the initial capacity deployed at each mobile base station (to form the coverage layer) is sufficiently high to meet PSA requirements with 10 MHz of spectrum. Therefore, while additional spectrum (which has an opportunity cost) increases the capacity of each cell, it does not decrease the number of sites needed to meet coverage requirements.

However, these results are highly driven by the underlying assumptions and should be treated with caution for several reasons. First, it is problematic to compare these results to the central case commercial option. As noted earlier, the Commission has not adopted a optimisation model for costing the PSMB delivery options. While applying the alternative assumption of 20 MHz of dedicated spectrum does reduce the costs of options 1 and 2, using alternative combinations of sites and spectrum in the commercial option could potentially lower the costs of this option too.

Second, the analysis assumes that the unit cost of spectrum remains constant as the amount used is increased from 10 MHz to 20 MHz. In practice, the actual cost of this resource could be materially higher, given the large (and growing) demand for spectrum that can be used to deliver mobile broadband. This, in turn, would erode some of the cost savings associated with a larger quantum of dedicated spectrum (that said, as discussed in the sensitivity analysis section below, assumptions about spectrum costs are not a significant driver of total PSMB delivery costs, all else equal).

In any case, even with 20 MHz of dedicated spectrum, the dedicated and hybrid options remain more expensive than the commercial option. This reflects the cost savings and efficiencies inherent in the commercial option that are separate to the amount of spectrum that is available, such as greater scope to share existing infrastructure.

Sensitivity analysis

Aside from option design, the central case results were based on various assumptions about the amount and value of specific network inputs. In reality, there is uncertainty attached to the precise value of many of these inputs. There could be various unforseen reasons why they end up being higher or lower than assumed. Therefore, an important consideration is whether the results (and in particular, the cost ranking of options) are robust to alternative assumptions and inputs.

To assess this, the Commission undertook two stages of sensitivity testing.

- A partial sensitivity analysis, in which key input parameters were varied one at a time to their estimated lower and upper bound values, to test the materiality of each input for the estimated costs of each option (table 6.4).
- 'Best' and 'worst' case scenario testing, in which several parameters were varied simultaneously in the same manner for each option — by setting all of the parameters to either their upper or lower bound values.

This section identifies the key insights from the above analysis — a full exposition is contained in appendix C (section C.8).

Partial sensitivity analysis

A key insight from the partial sensitivity analysis is that while varying particular parameters changes the cost relativities between options, it does not affect their cost ranking (table 6.5).

Sensitivity analysis suggests that some parameters have only a marginal effect on the estimated costs, and therefore do not affect the cost relativities across options. For example, varying the cost of new site build has a relatively minor impact on the costs of the dedicated and hybrid options because of the small percentage of these 'greenfield' sites that are assumed as a proportion of total sites. Similarly, based on the range of spectrum opportunity costs assumed, varying the estimated unit cost of spectrum has a minimal impact (in the order of 2 to 4 per cent) on the total cost of the dedicated and hybrid options.

Varying other parameters has a material impact on the absolute costs of each option and changes the cost relativities between them, but not their cost ranking (table 6.5).

For example, the cost differential between the dedicated, hybrid and commercial options is most sensitive to assumptions about the unit cost of radio access network equipment and site leasing. Specifically:

- varying the cost of radio access network equipment to its upper bound increases the costs of the dedicated and hybrid options by 9 to 14 per cent, and applying the lower bound reduces it by about 7 to 11 per cent

- varying the cost of site leasing to its upper bound increases the costs of the dedicated and hybrid options by 3 to 9 per cent, and applying the lower bound reduces it by 3 to 6 per cent.

Other parameters have a material impact on the absolute costs of each option, but vary in broadly similar magnitudes across options. For example:

- varying the unit cost (per site) of backhaul has a significant impact on the costs of all options, in the order of 5 to 10 per cent higher or lower
- varying network operating costs, as a fixed proportion of the network capital costs, increases or decreases the total costs of each option in the order of 2 to 4 per cent.

Table 6.4 **Summary of partial sensitivity analysis tests**

Upper and lower bound input parameters tested

Parameter	*Lower bound*	*Central case*	*Upper bound*
Network design features			
Site new build (% of total coverage sites)[a]	0	5	15
Civil site hardening (% of sites hardened)	0	5	10
Asset life span (site equipment and core network) (years)	6	8	10
Capital expenditure unit costs			
Site new build cost ($ per site)	150 000	300 000	500 000
Site radio equipment costs ($ per site)	50 000	80 000	120 000
Opportunity cost of spectrum ($ per MHz per person)	0.50	1.00	1.36
Operating expenditure unit costs			
Network operating costs (% of network capex unit costs)	5	7.5	10
Backhaul rental costs, metro[b] ($ per site per annum)	15 000 (option 1) 10 500 (others [c])	20 000 (option 1) 14 000 (others)	25 000 (option 1) 17 500 (others)
Backhaul rental costs, regional [d] ($ per site per annum)	20 000 (option 1) 14 000 (others)	25 000 (option 1) 17 500 (others)	30 000 (option 1) 21 000 (other options)
Site leasing costs ($ per site per annum) [e]	15 000 (metro) 10 000 (regional)	20 000 (metro) 12 500 (regional)	25 000 (metro) 20 000 (regional)
Other parameters			
Discount rate (%)	3	7	11

[a] Applies to the dedicated option only. [b] Metro areas are those covered by dense urban, urban and suburban geotypes. [c] Other refers to options 2, 3 and 4. [d] Regional areas are those covered by rural and remote geotypes. [e] Applies to the dedicated and hybrid options only.

Source: Productivity Commission estimates.

Table 6.5 **Partial sensitivity analysis — summary of results**

Percentage changes relative to the central case

	Dedicated		*Full coverage hybrid*		*Targeted coverage hybrid*		*Commercial*	
Parameter	*Lower*	*Upper*	*Lower*	*Upper*	*Lower*	*Upper*	*Lower*	*Upper*
Site new build	-3.3	6.6	-3.6	7.2	-1.5	2.9	0.0	0.0
Civil site hardening	-0.3	0.3	-0.3	0.3	-0.5	0.5	-0.7	0.7
Asset life span	4.6	-3.0	4.7	-3.1	3.4	-2.3	2.4	-1.6
Site new build cost	-1.6	2.2	-1.8	2.4	-0.7	1.0	0.0	0.0
Site radio equipment costs	-9.3	12.4	-10.5	14.0	-7.0	9.3	0.0	0.0
Opportunity cost of spectrum	-2.1	1.5	-2.9	2.0	-4.3	2.9	-3.1	2.1
Network operating costs	-3.9	3.9	-4.1	4.1	-3.0	3.0	-2.3	2.3
Backhaul rental costs	-6.6	6.6	-5.1	5.1	-7.4	7.4	-10.7	10.7
Site leasing costs	-5.4	7.8	-5.8	8.6	-3.0	3.0	0.0	0.0
Discount rate	40.3	-25.2	39.3	-24.7	36.0	-22.8	35.6	-22.5

Source: Productivity Commission estimates.

Best and worst case sensitivity testing

While varying individual parameters one at a time provides context for the importance of those parameters to estimated costs, it does not provide an estimate of the best or worst case outcomes. To do this, the parameters set out in table 6.4 (excluding the discount rate) were varied simultaneously for each option.

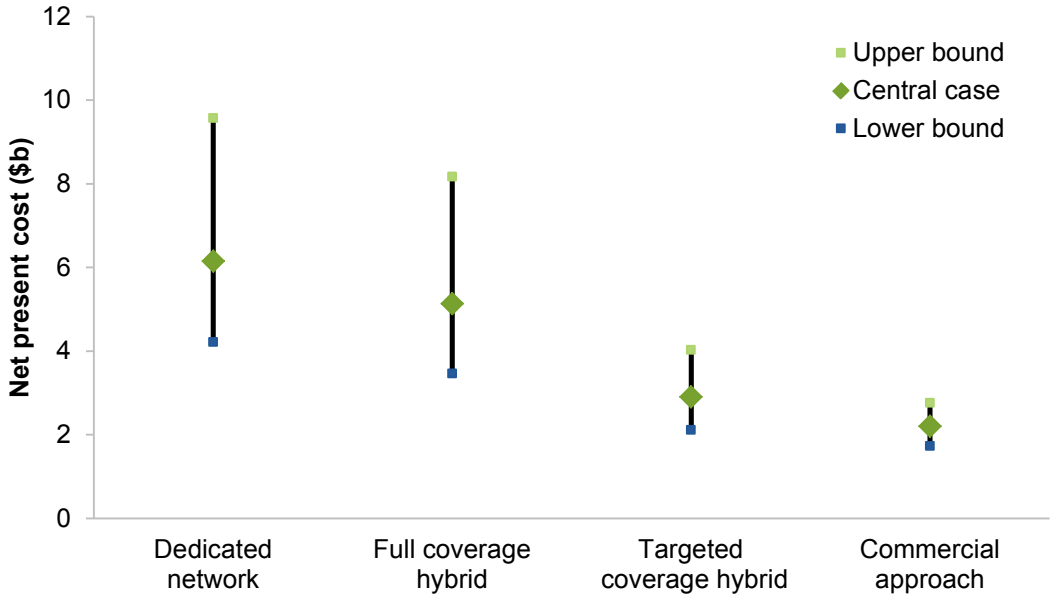
Varying key parameters simultaneously has a material effect on estimated costs (figure 6.2). However, the relative ranking of delivery options is unchanged. Moreover, the estimated range of costs for the commercial option is small compared to the other options. Some input values that are only relevant to the dedicated and hybrid options are highly uncertain (such as site leasing and base station equipment costs), and so a wide range of values for these inputs was considered in the sensitivity analysis.

FINDING 6.1

A commercial approach is the most cost-effective way of delivering a PSMB capability to PSAs.

The Commission's analysis indicates that a dedicated network is nearly three times more expensive than a commercial option. The cost difference between a hybrid and commercial option is lower and narrows as the size of the dedicated network component decreases.

Figure 6.2 **Sensitivity analysis**
Best and worst case



Source: Productivity Commission estimates.

6.4 Evaluation of risks

All infrastructure and service delivery projects involve risks. Risk can be defined as any uncertain but quantifiable consequence of an activity, be it in terms of costs or benefits. Risks can be project specific (such as technology risks), sector specific (such as regulatory risks) or economy-wide (such as inflation risk), and can change over time. These risks can have implications for the costs and benefits of different delivery options for PSMB. This will depend on the likelihood that a risk will occur, and the consequences if it does. While some of these risks can be reduced or avoided, residual risks can remain. (Chapter 7 discusses the role of risk allocation in risk management.)

Some risks differ between PSMB options

Some risks associated with delivering PSMB will vary little between delivery options — for example, the risk that suitable applications will not be developed applies to dedicated, commercial and hybrid options. Other risks could vary in a material way depending on the delivery option. This latter category of risks is the focus of this section.

Study participants have raised a number of issues which indicate that different options will involve different risk factors. These have been categorised as:

- technical risks — for example, risks relating to whether the capability meets PSA service requirements, or whether new technology is integrated over time (ARCIA, sub. 2; CDMPS et al., sub. 7; Motorola, subs. 12, DR43; NSW Telco Authority, sub. 30; Telstra, sub. 19; Victorian Government, subs. 28; DR44)
- commercial risks — for example, risks associated with PSAs being locked into a specific supplier, or difficulties with contracting (ARCIA, sub. 2; ATF, sub. 4; CDMPS et al., sub. 7; NSW Telco Authority, sub. 30; VHA, sub. 11; Victorian Government, subs. 28; DR44)
- third-party risks — for example, the risk of adverse impacts on non-PSA users arising from disruption in the quality of service they receive over mobile networks, or due to reduced competition in the mobile market (ARCIA, sub. 2; Ericsson sub. 10; VHA, sub. 11; Victorian Government, subs. 28; DR44).

Risks have been considered qualitatively

Ideally, a cost–benefit analysis would assess costs and benefits using expected values (a probability-weighted average of all possible values) or certainty-equivalent values (OBPR 2014a, 2014b; PC 2014b). However, there is insufficient empirical information available, both in the literature and from study participants, for the Commission to analyse risks quantitatively. Such a task would require a detailed understanding of each risk factor, the probability the risk will be realised, and how it would manifest differently across PSMB delivery options. As such, the Commission has evaluated risks in this study through a qualitative discussion of key risks that might differ across PSMB options.

Technical risks

There is uncertainty about the precise service standards that could or would be achieved for priority services

In the Commission's view, there is sufficient evidence to be confident that it is technically possible to deliver priority network access to certain users without dedicated spectrum, even when a mobile network is congested (chapter 5). However, there is uncertainty around precise levels of network accessibility that could or would be delivered under alternative PSMB delivery options. While Telstra has conducted trials of its LANES technology, including most recently at the AFL Grand Final, the outcomes of these trials have not been made public.

Similarly, while the Commission has found that it is technically feasible to implement dynamic changes to the priority settings of PSA users and applications under all delivery options, the service levels that could or would be delivered are uncertain.

Study participants have predominantly attributed technical risks around priority network access, and dynamic changes to priority settings, to the commercial option. However, these risks would also need to be identified and managed in the hybrid and dedicated options — for example, where the dedicated channel for PSAs is operating at capacity but specific users (such as incident commanders) need to be able to access the network, or where officers moving into an emergency area need to have their priority status upgraded instantaneously. This could be the case during a large scale incident, or where some of the network capacity has been leased to other users but needs to be instantaneously switched over to PSAs in the event of an emergency.

Pilots of a commercial approach to delivering PSMB services, and more transparent sharing of the outcomes, would provide an opportunity to overcome uncertainty about the service levels that can be achieved with respect to priority network access, and dynamic changes to PSA priority settings (chapter 7).

A dedicated network may be at greater risk of delay

Any delay in the rollout of PSMB (beyond the scheduled commencement date) could reduce its benefits (as they will also be delayed). Delay risks are likely to be higher under the dedicated and hybrid options because:

- spectrum availability may have to wait until a formal spectrum allocation decision is made by the Australian Communications and Media Authority (chapter 5). This process may also be dependent on ongoing international processes to agree on harmonised spectrum for PSMB
- these options require significantly more upfront capital investment and network planning relative to commercial options, and there is evidence that lengthy, complex projects are more likely to overrun their expected delivery dates than projects involving less new infrastructure and investment (PC 2014b; Shrestha, Burns and Shields 2013).

Technology upgrades might prove less economic under a dedicated approach

Commercial mobile networks are continually upgraded as mobile carriers make new investments to keep up with evolving technology and competitor offerings (Ericsson, sub. 10. Optus, sub. 18; Telstra, sub. 19). Some of these upgrades have high fixed costs that are largely independent of the number of users on the network (for example, rolling out the coverage layer for an updated mobile network technology standard, such as LTE).

Mobile carriers operate multiple technologies, have large portfolios of spectrum and have large user bases (millions of subscribers) over which to recover the costs of new

investments (chapter 5). By contrast, a dedicated network option would likely be more constrained in acquiring mobile broadband compatible spectrum, and would have significantly fewer users than commercial networks. In addition, some study participants have argued that government funding constraints could limit scope for large capital upgrades (BAI, sub. 1).

For these reasons, future technology upgrades (such as to fifth generation or '5G' mobile technology) on a dedicated network may fail to realise the same economies of scale and scope as a commercial option (or a hybrid option, depending on its design), leading to high per-user upgrade costs. This creates a risk that a dedicated network option (or the dedicated component of a hybrid option) would not be able to incorporate new technologies as quickly, thus leading it to lag behind the service capability available on commercial networks. In turn, this may create risks that parts of the PSMB network cannot take full advantage of new technology, applications and devices developed for consumer markets.

Commercial risks

A commercial approach is more susceptible to supplier lock-in

Supplier lock-in occurs when a customer is dependent on a supplier for a service and is unable to change supplier without incurring significant costs (chapter 7). There are international examples of supplier lock-in influencing future investment decisions in public safety communications networks (box 6.6).

Box 6.6 Supplier lock-in and Airwave UK

Airwave is the current provider of the TETRA land radio system used by police forces and other emergency personnel in the United Kingdom. The Airwave network is commercially owned (including spectrum) with the UK Government contracting with Airwave to acquire services. The cost of this network to government has been much higher than anticipated.

The original estimate was a core service charge of £1.18 billion over 19 years, in monthly instalments, plus £290 million over 19 years for optional services. While total service charges to date are not available, annual reports show that the UK Government paid almost £500 million over the period 2010–2012. This figure does not include £80–100 million per year in charges for other services (such as data and cellular calls) that are made separate to the Airwave network.

In part, the cost increases have been a result of unforseen service additions (such as extensions into the London Underground) that were not envisaged at the time the original contract was signed. Further, usage has been well above expectations, resulting in expensive penalty charges for calls exceeding the pre-arranged limit. There have been reports of police officers being ordered to send text messages rather than use the Airwave network for routine voice calls.

Since 2012, the UK government has sought to replace the existing Airwave network with a PSMB capability (cost is widely seen as a major motivation (appendix B)).

Sources: Delgado (2010); NSW Telco Authority (sub. 30); SCF Associates (2014); UKNAO (2002).

Supplier lock-in can arise in two ways — as a result of a supplier using non-standardised technology (for example, when there is only one supplier of proprietary equipment) or as a result of significant and unrecoverable investments being sunk into a single supplier, which makes it more difficult to change to an alternative provider at a later date (VHA, sub. 11; Victorian Government, subs. 28, DR44).

In principle, the use of open standards-based solutions for mobile base station equipment, backhaul and end-user devices means that the risks of supplier lock-in due to proprietary technology would be low under any PSMB delivery option (NEC, sub. 5; Telstra, sub. DR41) — and, in particular, lower than the risks of lock-in with LMR technology (chapter 2). However, any PSMB arrangement that requires significant investment in a single mobile carrier's network (such as a hybrid or commercial option where a single mobile carrier upgrades its core network or undertakes extensive site hardening) represents a sunk investment that may have to be re-incurred should PSAs wish to switch suppliers in the future, even if open technical standards are used (VHA, sub. 11). This places PSAs at risk of lock-in.

Knowledge that switching suppliers would result in some of these 'sunk' costs being reincurred can influence the pricing behaviour of an incumbent supplier, as evidenced in the United Kingdom (box 6.6). Similar pricing incentives could prevail once a PSMB network has been built — for example, if a PSA or state government considers that it has only one realistic choice of supplier for continued PSMB services, which would likely raise the costs of extending the service or procuring new network features (Victorian Government, sub. 28). The NSW Telco Authority (sub. 30) sees this risk as particularly acute if the commercial provider also has control over any dedicated spectrum used by PSAs.

There are strategies available to governments to avoid becoming locked-in — such as public ownership of assets or aligning the length of contracts with the economic life of assets — which can be applied to all delivery options (chapter 7). Spectrum is one key asset that could remain government owned and be re-used with another supplier (NSW Telco Authority, sub. 30). However, in a commercial or hybrid option, public ownership may be difficult to apply further, as it is implausible for investments in mobile carrier networks (such as network hardening and core upgrades) to be owned by, or transferred to, governments. There may be greater scope to align a commercial contract's length with asset lives, however, because of the wide mix of assets used (with diverse asset lives) and the potential to stagger investments in network infrastructure over time. The extent to which this can effectively mitigate the risk of lock-in is unclear.

In addition, options which use multiple mobile carriers for service delivery can potentially allow investments to be spread over multiple networks. Alternatively, site hardening could be targeted to those sites where multiple carriers have co-located their LTE equipment. These strategies may lower the risk of lock-in by reducing the amount of investment sunk into any one network, improving contestability for future PSMB contracts and upgrades (NSW Telco Authority, sub. 30; VHA, sub. 11).

Handset costs could differ across options

End-user devices are compatible with a finite range of frequencies. Manufacturers typically design their devices to be compatible with international standards and frequencies used in consumer markets around the world. Under a commercial option, there would be scope for PSAs to use 'off the shelf' devices (such as consumer handsets) that are already compatible with the spectrum used on mobile carrier networks. By contrast, scope to do this would be more limited under a dedicated PSMB approach if the spectrum band on the dedicated network is not widely supported by device manufacturers, and equipment needs to be customised to meet the needs of Australian PSAs — with consequently higher costs. These costs could persist over time to the extent that PSAs become locked in to using a spectrum band that is not widely supported in other countries. Efforts to harmonise spectrum bands internationally for PSMB so that spectrum utilised is also compatible with off the shelf handsets is one mechanism for mitigating this risk (chapter 5).

Harmonisation with frequency bands used for PSMB elsewhere in the world is also a relevant consideration where PSAs seek to procure customised devices tailored to their specific needs. The unit costs of these devices will be influenced by the scale of the global market. Work is currently underway at an international level to harmonise spectrum bands used for PSMB across the Asia–Pacific region (appendix B). For specialised PSA devices, there could be a greater risk that customisation is required under a commercial option (where spectrum bands do not match those used for public safety in other countries) than under a dedicated approach (where there may be greater alignment).

The above challenges are likely to be greatest under a hybrid option. End-user devices in such an option would need to be compatible with the spectrum used on one or more commercial networks in addition to the spectrum used over a dedicated network. Depending on the specific frequency bands used on each network, this would heighten the risk that 'off the shelf' devices are not readily available (either on global consumer or public safety markets) and need to be customised for Australian PSAs.

Multi-carrier options mitigate some risks but introduce others

A multi-carrier PSMB option could involve overlapping or adjacent networks (chapter 5). Some of the advantages and disadvantages of multi-carrier options (relative to a single carrier option) are common to both overlapping and adjacent network options. For example, relying on multiple carriers is expected to reduce the risk of supplier lock-in, as discussed above. On the other hand, technology upgrades could be delayed due to the difficulties associated with coordinating the undertaking of these upgrades across multiple network operators. There is also a risk that services are interrupted as PSAs move between networks.

Both types of multi-carrier options would likely require that roaming arrangements are in place, and/or handsets are modified, to ensure PSAs can operate on multiple networks as required. However, roaming arrangements are particularly critical for overlapping

multi-carrier options (where PSA users would be expected to regularly and instantaneously move between networks as their capacity needs, and the availability of commercial networks, changes). By contrast, the incidence of PSAs crossing network borders would be relatively lower under an adjacent multi-carrier option, potentially reducing the breadth and complexity of the roaming agreement required.

In the Commission's view, it is technically feasible to implement roaming arrangements as part of a PSMB solution (chapter 5). That said, roaming agreements are relatively rare in Australia, reflecting the significant commercial and coordination barriers involved (especially if a 'seamless' roaming experience is sought). Some study participants have expressed a view that the potential impact of roaming arrangements on the commercial operators makes it unlikely that mobile carriers will be willing to support roaming at a reasonable cost (NSW Telco Authority, sub. 30).

Pursuing a multi-carrier option could also add to the time taken to put a PSMB capability in place (relative to a single carrier option). While all options for delivering a PSMB capability will require costly and time-consuming negotiations, the chance of stakeholders not reaching agreement — or the tendering process failing — potentially increases as the number of parties involved increases, particularly where those parties have conflicting objectives (Mnookin 2003).

Ultimately, it will be up to governments and PSAs to weigh up whether the benefits of utilising two or more mobile carrier networks as part of a PSMB solution justify the additional costs and risks involved. Some of the benefits will vary depending on the type of multi-carrier option pursued — for example, using multiple, overlapping carrier networks to deliver PSMB could improve service reliability (by increasing network redundancy), whereas using different carrier networks in different geographic areas could increase contestability at the procurement stage (chapters 5, 7).

Third-party risks

Non-PSA users may experience changes to their quality of service

Delivery of a PSMB capability via commercial or hybrid options could have positive or negative spillovers for non-PSA users of mobile broadband networks.

On the positive side, investments made by mobile carriers to improve network reliability and capacity could benefit non-PSA customers (for example, if these customers are able to access additional capacity when it is not being used by PSAs) (CDMPS et al., sub. 7). This could increase the value that some mobile subscribers derive from their mobile service if this service quality improvement was not fully captured in revised consumer prices.

On the negative side, access and priority service levels granted to PSAs that displace commercial customers or degrade their quality of service during certain periods of time would be disruptive for these consumers, and may have flow on negative implications for

the community more broadly. For example, negative spillover effects on non-PSA users have the potential to be particularly acute during disasters or busy periods (such as New Year's Eve) when mobile networks are already heavily congested. Study participants submitted that reducing the public's access to mobile carrier networks during emergencies could compromise their ability to contact emergency services (NSW Telco Authority, sub. 30; PFA, sub. DR40). The Victorian Government (sub. DR44) is concerned that such degradation of commercial services could place the mobile carriers at a higher risk of liability or indemnity — at least relative to a dedicated approach. Difficulties in accessing mobile carrier networks could also result in valuable information that would have been uploaded and disseminated via social media (such as photos and videos) being unavailable (NSW Telco Authority, sub. 30). This could impact on the situational awareness of both PSAs and the broader public.

The decisions taken by mobile carriers in delivering a PSMB capability would largely determine whether the positive or negative effects are more significant. On the one hand, mobile carriers can be expected to have strong incentives not to degrade the quality of service offered to their non-PSA subscribers (including due to risk of customer churn) and would likely carefully manage the impact of delivering PSMB on their networks over time.

On the other hand, rather than add capacity to the entire network and maintain quality of service during these unplanned incidents, mobile carriers might allow a temporary reduction in service levels to commercial customers located in the immediate area. The costs of doing this (for example, through compensation to non-PSA users, or via non-PSA users switching to other carriers) could be less than adding additional permanent capacity.

In sum, the net result on quality of service for non-PSA users from an approach which involves them sharing network capacity with PSAs is uncertain, as is the value non-PSA users would place on any impacts. How these spillovers would vary across the commercial and hybrid delivery options is also uncertain. That said, the spillovers would likely be reflected in the prices charged by mobile carriers (to both PSA and non-PSA users), and mobile carriers could be expected to seek to minimise any adverse impacts on their other customers.

The PSMB delivery option may impact (positively or negatively) on competition

Some study participants argued that the PSMB delivery option chosen could impact on the competitive dynamics in the broader mobile market, positively or negatively.

On the negative side, some study participants noted that the degree and level of competition in the commercial mobile market is less than desirable to deliver competitive outcomes for a PSMB capability, particularly given Telstra's coverage advantage over other mobile carriers (VHA, sub. 11; Victorian Government, subs. 28; DR44). Study participants also expressed concern that any public funding directed towards improving mobile coverage in 'thin' rural markets for PSMB will lead to improvements in Telstra's mobile network (either by extending coverage or increasing quality of service), which

would further entrench its position in the market (VHA, sub. 11; Victorian Government, subs. 28; DR44).

On the positive side, some study participants view PSMB as an opportunity to promote deeper competition in the mobile market more broadly, particularly in 'marginal' regional areas where natural monopoly characteristics mean there is only ever likely to be one network operator (Victorian Government, sub. 28). Additionally, some proponents submit that a dedicated network option could promote greater competition in the mobile market — for example, if the network operator leased back capacity to the market when it is being underutilised (PFA, sub. 8, DR40; Rivada, sub. 9, DR38).

Study participants put forward various mechanisms for facilitating contestable and competitively priced service offerings for PSMB, and to promote competition in the mobile sector (chapter 7). These include:

- the design of procurement mechanisms to encourage greater competitive tension among bidders (Alcatel-Lucent, sub. 15; NEC, sub. 5; NSW Telco Authority, sub. 30; Rivada Networks, sub. 9; VHA sub. 11; Victorian Government, sub. 28)
- the use of regulation to deliver more competitive regional mobile telecommunications service outcomes, or to ensure there is a sufficient regulatory framework that underpins priority access, quality of service and network arrangements for PSMB delivered over commercial networks (NSW Telco Authority, sub. 30; Optus, sub. 18; PFA, sub. 8; Victorian Government, subs. 28; DR44)
- aligning PSMB investments with other Australian Government telecommunications programs in order to maximise efficient investment, such as utilising infrastructure built as part of the Mobile Black Spot program and National Broadband Network to support mobile telecommunications investment in regional markets (ARCIA, sub. 2; CDMPS et al., sub. 7; Optus, sub. 18; Victorian Government, subs. 28; DR44).

Best-practice policymaking involves identifying a policy problem, setting well-defined objectives and evaluating options for meeting those objectives (chapter 3). There is merit in governments considering how the approach to delivering a PSMB capability will interact with other objectives and policies they have in place — for example, Australian Government schemes that subsidise landline communications and mobile network extensions in regional areas.

Nevertheless, designing PSMB procurement to achieve objectives other than value for money procurement of a PSMB capability potentially introduces a new set of risks that would also need to be evaluated. These include the risks that:

- pursuing multiple objectives can lead to adoption of higher-cost solutions (particularly where there is a lack of transparency about which objective takes precedence)
- redesigning telecommunications policy through the alignment of existing programs and legislation delays the implementation of a PSMB capability.

These factors need to be weighed up, along with their associated costs and benefits. That said, competition issues in the mobile telecommunications market are likely to be more appropriately addressed through existing policy and regulatory mechanisms than indirectly through the design of PSMB procurement. There are several mechanisms already in place for regulation in the telecommunications sector (chapter 7).

FINDING 6.2

The nature and magnitude of risk varies across PSMB delivery options. For example, the risk of governments becoming locked in to using a single supplier is most pronounced under a commercial approach, while a dedicated network is most susceptible to delays and technological obsolescence. However, risk and uncertainty are common to all PSMB delivery options and no option is clearly preferred on the basis of risk factors alone.

6.5 Differences in benefits between options

Two main types of benefits are expected to flow from a PSMB capability — improved public safety outcomes (such as lives and property saved and improved officer safety) and cost savings (or productivity gains) in the delivery of public safety services.

There are multiple complexities in quantitatively estimating the benefits flowing from a PSMB capability, including that:

- many benefits are non-monetary and will not be reflected in cash flows
- limited evidence makes it challenging to estimate the value the public places on non-monetary benefits
- there is significant uncertainty as to how a PSMB capability will be used by PSAs (chapter 3).

As such, benefits have not formed part of the quantitative analysis. However, as the options under evaluation have been designed to deliver a similar level of PSMB capability, the impact of each option on public safety outcomes (and thus, its benefits) is not expected to vary markedly.

That said, the time it takes to deliver a PSMB capability, and the flexibility afforded to PSAs once it is in place, could vary across delivery options, in turn affecting the relative benefits of alternative options.

Benefits will be realised sooner under commercial and hybrid options

A dedicated network is expected to take longer to deploy than the commercial and hybrid options (chapter 5), and technological upgrades are expected earlier on commercial

networks (section 6.3). All else being equal, it is preferable to realise a given benefit earlier than later. Commercial and hybrid options are therefore likely to provide larger benefits by bringing benefits forward, relative to a dedicated option (Telstra, sub. DR41).

Commercial and hybrid options can scale up network capacity in the short term

Demand for PSMB services is highly uncertain and is likely to be influenced by a complex range of factors (chapter 4). Under a dedicated option, there is a hard upper bound on capacity (at least in the short term) as the network is not able to accommodate any PSA demand beyond what it is initially provisioned to meet. Any excess demand beyond this amount will require capacity rationing until more capacity can be added (either by way of transportable mobile cells or by adding permanent network capacity).

By contrast, commercial and hybrid options offer scope to scale up capacity as it is needed — a level of flexibility that could provide additional benefits during unplanned incidents. This might become a particularly important feature if PSMB traffic or capacity turns out to be higher than expected — either in the form of unexpected 'peaks' or due to a higher rate of demand growth.

Reservations about commercial options could delay benefits

Study participants indicated that PSAs have reservations about sharing a network with non-PSA users, or ceding a level of control to a mobile carrier (ARCIA, sub. 2; ATF, sub. 4; PFA, subs. 8, DR40).

Previous mission critical communication networks have generally been 'private', that is, built and operated for the exclusive use of PSAs. These networks have, in general, been controlled by PSAs or a government agency acting on their behalf. Commercial networks are a departure from this status quo — they are both shared with the general public and shift the locus of network control away from PSAs to a private company.

To utilise any PSMB capability to its fullest potential, PSAs will need to implement significant organisational and behavioural changes within their organisations, and will also need to build trust that the technology will work when it needs to (CDMPS et al., sub. 7; CDMPS, sub. DR42). There are various ways that confidence in a PSMB capability could be developed in a way that allows such organisational changes to take place, such as the effective piloting of commercial options (chapter 7).

7 Implementing a PSMB capability

Key points

- The Australian, state and territory governments need to decide whether and how to become involved in providing public safety mobile broadband (PSMB) to their public safety agencies (PSAs).
- If jurisdictions choose to facilitate PSMB, they will need to weigh up the costs and benefits of different levels of network capacity and quality of service. There would be benefits in each creating a jurisdiction-wide implementation agency to minimise duplication.
- Prices that reflect the true cost of providing PSMB would encourage PSAs (as users) to seek out efficient uses of it.
- Each PSA will need to revise operational procedures and implement training programs for its staff. Ministers in each jurisdiction should lead the development of protocols between PSAs for sharing information and, where PSAs share a capability, for prioritising users.
- Australian, state and territory government ministers should agree on a common set of minimum technical protocols — covering networks, devices and applications — to facilitate interoperability across jurisdictions and agencies.
- Australian Government intervention in spectrum allocation processes is not necessary to deliver a PSMB capability. State and territory governments do not face any unnecessary regulatory impediments to accessing spectrum.
  - Any spectrum licenced for PSMB should be priced at its opportunity cost.
- Contracts negotiated between governments and commercial entities would be a more appropriate way to secure a PSMB capability than regulatory compulsion.
- Value for money should be the primary objective in public procurement, but achieving this will be challenging in Australia's telecommunications market. There is a small number of network operators and equipment suppliers, and some parts of the country are covered by a single network.
- Jurisdictions can seek more competitive procurement outcomes by:
  - benchmarking bids against other cost data and making tender processes transparent
  - splitting up tenders by service and/or region to encourage a larger number of bidders
  - negotiating on behalf of their PSAs
  - leveraging their infrastructure and spectrum holdings in negotiations
  - using short-term contracts that require adherence to open international standards.
- The challenges associated with a commercial approach to PSMB (the most cost-effective deployment approach) could be investigated through small-scale pilots. This would not lock jurisdictions into a wide-scale commercial rollout — or preclude them taking a dedicated or hybrid approach — should the pilots fail or circumstances change.

Even where a public safety mobile broadband (PSMB) capability uses the most efficient combination of inputs, it can impose large unnecessary costs if it is implemented poorly. This chapter examines how PSMB can be implemented efficiently. It covers institutional and governance arrangements (section 7.1), national coordination and protocols (section 7.2), spectrum allocation (section 7.3), the role of regulation (section 7.4), public procurement (section 7.5) and the timing of implementation (section 7.6).

7.1 Institutional and governance arrangements

Institutional and governance arrangements shape how public projects are managed and delivered. These arrangements are most effective when responsibilities are assigned to the parties with the right authority and expertise to undertake them, risks are assigned to the party best placed to manage them, and accountability mechanisms give parties an incentive to fulfil their duties in the interests of the community as a whole. The Commission has previously set out principles that can guide governments in crafting these arrangements (box 7.1).

Box 7.1 Principles for good governance in public infrastructure

Roles and responsibilities are clearly defined

All parties should have clearly defined roles and a clear understanding of their responsibilities. This includes a division of responsibilities between elected governments and entities charged with developing investment plans and delivering infrastructure services.

Ministers are well placed to make decisions about the public interest, set policy objectives and develop policy or regulatory frameworks to guide the functions of delivery entities and regulators. By contrast, decisions related to service provision and applying regulations are better left to institutions that are independent of — but accountable to — governments, to reduce the risk that decisions are politicised. In particular, independent entities are usually better placed to make commercial, investment, procurement and regulatory decisions.

Entities are held accountable for their actions

Public entities that report to ministers (via their boards) can be held accountable for meeting policy objectives and acting in accordance with requirements. Requiring entities to report publicly on their processes, operations and outcomes can provide a further layer of accountability. Regulatory decisions and ministerial directions should be published.

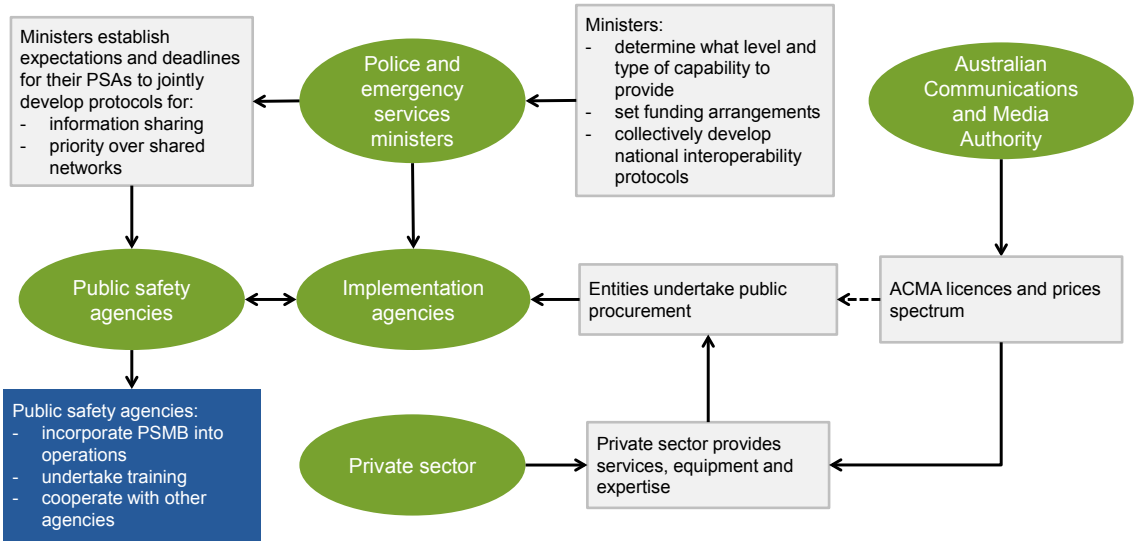
Entities possess sufficient capability to fulfil their responsibilities

Governments need to consider whether each party has the appropriate resources and capability to fulfil its assigned responsibilities (including suitably skilled staff). In practice, this can mean ensuring that infrastructure delivery agencies have sufficient technical and commercial 'know how'. It can also mean assigning responsibilities to entities that have the most appropriate expertise and authority.

Sources: PC (2011, 2014b).

All jurisdictions and their public safety agencies (PSAs) will have a role to play in implementing a PSMB capability. These roles are summarised in figure 7.1 and discussed throughout this chapter.

Figure 7.1 **Roles and responsibilities for implementing PSMB**



State and territory governments are primarily responsible for PSMB

State and territory governments have primary responsibility for public safety and emergency management (chapter 2). The Australian Government also has some direct public safety responsibilities, including national security, border control and oversight of some PSAs (such as the Australian Federal Police). In exercising their responsibilities, jurisdictional governments set policy and funding arrangements for their PSAs. They are also accountable to the community for the performance of their PSAs.

Accordingly, each individual government (and relevant minister(s) in particular) will need to decide whether to become directly involved in facilitating a PSMB capability and, if so, how. Governments may choose to make decisions about the provision and procurement of PSMB services themselves, or leave these to individual agencies (acting individually or collectively). In the Australian Government's case, it could negotiate and purchase access to state or territory based PSMB capabilities or allow its PSAs to negotiate this directly.

Some duties are best performed by governments. Government ministers are directly accountable to their communities and so would be best placed to set PSMB policy objectives, timelines and funding arrangements. For example, police and emergency services ministers in each jurisdiction could set clear expectations of what outcomes they expect from a PSMB capability (in terms of improved PSA operations) and over what timeframe this capability should be provided. They could also set clear requirements for

competitive tendering and public reporting on progress. Further, ministers will need to lead efforts to set national interoperability protocols (section 7.2).

Tradeoffs will need to be made

Where governments choose to facilitate the deployment of a PSMB capability for their agencies, they will need to make tradeoffs between the level and type of capability to provide and the cost involved. In deciding which specific deployment approach to use for PSMB (dedicated, commercial or hybrid) and in implementing that approach, jurisdictions — in consultation with their PSAs — will need to weigh up the costs, benefits and risks of:

- the specific network capacity and quality of service levels (including reliability, security and so on) to be delivered to PSAs
- establishing arrangements with other jurisdictions that would allow PSAs to roam between PSMB networks
- providing a permanent PSMB capability outside of the footprint of commercial mobile carrier networks or relying on other communications technologies in these areas.

This report provides a framework for making these tradeoffs and draws out key drivers of differences across deployment approaches. Ultimately, each jurisdiction (or PSA) will need to make these tradeoffs transparently in deciding on the most suitable course of action to take. This will be driven by its individual circumstances, including its population distribution, geographic area, natural hazard profile, existing infrastructure and the coverage footprints of mobile carrier networks (Victorian Government, sub. 28).

There is a risk of a PSMB capability failing to meet public safety requirements under any deployment approach, and ultimately this risk will fall on governments (section 7.5). In deciding whether to intervene to facilitate PSMB, and in specifying capacity and quality of service requirements for such a capability, jurisdictions will need to consider how much risk they are willing to bear and articulate this transparently.

Accountability mechanisms are required

Where governments choose to be involved in implementing PSMB, they will need to establish institutional and governance arrangements in line with good-practice principles (box 7.1). These arrangements will generally need to be established at a jurisdiction-wide level, although in some cases two or more jurisdictions could opt to work together on particular aspects (section 7.2).

There are technical and commercial decisions that would be best delegated to experts. Individual jurisdictions could establish a government-owned agency to undertake these duties, or task an existing agency (discussed further below). These implementation agencies will need to be held accountable to governments (and the community) and to PSAs. As part of this, they will need to consult widely with PSAs on an ongoing basis. One

way to facilitate this would be for jurisdictions to appoint representatives from each PSA to the board of the implementation agency.

Governments can further facilitate accountability by putting in place frameworks for monitoring and publicly reporting on PSAs' activities and the outcomes they achieve for the community (such as crime rates or incident response times). This kind of reporting can help to show how PSAs are using a PSMB capability and the public safety outcomes it is helping to deliver. Robust reporting can also help governments and the community to compare the costs of providing PSMB over time against the benefits being achieved.

However, good reporting is not always easy. Some PSA activities and outcomes are already publicly reported by governments, including on a national basis through the annual *Report on Government Services* (SCRGSP 2015). But the indicators currently reported against do not cover all aspects of PSAs' performance, often because accurately measuring some outcomes or linking these to the performance of individual PSAs is difficult. Ongoing improvements in performance measurement may be needed to improve awareness of how specific PSA activities affect community outcomes, and to reduce unintended consequences that can arise where efforts are focused on areas that are measured at the expense of those that are not.

There would be benefits in using jurisdiction-wide implementation agencies

Implementing a PSMB capability will involve a number of technical and commercial tasks. These could include:

- developing the technical specifications that a PSMB capability would need to meet
- performing technical analysis and market testing
- procuring a PSMB capability (and supplementary services)
- long-term investment planning
- enforcing technical and operational protocols across PSAs within the jurisdiction to enable interoperability (such as network and software compatibility and information-sharing protocols)
- performing network control tasks and providing day-to-day operational support.

While some of these tasks could be performed by individual PSAs, there would be benefits in jurisdictions establishing an agency to undertake some (or all) of them jointly, on a jurisdiction-wide basis, in line with policy objectives set by ministers and in close consultation with PSAs.

History suggests that a coordinated approach at the jurisdiction level is likely to be more effective than letting each PSA independently make procurement decisions. This has led to duplication of investments in land mobile radio (LMR) networks and significant

constraints on device interoperability across agencies in many jurisdictions (chapter 2). By contrast, a coordinated approach would help to minimise duplication of equipment and procurement, and could lead to economies of scale (for example, where purchasing a larger number of handsets would reduce the unit cost) (Victoria Police, sub. 17).

A jurisdiction-wide approach would also offer opportunities for each government to coordinate PSMB investments with those in LMR networks or other government programs (such as mobile black spots initiatives). Some state governments have already established dedicated agencies to manage PSA communications and invest in LMR networks at the statewide level (box 7.2), and could potentially task these agencies with the planning and implementation of a PSMB capability where they have not done so already.

Box 7.2 Public safety communications agencies

New South Wales

The NSW Telco Authority was established in 2011 to coordinate radio telecommunications policy and services for all NSW Government agencies (including police, fire and ambulance). The authority is responsible for managing spectrum holdings, procuring and delivering communications technologies, setting technical standards and consolidating government-owned infrastructure to remove unnecessary duplication and costs. The authority currently owns and operates the NSW Government Radio Network, with network management and maintenance outsourced to a private-sector provider. It is also in the process of taking over the planning, procurement and operation of radio networks for all state government agencies. The authority reports to the NSW Minister for Finance, Services and Property.

Victoria

The Emergency Services Telecommunications Authority manages the provision of communications for Victoria's emergency services agencies (police, fire, ambulance and the State Emergency Service). This includes procuring and delivering telecommunications services over several networks (the Metropolitan Mobile Radio, Mobile Data Network, Emergency Alerting System and StateNet Mobile Radio) and managing the associated spectrum. The authority also operates the Triple Zero emergency call service in Victoria and dispatches emergency services. It reports to the Victorian Minister for Emergency Services.

Queensland

The Public Safety Business Agency was established in 2013 to provide strategic and corporate services to Queensland's PSAs. This includes holding and maintaining infrastructure and communication technology assets. The agency has responsibility for the Government Wireless Network, a digital communications network that provides voice and narrowband data services to PSAs. It reports to the Queensland Minister for Police, Fire and Emergency Services.

Sources: ESTA (2014a); NSW Government (2015); NSW Telco Authority (sub. 30; 2014); PSBA (2014).

Some coordination at the jurisdiction level is therefore likely to be beneficial, though each government will need to decide what form this coordination should take and the corresponding governance arrangements. For example, an implementation agency could

facilitate a single PSMB capability that is used by all PSAs, or it could assist individual PSAs to make their own investment decisions.

The risk with a jurisdiction-wide PSMB capability is that it does not adequately meet the requirements of each PSA, thereby reducing take-up of the capability and hence its benefits. This was the experience in the United Kingdom in the past, where commercial mobile services were rolled out for police forces nationally without adequate consideration of how the technology would be used or engagement of individual forces (UKNAO 2012).

Such risks are more likely where there is considerable divergence in the needs of individual PSAs. This might be the case, for example, if PSAs are already at different stages of using mobile broadband services, are at different stages of investment in LMR networks, or are not yet ready to invest in PSMB. A less prescriptive approach may be warranted in these jurisdictions — for example, jurisdiction-wide agencies providing expertise and coordination, but leaving decisions about the timing of PSMB adoption and other matters to individual PSAs.

Pricing models can facilitate efficient use of PSMB

While government ministers are best placed to make decisions about funding arrangements, individual PSAs are best placed to decide how to use a PSMB capability, just as they are with their other inputs and resources. Jurisdictions can facilitate the efficient use of PSMB (and efficient investment in it over time) by insisting on efficient pricing models. In short, this would mean that the prices that PSAs pay for PSMB (for example, from an implementation agency) reflect the cost of delivering the service.

In most markets, consumers of a service are charged in line with their use of it, which gives them an incentive to use only as much as they are prepared to pay for. It also sends a signal to the service provider about customer demand and thus provides a basis on which providers can make investment decisions. When the prices paid reflect the true cost of delivering a service, this leads to allocative efficiency: a situation where resources are directed to their highest-valued uses.

PSAs will have to decide what level of capability they are willing to buy and compare the value they get from spending more on PSMB from spending their resources on other priorities or inputs (such as vehicles and equipment). Prices that reflect the underlying costs of delivering PSMB would effectively encourage PSAs to weigh up the benefits of using PSMB against the costs. Cost-reflective prices would also give them an incentive to manage their demands on the network, develop new ways to use PSMB in their operations, develop new applications and, ultimately, use PSMB to maximise the outcomes they deliver for the community (box 7.3).

Where governments choose to provide funds to assist their PSAs with additional costs that arise from taking up PSMB, assistance should be in the form of an increased budget allocation. Compared to alternative funding models (such as directly subsidising the

provision of PSMB), this would preserve the incentives PSAs have to use a PSMB capability efficiently.

Box 7.3 Prices can encourage efficient use of PSMB

In many markets for infrastructure services (such as electricity, water and transport), prices are used to recoup the costs of investing in and operating infrastructure. This can be done by way of a single fee (which is common in public transport) or a two-part tariff (as often used for urban water). In the latter case, an efficient model is to charge users a flat annual fee (reflecting capital costs) and a per-unit usage charge (reflecting operating costs).

A further model is package pricing (also known as bundling), which has been increasingly adopted by commercial mobile carriers for their business customers. This involves charging a flat per-month fee which covers a package of services up to a specified level (for example, a certain amount of data downloads or voice calls). Additional services, or usage above the predefined level, can incur additional charges.

The influence that pricing has on how a PSMB capability is used will depend on the structure of prices and the type of deployment approach. For example, under a commercial PSMB capability with per-megabyte billing (for data use above a predefined level), PSAs would need to weigh up the costs of using additional data against the benefits. In a hybrid model where PSAs can overflow onto commercial networks, they would need to identify when it is worthwhile to overflow, given the prices they would be charged for doing so. And under a dedicated approach, PSAs would need to pay for any additional network capacity or coverage that is required.

PSAs can also take steps to manage their network demands instead of simply paying more to increase their traffic levels. Indeed, PSAs will have an incentive to manage their own demand in periods when the network is congested or usage charges are high. Options include:

- delaying some business-critical traffic to a later time, or slowing non-urgent traffic down to allow greater capacity for more pressing needs
- prioritising specific public safety officers or applications over the network (with lower-priority users given slower speeds)
- moving some traffic on to Wi-Fi systems (and thus off the mobile network)
- downloading non-urgent data (such as video) directly from end-user devices, rather than transmitting these data over the network (‘store and forward’).

Some study participants noted that PSAs will need to actively manage their demands on a PSMB capability, for example, by varying video quality or data transmission speeds at different points in time to best meet operational needs (sometimes known as ‘compression and broadcast’) (CDMPS et al., sub. 7).

FINDING 7.1

Prices that reflect the cost of providing a PSMB capability would encourage PSAs to use it efficiently.

PSAs will need to adapt

As the end users of a PSMB capability, PSAs will need to play a central role in specifying what that capability should look like and in applying it to their operations. In working with suppliers and/or jurisdiction-wide implementation agencies, PSAs will need to articulate and document their requirements, in terms of network capacity, quality of service, and other metrics (chapter 4).

Moreover, irrespective of how it is delivered, the benefits of a PSMB capability will depend on how PSAs use it (chapter 3). PSAs themselves are best placed to determine how PSMB should be incorporated into their operations. This will require revising operational procedures and protocols, including to manage agency demands on a PSMB capability in peak periods. It may also require cultural change within PSAs. Agency heads are well placed to take leadership for these changes.

Making the most of a PSMB capability would also require each PSA to implement education and training programs for its staff (customised to its specific needs and applications) and to invest in developing new applications as technologies continue to evolve. This could include finding new ways to use mobile broadband to better deliver public safety outcomes, as well as adapting to changing community expectations about how members of the public can communicate with emergency services (for example, by uploading images and video or communicating over social media) (chapter 3). Efficient pricing models and accountability arrangements would give PSAs an incentive to make these changes.

Further, PSAs will need to agree on protocols for working together to make the most of PSMB. This process should be led by ministers, as set out below.

Ministers will need to facilitate greater cooperation among PSAs

There are institutional barriers to interoperability

PSMB presents an opportunity for PSAs to interoperate within and across jurisdictions using a common communications platform, with potentially significant benefits. However, interoperability requires more than just compatible networks, devices and applications (chapter 5). It also needs PSAs to be willing to work together and effectively share information where this would lead to better public safety outcomes — regardless of how a PSMB capability is delivered. This kind of 'agency interoperability' has many components, of which technology is just one (figure 7.2). Differences in operational procedures (and even terminology) have impeded effective cross-agency collaboration in the past (chapter 2). Indeed, study participants identified non-technological factors as significant barriers to interoperability (for example, Motorola, sub. 12; Victoria Police, sub. 17; Victorian Government, sub. 28).

Figure 7.2 **Elements of agency interoperability**

Source: Adapted from US Department of Homeland Security (2013).

An interoperable PSMB capability would allow much greater information sharing across agencies, including the sharing of new forms of information. But PSAs need to be willing to share information in the first place. Some jurisdictions already have protocols in place for sharing information and coordinating PSA communications, such as Victoria (Victoria Police, sub. 17; Victorian Government, sub. 28), or have stated an intention to develop these, such as New South Wales (NSW Government 2015). Information-sharing and security protocols may need to be reassessed and amended (or, where they do not exist, created) to make the most of PSMB. These could cover agencies working across state and territory borders as well as with other agencies within the same jurisdiction.

However, interoperability is not always necessary or even desirable. Agencies sometimes deliberately restrict what information they share with others, such as sensitive criminal information that needs to be tightly controlled (Victoria Police, sub. 17). This also needs to be taken into account as PSMB is adopted.

Greater information sharing between PSAs would have benefits that go beyond mobile broadband (especially within each jurisdiction, where different agencies need to work together frequently), but the institutional barriers to this occurring will be challenging to address. PSAs are unlikely to come to agreement quickly on how to share information over mobile broadband. There is a role for ministers to facilitate effective cross-agency collaboration by leading efforts to develop formal inter-agency protocols for such information sharing (within their jurisdictions). Specifically, ministers should set clear expectations and deadlines for when these protocols need to be put in place.

Prioritisation protocols are needed where agencies share a PSMB capability

Within each jurisdiction, PSAs will also need to cooperate when they share a common PSMB capability (for example, if a state government decides to procure a capability on behalf of all its agencies, or if two or more PSAs jointly procure PSMB services from a commercial mobile carrier). Many PSAs are used to having their own communications networks or their own dedicated channels on a shared network (that is, a 'partitioned' network, where each agency has a fixed amount of network capacity). However, this model can artificially constrain an agency's ability to scale up its data use during an emergency, and would be an inefficient use of network capacity (chapter 5).

Long Term Evolution (LTE) technologies offer a more flexible approach by allowing specific users and applications to be given a higher priority over a shared network while also protecting the security of communications (chapter 5). However, effectively sharing a PSMB capability will require PSAs to agree how their users and applications (such as image transfer, video streaming or text messaging) are to be prioritised in specific operational situations and when networks are congested — regardless of the PSMB deployment approach taken. Several study participants emphasised the need for protocols or agreements to underpin such sharing (box 7.4).

PSAs that use the same PSMB capability may voluntarily come to agreement on how to share the available network capacity. In some cases, however, reaching agreement will be difficult. Where multiple PSAs share a common PSMB capability, ministers in those jurisdictions should set expectations and deadlines for PSAs to come to agreement on a set of formal protocols for sharing network capacity.

Box 7.4 Participant views on PSAs sharing a PSMB capability

There does however need to be protocols developed between the agencies to manage the available capacity. It is likely that once PSMB becomes a reality, there will be latent demand emerging across the emergency services sector which cannot be predicted to any degree of accuracy at this stage. The best scenario is to have the representation and protocols in place to manage capacity issues on an on-going basis. (MFB, sub. 6, p. 15)

The management of competing demands will need to be agreed amongst PSAs and the necessary policies put in place. (Motorola, sub. 12, p. 24)

[R]eaching agreement between agencies as to the application of different priority levels for different agencies is something that will need to be agreed and will be dependent on a strong PSMB governance body able to negotiate these business operating processes. (Ericsson, sub. 10, p. 16)

It is suggested that something like a PSMB Dynamic Capacity Allocation Protocol would need to be developed in conjunction with the customer PSAs and the PSMB Managing Body and PSMB Service Provider(s). This Dynamic Capacity Allocation Protocol would provide a model to assess the severity and potential network impact of escalating incidents, and guide the decisions to reconfigure the PSMB service as necessary to support the PSAs. (Victoria Police, sub. 17, p. 14)

RECOMMENDATION 7.1

If individual governments decide to facilitate the deployment of a PSMB capability, police and emergency services ministers should set clear expectations and deadlines for PSAs under their jurisdiction to develop inter-agency protocols for sharing information over mobile broadband. These protocols should aim to achieve effective cross-agency collaboration and should include security procedures to safeguard sensitive information.

In jurisdictions where two or more PSAs share the same PSMB capability, ministers should also set expectations and deadlines for PSAs to develop protocols for prioritising specific agencies, users, devices and applications.

7.2 National coordination and protocols

While each jurisdiction will be primarily responsible for determining whether and how to deliver a PSMB capability, there may be benefits in some form of national coordination. Other federations have established governance models to coordinate the implementation of PSMB nationally (box 7.5).

Box 7.5 PSMB governance models in other federations

United States

In 2012, the US Congress established the First Responder Network Authority (FirstNet), a federal agency, to deploy a nationwide mobile broadband network for public safety communications. FirstNet holds 20 MHz of dedicated spectrum and will use this to build a dedicated network. It is required to notify the governor of each state how it will construct and operate the network in that state. However, governors can choose to opt out and instead build their own state-based network, provided this meets technical requirements set out in federal legislation. The precise operation of these rules, and the associated spectrum-sharing and funding arrangements, are yet to be fully clarified.

Canada

The Canadian Government has announced that it will allocate 20 MHz of spectrum for public safety use and licence this spectrum to a nonprofit national entity. This entity will not deploy or operate a mobile network itself. Instead, provinces and territories will each establish a regional service delivery entity to deploy a mobile broadband capability, using either the dedicated spectrum, commercial mobile services, or a combination of the two. These regional entities must comply with technical standards set by the national entity to ensure interoperability across provinces/territories and with the United States in border regions.

Source: Appendix B.

National coordination could cover some or all states and territories, but would require the buy-in and agreement of all that choose to get involved. In identifying areas where they should coordinate their efforts, individual jurisdictions will need to consider whether the benefits exceed the costs. Protocols in some areas could facilitate device and application interoperability (discussed below). However, jurisdictions may prefer to retain flexibility in other aspects of implementation.

Should there be a single national PSMB capability?

Several study participants advocated for a single national PSMB capability — that is, a single service used to provide mobile broadband to PSAs across the country (which might consist of a national dedicated network and/or nationwide contract for commercial services). Some argued that this would be necessary for achieving interoperability across jurisdictions — for example, by providing the same kind of capability in each state at the same time (ARCIA, sub. 2; BAI, sub. 1; Ericsson, sub. 10; NEC, sub. 5; Telstra, subs. 19, DR41). In principle, a single national capability could result in less duplication of infrastructure or equipment, and thus be associated with lower costs (chapter 6).

However, a single national PSMB capability would have several major disadvantages. It would constrain the flexibility of each jurisdiction to implement an approach that best meets its needs at least cost, or at the right time, given its other policy and funding priorities. There is also a risk of delays or cost increases arising from the need to get agreement from all jurisdictions on key design and implementation matters, or from sudden policy changes in any individual state or territory. And, not least, a single national capability could limit scope for jurisdictions to take different approaches and learn from each other over time (sometimes referred to as 'competitive federalism').

There could also be scope for the Australian Government to become more directly involved in the delivery of a PSMB capability within each state and territory, for example, by seeking to develop common service standards or by co-ordinating implementation throughout the states and territories (CAA, sub. DR36). However, such involvement would have risks. Individual states and territories are ultimately responsible (and accountable) for the actions and outcomes of their PSAs — and could effectively veto any attempt by the Australian Government to impose a PSMB capability that does not meet their requirements. The states and territories are also better placed to understand the specific needs of PSAs in their jurisdictions and tailor their policy interventions accordingly.

However, the absence of a fully national approach would not preclude some form of national cooperation among the Australian, state and territory governments. Similarly, it would also not rule out the Australian Government taking a policy leadership role to encourage the adoption of PSMB across states and territories, or by participating in the development of common technical protocols (discussed below).

Indeed, the Australian Government already provides national policy leadership and coordination through the Department of Communications (with responsibilities covering

telecommunications and spectrum policy) and the Attorney-General's Department (with responsibilities in emergency management and national security policy). Both departments could work with state and territory governments to facilitate the implementation of PSMB, including by sharing expertise and addressing any policy barriers to the efficient use of PSMB.

Common protocols would support national interoperability

PSMB presents an opportunity to achieve national interoperability as PSAs move towards a common communications platform. Compatible communications technologies will be essential for securing the benefits of interoperability between jurisdictions. There is thus a strong case for a set of common protocols to support interoperability across (and within) jurisdictions. Such protocols will be especially valuable where different jurisdictions facilitate a PSMB capability using different approaches or suppliers, or over different timeframes. Some kind of common national standards or protocols was favoured by many study participants (box 7.6).

The value of such protocols will be greatest where they facilitate network, device and application interoperability across jurisdictions yet do not constrain the flexibility of each jurisdiction to pursue a PSMB capability that best aligns with its individual policy and funding priorities. The starting point should be the creation of a set of requirements — before jurisdictions embark on any procurement process — that act as a minimum benchmark, such that one jurisdiction's actions do not unnecessarily constrain another.

Box 7.6 Participant views on national coordination and protocols

Victoria Police's concern is that without a National Governance Structure the opportunity will be lost to truly operate nationally in a joined up manner, and deliver such broadband capabilities within and across 'borders' in an unfettered secure and resilient manner. (Victoria Police, sub. 17, p. 9)

National interoperability needs to be viewed in terms of national governance protocols, common spectrum, compatibility of devices, ability to connect across networks, management of information within jurisdictions, agreed protocols for sharing information. (MFB, sub. 6, p. 10)

The PSMB capability therefore will provide opportunities for national interoperability if agreement can be reached between the States and Territories to the standards to be adopted, the design of their respective networks, and the method of network operation assuming that the PSMB capability will be provided on a network of networks basis. (CDMPS et al., sub. 7, p. 28)

[I]f a national, central forum were established to set the standards, policy frameworks, and user requirements for the nation's emergency services, then agencies would have the ability to coordinate their budget and procurement cycles to take advantage of collective purchasing power for broadband equipment and services. (Motorola, sub. 31, p. 7)

If PSAs build and manage PSMB networks then it may be beneficial to appoint a PSA telco authority to coordinate State/Territory solutions, and to establish a national committee to take responsibility for ensuring interoperability and defining standards and protocols for inter-agency use of the PSMB network. (VHA, sub. 11, p. 7)

The exact content of common interoperability protocols is a matter for jurisdictions to jointly agree on. Such protocols could cover the elements set out in box 7.7 to create a minimum platform for network, device and application interoperability across all jurisdictions. Protocols in these areas could help to reduce the need for individual public safety officers to use multiple sets of equipment when they cross state borders, and potentially lead to economies of scale in procurement (for example, by reducing the need for handset equipment to be customised differently for each jurisdiction). Aligning the protocols with open international standards as far as possible would minimise the impact of national protocols on the procurement of network services and improve the ability to achieve competitive procurement outcomes (section 7.5).

Box 7.7 Potential scope of common interoperability protocols

A set of common interoperability protocols could consist of one or more of the following requirements:

- all network technology and end-user equipment to fully comply with the open international standards for Long Term Evolution (LTE) technology developed by the 3rd Generation Partnership Project (3GPP)
- spectrum used in each jurisdiction to be within bands that have been standardised by the 3GPP for LTE
- end-user devices to be compatible with the spectrum bands used in all jurisdictions (either commercial or PSA-dedicated spectrum)
- end-user devices and networks to support a minimum common set of standardised software, covering end-user applications and data encryption technologies
  - common applications could cover text messaging, transfer of images or video, or systems for accessing national databases (such as CrimTrac)
  - PSAs or jurisdictions could have flexibility to use additional software, provided the minimum set is supported.

The above requirements are broadly similar to those that have been developed for FirstNet in the United States (FCC 2012).

In setting common protocols, jurisdictions will need to consider what level of interoperability they are prepared to achieve and how to meet this in the most cost-effective (or least restrictive) way. They will also need to consider the relative costs and benefits of attaining interoperability with other jurisdictions and how common protocols might affect their leverage and flexibility in commercial negotiations.

Jurisdictions may also choose to work collaboratively on other aspects of interoperability, such as protocols for storing and sharing information between PSAs across jurisdictional borders, potentially building on work to develop such protocols within jurisdictions (section 7.1). Jurisdictions could also work together to support cross-border roaming, which might be desirable where jurisdictions engage different mobile carriers for PSMB services.

However, the case for extending common protocols beyond what is required to achieve interoperability is weaker. There is a risk that a common national approach in some areas (such as the contractual service levels to be delivered or the timing of PSMB investments) would constrain the ability of individual jurisdictions to meet the specific requirements of their PSAs or constrain their negotiating power when undertaking procurement.

Several states emphasised that individual jurisdictions will need to retain autonomy on many aspects of PSMB. For example, the Government of South Australia (sub. 29, p. 3) submitted that while a national body should develop a governance framework for PSMB, it 'should not provide direct governance of state based PSMB requirements and services, or impose such items as upgrade cycles, technology restrictions and usage levels'. Similarly, the Victorian Government (sub. 28) submitted that only states and territories are in a position to define 'mission critical', and the NSW Telco Authority (sub. 30) contended that responsibility for the design and build of a PSMB capability remains with individual states and territories.

In any case, minimum protocols to support interoperability across Australia would not preclude two or more jurisdictions from jointly setting standards in other areas — or even jointly undertaking some procurement or implementation activities. This would be a matter for each jurisdiction to decide given its individual needs. For example, work by jurisdictions to consider whether and how to pursue cross-border roaming may best be done on a bilateral basis, as different jurisdictions will likely have very different requirements. Jurisdictions will need to make these decisions before embarking on procurement.

In developing interoperability protocols, jurisdictions could be guided by past work undertaken by the COAG Public Safety Mobile Broadband Steering Committee and COAG senior officials (chapter 1), as well as national technical standards that have been developed in the United States (FCC 2012) and other countries. They could also build on the *National Framework to Improve Government Radiocommunications Interoperability 2010–2020*, which was endorsed by all jurisdictions (through COAG) in 2009 to improve interoperability across LMR networks.

Police and emergency services ministers in each jurisdiction will need to lead efforts to agree on interoperability protocols. In developing protocols, ministers will need to consult closely with their PSAs, and could consider setting up formal working groups or forums for facilitating PSA involvement. Ministers could also seek the involvement of industry, technical experts and others.

Ideally, protocols should be put in place within one year. This would allow time for the protocols to be developed while reducing the risk of 'early mover' jurisdictions locking in technologies that preclude future interoperability with other jurisdictions. The protocols should be updated on a periodic basis as circumstances or technologies change (for example, as new standards incorporating public safety features are released by the 3rd Generation Partnership Project (3GPP)). For transparency, the protocols should be published.

Existing bodies may be well placed to facilitate and provide input to these inter-jurisdictional efforts. Several forums have already been established under the COAG Law, Crime and Community Safety Council, including groupings of officials such as the National Coordinating Committee for Government Radiocommunications and the Australia–New Zealand Emergency Management Committee. Such bodies would also be well placed to publicly report on progress in PSMB implementation across Australia (on a regular basis) and to act as a forum for jurisdictions (and their PSAs) to formally share information and experiences relating to the procurement, adoption and use of a PSMB capability. Further, these bodies could play a role in facilitating pilots of a commercial PSMB capability (section 7.6).

RECOMMENDATION 7.2

PSMB presents an opportunity for PSAs to interoperate within and across jurisdictions using a common communications platform, which would deliver significant benefits. To facilitate this, the Australian, state and territory governments should task police and emergency services ministers with agreeing to a set of minimum interoperability protocols within one year. These protocols should have the objective of facilitating national network, device and application interoperability.

7.3 Spectrum allocation

The Australian Communications and Media Authority (ACMA), an independent Commonwealth agency, is responsible for regulating, licensing and pricing radiofrequency spectrum in Australia. In doing so, it is guided by the *Radiocommunications Act 1992* (Cwlth). It is also guided by directions from the Minister for Communications, for example, to allocate spectrum to particular uses or to price or sell spectrum in a particular way (Department of Communications 2015b).

Two main objectives set out in the Radiocommunications Act are to:

> maximise, by ensuring the efficient allocation and use of the spectrum, the overall public benefit derived from using the radiofrequency spectrum (s. 3(a))
>
> make adequate provision of the spectrum:
>
> - for use by agencies involved in the defence or national security of Australia, law enforcement or the provision of emergency services; and
> - for use by other public or community services (s. 3(b)).

ACMA has developed a set of supporting principles for managing spectrum. These include allocating spectrum to the highest value use, using the least restrictive approach to achieve policy objectives, promoting both certainty and flexibility, and balancing the cost of interference and benefits of greater spectrum utilisation (ACMA, sub. 14).

All mobile broadband networks require access to spectrum. In a commercial approach to delivering PSMB, services would be delivered over commercial networks using the spectrum holdings of their commercial operators (chapter 5). By contrast, a dedicated or hybrid approach would require access to spectrum in areas where a new network is established. The spectrum used to deliver PSMB would have an opportunity cost under all deployment models (including a commercial approach), since it would be diverted from other uses.

There is limited spectrum available at present

There is limited spectrum that jurisdictions or PSAs could access at the present time. Most of the bands that are standardised for LTE (by the 3GPP) have already been licensed to other users, such as mobile carriers (ACMA, sub. DR35). The exception is 30 megahertz (MHz) of spectrum in the 700 MHz band, which is available for sale but has not yet been purchased.

ACMA (2015h) recently announced that it will progressively make available 30 MHz of spectrum (known as the '850 MHz expansion band') in part of the 803–960 MHz band. This spectrum is internationally standardised for LTE (including commercial services) under 3GPP bands 26 and 27, the latter of which has been identified by the International Telecommunication Union for public protection and disaster relief in the Asia-Pacific region (and both of which fall within a wider band identified for such uses globally) (appendix B). ACMA (2015h, p. 16) has stated that while the full 30 MHz will not be cleared of existing services until mid-2024, 'options exist that could see parts of this spectrum available much sooner'.

ACMA has identified spectrum for potential public safety use

ACMA has recently made several decisions relating to public safety spectrum. In 2010, it set aside a Harmonised Government Spectrum portion of the 400 MHz band to provide a common band for state and territory governments to use for their public safety LMR networks (although jurisdictions are under no obligation to migrate their networks to this band) (ACMA, subs. 14, DR35). It has also been phasing in a model of opportunity-cost pricing for LMR apparatus licences in this band, in response to congestion in densely populated areas of Australia (ACMA 2015f).

In October 2012, ACMA made an in-principle decision to set aside 10 MHz of spectrum within the 850 MHz expansion band to support the deployment of a PSMB capability (ACMA, sub. 14). ACMA's decision was made as part of an earlier PSMB policy process that called for a single frequency band to be made available for PSMB (chapter 1). ACMA (2015h; sub. DR35) has stated that it would await direction from the Australian Government before deciding how to allocate this spectrum, following the Government's response to the Commission's final report.

In 2013, ACMA allocated 50 MHz of spectrum in the 4.9 gigahertz band for exclusive use by PSAs (provided through a class licence). This frequency is suitable for several wireless technologies, including Wi-Fi and air-to-ground communications.

Australian Government intervention in spectrum allocation is not necessary to facilitate PSMB

There are two main ways that potential users of spectrum — including PSAs, state and territory governments and mobile carriers — can seek access to their own parcel of spectrum.

The first is to purchase a spectrum licence at auction or from an existing licence holder (box 7.8). To do this, jurisdictions or PSAs would need to compete with commercial mobile carriers and other prospective users of the spectrum. For example, once spectrum in the 850 MHz expansion band becomes available, jurisdictions or PSAs might choose to bid for part of this band at auction. Alternatively, they could bid for spectrum in other bands as it becomes available. Provided the spectrum is within an internationally standardised band for LTE, there is no technical reason why it could not be used as part of a PSMB capability.

Alternatively, potential users of spectrum could apply for an administrative allocation to be made by ACMA or the Australian Government Minister. In the case of PSMB, such an allocation would need to be based on an assessment of whether the benefits exceed the opportunity costs (the value of alternative uses). ACMA has previously indicated that any administrative allocation of spectrum to the states and territories for PSMB would likely be authorised using an area-based apparatus licensing regime (ACMA 2012), which could allow spectrum to be made available sooner in specific geographic areas (ACMA, sub. DR35).

Several study participants favoured an administrative allocation of dedicated spectrum for PSMB, and many argued that this should be in a common band across jurisdictions. In particular, participants argued that:

- harmonisation with spectrum frequencies used elsewhere in the world (either for PSMB or commercial LTE) could allow PSAs to benefit from economies of scale in the design and manufacture of end-user devices (Alcatel-Lucent, sub. 15; BAI, sub. 1; Motorola, sub. 12; Rivada Networks, sub. 9; Telstra, sub. 19; Victoria Police, sub. 17), or potentially give them access to a greater range of equipment (Victorian Government, sub. 28)
- a common spectrum band would support interoperability between PSAs in different jurisdictions of Australia (ATF, sub. 4; MFB, sub. 6; Motorola, sub. 12; NSW Telco Authority, sub. 30; Victoria Police, sub. 17; Victorian Government, sub. 28)
- there is a legislative objective to ‘make adequate provision of the spectrum’ for use by law enforcement and emergency services agencies, which can be interpreted to mean

that full consideration be given to allocating spectrum to support PSMB (PFA, subs. 8, DR40; Victorian Government, sub. DR44).

Box 7.8 Spectrum licence types

The Australian Communications and Media Authority uses three main types of licence to allow access to spectrum.

- **Spectrum licences** grant exclusive use of a defined band of spectrum within a defined geographic area. These licences have the most protection from interference and can be used for any technology (although there are limitations on transmission power, out-of-band emissions and other technical aspects). Licences are issued for up to 15 years, with fees paid up front. They are typically sold at auction and can be traded on secondary markets. Examples include mobile phone networks.
- **Apparatus licences** grant an exclusive right to use a specific transmitting device in a specific geographic location. Licences are usually issued for up to 5 years (and potentially longer for some devices), with fees payable annually. Licences are generally renewed, unless there are policy or legal reasons to do otherwise. Examples include air traffic control systems, fixed wireless links and land mobile radio networks.
- **Class licences** permit shared public use of a defined band of spectrum for specific low-power or localised transmitting devices. There are no licence fees, since licences are not issued to individual users. Examples include wireless headsets, television remote controls and Wi-Fi.

Holders of spectrum and apparatus licences can transfer the licence to another entity, or authorise third-party operation, provided the licence conditions continue to be met.

The Australian Government recently announced that it will replace the current legislative arrangements for spectrum management with new legislation that streamlines licensing and improves flexibility, in line with recommendations made in the recent *Spectrum Review*. The Australian Communications and Media Authority (sub. DR35) submitted that access to any spectrum allocated for PSMB would probably be authorised under a new licence type to be developed as part of this process.

Sources: ACMA (subs. 14, DR35; 2013a, 2013c, 2015a); Department of Communications (2015b); Turnbull and Fletcher (2015).

However, none of these arguments are compelling reasons for the Australian Government to intervene in spectrum allocation processes. Jurisdictions and PSAs are not precluded from purchasing access to a specific band of spectrum — or applying to ACMA for an administrative allocation — once it becomes available. While some study participants expressed concern that PSAs could be 'priced out' by competition from commercial carriers in a market-based process (Victorian Government, sub. DR44), such processes provide an efficient way to allocate spectrum to its highest valued use from the perspective of the community as a whole.

In addition, LTE technology already provides for a high degree of interoperability at the network and device levels, without the need for all jurisdictions to use the same spectrum band (chapter 5).

More importantly, a PSMB capability can be delivered without government (or PSA) ownership of spectrum licences. Indeed, the Commission has found that a commercial approach — using carrier spectrum — is the most efficient, effective and economical way to do this (chapter 6).

Spectrum allocation and licensing are matters for ACMA and the Australian Government. However, any jurisdiction that wishes to access spectrum for PSMB is not dependent on the Australian Government directing ACMA to allocate spectrum for this purpose. The Commission has not received any evidence that government agencies (including at the state and territory level) face unnecessary regulatory impediments to accessing spectrum, or that government agencies are on an unequal footing with other potential buyers.

Accordingly, the Commission does not consider that Australian Government intervention in spectrum allocation processes is necessary to facilitate a PSMB capability or for state and territory governments to access spectrum. Intervention in these processes to improve certain users' access to spectrum would have costs that would need to be weighed against the benefits.

Spectrum should be priced at opportunity cost

To facilitate efficient allocation and use of spectrum, it should be priced at its opportunity cost — the value of the next best use for the spectrum — regardless of how and to whom it is licenced. This would generally be the outcome in any market-based allocation where the price is set through a competitive process. In the event that jurisdictions or PSAs decide to purchase spectrum, they would need to consider whether the public safety or other benefits of holding spectrum outweigh the cost involved in purchasing it.

While opportunity-cost pricing of spectrum has not always been used in the past — especially where spectrum has been administratively allocated to public sector entities (Department of Communications 2015b; NSW Telco Authority, sub. DR46) — there have been moves in this direction by ACMA in its introduction of opportunity-cost pricing for the 400 MHz band. Opportunity-cost pricing is more efficient than the alternatives, and has previously been supported by the Commission (PC 2002) as well as by ACMA (sub. 14) and the Department of Communications (2015b). ACMA is well placed to estimate the opportunity cost of any spectrum licensed for PSMB, and to apply this to licence prices (along with any administrative costs involved in licensing).

Several participants advocated for the Australian Government to provide spectrum to state and territory governments (or their PSAs) for free or at a discounted price. They argued that this is justified because PSMB would generate significant non-monetary benefits to the community (PFA, sub. 8; NSW Telco Authority, sub. 30; Victorian Government, subs. 28, DR44).

However, the existence of significant benefits (an outcome) does not in itself justify subsidising a single input to a PSMB capability (spectrum). Nor do these benefits affect the

value of alternative uses of spectrum, which determine the opportunity cost. Any 'public interest' discount would reduce the incentive for jurisdictions to maximise the value derived from using spectrum (both monetary and non-monetary), including by sharing it with other users (discussed below). Moreover, the public safety benefits of PSMB arise from the capability as a whole and how it is used, not directly from holding a licence to use spectrum.

In practice, the opportunity cost of mobile broadband spectrum will most likely be determined by demand from commercial carriers. The Victorian Government (sub. DR44) submitted that spectrum that is internationally harmonised for public protection and disaster relief would have no uses other than PSMB (in the absence of regulatory changes), and thus no alternative value. However, the Commission's understanding is that such spectrum aligns with bands that have been internationally standardised for use on LTE networks (appendix B), and Telstra (sub. DR41) submitted that some handsets in the Australian market already support this band. ACMA (2015h) has already indicated that some or all of the spectrum in this band would be made available for commercial use.

Where governments choose to provide PSAs (or jurisdiction-wide implementation agencies) with additional funding to cover the cost of any spectrum they choose to purchase, it should be provided in a way that is not tied to the use of the spectrum (for example, through a general budget allocation). Untied funding can help to preserve incentives for PSAs to use spectrum efficiently.

RECOMMENDATION 7.3

If the Australian Communications and Media Authority licences spectrum for PSMB, it should be priced at its opportunity cost.

Leasing can allow for more efficient use of spectrum

Even where a particular licence holder has exclusive access to some spectrum, there may be more valuable uses in particular times or places. By leasing or selling their access rights to a third party when they do not need spectrum, licensees can facilitate more efficient use of spectrum.

Most spectrum licence types allow some form of leasing — for example, spectrum and apparatus licence holders can allow third parties to operate under their licence in certain situations, provided that the licence conditions are adhered to (and the other user has the technical ability to make use of the spectrum) (ACMA 2014f). However, public sector agencies (at the Australian Government level) have generally made little use of spectrum leasing where government budget policies have restricted them from retaining the proceeds of doing so (Department of Communications 2015b).

If jurisdictions or PSAs choose to purchase dedicated spectrum for PSMB, they could lease it to commercial mobile carriers (or sell access to spare network capacity on a wholesale basis) during periods were public safety traffic is low. The large and infrequent nature of peaks in PSA traffic demand (chapter 4) mean that there could be considerable potential for leasing spectrum to other users when it is not required for public safety.

Several study participants supported this approach. For example, the Police Federation of Australia (sub. 8) favoured the sharing of spectrum when not fully utilised by PSAs so that valuable spectrum is not wasted. Vodafone Hutchison Australia (sub. 11) and BAI (sub. 1) supported making spectrum available to other users when there is excess capacity on a PSMB network, while preserving priority access for first responders. Rivada Networks (subs. 9, DR38) put forward a model for doing this, whereby spare network capacity would be leased to mobile carriers (on a wholesale basis) to provide a revenue stream that would fund the rollout of a new mobile network, and 'ruthless pre-emption' technologies would allow PSAs to regain access to the full network capacity when required. The Victorian Government (sub. 28) argued that leasing arrangements could allow for greater economies of scale (where a larger network has lower unit costs to build) and allow more total capacity to be made available to PSAs during 'surge' events.

Spectrum leasing is being pursued as part of a PSMB capability in the United States (appendix B). It was also supported for public-sector spectrum holders more generally in the recent *Spectrum Review* (Department of Communications 2015b). In response to that review, the Australian Government announced that it would examine policy and financial arrangements for spectrum use by its agencies (Turnbull and Fletcher 2015). Separately, the NSW Government (2015) has stated its intention to sell excess capacity on its LMR networks to other users.

The Commission supports spectrum leasing in principle as a way to make more efficient use of scarce spectrum. Where jurisdictions or PSAs choose to hold PSMB spectrum, they could sell access to other users during periods of excess capacity or on a temporary basis before the spectrum is used to deliver PSMB services (or, where spectrum is held by an implementation agency on behalf of a government, the government could change budget rules where these impede spectrum leasing). However, spectrum sharing may only be practicable if PSAs can be assured that they will be able to access network capacity at times when they need it (chapter 5).

Spectrum licensing frameworks already support spectrum leasing. It will be important that conditions are not imposed on any PSMB licences that might inhibit this, as such conditions could limit jurisdictions' flexibility in how they can use spectrum as an input to a PSMB capability. Where individual jurisdictions purchase access to spectrum, they will need to weigh up the technical feasibility and risks associated with leasing it to other users against the benefits. In particular, contractual arrangements would need to clearly specify the conditions of any leasing and how public safety officers would be able to regain capacity in emergency situations.

7.4 The role of regulation

It would be unrealistic and uneconomic for a government to implement a PSMB capability without some form of private-sector involvement (section 7.5). However, commercial entities do not have the same incentives as governments — for example, commercial mobile carriers' shareholders generally expect them to maximise profits (PFA, sub. 8). As such, mobile carriers might not provide all the outcomes that PSAs want without adequate compensation or some form of regulatory intervention.

Governments can attempt to secure outcomes that markets would not otherwise provide by using two types of tools: regulatory intervention and commercial contracts. In identifying the right tool to use, governments need to weigh up the merits of each to the community as a whole.

Study participants identified several areas where regulation could help governments to secure a PSMB capability. Many noted the potential for the National Broadband Network (NBN) to provide backhaul or satellite broadband services for PSMB (ATF, sub. 4; Coutts Communications, sub. 20; CSIRO, sub. 16; VHA, sub. 11; Victorian Government, sub. 28). Some suggested that this would need to be accompanied by regulatory intervention. For example, ARCIA (sub. 2) argued that the NBN could provide backhaul capacity with the facilities and prices under government control. The Centre for Disaster Management and Public Safety, APCO Australasia and Victorian Spatial Council (sub. 7) called for the operational premises of PSAs to be given high priority in the NBN roll out.

Other participants supported regulatory interventions relating to the delivery of PSMB services over commercial networks. For example, the NSW Telco Authority (subs. 30, DR46) argued for the regulation of access, prices and minimum service levels, and the Victorian Government (sub. 28) advocated for a regulatory framework at the Australian Government level to underpin priority access, quality of service and network management arrangements. The Victorian Government (sub. DR44) also argued that Australian Government intervention in the telecommunications market would be necessary for state and territory governments to achieve an effective PSMB capability, though it did not specify exactly what form such intervention should take.

These views echo those put forward by an earlier parliamentary inquiry (PJCLE 2013). In addition, BAI (sub. 1) favoured mandating that all existing Australian mobile carriers allow public safety officers to roam onto their networks. Vodafone Hutchison Australia (sub. 11) raised the prospect of spectrum being sold to mobile carriers on the condition that PSAs are given priority access based on a set of pre-defined protocols.

Past studies have gone further, raising the possibility of using spectrum and carrier licence conditions to compel mobile carriers to provide a PSMB capability (with such conditions to be imposed either from the outset or in the case that commercial agreement cannot be reached). This could involve:

- placing conditions on new spectrum licences (ahead of auction) to require the licensee to provide a PSMB capability under specific price or non-price terms (Access Economics 2010), and potentially to allow the spectrum to be reassigned to another entity if the services are not adequately provided (SCF Associates 2014)
- adding new conditions to the operating licences of mobile carriers to require them to provide PSMB services (Access Economics 2010; SCF Associates 2014) or to allow PSAs to second commercial networks in defined emergency situations (PJCLE 2013).

Past inquiries have also raised the possibility of using legislative powers to compel mobile carriers to provide PSAs with access to spectrum or mobile networks during emergencies — for example, by enacting provisions in the Radiocommunications Act that could allow PSAs to access spectrum licenced to other users in a declared emergency (PJCLE 2013).

All the above forms of regulatory intervention would need to be implemented by the Australian Government or its agencies, which have primary responsibility for the regulation and allocation of spectrum (section 7.3) and the economic regulation of telecommunications services and infrastructure (discussed below). However, the case for regulatory intervention is weak and no compelling case has been made for why existing regulatory frameworks would not be appropriate.

Infrastructure access is already regulated

Existing regulatory arrangements in the telecommunications sector (box 7.9) are mainly designed to promote competition and the efficient use of, and investment in, infrastructure, especially in market segments and locations where there is only one supplier of a particular service. For example, the Australian Competition and Consumer Commission (ACCC) regulates access terms and prices for backhaul transmission (which is used to deliver mobile services) in some parts of Australia. The ACCC also administers a facilities access regime that provides an avenue for mobile carriers to access cell site infrastructure owned by other parties. This is supported by infrastructure-sharing provisions in industry codes.

Access regulations are implemented by the ACCC following careful and detailed analysis of a particular market. In deciding whether to regulate access conditions or prices, the ACCC carefully examines the impact that regulations may have on the efficient use of, and investment in, infrastructure (ACCC 2014b). Any additional regulations introduced for the purpose of a PSMB capability could potentially reduce incentives for future investment and ultimately leave the community worse off overall.

Competition laws apply to NBN infrastructure, just as they do to other forms of telecommunications infrastructure. While the NBN is owned by the Australian

Government, it is operated on a commercial basis at arm's length from government. As such, any change to existing regulatory frameworks and processes to compel access to NBN infrastructure for the purposes of a PSMB capability would need to be based on evidence of a problem (such as market failure) and the ability for government intervention to remedy the problem without creating other problems.

Box 7.9 Telecommunications regulation and policy

The Australian telecommunications sector is subject to various forms of regulation, some of which applies specifically to mobile networks.

The Australian Competition and Consumer Commission (ACCC) is responsible for the economic regulation of the telecommunications sector. It has powers to regulate service provision and set terms and conditions for third-party access to infrastructure.

Currently, the ACCC regulates mobile termination and backhaul transmission services (both of which are necessary inputs for the delivery of mobile services) under the *Competition and Consumer Act 2010* (Cwlth). Commercial backhaul services are regulated in many areas of the country, except where there is deemed to be sufficient competition (mainly between capital cities, within metropolitan areas and along some capital–regional routes) (ACCC 2014a). The ACCC does not regulate domestic mobile 'roaming' (where customers of one network can receive services from another network). However, commercial mobile carriers have voluntarily entered into roaming agreements at various times. At present, Vodafone has an agreement that allows its customers to roam on to the Optus network in some regional areas, and onto the Telstra 2G network along some highways in Victoria and Tasmania (VHA 2015).

Under the *Telecommunications Act 1997* (Cwlth), the ACCC is responsible for administering provisions that deal with rights to third-party access to a defined set of facilities, including transmission towers, sites of towers (such as land and buildings) and underground facilities. These provisions are reflected in the Facilities Access Code, compliance with which is a carrier licence condition, although access arrangements are typically negotiated commercially before they reach arbitration by the ACCC (ACCC 2013).

In addition, the telecommunications industry has developed a guideline for how it will cooperate during emergency situations. This is designed to provide a standard procedure for carriers to cooperate with each other for emergency response. It specifies how carriers should work together when a pre-planned service provider cannot efficiently meet the requirements of the emergency services (Communications Alliance 2013).

Further, governments have subsidy schemes in place relating to the mobile sector. Some have initiated 'black spots' programs to subsidise the extension of mobile carrier networks in regional areas or to support the deployment of backhaul transmission infrastructure in specific regional locations (chapter 5). There are also telecommunications policies of more direct relevance to public safety, including Triple Zero and Emergency Alert (chapter 2).

In practice, access to NBN infrastructure would best be secured for a PSMB capability on a commercial basis. NBN Co is already trialling the connection of backhaul to mobile cell sites and expects to provide connections between cell sites and NBN Points of Interconnect in the second half of 2016 (NBN Co 2015a).

There may be further policy developments in this area in the future. Recently, the Regional Telecommunications Review recommended that the Australian Government permit and resource NBN Co to provide carrier-to-carrier products in regional Australia, including backhaul for mobile carriers (RTIRC 2015). This review also proposed that governments consider making greater use of state-owned radio network infrastructure to deliver mobile coverage improvements for the public.

Regulation is a blunt way to encourage service delivery

Using regulation to compel private companies to deliver services to governments (or deliver services in a particular way) can be costly. Where regulations mean that a supplier is forced into providing a service, the supplier is likely to factor the cost of doing so into the prices it charges — or call for compensation. Regulations governing the telecommunications sector are already complex, and imposing further regulations could give rise to unintended consequences, such as reduced incentives for private-sector investment.

In addition, regulations on how a service is provided can limit the flexibility of suppliers to meet governments' objectives in the least-cost way. In all cases, the ultimate cost to governments (and taxpayers) may not be transparent, making it hard to assess whether the benefits of the regulation outweigh the costs.

In particular, imposing conditions on spectrum or carrier licences that compel commercial mobile carriers to deliver services to PSAs could lead to sub-optimal outcomes. Spectrum licence conditions could only be imposed on *new* spectrum ahead of it being auctioned, and would complicate the auction process (Access Economics 2010). Such conditions could also lead to spectrum remaining unsold if bidders consider that it would no longer be worth purchasing at the reserve price — a situation encountered in the United States when the federal government attempted to auction spectrum with conditions requiring the licensee to deliver a PSMB capability (appendix B).

Even if such spectrum were purchased, bidders would factor the cost of providing PSMB into their bids, meaning that the community effectively pays for PSMB services through lost spectrum revenues. Moreover, this model could lock governments in to using the mobile carrier that holds the spectrum licence for the duration of that licence (up to 15 years), or to any entity the carrier sells the licence to. Not only would this mean that the total cost of providing PSMB is not transparent, it may also reduce competition and ultimately prove more costly than the alternatives.

Carrier licence conditions would give rise to a different set of problems. While conditions could be applied to existing carrier licences, governments would need to choose whether to impose the conditions on all mobile carriers (which could be surplus to requirements) or single out one or more specific carriers (which could affect competition in the broader market) (Access Economics 2010). Either approach may require legislative changes to be made and, since these would be retrospective, would inevitably lead to calls for

compensation. Moreover, carriers might respond by raising the prices they charge to all customers and/or reducing the service levels provided to PSAs to the minimum permitted by the licence conditions (regardless of whether compensation is forthcoming). In addition, the imposition of licence conditions on all carriers (current and future) could raise barriers to entry in the mobile telecommunications market.

A more fundamental problem is that regulations cannot guarantee that the outcomes PSAs want will be met. As noted in chapter 4, defining the specific service levels that PSAs need in the near term is a difficult task with high information requirements. Specifying what will be required over the longer term is all but impossible. In the case of carrier and spectrum licences, it may be difficult or impossible to adjust licence conditions in the future as PSAs' needs change. This could mean that the conditions prove to be insufficient for future needs (Access Economics 2010) or limit PSAs' flexibility to adjust a PSMB capability to meet their evolving requirements. And, under any form of regulatory intervention, it would be difficult to tailor regulations to the different needs of each PSA and jurisdiction.

Contracts offer an alternative to regulation

Voluntary contracts offer a flexible alternative to many forms of regulation. They are the norm in most areas of government infrastructure and service delivery involving private-sector participation. Contracting offers considerably more flexibility to identify innovative and low-cost solutions, and to adjust arrangements over time as requirements change. Regulatory compulsion should only be used as a matter of last resort if commercial negotiations fail, and following a thorough evaluation of the costs and benefits (including an assessment of the least-cost form of regulatory intervention).

Commercial negotiations can be difficult in markets where there is a small number of suitable suppliers, or where a single supplier wields considerable market power. But ad hoc regulations requiring certain services (such as PSMB) be provided to governments are an indirect and likely ineffective way to address these market imperfections. Such regulations can damage incentives for future investment or lead to costs being shifted onto the broader community in a way that is far from transparent.

As noted above, regulatory frameworks are already in place to address a lack of effective competition in telecommunications markets. There is no compelling case for using regulatory intervention to deliver a PSMB capability: solely using commercial contracts would be optimal, including where particular service offerings are not currently offered by the private sector.

Reaching agreement on terms and prices that are acceptable to both parties can be challenging. Private markets do not always function perfectly or offer consumers everything they might want to buy at a price they are prepared to pay. In negotiating with commercial entities, governments will need to think carefully about how they specify their requirements and consider a range of ways in which these could be met at least cost

(section 7.5). Ultimately, governments (and the communities they represent) will need to consider how much they are prepared to pay for a customised service to be delivered.

7.5 Public procurement

The private sector will play an important role in the implementation of a PSMB capability. This could include some combination of:

- providing broadband services over a commercial mobile network
- designing, planning and constructing a mobile broadband network
- providing operational and maintenance services
- providing equipment (such as end-user devices) or other inputs (such as backhaul)
- providing space on mobile cell site towers for PSMB equipment
- delivering user training
- developing software and end-user applications.

The exact roles will depend on the PSMB deployment approach taken in each jurisdiction and the costs and benefits of using the private sector, relative to governments delivering these services themselves. Even in the case of a dedicated network, governments will need to use commercial entities to supply and/or install equipment.

Private-sector involvement can allow governments to draw on the expertise and experience that commercial mobile carriers and technology companies have with the development, use and deployment of mobile broadband technologies. Commercial entities tend to be more adept than governments in adopting new technologies and innovating to meet consumers' needs at least cost (Telstra, sub. 19). The private sector has also brought more rigour to the assessment of the costs and risks of infrastructure projects than governments often do (PC 2014b).

However, good procurement is difficult. Governments do not have complete information about companies' cost structures, technical capabilities or strategies. This means that procurement processes need to be carefully designed to elicit the least-cost provider of a service, leverage competition, allocate risks and agree on prices. There are several leading practices that can guide governments in this process, as set out in the Commission's recent inquiry into public infrastructure (PC 2014b). Some of these are elaborated on in greater detail throughout this section.

Value for money should be the primary consideration

Achieving value for money is the primary objective of most government procurement. This generally means obtaining a fit-for-purpose outcome from the private sector at least cost. In the case of PSMB, this would mean meeting the network capacity and quality of service requirements of PSAs (chapter 4) at the lowest long-term cost.

Some study participants raised additional policy objectives that could be targeted through PSMB procurement. For example, procurement could be designed to:

- avoid adverse impacts on competition in the broader mobile communications market (VHA, sub. 11)
- promote competition in specific market segments (such as in regional Australia) (Rivada Networks, sub. 9)
- promote universal access to mobile communications in regional areas (Optus, sub. 18).

There may well be opportunities to target such objectives through the delivery of new infrastructure or pro-competitive conditions placed on PSMB contracts. However, in the Commission's view, PSMB procurement would be a blunt tool for targeting these other policy objectives compared to the alternatives. In particular, legislation governing competition and infrastructure access in telecommunications markets is already in place and administered by the ACCC, and a range of separate government programs are already used to improve services in regional Australia (such as mobile black spot programs) (chapter 5).

Attempting to target additional objectives through PSMB procurement may not necessarily be a lower-cost or more effective way of meeting these objectives. It would make the total cost to taxpayers of implementing PSMB (separate from achieving other policy objectives) less transparent. Targeting additional objectives could also introduce complications and delays to the tendering process, for example, due to additional complexity or impacts on private-sector participation. And, not least, there is a risk that initiatives introduced through PSMB procurement fail to have a material impact on competition or consumer outcomes in the broader market.

In tendering for parts (or all) of a PSMB capability, jurisdictions (or PSAs) should seek to obtain value for money — that is, the best possible outcomes for the community as a whole, taking account of quality and risk as well as cost. This would mean identifying the least-cost way to meet the capacity and quality of service requirements of PSAs while complying with common protocols to support interoperability across jurisdictions.

As far as possible, governments should aim not to exacerbate any problems with competition in the broader market as they go through PSMB procurement. But to the extent that altering procurement processes reduces the value for money they can achieve — or if there are other policy objectives they wish to target — there should be a robust and transparent analysis of all available policy instruments. Objectives relating to broader

market competition or social outcomes should only be targeted through PSMB procurement where that is the least-cost way of doing so, and where any impact on the cost of procurement is explicitly identified and made public. Where governments are concerned about the impacts that procurement processes may have on market competition, they should first consider existing avenues for addressing any adverse impacts on competition (such as existing legislation administered by the ACCC) before altering procurement practices.

FINDING 7.2

Using procurement processes for PSMB to target policy objectives other than value for money — such as promoting competition in parts of the broader mobile broadband market or meeting equity objectives — would be a blunt, costly and non-transparent way to meet those objectives. Other policy instruments are likely to provide more effective alternatives for achieving additional objectives.

Competitive tendering can reduce costs and improve outcomes

Tendering is a standard and well-established feature of government procurement. It allows governments to seek proposals from a range of private-sector parties (including individual companies and consortia of companies) and select the proposal that meets their requirements at least cost. This process can encourage companies to bid competitively to win the tender.

Yet tenders are complex to design and the tender process can have a direct bearing on the final delivery cost of projects (PC 2014b). For example, highly specific design requirements can reduce the risk that policy objectives are not met and make it easier for governments to compare submitted bids. But too much specificity can limit bidders' flexibility to innovate and put forward lower-cost solutions. It can also deter some bidders if bids become too costly to develop, or if the project becomes too large or complex for some companies to handle — and thereby reduce competition (PC 2014b).

There are challenges specific to the Australian telecommunications sector

The challenges of designing a good tender process — and benefiting from competition between bidders — are amplified by features of the mobile telecommunications market in Australia (box 7.10). There are three commercial mobile carriers, which compete on coverage, price and service offerings. While all offer a high level of population coverage (above 95 per cent), there is wide variation in their geographic footprints and spectrum holdings.

In some parts of the country (especially regional Australia), only one commercial network is available, or there is only a single provider of backhaul transmission (RTIRC 2015).

While a single network can sometimes be economically efficient — where it can meet customer demand at lower cost than multiple networks — it can mean there is less consumer choice in particular areas. Moreover, the extensive physical infrastructure (such as base stations and radio networks) and spectrum required to provide mobile broadband coverage means that expanding a network is expensive. As a result, potential competitors can face high barriers to market entry, given that an operator would need to make significant capital expenditure to effectively compete (Optus, sub. 18).

Box 7.10 Mobile telecommunications markets in Australia

Since the early 1990s, several companies have constructed mobile phone networks in Australia. The specific technologies have varied over time, starting with analog services, 2G digital, 3G and 4G. Each technology has generally required a significant upgrade to infrastructure and equipment, and has co-existed with earlier technologies. Many handsets can operate across multiple types of network technology.

There are three mobile carriers at present: Telstra, Optus and Vodafone Hutchison Australia (other carriers have had a market presence in the past). Telstra has the largest 3G network, covering around 2.36 million square kilometres (km^2) and 99.3 per cent of the population, followed by Optus (around 1 million km^2 and 98.5 per cent of the population) and Vodafone (350 000 km^2 and 95.4 per cent of the population). Each carrier is in the process of building out its 4G network to attain a similar level of coverage. The three carriers also have very different holdings of spectrum across the country (chapter 5). In addition, a number of other companies (known as Mobile Virtual Network Operators) lease wholesale capacity from mobile carriers and sell services to retail consumers.

A separate market exists for backhaul transmission (the links, usually fibre-optic cable, between mobile base stations and the rest of the network). While there are many providers nationally, in many regional areas Telstra is the only provider.

Competition in the retail market is generally strong (especially for data services), and overall costs to consumers have been falling in recent years. For example, in June 2014, Telstra had a 45 per cent share of the retail market for mobile handset services, Optus 27 per cent and Vodafone 18 per cent (virtual operators comprised the remainder).

However, competition in the wholesale market is limited by the nature of mobile network infrastructure — in some areas, customer demand might only support the presence of a single network. Nevertheless, there is significant infrastructure-based competition, with consumer demand strong enough to support the presence of multiple networks in many metropolitan and regional areas.

Sources: ACCC (2014a, 2015b); Analysys Mason (2015); Optus (sub. 18); RTIRC (2015); Telstra (sub. 19).

Markets for network equipment and end-user devices may be more competitive since these markets are effectively global. However, Australia is a small part of the international market and may effectively be a 'price taker', with limited influence over what equipment is manufactured. Moreover, there are relatively few major suppliers and most have ongoing commercial relationships with the Australian carriers.

Study participants drew attention to the nature of competition in the mobile telecommunications market. Vodafone Hutchison Australia (sub. 11) noted that Telstra's large holdings of spectrum and backhaul infrastructure in regional areas make it difficult for other mobile carriers to enter and compete in these areas. The Victorian Government (sub. 28, p. 8) argued that 'the degree of competition and the level of coverage provided by commercial networks is less than that required to provide PSAs certainty of accessibility, affordability and quality of service'. It also contended that 'the commercial market in its current state is not in a position to deliver a PSMB capability', in part because 'there is not a homogenous competitive commercial mobile market, nor competitive breadth and depth to the market' (Victorian Government, sub. DR44, pp. 8, 25). The Police Federation of Australia (sub. DR40, p. 2) submitted that 'Telstra is likely to be the only viable service provider under the commercial provider model that you [the Commission] advocate because it has the largest geographic coverage for mobile broadband services'.

A small number of potential commercial partners for governments to contract with, coupled with high barriers to market entry, can raise the risk that tender processes will not be competitive. Governments could be left with few choices of supplier and 'monopoly price' bids that significantly exceed the underlying costs of supply. For example, if there was only one company that a government could realistically contract with to deliver PSMB, that company may have an incentive to inflate its bid (up to the expected cost of the government delivering PSMB itself).

A small number of potential commercial partners also introduces other risks into the procurement process. One is that the tender attracts no bidders. A supplier might consider that the benefits of the contract (additional business) do not sufficiently compensate for the costs and risks (such as the impacts on its other customers, costs of specific design requirements, reputational risks of failing to meet the government's needs, or the potential impact on its ability to compete in other markets).

There is also a risk that the commercial partner breaches the contract (or chooses to pay penalties specified in the contract rather than undertake specific actions). It may have an incentive to do so if it faces little effective competition, or is able to hold the government 'hostage' by revising prices after a large initial investment has been sunk.

However, governments are not powerless in dealing commercially with the private sector. They have several tools at their disposal to strengthen their bargaining position and/or make tender processes more contestable and competitive. While these tools will not always lead to a perfectly competitive tendering process, they can make a material difference to the value for money for taxpayers.

Benchmarking and transparency can shine a light on cost structures

Information can help governments to assess bids that are submitted through a tender process. Once a jurisdiction has decided on the specific nature of the PSMB capability it wants to implement, it could 'benchmark' cost information in the bids submitted. This

would essentially mean identifying comparable cost estimates from available sources (including internationally) to gauge whether the costs put forward in a bid are broadly reasonable and/or where further explanation needs to be sought from a bidder.

In addition, transparency can be valuable after a contract is signed. Many government contracts for infrastructure construction and delivery include 'open book accounting' provisions that allow the government client to inspect the supplier's financial records to assess the realised costs of construction (PC 2014b). Some have suggested that similar provisions be included in contracts for the delivery of PSMB services (TCCA 2013b), although governments would need to consider to what extent this might deter companies from bidding in a tender process.

Splitting up tenders can encourage greater competition

A more substantive strategy to improve competition in tender processes is to split a large project into a package of components, each of which is tendered separately (where this does not substantially undermine the efficiency of procurement or project delivery) (PC 2014b). This is likely to improve contestability and competition since the number of suitable suppliers tends to diminish as project size increases — for example, there would be very few companies that would be able to provide PSMB across the whole of Australia.

Splitting up tenders can also help where particular project elements require specific expertise, or timeframes mean that some elements need to be completed before others. Further, it can help to spread risk (and complexity) among a greater number of entities, thereby making it more attractive for a range of companies to participate and potentially leading to better overall risk management (NSW Legislative Council 2012; PC 2014b). Procurement guidelines issued by some state governments already support such an approach where it can improve value for money (for example, VDTF 2013).

The delivery of PSMB could be broken down into a package of tenders in two main ways:

- by technology or service — for example, tendering separately for service delivery over commercial networks, construction of new infrastructure, maintenance, end-user devices and training
- by geographic region — tendering separately for defined regions, for example, based on population density (inner metropolitan, suburban, rural) or the coverage footprints of existing mobile carriers (areas with multiple carriers separate to areas where only one carrier has coverage).

Such approaches have been used in procurement in other countries and sectors, including for PSMB (box 7.11). In addition, the Victorian Government (sub. 28, p. 9) submitted that 'Victoria considers it essential to unbundle procurement of network, services and terminals and avoid proprietary solutions'.

A further approach is to sign contracts with multiple providers of the same service. For example, a government might sign a contract with one mobile carrier to deliver a main PSMB service (with some network hardening) and a separate contract with another carrier to provide 'overflow' capability when additional capacity is required (that is, within the same region). Roaming agreements with multiple networks could also offer a way to provide greater reliability and redundancy for a PSMB capability (chapter 5). Some study participants expressed support for a multi-carrier approach (for example, Coutts Communications, sub. 20; CSIRO, sub. 16), although there were diverging views among carriers (box 7.12).

Box 7.11 Public procurement in other sectors and countries

Various techniques have been used in Australia and other countries to improve competition in public procurement processes by breaking large projects into smaller parts or by engaging multiple suppliers.

Rail projects in New South Wales and Victoria

Some state governments have split large projects into packages of smaller contracts to increase competitive tension in rail infrastructure procurement. For example, the NSW Government used packages of contracts (covering tunnel and station works, surface and viaduct works, and operations and maintenance) for its North West Rail Link project (Transport for NSW 2012), and has taken a similar approach to other large urban rail projects (NSW Legislative Council 2012). The Victorian Government used a package of six contracts, split up geographically, in the delivery of its Regional Rail Link project (VDTF 2013).

Australian Government air travel services

The Australian Government procures some air travel services on a 'whole of government' basis. In doing so, it has established a panel of airlines to provide both domestic and international services to government employees (Department of Finance 2015). Agencies are required to use the 'lowest practical fare' over four airlines when booking domestic flights.

PSMB in the United Kingdom and United States

Other countries have sought to improve competition in PSMB procurement by splitting tenders into a package of smaller contracts. In the United Kingdom, tendering for a national Emergency Services Network was split into four 'lots', each covering a different aspect of service delivery. Requirements were imposed for the suppliers of mobile network services and end-user services to be independent (although a single entity could submit bids for both), and for the provider of overall program management to be independent of the suppliers of other components (UK Home Office 2014).

In the United States, FirstNet has proposed breaking up procurement of a national PSMB network on a regional basis to increase competition among potential suppliers. Suppliers would be able to bid for one or more regions, or on a nationwide basis (Moore 2015).

At this stage, the Commission sees merit in governments (or their PSAs) tendering by technology or service, similar to how tendering occurs for some other government projects. There is also value in governments tendering for the delivery of PSMB services or

infrastructure by geographic region (under any deployment approach), provided this is feasible and there is a realistic prospect of it leading to better value for money in the long term. This could involve entering into contracts with multiple carriers following an open and competitive tender process.

Box 7.12 Views on a multi-carrier approach

Optus (sub. 18) submitted that allowing PSAs to access more than one mobile carrier network could lead to greater reliability. This is because the use of more disparate and geographically dispersed infrastructure could reduce the risk of a 'single point of failure' (for example, due to power outages or extreme weather events) causing one network to go down.

Vodafone Hutchison Australia (sub. 11) also favoured a model where PSAs can access multiple networks, which could lead to greater network capacity being available during critical incidents, maximise the use of spectrum and create greater redundancy in coverage. Vodafone Hutchison Australia further submitted that this could maximise contestability in procurement.

Telstra (sub. 19) had a different view. It submitted that a national partnership with a single commercial network operator would be the only realistic way to provide PSMB, given the need to provide rural coverage and the potential for fragmented implementation and coverage across states under a more disaggregated model. Telstra (sub. DR41) also drew attention to some of the technical challenges posed by roaming across networks and the potential impacts on the quality of service that can be delivered to PSAs.

Motorola (sub. DR43) argued that the use of multiple carriers to deliver PSMB would lead to increased technical complexity, which could compromise the delivery of a consistent and reliable service. Specifically, it pointed to difficulties in coordinating upgrades of network equipment and software across carriers.

However, a disaggregated tendering approach would pose costs and challenges that governments would need to work through. First, there would be administrative or transaction costs associated with preparing multiple tenders and evaluating a higher number of bids.

Second, there would be costs in achieving coordination across multiple infrastructure or service providers. For example, if different mobile carriers were to win contracts in different regions within a jurisdiction, roaming arrangements would likely need to be put in place to allow PSAs to move between networks. This would give rise to technological and commercial complexities that need to be resolved, and could potentially affect the quality of service delivered to PSAs (chapter 5). There would also be complexities for governments in managing the tender process, especially where a carrier is unwilling to enable roaming. Insistence on common technical standards across carriers and roaming agreements as part of the tender process could help to address some of the challenges.

Third, in some cases, a single bidder might be able to deliver services across multiple regions, or deliver related services, at a lower total cost than a mix of separate bidders (due to economies of scale or scope). In these situations, awarding contracts for separate regions or services to separate companies could be inefficient. In determining the size and scope of

contracts, governments will need to weigh these costs against the potential benefits that could be obtained from a more competitive procurement process (IC 1996).

In some cases, it may be possible to improve contestability without necessarily incurring high coordination costs or forgoing economies of scale. For example, allowing joint bids from consortia of suppliers (or allowing some tasks to subcontracted out) can allow for competition where there are few individual suppliers that could credibly provide the service over a large scale (IC 1996), or where it would be more costly for governments to take on the task of coordinating the activities of separate suppliers.

Allowing suppliers to choose whether to bid for a single geographic region or multiple regions can also create competitive tension. Even where a single company could supply all regions at lowest cost — and ultimately wins the contracts for all regions — the presence of competition in individual regions can put competitive discipline on the bids submitted. This kind of approach has been proposed as part of procurement for a PSMB capability in the United States (box 7.11). It would be preferable to restricting the number of regions a single supplier can bid for, as that may effectively forgo any economies of scale that result from using a single provider.

However, in some regions there may only be a single bidder — with a potentially inflated (above-cost) bid — or no bidder at all. This 'monopoly' problem is likely to arise in any tendering process where a single supplier is dominant in parts of the market, and is hard to avoid completely.

Even though splitting tenders up geographically cannot improve competition in regions with a single potential bidder (such as rural and remote areas), it does allow these regions to be treated separately from regions where there is greater competition. Where there is a risk that a supplier that is dominant in one region might use this dominance to 'cross subsidise' its bids in other areas (thereby allowing it to artificially reduce its bid price for those areas below that of its competitors), governments could consider requiring suppliers to bid for regions with limited competition separately. This separation of contestable from non-contestable elements would allow for greater transparency in bids and is generally considered part of good-practice procurement (IC 1996).

In many cases, it is likely to be more straightforward to split tenders by service type than by geographic region, especially where PSMB is to be delivered over a commercial mobile network. Nevertheless, it would be prudent for all jurisdictions — before entering into contracts — to thoroughly investigate the state of the market and the feasibility of splitting tenders geographically, where this has the potential to improve value for money over the long term.

Negotiating collectively can exert countervailing power

Further options are also available where a potential supplier (or suppliers) possesses market power. Governments can exercise countervailing power by acting as a single entity

in procurement. In the case of PSMB, this could involve a jurisdiction-wide agency taking responsibility for procuring a single jurisdiction-wide capability (section 7.1).

Having a single government body across the negotiating table (as opposed to dealing with multiple PSAs separately) would mean that private-sector bidders have to deliver on the project requirements at a reasonable cost or risk not getting the business. In principle, governments could add further discipline by using the threat of withdrawing future government work. This centralised approach might also ward off a situation where a large commercial partner attempts to play off multiple government agencies against each other. It could also allow for greater economies of scale in equipment purchasing and reduce scope for duplication across PSAs (section 7.1).

Some jurisdictions already procure communications inputs for their agencies on a centralised basis, including Victoria and Queensland (box 7.2). The NSW Government (2015) is in the process of centralising procurement of communications equipment and services for all its agencies, which it anticipates will reduce duplication and result in greater contestability (and hence value for money), while allowing agencies to focus more on their core business.

However, there are limits to what centralised procurement can achieve. The size of a PSMB contract is likely to be small relative to a commercial mobile carrier's total revenues, meaning that the potential loss of business may not be seen as a significant business risk (although this may depend on the jurisdiction and could be influenced by competitive dynamics in the market). And, as discussed below, centralised procurement may achieve little if governments do not have a credible outside option.

Infrastructure and spectrum holdings can give governments leverage

State and territory governments (and PSAs) already own substantial assets that could be used as inputs to a PSMB capability. This includes LMR sites and associated infrastructure (such as towers, power supplies and backhaul), in addition to apparatus licences to use spectrum (typically in the 400 MHz band). Jurisdictions may also have further spectrum at their disposal if they choose to purchase it for a PSMB capability.

Jurisdictions' bargaining power in commercial negotiations will depend, to a large degree, on the extent of their outside options. Ownership of infrastructure and spectrum gives a jurisdiction an option to bypass a potential supplier and build a dedicated PSMB capability itself (for example, by constructing a mobile network in a specific area, while retaining the option to use mobile carriers to expand the network further). This can give the jurisdiction additional leverage in negotiations. It could also potentially reduce the cost of a contract, for example, where reuse of existing government assets reduces the need for new investment or where the ability to share spectrum with a supplier induces lower bids (that take into account the value of this spectrum sharing).

However, the additional bargaining power could be limited by several factors. It could be constrained where jurisdictions opt to maintain a separate LMR capability in some areas, limiting the amount of infrastructure and/or spectrum that can be reused for PSMB. Bargaining power would also depend on whether a jurisdiction has purchased access to spectrum in an LTE-compliant band (section 7.3). And, not least, building a dedicated PSMB capability without mobile carrier involvement would only be a credible alternative if governments can do it at reasonable cost.

Jurisdictions therefore will need to carefully consider how best to leverage their existing infrastructure and spectrum holdings during commercial negotiations.

Open standards and short contracts can reduce the risk of 'lock in'

A challenge in any public procurement process is minimising the risk of being 'locked in' to a particular supplier. This can occur where a contract specifies delivery of infrastructure or equipment that is highly customised and which another supplier may be unable to supply (for example, because it is proprietary technology protected by intellectual property law, or because other suppliers are unable to replicate it at reasonable cost). Once this technology has been put in place (and the investment is 'sunk'), the supplier may have scope to behave opportunistically, such as by raising prices or refusing to supply newer technologies. Governments may face high costs or other impediments (such as legal action) in attempting to switch to an alternative provider.

Being locked in to a single supplier could also give that supplier an advantage over its competitors in future contract negotiations, to the extent that the initial investments reduce its costs of supplying the service in the future. This would reduce the ability for governments to secure competitive tendering outcomes over time (that is, in future procurement).

The risks of being locked in to a non-standardised solution offered by a single supplier were emphasised by many study participants (ACMA, sub. 14; Alcatel-Lucent, sub. 15; CDMPS et al., sub. 7; Coutts Communications, sub. 20; NSW Telco Authority, sub. 30; Telstra, sub. 19; VHA, sub. 11; Victorian Government, sub. 28). While this risk can arise under any PSMB delivery option (chapter 6), there are ways to reduce it.

Lock-in problems can sometimes be avoided through the careful crafting of contract clauses. But not all future contingencies can be foreseen at the time of contract negotiation, or even reflected in contracts. For example, if a new and unexpected mobile broadband technology or application was to emerge and PSAs wished to use it as part of a PSMB capability, they might only be able to do this on the prices and terms set by the company that provides the capability. Moreover, being locked in to using one particular supplier's technology could reduce a government's ability to switch to a lower-cost supplier in the future (or raise the cost of switching). There is also a risk that the proprietary technology becomes out-dated over time because it is incompatible with newer technologies or the supplier discontinues it.

Several strategies are available to governments to reduce the risk of being locked in to a single supplier. One is to use short contracts to allow for more frequent renegotiation or tendering, and thereby improve contestability. This can allow for more competition in the tender process and give governments more flexibility to respond to unanticipated contingencies (IC 1996) — such as some of the complexities that might arise once mission critical voice services can be delivered over LTE networks (chapter 5). Some participants explicitly favoured avoiding long-term contracts in the delivery of PSMB (for example, NSW Telco Authority, sub. 30).

However, tendering is a costly process, and the administrative and transaction costs can quickly add up when it is done repeatedly. Shorter contracts would also mean that the cost of capital investments made by the commercial partner would need to be amortised over a shorter period — thus raising the amount that governments and/or PSAs would need to pay each year. This could increase the risk for the commercial partner (inducing them to submit higher bids, or no bid at all) or mean that investments are written off before the end of their economic life (which may not be efficient).

Where large capital investments are required, a different strategy may be needed. In constructing a dedicated PSMB network, governments could use franchise contracts, whereby the network is constructed and managed by a commercial partner but the assets (such as equipment, spectrum and intellectual property) remain under government ownership. A related approach is the 'build, own, operate and transfer' model, where ownership of the assets reverts to the government after a specified period (which can also discourage suppliers from using government funds to pay for infrastructure they would have built anyway in the absence of a contract). Either approach would increase governments' ability to switch to an alternative company in the future (NSW Telco Authority, sub. 30).

Where solutions involving mobile carrier networks are pursued (and require hardening or other investments in those networks), governments can align the length of contracts with the economic life of assets as a way to avoid being locked in to a provider for longer than necessary. Using multiple providers for services and/or equipment can also reduce potential for lock in (NSW Telco Authority, sub. 30), as can the use of mobile sites that are shared by multiple carriers rather than those used exclusively by a single carrier.

Under any deployment approach, insisting on technology that complies with open international standards (such as the 3GPP standards for LTE) can improve governments' ability to switch suppliers in the future. This is a key strategy slated for use in New South Wales, where the government intends to move away from bespoke solutions for PSA communications (NSW Government 2015). Although imposing requirements for open standards would be unlikely to increase the number of potential bidders for an initial contract, it can help to achieve procurement that is more competitive over the long term. A general principle is to keep any customisation of infrastructure or equipment to a minimum, including by insisting on open standards and by using existing infrastructure to the greatest extent possible.

National interoperability protocols may assist in this process (section 7.2). Once these protocols are set, they would send a strong signal to potential suppliers about the minimum requirements that would need to be met through PSMB to provide the network, device and application interoperability that jurisdictions require.

RECOMMENDATION 7.4

Governments and PSAs that decide to deploy a PSMB capability should maximise value for money in procurement by using competitive procurement processes. In doing so, they should adopt strategies to increase the number of potential bidders and reduce the risk of becoming locked in to a single supplier.

Strategies include:

- benchmarking bids against other cost data and making tender processes transparent
- splitting up tenders by service and/or region
- governments negotiating on behalf of their PSAs
- leveraging infrastructure and spectrum holdings in negotiations
- using short-term contracts that require adherence to open international standards.

Efficient risk allocation can minimise costs

All contracts allocate risk. This can be explicit or implicit. In some cases, the true 'owner' of a risk may not be known until something goes wrong (or the contract is disputed in the courts).

In allocating risks, governments need to consider who can manage those risks at least cost. Good practice is usually to allocate a risk to the party that is better placed to reduce the underlying risk, or can do so at lower cost. Where neither party can feasibly reduce the risk, it should be allocated to the party that is better able to absorb the risk (either by purchasing insurance or by bearing the consequences when the risk is realised) (PC 2014a, 2014b).

Where governments allocate a risk to a commercial partner, this will be factored into the price that potential suppliers are willing to bid for a contract (even where markets are fully competitive). This can be an efficient outcome. Where governments instead retain a risk themselves, there will also be a cost — in terms of mitigating that risk or bearing the consequences if it is realised. Ultimately, governments will face some kind of liability associated with all risks a project is exposed to.

The question, then, is who each risk should be allocated to. Efficient risk allocation — allocating risks to the party that can manage these risks at least cost — can minimise the long-term costs of delivering a project. Doing this transparently (including by sharing

information on risks as part of the tender process) can also make it easier for each party to assess their risk exposure and thus facilitate greater interest in bidding for a tender (PC 2014b).

However, in making decisions about risk allocation, governments need to think through the impacts on private parties' willingness to bid for or enter into a contract. They also need to take into account risks that cannot easily or credibly be transferred to a commercial partner, and so must inevitably be borne by governments. This includes the risk that service delivery breaks down or the private sector is deterred from entering contracts with the government in the future (PC 2014b).

Commercial partners are better placed to manage supply-side risks

The commercial partner in a PSMB contract would be better placed than governments or PSAs to reduce some risks or to bear those risks if they are realised. These include risks associated with supplying products or services. For example, a commercial mobile carrier would generally be better placed to manage risks to equipment costs, construction times or technology changes. While the carrier may not be able to reduce other risks (such as earthquake risk), neither may governments, and allocating these risks to the carrier could strengthen its incentives to minimise the consequences of these events on PSA communications (provided that standard 'force majeure' provisions do not apply in such contracts (Access Economics 2010; TCCA 2013b)).

Governments can allocate supply-side risks to a commercial partner by expressing project requirements in terms of outcomes rather than inputs. By specifying the outcomes that governments are seeking (such as quality of service over a mobile network), a tender or contract can strengthen the commercial partner's incentive to meet these outcomes at least cost (since payment depends on achieving the outcomes). This would also give the supplier flexibility to change its mix of inputs in response to unexpected changes in costs, demand or technology (Harper et al. 2015; IC 1996).

For example, a mobile carrier delivering PSMB over its own network (a commercial approach) could achieve an agreed overall network reliability level through installing power supply backup at all its base station sites, hardening these sites, or increasing redundancy in cell overlaps and backhaul connections (chapter 5). Or the carrier could meet a given capacity requirement by installing more base stations, changing how it uses the spectrum it holds, or deploying transportable cells for large planned events. The best mix of these inputs will depend on many specific factors that the carrier is better placed to understand (and adapt to) than governments — such as the location of each site, relative costs and the network resources used to meet the demand from other customers.

Further, specifying contracts in terms of outcomes can give the commercial partner an incentive to manage supply-side risks that are not easily identifiable at the time a contract is signed or that are not well understood by governments. Outcomes-based contracts can thus help governments to avoid ending up in a situation where the commercial partner

complies with the specific clauses built into a contract (such as the reliability of specific network components) but does not deliver on a broader but unspecified objective that governments may have (such as overall reliability).

In addition, making contracts 'technology neutral' can help governments avoid being overtaken by rapid advances in technology, especially when procurement is protracted or long-term contracts are signed (CDMPS et al., sub. 7). Together with requiring adherence to open international standards, outcomes-focused and technology-neutral contracts can help governments to avoid project delays and/or being locked in to a high-cost solution.

Governments are better placed to manage demand-side risks

Some risks are better borne by governments or PSAs. These include the risk that PSAs' capacity requirements end up higher or lower than was originally envisioned when a contract was signed, or that quality of service needs change. These contingencies will need to be accounted for in contracts, as failing to do so would limit the ability to alter the PSMB capability if PSAs' needs change.

This is often done through pricing arrangements: clauses that specify who will bear the cost of changing the capacity or quality of service. Making governments or PSAs bear this cost would encourage them to trade off the value of service alterations against the cost. By contrast, if the commercial partner had to bear the cost, it would factor this risk into the amount it bids for the initial contract (or might even withdraw from bidding if its exposure to future costs is highly uncertain).

Governments and PSAs are better at managing these demand-side risks. They have the flexibility to decide if and when they need to expand a PSMB capability. By bearing the cost of doing so, they would be encouraged to manage their demands on the network in other ways, based on an assessment of relative costs and benefits. For example, where PSAs have to pay for capacity expansions, they have an incentive to delay some non-urgent traffic or prioritise certain users or applications over others (section 7.1).

7.6 A phased approach to implementation

The Commission has found that a commercial approach is the most cost-effective way to deliver a PSMB capability in Australia (chapter 6). However, some aspects of a commercial approach are yet to be demonstrated on a wide scale, including the ability to deliver priority network access to PSAs without dedicated spectrum. More work needs to be done by the Australian, state and territory governments (and their PSAs) to investigate the feasibility of a commercial approach and to better formulate the business case for PSMB by assessing the benefits and costs in greater depth.

Pilots can help to resolve uncertainties and build confidence

There would be merit in jurisdictions and their PSAs undertaking small-scale pilots to further investigate the feasibility of a commercial PSMB capability and to formulate the business case for PSMB. These pilots could build on trials that have occurred to date and should be focused on the most uncertain or contentious aspects of a commercial approach to delivering PSMB (such as the level of priority network access that commercial carriers can deliver). Pilots that cover real-world circumstances, including large-scale operations in inner-city areas — where networks are more likely to be congested — will be important for building the confidence of PSAs in the effectiveness of a commercial PSMB capability.

Pilots would allow jurisdictions and PSAs to:

- test the commercial mobile carrier market
- better understand and benchmark costs
- systematically evaluate how PSAs use the PSMB capability and the benefits this generates
- more thoroughly investigate the technical capability and/or commercial willingness of mobile carriers to provide PSMB services.

Importantly, pilots would not need to be conducted by every jurisdiction. Since all jurisdictions will benefit from the lessons learnt, one jurisdiction could undertake a pilot and share the outcomes with others. There is scope to conduct and evaluate pilots within the next 12 months, drawing on the principles set out in box 7.13. Indeed, the continuation of LMR voice networks in all jurisdictions until at least 2020 (chapter 2) provides a relatively low-risk environment for experimentation with PSMB data technologies.

Box 7.13 Design principles for PSMB pilots

- Pilots focus on the most uncertain or contentious aspects of a commercial PSMB capability (such as the level of priority network access that carriers can deliver).
- Pilots are small in scale but cover a range of operational and other conditions, such as congested mobile networks.
- Governments use competitive tendering to select commercial partners for pilots.
- Pilots are funded by governments (Australian, state or territory), though commercial partners are not precluded from covering some costs themselves.
- Jurisdictions consider working collaboratively to design and fund pilots in selected jurisdictions, to avoid duplicating work done by others.
- Pilots are professionally and independently evaluated, with the outcomes shared with other jurisdictions and published (excluding any commercial-in-confidence material).

A trial-based approach was explicitly supported by some study participants (for example, CDMPS, sub. DR42; Victorian Government, sub. 28). Moreover, some PSAs have already embarked on trials, including Queensland Police and Ambulance Victoria (chapters 1 and 5), although some study participants expressed concern that the results of some trials have not been made public (for example, NSW Telco Authority, sub. 30; Victorian Government, sub. DR44). The Australian Federal Police (pers. comm., 2 December 2015) expects to undertake some technology-based tests of LTE-enabled communications during 2016, which will involve a commercial network and are designed to provide practical insights into prioritisation and push-to-talk applications. The NSW Telco Authority (sub. 30) submitted that it would undertake a PSMB trial in September 2015, though the outcomes of any such trial have not been made public.

The outcomes of pilots can inform what steps jurisdictions take next. If the pilots are successful, jurisdictions could then begin to deploy or expand a permanent PSMB capability, subject to a suitable business case being developed.

However, if a pilot is deemed unsuccessful, jurisdictions will need to consider alternative courses of action. The first step should be to clearly identify the problem (or cause of failure) and investigate potential solutions. Where a feasible solution emerges it could be tested by way of a further pilot. Only if the problem is intractable — or the costs of addressing it exceed the costs of alternative deployment approaches — should jurisdictions consider proceeding with piloting or rolling out a hybrid or dedicated PSMB capability. However, this will be contingent on whether the problem can be addressed by way of dedicated spectrum, and should be based on an assessment of whether the benefits justify the higher overall costs (including additional infrastructure and equipment).

Undertaking pilots of a commercial approach to PSMB would not lock jurisdictions into rolling out a commercial PSMB approach more widely. Nor would it preclude governments from purchasing access to spectrum or further exploring a hybrid or dedicated PSMB capability (including by way of pilots). However, a successful pilot of a commercial PSMB capability would weaken the case for purchasing spectrum or constructing a dedicated network. Investing in a dedicated PSMB network *in anticipation* of commercial mobile carriers failing to deliver the requisite services — and without testing this by way of pilots — would represent a highly risk-averse and costly strategy.

Flexibility is paramount

Regardless of the deployment approach ultimately adopted, a flexible approach to rolling out PSMB would be beneficial. Remaining flexible to unexpected developments (such as in technology, demand or market structure) can be of considerable value in the face of uncertainty. It can also help governments and PSAs to implement a PSMB capability that meets their needs at least cost, in part by helping them to avoid making large and irreversible investments before they need to.

A phased approach to PSMB implementation would allow jurisdictions and PSAs to remain flexible, and was explicitly supported by several study participants (for example, ATF, sub. 4; Ericsson, sub. 10). Phasing would provide scope to collect information and resolve uncertainties over time, which can make it easier for PSAs to benefit from more sophisticated (or lower-cost) technology solutions as they emerge.

Phasing would also allow PSAs time to adapt their operations and procedures as PSMB is rolled out and would give them flexibility in the timing. Such an approach was supported by the Government of South Australia (sub. 29, p. 2), which submitted that 'agencies should be able [to] take up the PSMB at a pace that meets their needs and as appropriate technology, services and funding becomes available'.

Moreover, a phased approach would give PSAs time to better articulate their requirements for PSMB and to fine tune these over time. While the Commission used a range of capacity levels in its illustrative evaluation of PSMB delivery options (chapter 4), none of these are necessarily the best starting or end point for any jurisdiction. In practice, more work needs to be done to determine PSAs' network capacity and quality of service requirements, as well as to rigorously evaluate how PSMB affects public safety outcomes as it is rolled out.

In formulating implementation strategies, jurisdictions will also need to make decisions about whether and where to maintain LMR coverage, and about when their PSAs may be able to move voice communications onto a PSMB capability. Some jurisdictions might choose to progressively roll out a PSMB capability as their existing LMR networks come up for renewal (chapter 5). This could reduce the long-term costs of maintaining communications capabilities, to the extent that it reduces duplication and allows existing infrastructure to be repurposed (NSW Telco Authority, sub. 30; Victorian Government, subs. 28, DR44).

These decisions do not necessarily need to be made immediately, and some can be postponed to a future date. However, jurisdictions may need to start planning for future developments in voice technologies now, and should seek to maximise the flexibility to incorporate voice services onto PSMB in the future. Further pilots may be desirable as these technologies begin to emerge.

More generally, there is scope for jurisdictions to monitor and learn from ongoing experiences with PSMB (including technology and commercial offerings) in other countries. This includes trials that are already underway in the United States to test various aspects of LTE technology and applications, and to evaluate how mobile broadband can be incorporated into PSAs' operations (appendix B).

RECOMMENDATION 7.5

Governments and PSAs that decide to deploy a PSMB capability should take a phased approach to implementation by first undertaking pilots of a commercial PSMB capability on a small scale. Pilots would provide an opportunity to:

- demonstrate the technical and commercial feasibility of a commercial approach
- evaluate the costs, benefits and risks of PSMB
- develop protocols and procedures for information and capacity sharing by PSAs
- develop the business case and resolve uncertainties ahead of a wider-scale rollout.

Individual pilots could be funded by one or more jurisdictions working collaboratively, with the outcomes shared among them. Commercial partners in pilots should be selected through competitive tendering. The outcomes of pilots should be professionally and independently evaluated, and published.

A Public consultation

The Commission has actively encouraged public participation in this study.

- Following receipt of the terms of reference on 25 March 2015, an advertisement was placed in newspapers in Australia and a circular was sent to identified interested parties.
- An issues paper was released on 20 April 2015 to assist those wishing to make a written submission. Following the release of the issues paper, 31 submissions were received.
- A draft report was released on 23 September 2015 and 15 submissions were subsequently received: a total of 46 submissions were received throughout the study (table A.1).
- As detailed in table A.2, consultations were held with a wide range of stakeholders, both in Australia and overseas.
- Technical workshops were conducted in Sydney and Melbourne to test the proposed approach towards the quantitative analysis. A total of 32 organisations participated (table A.3).

In addition, the Commission received confidential information from a range of participants.

The Commission thanks all parties who have contributed to this study.

Table A.1 **Submissions**[a]

Participant	*Submission number(s)*
ACT Emergency Services Agency	25
Alcatel-Lucent	15
Australasian TETRA Forum (ATF)	4 #
Australian Communications and Media Authority (ACMA)	14, DR35
Australian Mobile Telecommunications Association (AMTA)	21, DR39
Australian Radio Communications Industry Association (ARCIA)	2
BAI	1
Centre for Disaster Management and Public Safety (CDMPS)	DR42
CDMPS, APCO Australasia and Victorian Spatial Council	7
Commonwealth Scientific and Industrial Research Organisation (CSIRO)	16
Council of Ambulance Authorities (CAA)	DR36
Coutts Communications	20
Department of Communications	23
Emerg Solutions	13
Ericsson	10, 26
Government of South Australia	29
HVHF Sciences LLC	DR34
Local Government Association of Queensland (LGAQ)	DR32
Metropolitan Fire Brigade (MFB) (Victoria)	6
Motorola	12, 31, DR43 #
NEC	5
NSW Telco Authority	30, DR46
Optus	18, DR37
Police Federation of Australia (PFA)	8, DR40
Push2Talk	24, DR33
RF Technology	3
Rivada Networks	9, 27, DR38
Selex-ES	22
Telstra	19, DR41
Victoria Police	17
Victorian Government	28, DR44 #
Vodafone Hutchison Australia (VHA)	11
Western Australian Government	DR45

a A hash (#) indicates that the submission includes attachments.

Table A.2 **Visits**

Participant

Brisbane

Dr Chris Flemming
Department of the Premier and Cabinet
Department of Science, Technology and Innovation
Queensland Ambulance Service
Queensland Fire and Emergency Services
Queensland Public Safety Business Agency
Queensland Police Service
Queensland Government Chief Information Office
Queensland Rural Fire Service
Royal Flying Doctor Service

Canberra

ACT Emergency Services Agency
Attorney-General's Department
Australian Competition and Consumer Commission
Australian Federal Police
Australian Maritime Safety Authority
Australian Mobile Telecommunications Association
Department of Communications
Department of Defence
Office of the Hon Malcolm Turnbull (Minister of Communications)
Office of the Hon Michael Keenan (Minister for Justice)
Police Federation of Australia

Hobart

Department of Premier and Cabinet (Tasmania) (teleconference)

Melbourne

Australasian Fire and Emergency Service Authorities Council (teleconference)
Australian Communications and Media Authority
Australian Radio Communications Industry Association
Centre for Disaster Management and Public Safety (University of Melbourne)
Council of Ambulance Authorities
Country Fire Authority
Department of Economic Development, Jobs, Transport and Resources (Victoria)
Department of Justice
Department of Premier and Cabinet (Victoria)
Department of State Development
Department of Treasury and Finance (Victoria)
Emergency Management Victoria
Ericsson
Metropolitan Fire Brigade (Victoria)

(continued next page)

Table A.2 (continued)

Participant
Melbourne (continued)
Motorola
Optus
Paul Harris (Consultant)
Telstra
Trinitas Pty Ltd (teleconference)
UXC Consulting*
Victoria Police
Victoria State Emergency Service
Perth
Department of Commerce (Western Australia) (videoconference)
Department of Fire and Emergency Services (videoconference)
Department of Parks and Wildlife (Western Australia) (videoconference)
Department of the Premier and Cabinet (Western Australia) (videoconference)
Western Australia Police (videoconference)
Sydney
Australian Council of State Emergency Services
Australasian TETRA Forum (ATF)
Centre for International Economics
Dr Peter Abelson (teleconference)
Fire and Rescue NSW
NBN Co Limited
Nokia
NSW Police Force
NSW Telco Authority
Robert James (iMediate Consulting)
Tetra + Critical Communications Association
Vodafone Hutchison Australia
International
ASTRID (Belgium) (teleconference)
Canadian Association of Chiefs of Police (Canada)
Communications Chambers (United Kingdom) (teleconference)
Dr Nick Fookes (United Kingdom) (teleconference)
Dr Robert Kenny (United Kingdom) (teleconference)
First Responder Network Authority (First Net) (United States) (teleconference)
New Zealand Police (teleconference)
Tero Pesonen (Finland)
Rivada Networks (Ireland and United States)
United Kingdom Home Office

* UXC Consulting was engaged to provide expertise on specific technical issues related to communications infrastructure and technology.

Table A.3 **Technical Workshops**

Participant
Melbourne
Alcatel-Lucent
Australian Radio Communications Industry Association
Centre for Disaster Management and Public Safety
Department of Premier and Cabinet (Victoria)
Ericsson
Government of Western Australia
Motorola
Nokia
Robert James (iMediate Consulting)
SA Health
South Australia Police
South Australian Country Fire Service
Tasmania Police
Sydney
ACT Emergency Services Agency
ACT Government
ACT Police
Attorney-General's Department
Australian Communications and Media Authority
Australian Mobile Telecommunications Association
Centre for International Economics
Council of Ambulance Authorities
Department of Communications
Dr Alex Robson
Dr Chris Flemming
Northern Territory Government
NSW Government
NSW Telco Authority
NSW Police Force
Optus
Queensland Ambulance Service
Queensland Government
Queensland Police Service
Telstra
Vodafone Hutchison Australia

B Domestic and international developments in PSMB

This appendix contains summary information on:

- previous reviews of public safety mobile broadband (PSMB) and policy background in Australia (section B.1)
- work underway in key multilateral forums and institutions to harmonise spectrum for delivery of a PSMB capability across international regions, and to develop technical standards for Long Term Evolution (LTE) technology (section B.2)
- summaries of the approach to PSMB in other countries (section B.3).

B.1 Previous Australian reviews and policy background

The need for interoperable public safety agency (PSA) communications has long been on the national agenda. In 2009, COAG endorsed the *National Framework to Improve Government Radiocommunications Interoperability 2010–2020* (COAG 2009). This set guiding principles for aligning narrowband communications systems across the states and territories, including by setting standards for interoperability and moving towards harmonised radio technologies and spectrum use. One of these principles was for jurisdictions to assess common requirements for high speed mobile data interoperability as well as emerging technologies that support increased interoperability. A mid-term review of the framework was planned for 2015.

Around 2010, work commenced to identify the need for PSMB and ways to deliver it. Much of this work has focused on the allocation of radiofrequency spectrum. Access to specific frequencies of spectrum is required to wirelessly transmit and receive information, and is a key input to any radio network. Spectrum policy and licensing is the responsibility of the Australian Communications and Media Authority (ACMA).

In 2010, the Australian Government Attorney-General's Department engaged the consultancy Gibson Quai — AAS (now called UXC Consulting) to analyse the benefits and costs of providing PSMB under five specific approaches (GQ-AAS 2010). These included establishing a dedicated network (using dedicated spectrum), using commercially provided services, and combinations of both. This work involved building up a detailed picture of PSA requirements (in consultation with PSAs across Australia) and using an engineering model of mobile networks to estimate the costs associated with each approach

(excluding the costs of spectrum). It was completed in November 2011. The findings, including demand and cost estimates, were not made public.

The Attorney-General's Department also commissioned a brief report on PSMB spectrum by Access Economics (2010). This drew on the outputs of the study by Gibson Quai — AAS to assess the relative merits of dedicated approaches (including the allocation of spectrum in the 700 megahertz (MHz) band or other spectrum), commercial approaches and a hybrid approach (using a dedicated PSA network but allowing for commercial arrangements). It found that a commercial approach was likely to have the lowest cost, and that organisational difficulties (such as reaching contractual agreements, managing market power and enforcing contract terms) would have to be very large to make other options preferable.

In May 2011, the Australian Government established a Public Safety Mobile Broadband Steering Committee (PSMBSC), comprising senior officials representing government agencies, PSA peak bodies and the COAG Standing Council for Police and Emergency Management (Attorney-General's Department 2011). The Committee was tasked with reporting on the most effective and efficient way for Australia's PSAs to obtain a reliable and robust mobile broadband capability that met their operational requirements. It was also required to work with ACMA to identify a suitable amount of spectrum to meet foreseeable operational needs.

The PSMBSC produced a National Implementation Plan in October 2012, and an Overflow Capabilities Sub Group Final Report in October 2013 (Victorian Government, sub. 28). Neither document was made public. The PSMBSC continued until April 2013, at which point COAG transferred responsibility for PSMB to a group of senior officials (COAG 2013). These officials were tasked with providing advice on establishing an appropriate PSMB capability, in consultation with the COAG Standing Council on Police and Emergency Management. This was to include advice on governance frameworks and the reservation of spectrum.

In November 2014, the Australian Government announced its intention to ask the Productivity Commission to undertake a 'first principles' analysis of the most efficient and effective way of delivering a PSMB capability by 2020 (Turnbull and Keenan 2014), with terms of reference provided to the Commission at the end of March 2015.

Parliamentary inquiries have favoured allocating spectrum for PSMB

Policy deliberations have also been informed by two parliamentary inquiries. In November 2011, the Senate Environment and Communications References Committee released an inquiry report on the capacity of communications networks and emergency warning systems during natural disasters. It recommended that the Australian Government 'allocate sufficient spectrum for dedicated broadband public protection and disaster relief (PPDR) radiocommunications in Australia', and that this be provided on the basis of interoperability among PSAs (ECRC 2011, p. vii).

A second parliamentary report was released in September 2013 following an inquiry into spectrum for PSMB conducted by the Parliamentary Joint Committee on Law Enforcement (PJCLE 2013). It found that mobile broadband technology is a significant enabler for improved public safety outcomes, which are in line with community expectations. It also favoured minimising PSAs' reliance on commercial operators for mobile broadband, given the limited resilience and security of commercial networks. The inquiry recommended that 20 MHz of spectrum in the 700 MHz band be allocated for the purposes of a PSMB network, and that proceeds from auctioning other spectrum in that band be used to finance the cost of PSMB spectrum.

Public safety needs are being reflected in spectrum policy

In October 2012, ACMA made an in-principle decision to set aside 10 MHz of spectrum within the 800 MHz band to support the deployment of a PSMB capability. At the time, the Australian Government announced that this spectrum would be subject to a 50 per cent 'public interest' discount for PSAs. ACMA also announced that 50 MHz of spectrum in the 4.9 gigahertz (GHz) band would be set aside for exclusive use by PSAs. This was formally licensed in June 2013 (ACMA, sub. 14).

In July 2012, the Premiers of New South Wales, Victoria, Queensland and Western Australia wrote to the Prime Minister to request that 20 MHz of spectrum be allocated for a national PSMB capability, and that part of the proceeds from the auctioning of spectrum in the 700 MHz band be used to construct the PSMB capability (O'Farrell et al. 2012).

In February 2013, all states and the ACT made a joint submission to the Standing Council on Police and Emergency Management and ACMA (ACT Government et al. 2013). In this submission, jurisdictions expressed concern that 10 MHz of spectrum in the 800 MHz band would not be adequate to meet their operational needs using PSMB. In particular, they noted that it would increase the cost of network construction and operation (relative to using 20 MHz of spectrum) and increase operational risks facing PSAs in 'mission critical' operations.

More broadly, the Department of Communications (2015b) has recently completed a review into Australia's spectrum policy and management framework. Its proposals included:

- replacing the current legislative framework with outcomes-focused legislation that facilitates timely spectrum allocations and greater flexibility of use (including through sharing and trading spectrum)
- requiring public sector agencies to report on their spectrum holdings and allowing them to lease, sell or share spectrum for their own benefit
- reviewing spectrum pricing arrangements to support efficient use and facilitate secondary markets.

In September 2015, ACMA released its updated five-year outlook for spectrum, noting that any decision on allocating spectrum to PSAs would be reserved pending the Australian Government's response to this report and clarification of government policy regarding PSMB (ACMA 2015b).

State natural disaster inquiry findings on communications

Inquiries into major natural disasters in some states have emphasised the need for a nationally interoperable PSMB capability. Following the Black Saturday bushfires in Victoria in 2009, a Royal Commission found that PSA communications systems were hindered by poor coverage, a lack of interoperability between agencies and insufficient investment in new technologies (VBRC 2010). It drew attention to the use of incompatible radio systems between metropolitan and regional police, and to congestion in PSA radio channels.

The Commission of Inquiry into the 2011 Queensland floods found that interoperability was limited across different parts of the radio network used by Queensland Police at the time, and between PSAs (QFCI 2012). It also found evidence of congestion and 'black spots' on radio networks used by PSAs. The Commission of Inquiry supported the establishment of a statewide digital radio network, and regarded the allocation of broadband spectrum to Australia's emergency service organisations as vital for avoiding congestion on narrowband networks and for achieving interoperability.

B.2 International spectrum harmonisation and technical standards

Spectrum harmonisation has multiple benefits

There are several reasons for international spectrum harmonisation. Radiowaves do not stop at national borders, so harmonisation minimises interference along borders, and also facilitates international roaming. Safety benefits arise, for example, where aircraft and airport communications can be internationally standardised. Harmonising spectrum across countries for specific technologies or applications also means that devices can be produced on a larger scale at a lower unit cost.

The International Telecommunications Union is the lead international forum

The International Telecommunication Union's (ITU) radiocommunications sector is the United Nations' specialised agency for information and communication technologies. Broadly, the ITU radiocommunications sector (ITU-R) is responsible for the development and maintenance of the international *Radio Regulations*, a treaty-level set of documents

which establish an international spectrum management framework. Australia is a member state of the ITU and conforms to its legal treaties (ACMA, sub. 14).

The ITU-R hosts the World Radiocommunications Conference every 3-4 years to revise the *Radio Regulations*, which include the agreed uses of particular spectrum bands. For spectrum allocation purposes, the *Radio Regulations* divide the world into three regions that loosely comprise — Region 1 of Europe/Africa; Region 2 of the Americas; and Region 3 of Asia and the Pacific (ACMA, sub. 14).

The ITU is working towards harmonising spectrum for PSMB

One of the objectives of the ITU-R is to encourage the harmonisation of spectrum used for particular purposes across countries. To this end, the World Radiocommunications Conference has previously made resolutions about the frequency bands to be used for PPDR in each of the three regions around the world. These suggested bands are not binding on members, as spectrum is often allocated for many years at a time, and governments therefore may not be free to allocate a certain spectrum band to public safety.

In Australia's region (Region 3, Asia-Pacific), the identified spectrum for PPDR as far back as 2003 has been mainly in the 400 MHz and the 800 MHz bands (box B.1). At the 2015 World Radiocommunications Conference, rather than harmonising spectrum by region only, a single frequency range was internationally harmonised for PPDR communications (694-894 MHz), leaving each country free to choose spectrum within that range for its own public safety operations. This spectrum covers several 3rd Generation Partnership Project (3GPP) bands that are harmonised for off the shelf user devices (ACMA 2015c).

The Asia–Pacific Telecommunity (APT) is the coordinating body for Region 3. The APT Wireless Group has responsibility for various aspects of emerging wireless systems in the Asia-Pacific region, such as promoting harmonisation and facilitating the uptake of new technologies. There are benefits to Australia from spectrum harmonisation:

> The benefits to Australians of the resultant economies of scale are not trivial. For example, the international harmonisation of the 'APT 700 MHz band' – a band used in Australia for 4G [fourth generation] services and fast becoming one of the key 4G bands worldwide – has greatly improved the opportunities for economies of scale for network and user equipment operating in that band. (ACMA, sub. 14, p. 4)

Standardising spectrum for public safety can facilitate greater interoperability between PSA officers from different countries, which may be required for emergencies that cross national borders or where PSA officers are sent to assist with an emergency in another country. This is in addition to the benefit of lower hardware costs due to larger-scale production of user devices and equipment.

Box B.1 PPDR spectrum harmonisation in the ITU

Public safety agencies (PSAs) have many reasons for using their own communications channels, and have done so historically. Thus, following the development of broadband communications technology and prior to any decisions being made about allocating spectrum for PSA broadband, the International Telecommunication Union recognised the opportunity for international harmonisation of spectrum for PSAs. The International Telecommunication Union nominated the benefits of harmonised frequencies as:

- economies of scale and lower costs for implementing specialised systems for public protection and disaster relief (PPDR)
- interoperability of systems on a regional and worldwide basis
- facilitation of local, regional, and world planning and coordination activities in spectrum use.

In 2003, a resolution urged governments to consider particular frequency bands for PPDR in each region. In Europe and Africa, certain bands around 400 MHz were considered; in the Americas, frequencies were suggested in the 700 MHz band, 800 MHz band and the 4.9 GHz band; and in Asia and the Pacific, suggested bands included 400 MHz, 800 MHz and 4.9 GHz. One of the Asia-Pacific bands has been internationally harmonised for commercial use (806-824 MHz uplink and 851-869 MHz downlink, also known as 'band 27').

At the 2015 World Radio Conference, it was further decided that an internationally harmonised frequency range for PPDR would best meet public safety needs while retaining flexibility for implementation in each jurisdiction (694-894 MHz). The other frequencies previously indicated as harmonised for PPDR in the Asia-Pacific Region remain in the agreement.

Sources: World Radiocommunication Conference (2015a, 2015b).

Many countries are still in the planning stages for allocating spectrum to PSMB — thus, a lot of attention is being given to early movers, who could influence the manufacture of PSA communications equipment. The United States allocated spectrum in the 700 MHz band for public safety use in 2012, and Canada subsequently announced that it would allocate spectrum in the same band. In region 3 (Asia and the Pacific) South Korea has announced plans to allocate spectrum in the 700 MHz band (despite the ITU recommending that countries in this region use spectrum in the 800 MHz band). This 700 MHz band is not aligned to the North American 700 MHz band, meaning devices designed for the United States will not be able to be used in South Korea (or Australia) without further modification. This is because the uplink frequencies of the 'band 14' spectrum being used for PSMB in the US conflict with the downlink frequencies of spectrum harmonised for 4G in the Asia Pacific plan (Telstra, sub. DR41).

There is a broad consensus that LTE will be used for PSMB

Various organisations — from both the telecommunication and public safety sector — have endorsed the use of LTE for PSMB. For example, the 3GPP (2013) has noted that:

> With NPSTC [National Public Safety Telecommunications Counsel, United States], TCCA [TETRA and Critical Communications Association, Europe], ETSI Technical Committee [The

> European Telecommunications Standards Institute] TETRA [Terrestrial Trunked Radio] and other organizations backing LTE there is now a clear global consensus that LTE will be the baseline technology for next generation broadband public safety networks.

The Association of Public-Safety Communications Officials (Australasia) has also endorsed LTE (APCOA 2011).

LTE has various enhancements compared to previous mobile technologies

The ITU-R released a report detailing the advantages of LTE for PPDR broadband compared to previous generation mobile technologies (ITU 2014). These include:

- better coverage and capacity, and more reliable services
- simplified, IP (internet protocol)-based architecture
- low latency and low packet loss, which are important for real time applications
- greater interoperability due to commercially standardised protocols and interfaces
- better security features and capabilities
- quality of service and prioritisation (enhancements are expected in 3GPP release 14)
- that they can be flexibly deployed with a wide range of channel sizes/carrier bandwidths.

3GPP plays the lead role in LTE standards development

Each generation of mobile telecommunications technology is defined by the technical standards that apply to it — these set out how hardware and software should be configured in order to be compatible with other technology and meet technical, safety and legal parameters. Various national and regional organisations debate and create standards, including for public-safety related communications. However, given the need for harmonisation, collaboration occurs on an international level between national and regional standards bodies, including 3GPP and others (box B.2). This is true of the technical standards being developed to support the delivery of mobile wireless technologies, including LTE.

Current 3GPP standards in development

In 2014, the 3GPP created a specialist working group responsible for the definition, evolution and maintenance of technical specifications supporting PSA mission critical communications (2015d). Mission critical voice over LTE is expected in Release 13 (which is expected to be frozen, with no further modifications or additions to functionality, in March 2016) (Wendelken 2014). Release 14 will include further work on mission critical video over LTE and mission critical data (3GPP 2015b) (chapter 5).

Although LTE is the current standard for mobile broadband communications, the next generation of communications is already being considered. Details of what 5G technology will offer will become available once the relevant 3GPP standards begin to take shape (ACMA, sub. 14).

Box B.2 3rd Generation Partnership Project (3GPP)

3GPP unites six telecommunications standard development organisations[a] to produce reports and specifications that define 3GPP technologies — for example to ensure that technology is compatible with previous and future user equipment. 3GPP has done significant work on the technical standards and technologies for Long Term Evolution (LTE), including technical work to produce enhancements to the LTE standard to support public safety applications.

Release 8 (frozen[b] in 2008) marked the beginning of LTE standards, introducing a new radio interface and core network, and enabling higher data speeds and lower latency. Features included a flat radio network architecture and an all Internet Protocol core network.

Release 9 (2009) introduced a number of refinements and new features including self-organising networks, location services and a more efficient way to deliver the same multimedia content to multiple destinations.

Release 10 (2011) provided a substantial uplift to the capacity and throughput of the LTE system and also took steps to improve the system performance for mobile devices located at some distance from a base station. It also included carrier aggregation, allowing the combination of up to five separate spectrum bands to enable higher bandwidths.

Release 11 (2013) included provisions for device-to-device communications, enhancements to carrier aggregation and the introduction of new frequency bands.

Release 12 (2015) was the first to include major work on the use of LTE for critical communications, with public safety features such as direct mode communications and system enablers for group call and mission critical push-to-talk.

In addition to the 3GPP, there are other umbrella standards organisations that seek to promote international harmonisation. For example, the Global Standards Collaboration created a Task Force on Emergency Communications that, in July 2014, presented a draft report collating the standards relevant to public safety across key nations.

[a] They are: the Association of Radio Industries and Businesses, Japan; The Alliance for Telecommunications Industry Solutions, United States; China Communications Standards Association; The European Telecommunications Standards Institute; Telecommunications Standards Development Society, India; Telecommunications Technology Association, Korea; Telecommunication Technology Committee, Japan.

[b] Frozen means no further modifications or additions to functionality: only essential corrections can be made following freezing.

Sources: 3GPP (2015c), ACMA (sub. 14), Brydon (2012), GSC (2014).

B.3 Approach to PSMB in other countries

A diverse range of approaches is being considered to deliver PSMB internationally. While some countries have made significant progress in planning for a PSMB capability, there is currently no network in place which provides PSAs with a 'public safety grade' mobile broadband capability. While some countries are planning to construct dedicated mobile broadband networks for their PSAs, all are expected to make significant use of existing commercial infrastructure and expertise.

United States

The US Government is planning to build and operate a nationwide LTE network exclusively for PSAs. A government authority (FirstNet) was established in 2012 to manage the delivery and operation of the network. Federal funding (US$7 billion) and dedicated spectrum (20 MHz in the 700 MHz band) have been set aside for this project.

Policy context

The original US Government plan to deliver a PSMB capability involved using commercial service providers (Telstra, sub. 19). To facilitate this, the Federal Communications Commission auctioned 10 MHz of spectrum in the 700 MHz band (known as the 'D block') with requirements that it be made available to PPDR users under certain circumstances (but could be used by a commercial provider at other times).

However, commercial mobile providers did not purchase this spectrum, and subsequently the US Government decided to allocate it for a public safety network (combined with 10 MHz of spectrum already licensed to public safety), and created FirstNet. There were two key motivations for the establishment of FirstNet. The first was that a lack of interoperability had hampered the overall effectiveness of public safety operations during various emergency incidents — including the terrorist attacks in September 2001 and Hurricane Katrina in 2005 (USGAO 2015). The second was concerns that commercial mobile networks were not satisfactory for public safety needs (FirstNet 2015c).

FirstNet is responsible for ensuring the network provides a single interoperable platform for public safety communications, and is delivered cost-effectively, including through leveraging existing infrastructure and assets (Essid 2012; FirstNet 2015c).

A recent report identified challenges with the implementation of the project — including the approach to procurement, conflicts of interest, slower than expected progress in some areas, and concerns that the US$7 billion in federal funding would be insufficient to facilitate the deployment and maintenance of the network (USGAO 2015). This report also noted that estimates of the costs of constructing and operating the FirstNet network range from US$12-47 billion over the first 10 years.

Governance and institutional arrangements

Provision of a PSMB capability in the United States has been centralised at the national level. FirstNet has its own Board of Directors which includes representatives from the Federal Government (Attorney-General, Secretary of Homeland Security, Director of the Office of Management and Budget), PSAs, local, state and federal government, and the wireless industry (FirstNet 2015c).

FirstNet is expected to become a self-sustaining business model. While FirstNet's business plan is still taking shape, it is envisaged that revenues will come from user fees and agreements with contractors that will leverage the value of any excess network capacity (FirstNet 2015c). FirstNet has also approved five 'early builder' arrangements to lease spectrum and provide technical support for the roll-out of PSMB in particular areas, for example in Harris County, Texas (box B.3). Under these arrangements, each 'early builder' will report back on a set of key learning initiatives, providing information that can be used during the national deployment process (FirstNet 2014).

Box B.3 'Early builder' arrangements: Harris County, Texas

FirstNet negotiated an 'early builder' spectrum licensing arrangement with the State of Texas in August 2014. Key learning opportunities specified for the Texas (Harris County) PSMB roll-out included:

- operational training
- operations during special events (when commercial networks sometimes reach capacity limits)
- analytics on user and network usage
- evaluating extended Long Term Evolution (LTE) coverage for rural areas.

In May 2015 it was reported that LTE in-vehicle-routers were being installed in patrol cars, providing police officers in the field with network capabilities similar to those available back at the station or office. Benefits included increased efficiency, remote management of resources and greater situational awareness.

Source: FirstNet (2015).

Cooperation and consultation between different levels of government is evident in the approach. The law that established FirstNet requires it to consult with federal, state, tribal and local public safety entities to ensure that the network is designed to meet each state's needs. To streamline these efforts, a single point of contact was established by the Governor in each state. FirstNet began these consultations in 2013 and they are ongoing (FirstNet 2015d).

Individual states will have a choice to 'opt in' or 'opt out' of the project — but either way they must deliver a PSMB capability that meets minimum technical standards, and is interoperable with FirstNet's network. Once FirstNet has completed its 'Request for Proposal' process for building, operating and maintaining the network, a state has 90 days

to agree to allow FirstNet to construct a radio access network in that state, or notify its intention to deploy its own — then the Federal Communications Commission will either approve or disapprove a state plan (FirstNet 2015d).

Network design features

FirstNet is seeking comprehensive network and service solutions covering all US states, territories, and tribal nations. At the network level, this includes:

- the deployment and provisioning of a nationwide core network
- all radio access network components for 'opt-in' states
- backhaul, aggregation and national transport networks, and data centres
- deployable capabilities.

FirstNet's network planning and design is an ongoing process. In April 2015, FirstNet released a draft Request for Proposal which outlined its current thinking on coverage objectives, minimum technical requirements and performance standards (FirstNet 2015a).

- Coverage — minimum coverage objectives for each state have been established following consultation. Coverage is defined as a minimum of 768 Kbps downlink and 256 Kbps uplink (at the cell edge with 50 per cent loading). Coverage requirements must meet or exceed an 'average downlink throughput per square mile' data rate — differentiated depending on the population density and other characteristics of different geographic regions.
- Minimum technical requirements — the Federal Communications Commission (2012) approved minimum technical standards for achieving nationwide interoperability for PSMB which FirstNet is required to abide by. These include complying with 3GPP, and open, non-proprietary standards.
- Performance standards — including annual end-to-end user service availability of 99.9 per cent, priority and pre-emption mechanisms which can be managed statically and dynamically by public safety users, and integration of radio access networks of states that 'opt out'.

Some of the objectives outlined by FirstNet are intended to be broad enough to allow potential contractors to find innovative ways to meet or exceed these standards (FirstNet 2015f). In designing its network, FirstNet is also required to seek out opportunities to leverage existing telecommunications infrastructure and assets. This includes exploring public/private partnerships that can help support and accelerate the creation of the network.

The ability to provide PSAs with 'local control' is currently being considered in the context of the FirstNet rollout in the United States. Local control refers to the ability of PSAs to dynamically configure communication priorities to adapt to changing needs, for

example, when responding to an incident. This requires both technical solutions and organisational procedures to be developed and agreed upon (NPSTC 2015b).

From a service application perspective, FirstNet's initial focus is to support mobile data services, with mission critical voice communications expected to be integrated in the coming years (USGAO 2015). In the meantime, US states are expected to continue to invest in their land mobile radio (LMR) networks, although these are eventually expected to interoperate with the FirstNet network (FirstNet 2015c).

Supporting analysis

Some publicly available studies were undertaken prior to the creation of FirstNet. The Federal Communications Commission undertook work in this area in 2010. A technical analysis found that a dedicated network with access to 10 MHz of spectrum in the 700 MHz band would provide more than the required capacity for day-to-day public safety communications, and for a range of emergency scenarios it considered (FCC 2010b). While this network would not cater for the largest emergencies, it was found that access to another 10 MHz of spectrum would still be insufficient in these cases. Accordingly, priority access and roaming on commercial networks was noted as critical to providing adequate capacity in extreme situations, and more cost-effective.

A broadband network cost model developed by the Federal Communications Commission (2010a) indicated that PSAs could leverage the deployment of 4G commercial wireless networks to greatly reduce the overall costs of constructing their nationwide broadband network. Specifically, it found that an approach which leverages off existing commercial infrastructure could save more than US$25 billion (US$9.2 billion in construction and US$15-20 billion in operation and maintenance) over the first ten years.

In the lead up to the allocation of the 'D block' spectrum for public safety, a study by Ford and Spiwak (2011) considered whether additional 'D block' spectrum should be assigned to public safety or auctioned. It found that assignment to public safety would provide at least US$3.4 billion more in social benefits than it if were auctioned. This study did not attempt to quantify the costs of developing a dedicated PSMB network, or the benefits of public safety use of spectrum, noting that:

> Perhaps the most daunting, yet relevant, question regards the social benefits of 'public safety.' *Such benefits are real but difficult to quantify* and, absent immediate crisis, prone to be undervalued. … For the moment, we choose to set aside the quantification of the benefits of an additional 10 MHz of spectrum for public safety, looking instead at the cost side of equation. (2011, p. 10)(emphasis added)

Current status

FirstNet approved the Request for Proposal in December 2015 (FirstNet 2015b). Trials are currently being conducted to test the readiness of public safety grade LTE technology for

use in the field through the 'early builder' agreements (box B.3). Other trials are also being run, for example, a temporary network was deployed for the 2015 Alpine World Ski Championships using cells on wheels in difficult to reach locations. This network trial demonstrated several key applications, including:

- live-streaming video cameras providing situational awareness to the command centre
- a push-to-talk group communications program running on ruggedized handsets
- a situational awareness application for resource tracking
- web browsing and general internet connectivity (Bratcher 2015).

United Kingdom

The UK Government is currently in the process of procuring a new Emergency Services Network (ESN) to fully replace its current narrowband network for PSAs by 2020. The ESN will mean that PSA voice and broadband data services are delivered over a single network. This project involves contracting with commercial networks to deliver the radio access component of a PSMB capability, without the allocation of dedicated spectrum for PSA use, but with priority access.

Policy context

Since the early 2000s, a single communications network has provided mission critical voice and narrowband data services to PSAs across the United Kingdom. This network, which is based on Terrestrial Trunked Radio (TETRA) digital technology, covers around 97 per cent of the UK landmass and provides some underground and air-to-ground coverage (PA Consulting Group 2013). It is operated by Airwave, a private-sector company, under contracts that begin to expire in September 2016 and will be fully expired by 2020 (UK Home Office 2015b).

The Airwave network does not have sufficient capacity to support many data applications, and PSAs have expressed concerns about the quality of service offered over commercial mobile networks (Analysys Mason 2012; PA Consulting Group 2013). Although PSAs have made increasing use of commercial mobile broadband in the United Kingdom, most do not rely on it for mission critical functions (Cole and Hawker 2014).

Since 2012, the UK Government has sought to move to a single integrated network to provide mobile voice and broadband data services to PSAs. This network is intended to replace the existing Airwave network over the period 2017–2020, and ultimately provide mobile broadband data services to an estimated 250 000 operational staff across over 400 national and local government agencies (UK Home Office 2014).

Cost is widely seen as a major motivation for moving towards an integrated mobile broadband solution by 2020 — contracts with Airwave for the network and related services

total around £400 million per year (SCF Associates 2014). The UK Government announced that it expected the ESN to save around £1 billion over the next 15 years (UK Home Office 2015b). (Savings are now estimated at around £3 billion for that period (UK Home Office, pers. comm., 5 December 2015).)

Governance and institutional arrangements

The provision of a PSMB capability has been centralised at the national level. The UK Home Office (through its Emergency Services Mobile Communications Programme) formally commenced a tender process in April 2014, in which procurement was initially divided into four contracts or 'lots':

- lot 1 — delivery partner (program management, including procurement of end-user devices and the transition of PSA users on to the new network)
- lot 2 — user services (provision of end-to-end systems integration, management of user accounts and provision of user services)
- lot 3 — mobile services (provision of a national mobile network by a network operator to the resilience and other standards required by PSAs)
- lot 4 — extension services (extension of mobile network infrastructure beyond the lot 3 area) (UK Home Office 2014, 2015a).

The extension services tender (lot 4) was cancelled early in the process (Clemons 2015). A new project called Extended Area Services was established to replace lot 4 and will see the network of the lot 3 provider extended to 97 per cent geographic coverage, matching the existing LMR network. To limit the incentive to include more cells than needed to extend service coverage to PSAs, ownership of new tower builds will revert to the government at the end of the contract. Transportable cells may be used in events such as floods where permanent cells are damaged (UK Home Office, pers. comm., 5 December 2015).

The UK Home Office (2014) estimated the value of all contracts (excluding extension services) at £380 million to £870 million, of which mobile services were estimated at £200-£530 million. Each contract is anticipated to have a duration of 5 to 6 years. After this, the mobile and user services contracts are to be re-tendered (Shipley 2015).

The main procurement process is being supplemented by other initiatives.

- A separate contract is expected to be signed with the winning bidder for mobile services, covering 'business critical' mobile services provided on a wholesale basis (at agreed prices) (SCF Associates 2014).
- Procurement processes are underway for the provision of user devices, vehicle installations, an 'air to ground' network, and upgrades to control rooms (UK Home Office 2015a).

Network and service features

Service features to be provided by the mobile services contract (lot 3) will meet or exceed service levels currently provided on the LMR network, to provide 'an enhanced mobile communications service with highly available full coverage' (UK Home Office 2014). A report by SCF Associates (2014) points to requirements that include the same or greater resilience as the Airwave network (with 5 to 7 days of power supply backup at key sites), the provision of public safety features for data and voice (such as group call, push-to-talk and direct-mode communications), and priority of emergency services users over commercial customers on the network. To meet these, some modification or 'hardening' of commercial networks is anticipated. Other official sources state that the new network would need to provide public-safety functions and end-to-end security (Shipley 2015), and a high level of 4G coverage (98 per cent by population on an in-building basis, and 90 per cent geographic coverage) (UK Home Office 2015a).

PSA users will have prioritised network access and capacity without the need for dedicated spectrum. This will be achieved using standard LTE features, however, as these features are not yet widely deployed, the ESN will use pre-standards with an upgrade to open standards as they are adopted by 3GPP. There will be extensive testing and trials before any PSA transitions to the ESN. Once PSA users have priority over other traffic, it is anticipated that network capacity will be sufficient for all PSAs and further prioritisation will not be required (UK Home Office, pers. comm., 5 December 2015).

In addition, interfaces with the Airwave network are to be implemented at the control-room level to support the gradual transition of PSA users onto the mobile broadband network (SCF Associates 2014).

Supporting analysis

A strategic business case for the ESN was prepared by the UK Home Office, and approved in 2012 (WYFRA 2013). User requirements were planned to be finalised by the end of 2013 (Shipley 2013). However, neither document has been made public.

The four options examined were:

- continuation of the Airwave network with the addition of advanced data capabilities
- building a new TETRA (narrowband) network
- building a new LTE network to public safety specifications (using dedicated spectrum)
- forming contracts with commercial LTE network owners to deliver services to PSAs under specific service-level agreements (Clemons 2015).

Sources indicate that the commercially procured service was estimated to deliver the best value for money (SCF Associates 2014) — with a cost in the order of £3.7 billion, around

£1 billion less than the first two TETRA-based options, and at least £3 billion less than building a new LTE network (Clemons 2015).

Current status and next steps

The first contract was awarded to Kellogg Brown & Root Limited in August 2015, with Motorola (Lot 2) and EE (Lot 3) the preferred bidders for the remaining contracts (UK Home Office 2015a), however lot 3 is currently suspended due to a legal challenge (Williams 2015). The winning bidder of lot 1 will be responsible for managing the rigorous testing and trials program (Wendelken 2015).

Canada

The Canadian Government has set aside 20 MHz of spectrum in the 700 MHz band for the development of a public safety broadband network. Interoperability across the border with the United States has been a key consideration, and this is the same spectrum band as reserved for public safety in the United States. The expectation is that provinces and territories will be able to choose whether to construct a dedicated mobile broadband network using this spectrum, or to procure services from commercial carriers.

Policy context

The Canadian Government has been consulting with stakeholders on the potential allocation of spectrum for PSMB since at least 2011. In that year, emergency management ministers from the provinces and territories recommended to Industry Canada (the spectrum regulator) that 20 MHz of spectrum in the 700 MHz band be set aside for public safety (Public Safety Canada 2012).

In 2012, an announcement was made to set aside 10 MHz in the 700 MHz band for public safety, with further consultation to be undertaken on adding another 10 MHz (Public Safety Canada 2012). The need for interoperability across the United States border (along which much of Canada's population resides) was prominent in consultations (Industry Canada 2012).

The allocation of the additional 10 MHz was announced as part of the 2015 Canadian Government budget, bringing the total allocation for public safety to 20 MHz (Government of Canada 2015). The Government also announced that it would provide C$3 million over two years from 2016-17 to take initial steps to establish a Public Safety Broadband Network (Government of Canada 2015).

Governance and institutional arrangements

While governance arrangements are yet to be finalised, there are indications that the provinces and territories will have primary responsibility for funding and providing PSMB.

A national nonprofit entity is to be established to develop national standards for interoperability and enter into roaming agreements with commercial networks and FirstNet in the United States (Public Safety Canada 2012, 2013). It will also hold the licence for the spectrum and be responsible for constructing, maintaining and operating a core network that would allow for linking networks in each province and territory.

The spectrum would be sub-licensed to a 'regional service delivery entity' in each province and territory (Public Safety Canada 2012, 2013). These entities would then deploy a mobile broadband capability, using either the dedicated spectrum, commercial mobile services, or a combination of the two. In doing so, they would be required to adhere to national standards for interoperability across provinces and with the United States. They would also be required to fund their networks by establishing cost recovery models for services provided to users.

A separate process is underway between Canada and the United States to harmonise their prospective public safety broadband networks and to establish protocols to minimise interference in border areas (NPSTC and CITIG 2015).

Network and service features

Few network design features have been agreed on to date. An exercise conducted in 2013 to identify network architecture requirements (in consultation with PSAs, government officials and other stakeholders) indicated that the network(s) would be based on LTE technology. It also set out expectations of a high level of security and resilience (including no single points of failure and hardening of network equipment), as well as the prioritisation of public safety traffic during periods of network congestion (CSS 2013).

It is likely that each province or territory will have its own core network, and these will be linked to a national core network to facilitate communications across jurisdictions (CSS 2013; Fournier 2015). This is to be supported by roaming agreements that allow users to access their information when on another network, as well as arrangements to allow federal PSAs to access the networks in each province or territory (CSS 2013).

The network architecture exercise envisioned that roaming agreements would be established with commercial carriers to improve geographic coverage, and that deployable broadband communications infrastructure would be used to respond to incidents in isolated areas where it is not feasible to provide permanent radio coverage (CSS 2013). These systems will likely use satellite backhaul or operate on a standalone basis (that is, not directly connected to wider networks).

In addition, there are likely to be gateways between PSMB networks and existing LMR networks used to provide mission critical voice services (CSS 2013). These narrowband networks are expected to continue for the foreseeable future.

Supporting analysis

In 2011, the Centre for Security Science (part of Defence Research and Development Canada) conducted a technical assessment of the 700 MHz spectrum requirements for mobile broadband data communications (CSS 2011). In consultation with PSAs and other stakeholders, it developed several incident scenarios to assess data throughput and application requirements. The analysis found that PSAs would need access to more than 20 MHz of spectrum to conduct missions during commonly occurring major emergency situations.

Current status and next steps

Consultation on the policy, technical and licensing framework for the public safety spectrum is ongoing (Industry Canada 2012). The financing, structure and governance of the Canadian network are yet to be finalised, and the spectrum has not yet been licensed or priced (Solomon 2015). Work still needs to be done to develop standards and address network sharing, dynamic prioritisation, spectrum coordination and cross-border interoperability (Fournier 2015).

A permanent network is not expected to be in place for another three to five years, however, several initiatives are underway across Canada to construct test networks (using LTE technology in the public safety spectrum band) (Solomon 2015). For example, Industry Canada is testing a network in the 700 MHz band in Ottawa, which involves evaluating and testing equipment, software and applications. Work is also underway to establish a national capability for testing deployable mobile cells, which are intended to be used in remote areas or when conventional networks are damaged (Fournier 2015).

South Korea

In July 2014, the South Korean Government announced plans for SafeNet, a PSMB network using LTE technology, to be deployed by 2017. It was subsequently announced that 20 MHz in the 700 MHz band had been allocated for this purpose (LTE-Applications 2014).

Policy context

On 16 April 2014, the Sewol ferry capsized off the South Korean coast, killing 304 people, most of whom were high school students. According to the National Task Force for Korea Public Safety Broadband Network, the event ‘brought attention to the urgent need for

establishing a nationwide public-safety broadband network for sharing information and communicating among public-safety agencies' (Zilis 2014).

Rescue and response efforts were hindered by a lack of communications interoperability between responding agencies. At the time, PSAs each operated separate voice networks on a variety of frequency bands, using a variety of technologies that were not interoperable with each other (Zilis 2014).

Network design features

SafeNet will be a dedicated network for approximately 200 000 users from 324 agencies including police, fire, Coast Guard, military, provincial administrative offices, electricity, gas and forest services. The network is intended to provide full geographical coverage for day-to-day as well as mission critical usage. Although the network will support both voice and data services, it is envisaged that legacy networks will be retained as backup (Kim nd).

Governance and institutional arrangements

To date, planning for SafeNet has largely been overseen by the Ministry of Security and Public Administration. Additionally, the Ministry of Science, Information and Communication Technology, and Future Planning has made recommendations in relation to the choice of technology, frequency band and procurement method. It is envisaged that a new agency, the Ministry of National Security, will soon be established and charged with national security matters, including the network (Zilis 2014).

Although SafeNet is a dedicated network, it will leverage existing commercial infrastructure, including commercial backhaul and base station infrastructure. It is estimated that the network will cost US$912 million to construct, including a US$43 million pilot (Cho 2015).

Current status and next steps

The network is to be rolled out in phases. In the first phase, the network will be piloted in selected areas in the Gangwon Province, including Pyeongchang, where the 2018 Winter Olympics will be held. Rollout of the network will focus on rural areas first, which, unlike urban areas, currently do not have a unified network. In the second phase, the network will be extended to cover other provinces, and phase three will cover metropolitan cities. It is envisaged that the third phase will be completed in 2017 (Kim nd).

SK Telecom (Korea's largest commercial mobile carrier) claims to be the best candidate for the network roll-out, having done much of the work for the pilot project and citing experience that includes developing an LTE-based railroad wireless communication network and an LTE project for the Air Force (Shin 2015).

New Zealand

PSAs in New Zealand — and police in particular — have started using mobile applications, tablets and smartphones on a wide scale. However, services are delivered over commercial carrier networks, rather than a dedicated public safety network.

Policy context

Mobile broadband has already been taken up by PSAs in New Zealand, although LMR voice systems remain in extensive use. In 2013, New Zealand Police signed a contract with Vodafone for mobile broadband services as part of its Policing Excellence program. The 10-year contract includes the provision of smartphones and tablets in addition to mobile broadband services. The total cost of the rollout was estimated at NZ$159 million (Key 2013).

As of December 2014, around 14 000 mobile devices had been deployed to police across New Zealand. In addition, a Mobility Innovation Lab and Experience Centre has been established to develop and test new mobile broadband applications and technologies to support policing operations (Woodhouse 2014).

In 2014, the St John Ambulance service started rolling out an 'electronic patient report form' project. This involved equipping officers with mobile tablets so that paper forms can be replaced with electronic records, and installing Mobile Data Terminals in ambulances to allow officers to communicate their status during a response and their availability to accept jobs (Paredes 2014a). The project will allow ambulances to collect and share more 'vital sign' information with hospitals while patients are in transit.

Network and service features

No information is publicly available regarding mobile broadband service features on the commercial network currently used by New Zealand Police, such as additional coverage, priority or network reliability.

The New Zealand Government has announced the Next Generation Whole of Government Radio Network program, with the aim of replacing existing government radio networks with a PSMB network. This will include:

- hardening of commercial networks
- priority access for PSA traffic
- service quality standards (New Zealand Government 2015).

This communications upgrade will also provide interoperability (which is limited under current LMR networks) and will include an extension of cellular coverage from 44 per cent geographic coverage to an estimated 88 per cent (New Zealand Government 2015).

Supporting analysis

A review of the Policing Excellence program found that mobile broadband has allowed police officers to use mobile devices to access email and maps, take photos, share documents and make phone calls. This includes:

- accessing police-specific applications and databases (relating to people, vehicles and locations) from the field
- accessing real-time information on police operations through a Mobile Responder application
- making calls to a dedicated number to dictate information about an incident (which is then transcribed and stored in a database) (New Zealand Police 2014; Paredes 2014b).

These applications have been credited with improving decision making, access to information, officer safety and situational awareness, while reducing time spent on paperwork and data entry. In the 12 months to June 2014, mobile broadband allowed police officers to make an estimated 2.9 million database queries, gain an additional 30 minutes per officer per shift (totalling 520 000 hours per year), and reduce demands on voice radio networks (New Zealand Police 2014). The productivity benefits over the life of the 10-year contract with Vodafone have been estimated at NZ$305 million (Vodafone 2013).

Current status and next steps

Trials of the Next Generation Whole of Government Radio Network are expected to take place in 2018, with agencies transitioning from LMR networks to the new PSMB network from 2019. Police and fire analog radio networks in rural areas will reach end-of-life at the end of 2019, with other components of current LMR networks being decommissioned at later stages. All government and PSA communication services will be provided by a commercial service partner or partners by 2023 (New Zealand Government 2015).

Belgium

Since 2014, a 3G mobile broadband service — Blue Light Mobile — has been available to PSAs across Belgium.

Blue Light Mobile provides PSAs with access to Belgium's three commercial carriers, as well as select carriers from adjacent countries in border areas. To achieve multiple carrier access, ASTRID acts as a mobile virtual network operator and enters into international roaming agreements with the relevant commercial carriers. PSAs then access the Blue Light Network by using an internationally registered Subscriber Identity Module (SIM) card, affording them international roaming status (and access to all carriers) inside Belgium.

Blue Light Mobile is not considered a mission critical service, as there is no guaranteed access for PSAs during periods of congestion, nor an ability to seamlessly roam across networks. However, Blue Light Mobile offers an enhanced quality of service relative to commercial best efforts, with PSAs receiving priority once they have accessed the network, increased reliability due to coverage overlap between carriers, as well as some enhanced security options.

Policy context

Since 1998, ASTRID has supplied the Belgian police, fire and ambulance services with national radio communications, and paging and dispatch services. The ASTRID radio network operates on the TETRA standard in the 380-400 MHz frequency band (which is exclusively reserved for emergency and security services across Europe). The network achieves complete in-vehicle geographical coverage of Belgium (ASTRID 2011b).

In 2012, ASTRID initiated a study into how an efficient mobile broadband data network could be established across Belgium. This study was driven in part out of concern that PSAs were seeking individual PSMB solutions from different commercial cellular operators, fragmenting systems and applications across PSAs. The study concluded that a commercial solution was the most viable option as:

- spectrum harmonised for PPDR across the European Union is not yet available
- immediate budgetary constraints ruled out a fully dedicated solution (TETRA Applications 2012).

Use of commercial networks is seen as a temporary solution. It achieves some short term goals (such as providing a common PSMB capability to all PSAs) while simultaneously acting as a form of 'pilot' upon which the business case for a fully dedicated PSMB network can be based.

Governance and institutional arrangements

The Blue Light Mobile network is operated by ASTRID, a company established under Belgian public law that is jointly owned by the federal government and Belgian towns and provinces (ASTRID 2011c). Under the law, ASTRID is required to establish, run, maintain and implement a radio communications network for voice and data transmissions for Belgian emergency and security services, amongst others.

Network design features

Roaming is enabled via an internationally registered ASTRID SIM card, as ASTRID has negotiated international roaming agreements with the relevant commercial providers on 3G networks. The SIM cards have a 'preferred' or default network, and will switch to other commercial network whenever coverage is lost (ASTRID 2011a; TETRA Today 2014).

Each organisation using the Blue Light network can individually choose the preferred network to which their devices will connect (ASTRID 2014b). However, the Commission understands that roaming between networks is not seamless, with handover from one network to another requiring disconnection, searching, reconnection and authentication with the new network, a process that can take up to two minutes.

Network reliability is enhanced through the use of multiple carriers providing coverage overlap, although no hardening of the commercial networks (such as increased battery back-up or civil works) has been undertaken. The TETRA network (which covers 100 per cent of Belgium's landmass) is used as a back-up in the event that all commercial 3G networks are saturated or defective. Switching to TETRA is not automatic and requires manual input from the user (ASTRID 2014b).

While not a mission critical service, there are network elements which provide for a quality of service beyond a commercial 'best efforts' basis. Once access to the network is achieved, PSA users receive a measure of priority through a 'guaranteed minimum bitrate', and commercial customers are allocated any residual capacity. This minimum bitrate is set in advance (that is, it cannot be varied in real-time) and is only available on the user's designated primary network (ASTRID 2014b). Further, security is enhanced through the use of a Virtual Private Network between a common ASTRID database and the PSAs. For applications and data stored outside of ASTRID's common database, security features (such as encryption) are the responsibility of each agency (ASTRID 2014a).

Supporting analysis

The Commission is not aware of any studies evaluating the costs and/or benefits of a PSMB capability in Belgium. However, data and experience gathered from Blue Light Mobile will form the basis of a business case for any future dedicated PSMB network.

Current status and next steps

Blue Light Mobile is fully operational, with police, fire and ambulance all using the service. Police have proved to be the heaviest users. In the short term, PSAs are seeking additional functionality to increase reliability, such as guaranteed access. In the long term, Blue Light Mobile is a temporary solution on the path to a fully dedicated national PSMB network.

Finland

Finland is deploying a hybrid PSMB network following a staged, incremental approach. Starting with a non-mission critical commercial network, a targeted dedicated network is expected to be built once spectrum becomes available. The current TETRA network will run in tandem with the deployment of PSMB until it reaches end-of-life around 2030.

Network design features

Currently, a non-mission critical PSMB capability is provided through the commercial carriers, with critical voice and data messages continuing to be sent via LMR (narrowband) networks (Pesonen 2015).

The hybrid will initially consist of a dedicated 'mini-core' network which houses sensitive PSA data, with LTE radio access continuing to be provided through commercial networks. In part, the need to house PSA sensitive subscriber data separately from the commercial core is due to concerns of future commercial core 'virtualisation' — where key core network functions could be located outside of Finland (Pesonen 2015).

Once spectrum has been allocated for PPDR, it is expected that the LTE core will be upgraded to a 'full core' to support the dedicated component of a hybrid PSMB. The dedicated component is expected to target high population areas, along with 'high-risk' areas (for example, some major highways). Commercial LTE networks will continue to be used in areas outside the dedicated footprint (Pesonen 2015).

Only when broadband service availability and reliability meets PSA mission critical requirements will LMR networks be dismantled, and this, too, will be a staged process beginning in rural areas when the narrowband network spare parts stock runs out (ATF, sub 4; Airbus Group 2015).

Policy context

The five-step plan to implement a PSMB capability for PSAs is being led by VIRVE, the operator of Finland's LMR network. The transition pathway will begin in the next 5-10 years and will deliver a government-controlled hybrid solution (of dedicated and commercial LTE networks) when the current TETRA network reaches the end of its life around 2030 (Vinkvist, Pesonen and Peltola 2014).

Supporting Analysis

A study considering the availability of public safety networks and the associated costs and benefits of improving availability in different conditions was conducted. It found that the most effective means to improve availability to mission critical levels would be to duplicate transmission links, backup the power supply and monitor mobile traffic in real time. With these improvements, it was estimated that service availability could be increased from 99.1 per cent to 99.9 per cent. The benefits of this improvement outweigh the costs only in highly populated areas. In part, this has been used as justification for a hybrid network with a targeted dedicated component in major population centres (Peltola and Hammainen 2015).

C Quantitative methodology and results

C.1 About this appendix

This appendix documents the quantitative analysis undertaken by the Commission as part of assessing indicative costs of delivering a public safety mobile broadband (PSMB) capability via different delivery options.

The quantitative approach discussed in this appendix is limited to assessing the relative cost effectiveness of different options for delivering a PSMB capability and identifying the key drivers of cost differentials between options. That is, it aims to develop cost estimates for different delivery options for the purpose of 'screening', rather than setting out a detailed business case for a PSMB capability per se.

In particular, the quantitative analysis does not provide insights into the benefits or risks of a PSMB capability or the extent to which these benefits or risks vary between delivery options. Moreover, the institutional and regulatory arrangements required to deliver a PSMB capability via any of the options are outside the scope of the quantitative analysis. (These issues are discussed qualitatively in chapter 7.)

The Commission's quantitative approach was discussed at two workshops, one in Melbourne on 23 June 2015 and the other in Sydney on 25 June 2015. Participants included representatives from public safety agencies (PSAs), academia, commercial mobile carriers, equipment providers, telecommunications industry experts and government officials. The Commission also conducted one-on-one meetings with selected participants to validate some of the technical inputs.

In accordance with the *Productivity Commission Act 1998* (Cwlth), the Commission appointed Network Strategies as a referee for the purpose of reporting on the quantitative analysis. This report is included in appendix D. The computer files to run the quantitative analysis are also publicly available on the Commission's website. The structure of this appendix is as follows.

- The core framework is discussed in sections C.2–C.5.
- The parameters for the analysis and their calibration are discussed in section C.6.
- The results are discussed in section C.7.
- The results from alternative option designs are reported in section C.8.
- Sensitivity analysis is discussed in section C.9.
- Costs that are excluded from the quantitative analysis are set out in C.10.

C.2 Overview of the quantitative framework

The objective of the quantitative analysis is to identify indicative cost differences between different options for delivering a PSMB capability. The choice of framework and methodology has been driven by its suitability for this purpose.

In particular, the fit-for-purpose framework and methodology is designed to:

- be capable of constructing representative mobile networks for different options in a manner that yields broadly comparable outputs
- have sufficient descriptive power, so as to allow different options to be characterised differentially within the framework
- calculate the incremental costs of a specified network in such a way that preserves relative cost magnitudes between options
- identify key drivers of cost differences, particularly those arising from differences in:
  - the geographic footprint of the dedicated portion of the network
  - the number of mobile carriers involved
  - arrangements relating to PSA traffic overflow
- allow key assumptions and parameter values to be varied
- cover a time horizon sufficient to capture network rollout, upgrades and technology replacement cycles.

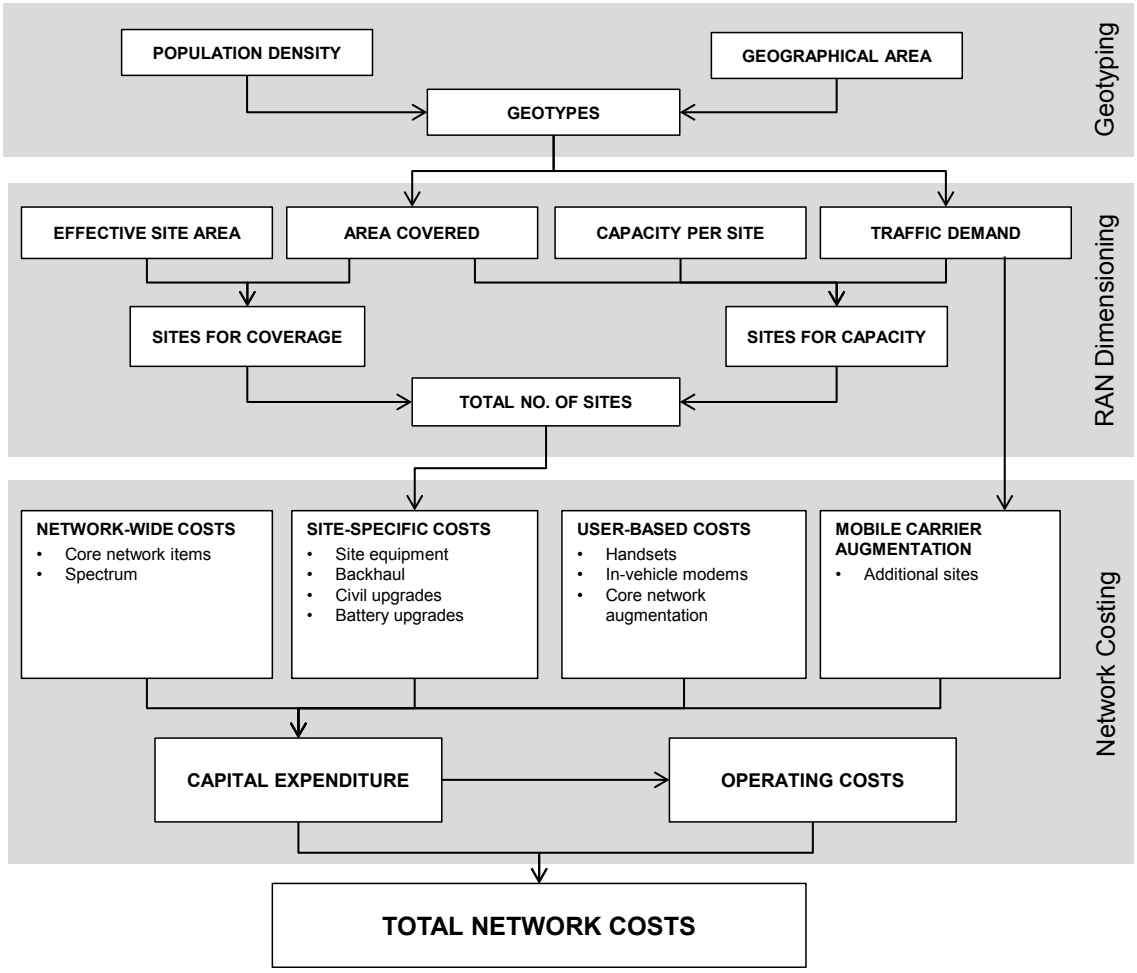
Importantly, the framework and methodology applied is not designed to necessarily:

- produce precise estimates of the costs of a particular option, or individual components
- describe what the architecture of a PSMB network would look like in practice
- identify the optimal mix of inputs for delivering a PSMB capability.

An overview of the framework for quantitative evaluation is depicted in figure C.1. The framework can be described as a bottom-up approach, which is generally viewed as preferable for calculating investment costs (Brinkmann et al. 2007; Smura 2012). The approach taken is also modular, in the sense that the overall framework can be subdivided into smaller distinct parts, each of which is discussed in further detail below.

- The geotyping module links geographic areas to demand characteristics, via the assignment of geotypes (section C.3).
- The radio access network (RAN) dimensioning module determines the number of sites required to provide coverage and meet capacity requirements (section C.4).
- The network costing module calculates selected capital expenditure and operating costs associated with delivering PSMB (section C.5).

Figure C.1 **Framework for evaluating costs**



Since the early 1990s, techno-economic modelling has been used to analyse and compare the economic feasibility of emerging telecommunications networks and services (Smura 2012). The objective is to compare technical options to determine the most cost-effective solutions and to identify the parts of the network that contribute most to overall costs. The modelling is multidisciplinary in combining engineering and economic methods.

The framework applied in this study has similarities with this type of approach and is in part based on other models of mobile networks in the literature (Analysys Mason 2015; GQ-AAS 2010, 2011b, 2011c). However, the framework applied here is adapted to the specific nature of this study. It should be noted that certain costs are not accounted for as part of the quantitative analysis. These are discussed in greater detail in section C.10.

C.3 Geotyping

A key step in evaluating the cost of delivering a PSMB capability involves identifying how demand for and supply of PSMB services would vary over Australia's geographic area. This study adopts a 'geotyping' approach to identifying the demand and supply characteristics of geographic areas. Accordingly, Australia's geographic area is divided into classes or geotypes, whereby all areas with the same geotype have the same characteristics on average. Specifically, areas within a geotype class are deemed to share similar demand profiles for PSMB services and hence require similar network solutions to meet this traffic.

Why use geotypes?

A site-by-site approach would be data intensive

One approach to this task is to dimension the network on a site-by-site basis, taking into account the unique traffic and geographic characteristics of local areas. However, such an approach would have extremely high informational requirements, including comprehensive geographic data and robust traffic forecasts. It is also unlikely that this level of detail is necessary for understanding the relative cost of different options (as opposed to the magnitude of costs per se).

A benchmarking approach could overestimate costs

Another approach would be to use the networks of mobile carriers as a benchmark for the architecture of a PSMB. However, a limitation of this approach is that mobile carrier networks are designed to meet commercial traffic, which is likely to be considerably greater than PSMB traffic (due to a greater number of users), especially in metropolitan areas. As a result, a benchmarking approach risks significantly overestimating the total number of sites and therefore the cost of delivering a PSMB capability via any option. Additionally, under a benchmarking approach, it is difficult to identify the key drivers of costs, as many of the key cost items are derived from a top-down analysis.

The approach taken is fit for purpose

This study uses geotypes for the purpose of describing areas of similar demand and supply characteristics. One limitation is that an approach relying on averaging across geotypes does not take into account the idiosyncrasies of specific geographic areas. Nevertheless, the specified characteristics are representative of the geotype class as a whole, as variances within the geotype class are assumed to counterbalance each other. For example, an especially rugged geographic area that requires more cells for coverage will be counterbalanced by flatter areas that require fewer.

How are geotypes assigned?

It is first necessary to determine the basis on which geographic areas are assigned a geotype. This has been done with reference to two key criteria.

The first is that the specification of geotypes must be implementable, in the sense that there must be an empirical basis for mapping geographic areas within Australia to a geotype. For example, the assignment of geotypes on the basis of projected PSMB traffic profiles in different geographic areas would not meet this criterion, because no such dataset exists.

Second, the basis on which geotypes are defined must also yield classes whose members are sufficiently homogenous in terms of PSMB demand and supply characteristics. That is, any geographic area should ideally be more similar to areas with the same geotype than to areas of a different geotype. For example, the assignment of geotypes on the basis of rainfall levels would not meet this criterion, because there is no reason to believe that areas with similar rainfall would have similar PSMB requirements.

In view of this, geotypes have been specified on the basis of population density. This is based on the assumption that population density is a reasonably good indicator of:

- where assets (including lives and property) are physically located and hence where PSA activity is likely to be concentrated
- the type and frequency of incidents that are likely to occur.

As such, population density can provide an indication of the nature of demand for PSMB services and hence the type of network solutions that would need to be implemented in each area. A similar approach has also been used in other studies (Analysys Mason 2015).

Accordingly, five geotypes based on population density have been specified (table C.1). These threshold definitions have been adopted from ACMA (2014b) with some modifications. Specifically, while ACMA distinguished between metropolitan and regional areas in the urban and suburban geotypes, this study does not.

Table C.1 **Geotype definitions**

Geotype	*Resident population density (persons/km^2)*
Dense urban	3 000+
Urban	1 250 – 3 000
Suburban	100 – 1 250
Rural	0.2 – 100
Remote	less than 0.2

Source: Adapted from ACMA (2014).

What statistical data are used?

Once the decision has been made to use the geotype definitions (table C.1), there is still the question of what statistical data are used to categorise and aggregate geographic areas into geotypes. The ABS reports population data at a number of different levels of aggregation ('spatial units'), meaning various levels of geographic granularity could be used (box C.1).

Box C.1 Spatial units in the Australian Statistical Geography Standard

The ABS publishes geographic statistics using a common hierarchical classification system of geographic regions called the Australian Statistical Geography Standard (ASGS). Under this Standard, geographic areas are classified within the following taxonomic ranks ('spatial units').

Spatial unit	*Count*	*Smallest block (km^2)*	*Largest block (km^2)*
Mesh Block	347 627	0.0001	165 217.0
Statistical Area Level 1 (SA1)	54 805	0.002	328 721.5
Statistical Area Level 2 (SA2)	2 214	0.8	519 519.0
Statistical Area Level 3 (SA3)	351	10.6	714 833.2
Statistical Area Level 4 (SA4)	106	57.6	2 298 053.2
Greater Capital City Statistical Areas	34	217.7	2 520 156.3
State and Territory	9	217.7	2 526 574.2

For each of these spatial units, the ABS reports on the size (in km^2) of each block as well as the Usual Resident Population based on 2011 census data. For SA2 spatial units and larger, the ABS also reports Estimated Resident Population on an annual basis.

Sources: ABS (*Australian Statistical Geography Standard (ASGS): Volume 1 – Main Structure and Greater Capital City Statistical Areas, July 2011*, Cat. no. 1270.0.55.001; *Socio-economic Indexes for Areas (SEIFA), Data Cube only, 2011*, Cat. no. 2033.0.55.001).

The choice of spatial unit has significant implications, as there are tradeoffs associated with the level of granularity used.

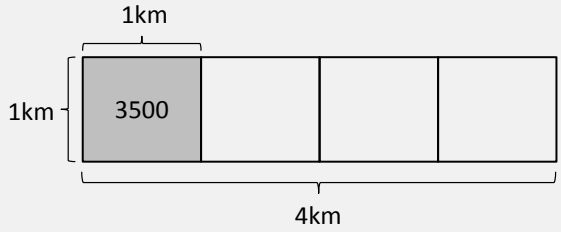
On the one hand, the choice of a spatial unit with larger boundaries runs the risk of aggregating very dissimilar areas into the same block. Areas within the same block are treated as though they were homogenous, whereas in practice populations tend to be clustered in towns and cities. This could lead to excessive 'averaging' of population density, which would misrepresent the geographic distribution of Australia's population. An example of this is discussed in box C.2.

On the other hand, a spatial unit with boundaries that are too small will not accurately reflect the geographic scale at which networks are designed. This could cause excessive fragmentation of geotype areas for the purpose of network dimensioning. Specifically, if the coverage of a network cell is larger than the size of a statistical block, there may be

inaccuracies in the calculation of how many cells are required. An example of this is discussed in box C.3.

Box C.2 Large blocks lead to 'averaging' of population density

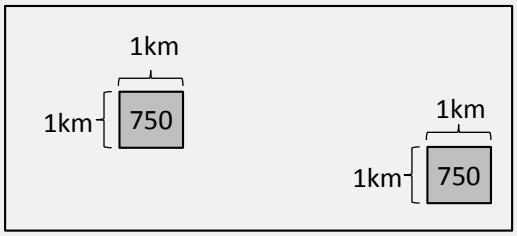
Consider four small geographic blocks, each with dimensions of 1 km x 1 km (illustrated below). Suppose one of these blocks (say, a town) has a residential population of 3500 and the other three have a residential population of zero. At this level of aggregation, the first block would be assigned a dense urban geotype, and the remainder would be classified as remote.



However, suppose these four areas were aggregated into one large block. Now, the larger block would be assigned a suburban geotype. For the purpose of network dimensioning (discussed later), this carries the implicit assumption that the residential population is uniformly distributed across all four smaller blocks; as a result, the network would need to provide coverage to all four blocks (which is not the case).

Box C.3 Small blocks lead to fragmented geotype areas

Consider two small geographic blocks (illustrated below), each with dimensions of 1 km x 1 km, a residential population of 750 and hence a suburban geotype. The surrounding areas are uninhabited, with a residential population of zero.



For the purposes of network dimensioning, the two blocks would be combined to obtain the total coverage area for the suburban geotype class (section C.4). As a result, coverage for this geotype class is determined as though its areas were contiguous.

However, if a network cell has an effective site area sufficiently larger than a single block (say, 2 km^2), the number of cells required will be underestimated. In this case, the network dimensioning approach would report that one cell (of 2 km^2) is required to provide coverage to the two blocks (of 1 km^2 each), whereas in practice, because the blocks are nonadjacent to each other, two cells would be required.

Bearing these considerations in mind, the decision was made to use data reported by the ABS at the SA2 level. This was chosen with a view to minimising the size of blocks, subject to the smallest block being no smaller than the coverage area of a single cell (sections C.5 and C.6). (Data reported at the SA1 level were deemed to be too granular, with the smallest SA1 block being 0.002 km^2 in area, compared with 0.8 km^2 for the smallest SA2 block.)

For each block, population density is calculated by dividing estimated residential population (as at 2014) by the total area of the block. Each block is assigned a geotype on the basis of population density. Table C.2 summarises how the area and population of Australia is distributed between each geotype class.

Table C.2 **Area and population within geotypes**

Geotype	*Density*	*Population*	*Area*	*Average population density*	*Percentage of total population*	*Percentage of total area*
	pop/km^2	millions	km^2	pop/km^2	%	%
Dense urban	>3 000	3.07	740	4 146	13.75	0.01
Urban	1 250 – 3 000	7.83	4 067	1 924	35.05	0.05
Suburban	100 – 1 250	7.42	22 130	335	33.22	0.29
Rural	0.2 – 100	3.78	1 423 207	2.7	16.95	21.03
Remote	<0.2	0.23	6 237 665	0.04	1.03	78.62
All		22.32	7 687 809	2.9	100.00	100.00

Sources: ABS (*Australian Statistical Geography Standard (ASGS): Volume 1 – Main Structure and Greater Capital City Statistical Areas, July 2011*, Cat. no. 1270.0.55.001; *ABS.Stat – ERP by SA2 (ASGS 2011), 1991 to 2014*).

C.4 RAN dimensioning

A radio access network consists of typically thousands of sites (or 'cells'), both logical and physical (box C.4). The number of sites required over time for a PSMB network has implications for the volume of inputs (such as site equipment and site upgrades) required and hence the total cost of delivering a PSMB capability.

Box C.4 Logical and physical sites

Some of the literature on mobile networks differentiates between logical and physical sites. For example, Analysys Mason (2015, pp. 2–3) stated that:

> … [t]he total number of logical sites [refers to] the total number of 2G sites plus the total number of 3G sites plus the total number of 4G sites. It should be noted that the total number of logical sites is considerably higher than the total number of physical sites in Australia, because it is quite common for the operators to co-locate more than one technology on a single physical site; and in some cases a single physical site may also be shared by more than one operator.

A 'site' used for delivering a PSMB capability generally refers to a particular logical site and the physical site on which it is located. Often, these physical sites are shared with other communications service providers, such as mobile carriers or land mobile radio networks. A special case is a 'greenfields site build', which implies a new physical as well as a new logical site.

Source: Analysys Mason (2015).

As discussed in section C.3, a site-by-site approach to estimating the number of sites is considered too data intensive for the task at hand. Similarly, use of commercial mobile carrier networks as a benchmark would not be appropriate for all areas, as it would likely overestimate the number of sites required in more densely populated regions, since these networks are designed to meet commercial traffic.

This section discusses how the number of RAN sites for the dedicated component of a network is estimated. The approach to RAN dimensioning stems from the broader geotyping framework that links geographic areas to PSMB demand and supply characteristics. For each year within the time horizon, it calculates the number of sites required for each geotype class in each state ('state–geotype class').

A two-pronged approach to estimating sites

The number of required sites is estimated using two different methods, depending on the geotype of the area to be covered.

Dense urban, urban and suburban areas

In dense urban, urban and suburban areas, the number of sites is calculated using a bottom-up approach (the 'RAN dimensioning approach'). This involves calculating, for each state–geotype class, the number of sites necessary for coverage ('coverage sites') and the number of additional sites required to meet a specified level of traffic ('capacity sites'). The RAN dimensioning approach is discussed in further detail later in this section.

Rural and remote areas

In general, larger SA2 blocks tend to have a lower population density, with the largest 20 per cent of blocks exclusively classified as regional or remote. In these areas, population is not uniformly distributed over the block area, but is typically concentrated in a small number of population centres. Additionally, these areas are more likely to include economic assets that are not tied to reported population centres, such as roads and rail lines. For these reasons, SA2 blocks as a whole would not be a good indicator of where PSA operations take place and hence where PSMB services would be required.

As a result, the required number of sites is estimated by reference to the number of physical 3G sites operated by mobile carriers in the 850 or 900 MHz band (table C.3). It is assumed that mobile carrier sites in these areas and bandwidth are coverage-dimensioned; therefore, 100 per cent of those sites would need to be used by a PSMB network in order to achieve the same level of coverage. This will overstate the number of sites required if some of these sites are deployed for capacity rather than coverage purposes.

Table C.3 **Number of unique mobile carrier 3G sites**
For rural and remote areas

	Rural			*Remote*		
	Telstra[a]	*Optus*[b]	*VHA*[c]	*Telstra*[a]	*Optus*[b]	*VHA*[c]
NSW	697	704	313	72	29	16
Vic	579	529	212	31	27	10
Qld	553	461	200	176	66	16
SA	257	202	115	70	27	15
WA	280	186	119	308	45	17
Tas	137	80	29	0	0	2
NT	45	24	9	55	6	6
ACT	16	21	13	1	4	2
Total	**2 564**	**2 207**	**1 010**	**713**	**204**	**84**

[a] 850 MHz band. [b] 900 MHz band. [c] 850 and 900 MHz bands.

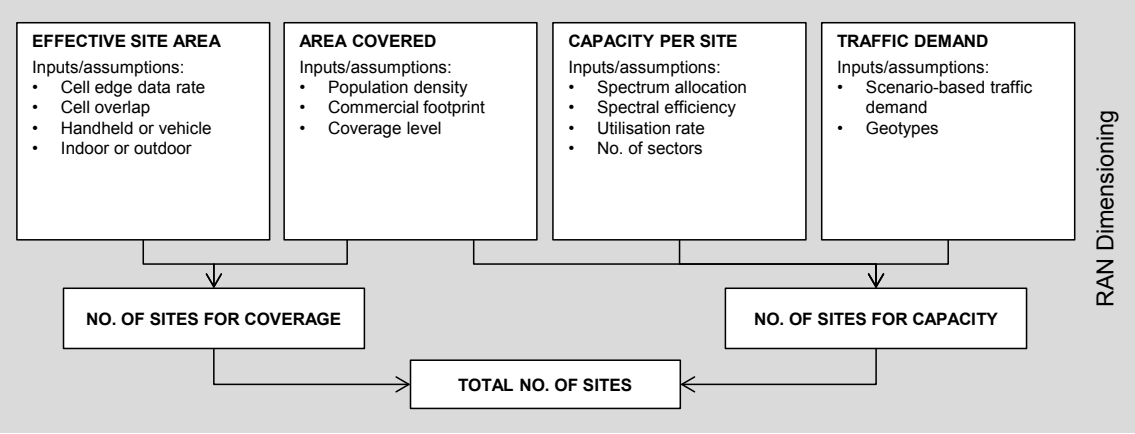
Sources: Productivity Commission estimates based on ACMA (2015g); ABS (*Australian Statistical Geography Standard (ASGS): Volume 1 – Main Structure and Greater Capital City Statistical Areas, July 2011*, Cat. no. 1270.0.55.001; *ABS.Stat – ERP by SA2 (ASGS 2011), 1991 to 2014*).

Overview of the RAN dimensioning approach

The RAN dimensioning approach is a bottom-up approach for estimating the number of sites required to service a specified coverage area. It does so by calculating the number of coverage and capacity sites in each state–geotype class within the coverage area (figure C.2).

For each state–geotype class, the total number of sites required is the maximum of the number of coverage sites and the number of capacity sites. In practical terms, this is equivalent to rolling out the required number of coverage sites, with additional capacity sites targeted to meet high-traffic areas where necessary.

Figure C.2 **Overview of the RAN dimensioning approach**



RAN dimensioning approach: coverage sites

For each state–geotype class, the RAN dimensioning approach calculates the number of coverage sites required. The number of coverage sites is given by the total area to be covered, divided by the effective area of each site ('effective site area'), rounded up. That is, for each geotype (G) in each state (S):

$$coverage\ sites_{G,S} = \left\lceil \frac{total\ coverage\ area_{G,S}}{effective\ site\ area_{G,S}} \right\rceil$$

It is assumed that the number of sites required to provide coverage to these areas will not change over time.

Total coverage area

The coverage area for each state–geotype class is calculated using ABS data relating to the geographic size of SA2 divisions. Table C.4 summarises the total geographic area in each geotype for each state and territory.

Table C.4 **Geographic area of geotypes**
By state and territory

State	*Dense urban*	*Urban*	*Suburban*	*Rural*[a]	*Remote*[a]	*Total*[b]
	km^2	km^2	km^2	km^2	km^2	km^2
NSW	523.7	906.4	6 916.2	482 206.9	310 255.6	800 808.8
Vic	234.2	1 059.6	5 679.5	193 337.3	27 185.1	227 495.7
Qld	75.2	870.9	4 889.3	336 757.1	1 387 365.6	1 729 958.1
WA	..	442.5	1 485.9	138 039.1	844 211.8	984 179.3
SA	27.2	623.2	2 494.4	174 543.0	2 348 886.3	2 526 574.2
Tas	..	42.6	878.7	54 004.8	13 092.1	68 018.2
NT	1.5	38.8	133.6	53 986.8	1 294 038.0	1 348 198.7
ACT	1.4	181.9	88.3	918.9	1 167.4	2 357.9
Other	..	..	..	217.7	..	217.7
Total[b]	**863.2**	**4 166.0**	**22 565.9**	**1 434 011.6**	**6 226 202.0**	**7 687 808.6**

[a] The RAN dimensioning approach is not applied to these geotypes. [b] May not sum due to rounding. .. Not applicable

Source: ABS (*Australian Statistical Geography Standard (ASGS): Volume 1*, Cat. no. 1270.0.55.001).

Effective site area

For each geotype (G), the effective site area (ESA) is calculated using the following equation:

$$ESA_G = \pi \times (r_G)^2 \times (1 - CO)$$

where r_G is the cell range (or 'maximum cell radius') for that geotype and CO is a factor describing how cells overlap with each other. A greater CO indicates greater cell overlap and lower unique coverage. For example, CO = 0.25 implies that the effective site area is 0.75 of the total area of the circle.

Estimating the maximum cell radius requires an understanding of the factors that influence it. This involves using:

- a link budget to estimate the maximum allowable propagation loss (MAPL), which is a metric of how much signal degradation can be tolerated
- a propagation model, with various embedded assumptions, to translate an MAPL estimate into a maximum cell radius.

A link budget is an engineering tool which — accounting for all the expected gains and losses — calculates the maximum path loss between the transmitter and the receiver. From a technical perspective, link budgets can involve many different inputs and assumptions, including (ECC 2013):

- the maximum base station transmission power
- the signal to noise ratio
- the type of receiver (handheld or vehicle device), which affects 'body loss'
- whether the receiver is indoors or outdoors (since buildings contribute to signal losses)
- minimum cell edge data rate (since a higher data rate requires a stronger signal).

Propagation models are used to estimate a relationship between signal losses and distance from the antenna. The maximum cell radius is taken to be the distance at which signal losses are equal to the MAPL. There are various propagation models, with different inputs and assumptions, including assumptions about antenna height. The choice of propagation model — along with assumptions about the height of a base station antenna — can have a material effect on estimated cell ranges.

Calibration of cell radius for each geotype is discussed further in section C.6.

RAN dimensioning approach: capacity sites

Determining the number of sites required for capacity requires translating expected user requirements into network capacity measures. In this study, network capacity requirements are determined using illustrative traffic scenarios, which specify the level of traffic that must be met within a given area.

For each state–geotype class, the number of capacity sites (for both downlink and uplink traffic) is calculated as the volume of total traffic, divided by the capacity of each site, rounded up. That is, for each geotype (G) in each state (S):

$$capacity\ sites_{G,S} = \left\lfloor \frac{total\ traffic_{G,S}}{site\ capacity} \right\rfloor$$

The number of capacity sites will grow from year to year, in line with growth in traffic.

Traffic scenarios

For each geotype (G), uplink and downlink traffic per square kilometre (in Mbps/km^2) for each year (t) is described by the following equation:

$$traffic_{G,t} = traffic_{G,1} \times (1 + G)^{t-1}$$

where:

- $traffic_{G,1}$ is the initial level of (uplink or downlink) traffic per square kilometre, for a given geotype
- G is the annual rate of growth in (uplink or downlink) traffic per square kilometre.

These values are calibrated with reference to traffic scenarios, as discussed in chapter 4. Total traffic for each state–geotype class is calculated for each year by multiplying traffic per square kilometre by the total area in each state–geotype class.

Site capacity

For uplink and downlink, the capacity per site (SC) in year t is calculated using the following equation:

$$SC = S \times SA \times SE_t \times U$$

where:

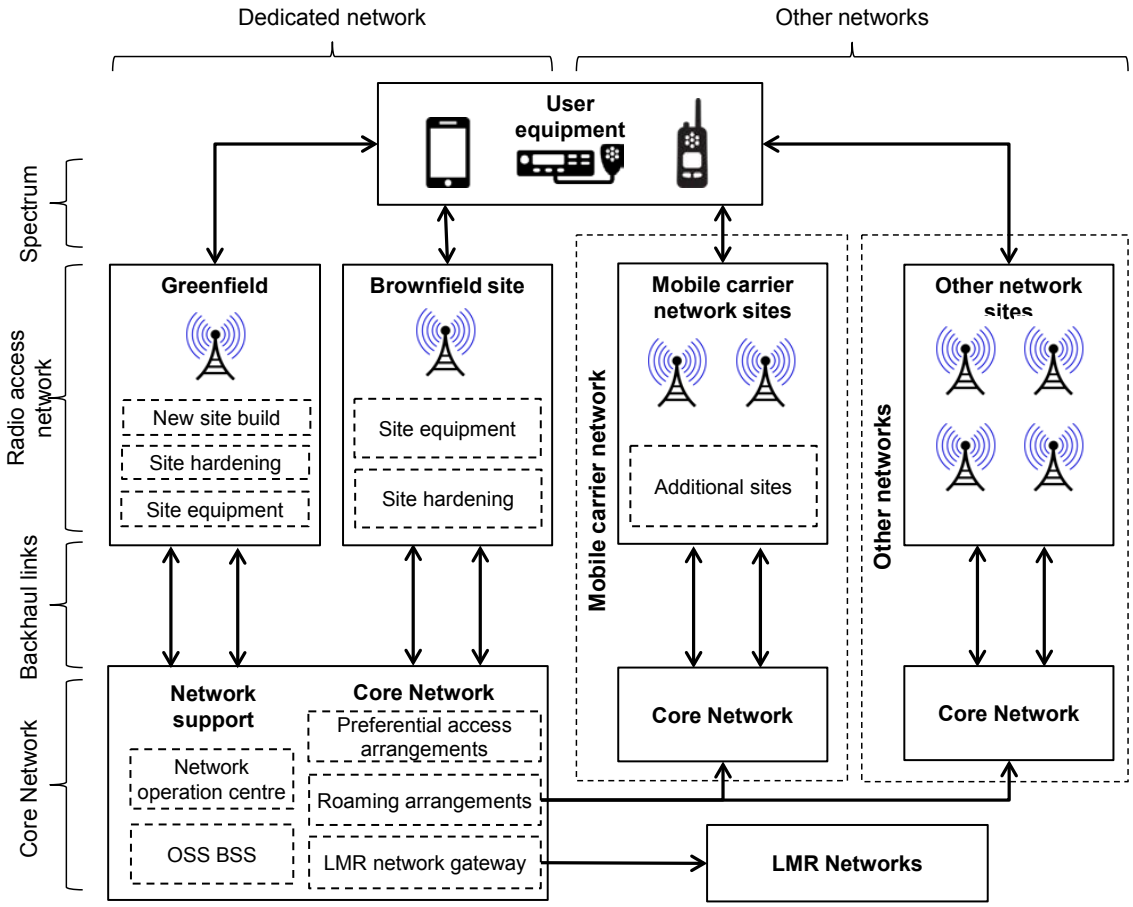
- S is the number of sectors per site. In the dense urban, urban and suburban geotypes, it is assumed that each site has three sectors ($S = 3$)
- SA is the spectrum allocation to be used in MHz. For options involving a dedicated network, this is the quantum of dedicated spectrum. For commercial approaches, this value is set sufficiently high so that the number of capacity sites is non-binding. This means that, for commercial approaches, only the number of sites required for coverage will be hardened, and PSA capacity requirements in excess of this will be met by other commercial network sites
- SE_t represents spectral efficiency in bits per second per Hertz (bits/s/Hz) in year t. This is a measure of how much information can be carried by a particular amount of spectrum and depends on the development of technology over time. It is influenced by two key factors: the types of antennae deployed and the capabilities of the end-user devices on the networks. Spectral efficiency typically increases in step with new versions of mobile technology (such as 3G to 4G standards) and improved antenna technology, though it can take time for base stations to be upgraded to the latest standards and there are technical limitations on how far it can continue to improve (Analysys Mason 2015)
- U is the maximum cell loading factor, which is a measure of how much a network can be practically loaded before users experience material issues with quality of service. High cell loading can lead to congestion and materially slow down data transmission.

The calibration of these values is discussed later in this appendix (section C.6).

C.5 Network costing

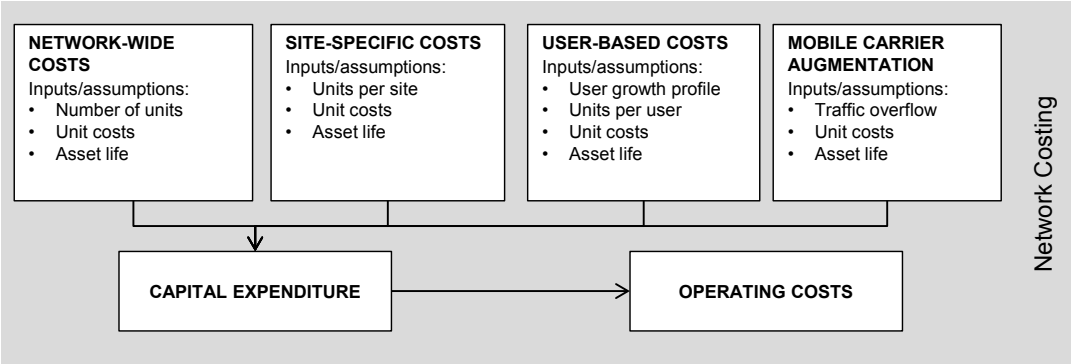
Communications networks are comprised of many different component parts. Figure C.3 gives a stylised representation of how information is transmitted across a mobile broadband network and highlights some of the key infrastructure, equipment and technologies that would be required to deliver a PSMB capability.

Figure C.3 **Stylised PSMB network**



The network costing module of the quantitative analysis estimates the capital expenditure and operating costs of delivering a PSMB capability under different options. A bottom-up costing approach is taken, whereby the total cost is estimated by aggregating individual component costs. An overview of the approach to network costing is depicted in figure C.4.

Figure C.4 **Overview of network costing approach**



Approach to estimating capital expenditure

The value of capital expenditure items ($CAPEX$) is calculated as the product of discounted unit costs and the number of additional units required in each time period, summed across all items and over time:

$$CAPEX = \sum_{j=1}^{N} \sum_{i=1}^{T} \delta_i \times unit.cost_j \times no.units_{i,j}$$

where δ_i is the discount factor, for all cost items in $\mathrm{N} = \{1, 2, \ldots N\}$ and all years within the time horizon $\mathrm{T} = \{1, 2, \ldots T\}$.

The unit cost of each capital expenditure item is specified exogenously. Calibration of unit costs is discussed further in section C.6.

For each item, the total number of units required is derived in one of four ways.

1. For some cost items, the total number of units required is specified *exogenously*.
2. In cases where the total number of units required is *site dependent*, the number of units is expressed as a proportion of RAN sites.
3. For some cost items, the number of units required is *user dependent*. This includes end-user devices and augmentation of mobile carriers' core networks to account for increases in traffic.
4. Some capital expenditure arises from the *augmentation* of existing mobile carrier RAN infrastructure. For options involving overflow of traffic onto commercial networks, this includes any upgrades to those networks necessary to meet increased traffic volumes.

For each of these items, the number of additional units required each year is also affected by rollout times and the length of asset lives (discussed below).

Table C.5 summarises capital expenditure items and how they are captured and represented in the quantitative analysis.

Table C.5 **Capital expenditure items**

Cost item	*Variable name(s)*	*Type*	*Description*
Radio access network			
New deployment	NewSiteBuildMetro	site-dependent	Greenfields site in dense urban, urban or suburban area
	NewSiteBuildRegional	site-dependent	Greenfields site in rural or remote area
Site equipment	SiteEquipment	site-dependant	Costs associated with deploying new site equipment, including installing a new eNodeB and site works
Site hardening costs			
Power backup	Battery20	site-dependant	Additional 20 hours of power backup
	Battery24	site-dependent	24 hours of power backup
Civil site upgrade	Civil	site-dependant	Civil and security upgrades to a site
Core network and add-ons			
New deployment	CoreNational	exogenous	Deployment of new national core network (including redundant core)
	CoreState	exogenous	Deployment of new state core network (including redundant core)
Preferential access	PreferentialAccess	exogenous	Upgrades to a core network to allow preferential access
LMR network gateway	LMRIntegration	exogenous	Upgrades to core network to link to LMR networks
OSS, BSS	OSSBSS	exogenous	Operation and billing support systems and other network management
User equipment			
End-user devices	Handset	user-dependent	Off-the-shelf mobile device
	RuggedisedHandset		Ruggedised mobile device
	IVModem		In-vehicle device
Spectrum			
Dedicated spectrum	Spectrum	exogenous	Spectrum to support dedicated network
Mobile carrier network augmentation			
New sites	RANMNO	augmentation	Costs associated with deploying additional mobile carrier sites required to meet PSA traffic, including co-location costs
Core network augmentation	CoreMNO	user-dependent	Mobile carrier core network augmentation required to meet PSA traffic
Spectrum	MNOSpectrum	augmentation	Apportionment of spectrum costs

Exogenous items

The number of units required for some items is determined exogenously, generally as part of option design (chapter 6).

- For all options involving a dedicated network, the quantum of dedicated spectrum is specified as part of option design.
- Whether the core network is shared nationally or not has implications for the number of core network items required. Where a new core network is deployed, it is assumed that new operations and business support systems and network operations centre would also be required to manage and operate the network.
- The number of mobile carriers involved in delivering the network has implications for the extent of LMR integration required.

Site-dependent items

For some items, the total number of units required depends on and is expressed as a proportion of the number of RAN sites. These items fall into two broad categories: items relating to site builds and site hardening.

Radio access network

It is assumed that the deployment of the dedicated component of the network is comprised of a mix of brownfield and greenfield site builds. For the proportion of sites requiring a greenfield build, a new site build cost is applied.

It is also assumed that new site equipment is required at all RAN sites, regardless of whether the build is greenfield or brownfield. This is because it is assumed that the use of dedicated spectrum (which underpins the dedicated network) is not supported by equipment that is currently installed at RAN sites. That said, the extent of new equipment required, and whether some equipment can be shared, is tested through sensitivity analysis (section C.8).

Hardening

To meet PSA reliability requirements, it is assumed that a proportion of sites are subject to some form of network hardening under all options. For the purposes of quantitative evaluation, hardening is assumed to involve three categories of capital investment:

- installation of additional battery backup at some proportion of mobile sites (beyond the capabilities already deployed at mobile carrier sites)

- civil works to increase the physical resilience of some proportion of mobile sites to protect against failures caused by high winds, fire and floods (such as by strengthening masts), and measures to improve site security
- deployment of new backhaul links at some proportion of mobile sites without geographically diverse backhaul (to ensure redundancy of transmission).

Of these, additional battery back-up and civil upgrades are treated as site-dependent items. The cost of deploying new backhaul links is captured as part of backhaul operating costs (discussed later).

User-dependent items

The number of units required of some items is expressed as a proportion of PSA users from year to year. For each geotype (G) in each state (S), the number of users in year t is determined as:

$$No.users_{G,S,t} = N_{G,S} \times \left(1 + R_{G,S}\right)^{t-1}$$

where $N_{G,S}$ is the number of users in year 1 and $R_{G,S}$ is the rate of growth from year to year.

Two types of capital expenditure items are treated as being user-dependent: end-user devices and core network augmentation.

End-user devices

The number of end-user devices required is causally dependent on the number of PSA users. This includes standard handsets, ruggedised handsets and in-vehicle modems.

Core network augmentation

For options involving a mobile carrier network, total capital expenditure also includes any upgrades of the mobile carrier core network required to meet additional PSA traffic (as preferential users). The magnitude of core augmentation required from year to year is also estimated with reference to the number of devices. In practice, the core network is augmented to account for increases in the volume of traffic over time. However, given the lack of robust traffic forecasts for a PSMB capability, the Commission's analysis uses the number of PSA users as a proxy for total traffic volumes.

Augmentation of mobile carrier networks

For options involving a commercial mobile carrier network, total capital expenditure includes any incremental investments made to the network in order to meet additional demand that derives from PSA traffic over the evaluation period ('overflow traffic').

This is based on the premise that while adding PSA traffic to an existing commercial mobile network may not lead to the same requirement for upfront capital expenditure as in a dedicated option, it is not costless. In particular, any additional traffic can be expected to have an effect on forward looking capital and operational decisions by mobile carriers. The extent of this impact will depend on a range of factors, including:

- the amount of PSA traffic
- the timing and duration of PSA traffic loads
- the manner in which PSA traffic interacts with existing traffic on commercial networks, which have been dimensioned to accommodate some measure of 'busy hour' demand at each cell site.

Table C.6 summarises how PSA traffic is carried across the dedicated and mobile carrier networks under the different options specified in this study.

Table C.6 **How PSA traffic is carried under different options**

Approach	*Dedicated network*	*Mobile carrier network*
Dedicated	All PSA traffic	..
Commercial	..	All PSA traffic
Hybrid, geographic areas with dedicated network	Some PSA traffic	Some PSA traffic (overflow traffic)
Hybrid, geographic areas without dedicated network	..	All PSA traffic

.. Not applicable

Characterising overflow traffic

As discussed in chapter 4, the Commission has adopted a scenario-based approach to characterising the level of capacity delivered by a PSMB capability. Accordingly, the total network is dimensioned to meet the level of capacity arising from certain scenarios.

For options involving a mobile carrier network component, the volume of overflow traffic is expressed as a proportion of total traffic — that is, for each geotype (G) in each state (S):

$$overflow\ traffic_{G,S} = \omega_G \times total\ traffic_{G,S}$$

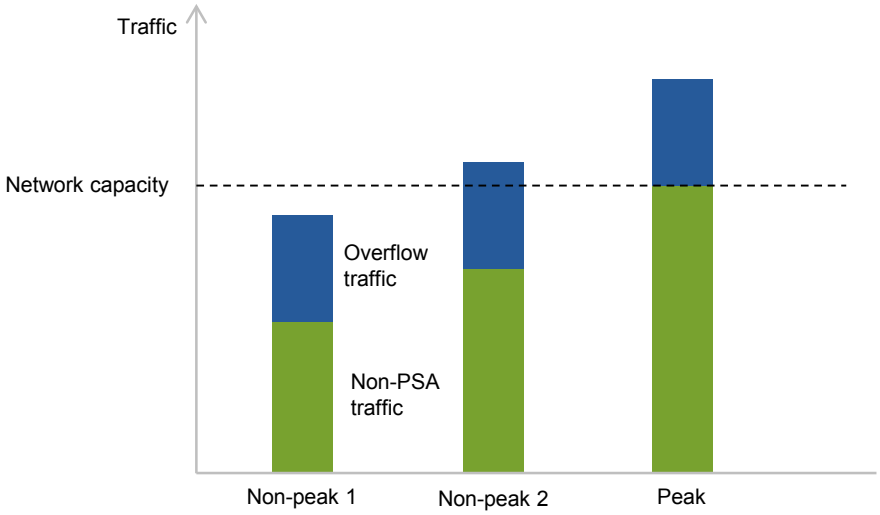
where ω_G is a constant that describes the proportionate relationship.

Overflow traffic and excess capacity on the mobile carrier network

The effect of overflow traffic on the mobile carrier network at any given instance will depend on how much excess capacity is in that network at the time. The degree of congestion on a network depends on total traffic volumes, so overflow traffic is less likely to cause congestion when commercial traffic is low than when commercial traffic is high.

Figure C.5 depicts how the same volume of overflow traffic could have different implications for a mobile carrier's network, depending on the level of non-PSA traffic and whether PSA overflow demand coincides with commercial peak periods.

Figure C.5 **Overflow traffic and excess capacity**



For dense urban, urban and suburban areas, this analysis is agnostic about *when* PSA overflow occurs — specifically, this means that overflow traffic could coincide with commercial peak usage and hence mobile carriers will need to dimension their networks to meet traffic in such an eventuality. It is also assumed that, during the commercial busy hour peak, mobile carriers have zero excess capacity that can be leveraged to meet overflow traffic. This assumption could lead to an overestimate of the cost of capacity augmentation on carrier networks, on the basis that mobile carriers have:

- significant portfolios of spectrum to draw on
- heterogeneous networks made up of various technologies and diverse cell types
- access to technologies and alternative technologies to boost capacity in localised areas, such as carrier aggregation, Wi-Fi networks and deployable cells (chapter 5).

As discussed in section C.4, it is assumed that, for the duration of the evaluation period, the RAN in rural and remote areas is coverage dimensioned. Here, it is further assumed that, in these areas, there is sufficient excess capacity to meet any overflow traffic during the

evaluation period, which will tend to underestimate costs in these areas. (In practice, additional traffic could also be met using alternative or supplementary technologies, which are not included in the quantitative analysis.) To capture this, the level of overflow traffic in these areas is set to $\omega_G = 0$, which is equivalent to setting $additional\ sites_{G,S} = 0$ in these geotypes.

Estimating mobile carrier response to overflow traffic

In general, mobile carriers can provision for additional traffic in one of three ways:

1. building additional sites to increase capacity in targeted areas
2. purchasing additional spectrum to allow existing sites to carry more traffic
3. using existing capacity, but possibly lowering the quality of service provided to other customers.

In the absence of detailed information about each mobile carrier's network architecture at a site-by-site level, the likely pattern and intensity of PSA demand across mobile sites or in different areas, as well as accurate information about the relative cost of different approaches, it is impossible for the Commission to predict how, in practice, network augmentation would be implemented.

For the purpose of quantitative analysis, the cost of capacity augmentation is estimated by evaluating the number of new sites that would be needed to carry overflow traffic. This approach takes the coverage footprint of mobile carrier networks as given; therefore, estimating the mobile carrier response to overflow traffic centres on capacity augmentation and does not dimension for coverage. Specifically, for each geotype (G) in each state (S), the number of additional sites is calculated by dividing total overflow traffic by the capacity of a single site:

$$additional\ sites_{G,S} = \frac{overflow\ traffic_{G,S}}{site\ capacity}$$

This is based on the assumptions that:

- there is no change in mobile carrier spectrum holdings
- there is no degradation of service quality to other customers.

In other words, it is assumed that additional traffic on mobile carrier networks is met exclusively through additional site builds. It is expected that these assumptions will overestimate the cost of mobile carrier capacity augmentation, as they discount the fact that the same level of augmentation could be achieved on a mobile carrier's network at less cost using a different mix of inputs (that is, a mix of additional spectrum, additional sites and existing capacity, or use of alternative technologies).

This approach also assumes that overflow traffic is spread across the network in a particular way, bearing in mind the fact that sites are not divisible over different geographic areas. That is, an additional site can only provide additional capacity to areas within its cell radius, whereas in practice overflow traffic might be spread over a wider geographic area. However, because capacity augmentation to meet overflow traffic would likely take place as part of a mobile carrier's broader investment plans to meet increased demand generally, additional sites can be shared between PSAs and other users. In that sense, additional sites for overflow traffic is used a proxy for the costs that would be attributed to PSAs.

Effect of additional sites on the use of existing spectrum holdings

To support the use of additional sites, mobile carriers would need to use some of their existing spectrum holdings to make these sites operational. In principle, the opportunity cost of doing so should be assessed with reference to the extent to which that spectrum's present and future use is encumbered by its use at these additional sites.

In sparsely or moderately populated areas, where sites are widely spaced, it is likely that additional sites will have zero effect on the use of spectrum by other sites, whether existing or future. However, in areas with high site density, it is possible that additional sites could negatively impact the efficiency of how spectrum is used at nearby sites.

In this study, the opportunity cost of using spectrum owned by mobile carriers is apportioned between PSA and non-PSA usage based on the portion of total network capacity used by PSAs. This is intended to capture the long run average cost of using mobile carrier spectrum parcels for delivering a PSMB capability as a proxy for the incremental cost of doing so.

Other possible approaches

The Commission has identified two alternative approaches to estimating the cost of mobile carrier network augmentation to meet overflow traffic.

The first approach involves using Analysys Mason's mobile network forecasting model, which was prepared for ACMA (Analysys Mason 2015). This model was designed to estimate the tradeoffs between spectrum and network infrastructure in meeting additional capacity requirements. At present, a version of this model that uses placeholder values for some variables is publicly available. However, because many key variables have been redacted and others are measured differently to the Commission's analysis (for example, in the Analysys Mason model, traffic demand is in the form of an annual volume whereas the Commission's analysis determines network capacity using traffic per second per square kilometre), use of this model has significant additional informational requirements.

Alternatively, mobile carriers' historical and forecasted capital expenditure could be used as an indication of the cost of increasing capacity over time. Accordingly, the growth in mobile carriers' subscriber bases could be considered analogous to adding PSA overflow traffic to the network (although services delivered to PSAs would require higher quality of service levels). An example of this is given in box C.5.

Box C.5 **Use of capital expenditure data to estimate augmentation costs**

Historical and prospective capital expenditure data could be used to estimate how increases in carriers' subscriber bases are matched by incremental investments.

By way of illustration, Telstra announced that over three years to June 2017 it expects to have invested more than $5 billion into its 4G mobile network. In its 2014 annual report, it reported that total retail mobile subscribers grew from 12.2 million to 16.0 million in the three years between 2011 and 2014. Assuming that Telstra would experience a similar growth in its user base in the three years to June 2017, the average capital expenditure per user (and hence the average additional cost per user) is approximately $1351.

Source: Telstra (2014b).

However, this approach faces several difficulties, including:

- the availability of sufficient data points
- the fact that historical data would include coverage (as distinct from capacity) investments and other investments which are fixed costs
- the difficulty of mapping capacity investment costs to a corresponding increase in network capacity, given the limited information available.

Timing of capital expenditure

The present value of capital expenditures is also affected by when costs are incurred. This includes considerations of when assets are rolled out, how frequently they are replaced and the timeframe captured by the evaluation period.

Rollout schedule

For each capital expenditure item, a schedule of how long it takes to roll out the asset is specified. In general, items that are essential to the operation of the network as a whole (such as the core network) are assumed to have a rollout period of one year. Items that are more 'scalable' (such as handsets and site equipment) are generally assumed to have longer rollout periods.

For simplicity, it is assumed that investment costs are incurred at the same time as an asset is rolled out. It is also assumed that assets are rolled out uniformly over the rollout period;

for example, if handsets have a rollout period of five years, it is assumed that 20 per cent of the total number of handsets would be rolled out in each of those years.

Asset life span and replacement

The asset life span for each capital expenditure item is also specified, which defines how often an asset must be replaced. It is assumed that, when the asset is replaced, the replacement schedule is identical to the rollout schedule.

If the replacement schedule extends beyond the time horizon of the quantitative analysis, only capital expenditures made within the time horizon are counted. Furthermore, at the end of the time horizon, the asset will be deemed to have been partially replaced, in accordance with the proportion of the replacement schedule that falls within the time horizon.

For example, suppose the replacement of site equipment takes five years and begins in year 17. If the time horizon for the analysis is 20 years, only the investments made in years 17–20 (that is, four years) will be counted and at the end of the time horizon the asset will be deemed to have been 80 per cent replaced.

Residual value of assets

Some capital expenditures have an economic life that extends beyond the time horizon of the quantitative analysis. In such cases, it is inappropriate to attribute all of the investment cost to the time horizon being analysed. In particular, investments made in the later years of the time horizon will be used for fewer years than the length of their economic life.

As a result, correction needs to be made for the proportion of the investment that operates outside of the time horizon. Accordingly, capital costs are truncated by first calculating the residual value of the asset at the end of the time horizon, assuming linear depreciation of the asset. The residual value is then applied as a negative capital expenditure at the end of the time horizon.

For example, suppose site equipment is replaced in year 17 and has a life span of eight years. If the time horizon for the analysis is 20 years, the residual value of the asset is calculated for the duration of its life span outside the time horizon (that is, years 21–24).

Operating costs

Based on approaches to calculating operating expenses in other studies (Brinkmann et al. 2007; Ofcom 2006) and feedback from participants, three categories of operating costs have been identified:

- direct network operating costs

- network support operating costs
- common organisational-level costs.

The manner in which direct network and network support operating costs are estimated is discussed below. Common organisational-level costs have not been quantified as part of the analysis (section C.10).

Direct network operating costs

Direct network operating costs include those relating to the operation and maintenance of elements directly related to providing a Long-Term Evolution (LTE) service capability, such as site equipment and core network infrastructure.

It is common practice to estimate the annual operating costs of particular items using expense ratios (Brinkmann et al. 2007; Nokia Siemens Network 2010). Expense ratios describe how operating expenditures vary in proportion to the value of another expense, and implicitly define a production relationship between two outputs.

In the present analysis, direct network operating costs for each item are estimated as a proportion of initial capital costs on a per-unit basis. In other words, the total direct network operating cost is calculated as the product of year-one unit costs (discounted), the number of operational units and a scalar that describes the proportionate relationship between operating and capital costs (α_j), summed across all items and over time:

$$OPEX.DN = \sum_{j=1}^{N} \sum_{i=1}^{T} \alpha_j \times \delta_i \times unit.cost_{1,j} \times no.units_{i,j}$$

where δ_i is the discount factor, for all cost items in $\mathrm{N} = \{1, 2, \ldots N\}$ and all years within the time horizon $\mathrm{T} = \{1, 2, \ldots T\}$.

This treatment of direct network operating costs assumes a linear relationship between direct network operating costs and initial capital costs, which also implies that:

- there are no scale efficiencies in operation and maintenance
- the composition of the network operator's assets is common across all options
- the tradeoff between capital investment and operating expenses is the same across all options.

Network support operating costs

Network support operating costs include annual site rental costs (for co-location at brownfield sites) and the annual purchase of backhaul capacity from mobile sites back to some point of interconnection, which connects to the core network. These costs are

estimated using per-unit market prices for site rental and backhaul capacity as a guide, on the assumption that these prices are the best publicly available estimates of underlying resource costs.

Specifically, the total network support operating cost is calculated as the product of discounted market prices and the number of operational units, summed across all items and over time:

$$OPEX.NS = \sum_{j=1}^{N} \sum_{i=1}^{T} \delta_i \times unit.cost_j \times no.units_{i,j}$$

where δ_i is the discount factor, for all cost items in $\mathrm{N} = \{1, 2, \ldots N\}$ and all years within the time horizon $\mathrm{T} = \{1, 2, \ldots T\}$.

Site leasing costs

The site leasing cost variable captures the opportunity cost of deploying new equipment at an existing site, as the use of space at a site precludes future use of that space for an alternative purpose. This is true regardless of whether the site is a greenfield or a brownfield site. The opportunity cost is also incurred regardless of who owns the site; in particular, for government-owned sites (such as those used in LMR networks), the opportunity cost is the forgone value of alternative uses, such as leasing the space to another user.

However, under the commercial and hybrid approaches, it is assumed that mobile carriers use *existing* spaces. That is, mobile carriers replace their current site equipment with new site equipment in the same space. In these instances, there is no opportunity cost of deploying a new site, as no additional space is being used. This is true regardless of whether the site is owned by that carrier or by a third party.

Backhaul transmission costs

The backhaul transmission component of a mobile network comprises the links between the core network and each site (chapter 5). Broadly speaking, backhaul transmission is made up of three elements (ACCC 2014a):

- transmission between a group of mobile sites
- transmission from a point of aggregation to the core network (for example, from a town back to a capital city)
- transmission between one core network and other networks (for example, between capital cities).

Quantifying the costs of backhaul transmission networks is difficult because these networks are often complex in structure and topology. Various technologies are used for

backhaul, including optical fibre, microwave and satellite, each with different technical properties, limitations and costs. Microwave is often cited as the dominant technology for transmission between sites and points of aggregation, with fibre more commonly used for trunk backhaul and in metropolitan areas. There is, however, significant variation between countries and mobile carriers (Ericsson 2013b).

Additionally, some elements of mobile backhaul transmission networks (particularly those responsible for carrying traffic to and from large numbers of sites) are designed in a 'ring', 'mesh' or 'tree' pattern to ensure there are multiple ways in which transmission traffic can be routed (ACCC 2014a; Ericsson 2014a; Nadiv and Naveh 2010). Other elements, such as links to individual mobile sites, may not have geographic diversity (Alcatel-Lucent, sub. 15; Optus, sub. 18).

Further, because mobile sites do not always operate at maximum capacity, traffic from multiple sites will not be perfectly coincident. Accordingly, backhaul networks are typically dimensioned according to an 'overbooking factor', the level of which will depend on their position in the broader network. These techniques allow mobile carriers in particular (who aggregate and carry large volumes of traffic) to exploit the distribution of traffic across multiple sites.

In the absence of detailed information about the expected topology of a PSMB backhaul network, this analysis takes a simplified approach to estimating backhaul costs. Specifically, they are estimated through a representative per-site cost that is intended to capture carriage of traffic between mobile sites to some point of aggregation, and an annualised cost for new backhaul links to add greater geographic diversity to some proportion of sites (for hardening purposes).

For options involving commercial networks, it is assumed that the per-site backhaul cost is proportionately smaller. This assumption is made on the basis that:

- PSAs represent a very small proportion of the total customer base already served by mobile carriers
- mobile carriers already have (often high capacity) backhaul in place to their sites and may be able to add additional capacity at a lower per unit cost (there is some evidence that the per-unit costs of adding backhaul fall as more is purchased)(section C.6)
- mobile carriers are better able to optimise their broader network resources by using statistical multiplexing and differentiated classes of service to manage traffic loads within their backhaul/aggregation networks. In other words, meeting PSA traffic will not necessarily require significant additions to backhaul resources compared to the current capacity they utilise (Nadiv and Naveh 2010).

C.6 Calibration and inputs

This section discusses the key assumptions and estimated parameters used in the quantitative evaluation. In calibrating these assumptions and inputs, the Commission has reviewed a range of publicly available sources and studies (box C.6) and drawn on submissions from participants. Feedback on certain technical matters regarding LTE networks was also sought from participants with relevant expertise in this area.

Box C.6 **Studies reviewed to inform inputs and assumptions**

Australian reports

- Analysys Mason (2015), *Mobile Network Infrastructure Forecasts.*
- Ernst and Young (2011), *Benefit Cost Analysis of National Broadband Capacity of Emergency Services Organisations.*
- Gibson Quai–AAS (2011), *Public Safety Broadband Delivery Models (Project 2) for Public Safety Mobile Broadband Steering Committee, Final Report* (publicly redacted version).
- Access Economics (2010), *Radiofrequency Spectrum Options for Public Safety Agencies* (publicly redacted version).

International reports

- Alcatel-Lucent (2011), *High Level Total Cost of Ownership Comparison: Stand Alone Public Safety Network vs. Public Private Partnership,* Bell Labs.
- Federal Communications Commission (2010), *A Broadband Network Cost Model*, OBI Technical Paper No. 2.
- Nokia (2010), *Mobile Broadband with HSPA and LTE – Capacity and Cost Estimates*.
- Ericsson (2014), *Microwave Towards 2020 – Delivering High Capacity and Cost-Efficient Backhaul for Broadband Networks Today and in the Future*.
- ECC (2013), *User Requirements and Spectrum Needs for Future European Broadband PPDR Systems.*
- NPSTC (2012), *Priority and Quality of Service in the Nationwide Public Safety Broadband Network.*
- SCF Associates (2014), *Is Commercial Cellular Suitable for Mission Critical Broadband?,* Report for the European Commission.

General parameters and assumptions

Social discount rate

In accordance with the Office of Best Practice Regulation guidelines on cost–benefit analysis (OBPR 2014b), a real discount rate of 7 per cent is used in calculating the net present value of each PSMB delivery option. As part of the sensitivity analysis, net present values are also calculated using real discount rates of 3 and 11 per cent (section C.8).

Time horizon

The Commission sought feedback from participants on the appropriate time horizon for the quantitative analysis. Two participants provided views:

- Telstra (sub. 19) proposed a 15-year time period based on the propensity for costs and benefits discounted over a longer period of time to approach zero and the fact that spectrum licences in the 700 MHz band have a duration of 15 years.
- CDMPS et al. (sub. 7) suggested a horizon out to 2040 will take into account the release to market of 3GPP mission critical public safety communications standards-based products by 2020, and provide a 20-year period in which temporal changes in technologies and consumer demand can be reasonably assessed.

The quantitative evaluation in this study is based on a 20 year time horizon (2018–2037).

Network dimensioning: coverage

Coverage area

An underlying assumption for the quantitative evaluation is that all PSMB delivery options provide coverage to match the overall coverage footprint (99 per cent of the population) of mobile carriers nationally — but with different mixes of dedicated and commercial network elements depending on the option. Geotypes have been used as a basis for defining the coverage areas (table C.7).

- In options 1 and 2, the dedicated PSMB network (supported by dedicated spectrum) covers 99 per cent of the population, which translates to 100 per cent coverage of dense urban, urban and suburban geotypes, and partial coverage of rural and remote geotypes.
- In option 3, a dedicated PSMB network (supported by dedicated spectrum) covers dense urban and urban areas only.
- In option 4, commercial mobile carrier network coverage is used in all areas.

Table C.7 **Coverage of options by geotype category**

Option	*Dense urban*	*Urban*	*Suburban*	*Rural*[a]	*Remote*[a]
Option 1	Dedicated	Dedicated	Dedicated	Dedicated	Dedicated
Option 2	Dedicated and commercial	Dedicated and commercial	Dedicated and commercial	Dedicated and commercial	Dedicated and commercial
Option 3	Dedicated and commercial	Dedicated and commercial	Commercial	Commercial	Commercial
Option 4	Commercial	Commercial	Commercial	Commercial	Commercial

[a] Coverage in these areas is provided using a number of sites equal to existing mobile carrier sites (that is, it roughly matches the coverage footprint of existing mobile carrier networks); as such, not all of the geographic area has coverage.

RAN dimensioning approach

A number of inputs are required for the RAN dimensioning approach, including the geographic area of each state–geotype class, estimated max cell radii (based on various assumptions, such as antenna height and whether indoor or outdoor coverage is targeted), and an assumed cell overlap. Input on engineering matters was sought from a range of participants.

The various assumptions relating to maximum cell radius and the central case estimates are set out in table C.8. Given that mobile carrier networks generally provide indoor coverage in dense urban, urban and suburban areas, it is assumed that a dedicated PSMB network would need to meet a commensurate standard of coverage.

Table C.8 **Assumptions used for maximum cell radius**

Indoor or outdoor	*Cell edge data rate*	*Dense urban*	*Urban*	*Suburban*
	kbps	km	km	km
Indoor	100	1.15	1.45	3.4
Indoor	256	0.875[a]	1.10[a]	2.6[a]
Indoor	750	0.6	0.75	1.8
Outdoor	100	2.5	3.14	7.43
Outdoor	256	1.75	2.20	5.2
Outdoor	750	1.25	1.57	3.7

[a] Central case estimate. These assumptions were not varied as part of the Commission's analysis, but the ability to do so was retained for the benefit of future users.

In all instances, the cell overlap factor is set equal to 0.18. This approximates the level of overlap associated with an interlocking hexagonal arrangement of cells.

Benchmarking approach

For the benchmarking approach, publicly available data from the RadComms database (ACMA 2015g) are used to identify how many sites mobile carriers currently have, where they are located, how many are co-located, and what spectrum is deployed at each site.

Because the intention is to identify the number of sites used to provide a coverage layer, only those sites using lower frequency spectrum are counted (based on the assumption that lower frequency spectrum is typically deployed for coverage purposes). Specifically, the mobile carrier site counts are based on sites deploying 850 and 900 MHz band spectrum.

The number of sites in each geotype is estimated by:

- creating a geotype map of Australia by importing SA2 shapefile data from the ABS into mapping software (QGIS), with geotypes assigned on the basis of population density
- overlaying the location of the sites used for coverage onto the geotype map
- running a 'points in polygon' program, which counts the number of sites in each geotype (table C.3).

For each state–geotype class, the number of sites required for coverage is set equal to the maximum number of sites operated by any one carrier within that area. This is intended to capture the maximum coverage area offered by any mobile carrier in each state–geotype class.

Network dimensioning: capacity

Once a coverage layer is in place, additional sites are added when PSA traffic demand exceeds the capacity provided by the network. This is done so based on the average capacity of each site, which is derived using various assumptions and inputs (table C.9). These assumptions were derived with input from network engineers and communications service providers. A more detailed explanation of capacity dimensioning is presented in section C.4.

Table C.9 **Capacity dimensioning inputs**

Parameter	*Central case*
Average cell spectral efficiency	
downlink in 2018	1.6 bits/sec/Hz
uplink in 2018	0.79 bits/sec/Hz
downlink in 2037	3.37 bits/sec/Hz
uplink in 2037	1.66 bits/sec/Hz
Annual growth in spectral efficiency	4 per cent
Maximum cell loading factor	75%
Number of cell sectors per site	
dense urban, urban and suburban geotypes	3
rural and remote geotypes	1

Spectrum allocation

For the purposes of the quantitative analysis, it is assumed that spectrum in the 800 MHz band would be used for PSMB. This is consistent with ACMA's previous proposition to allocate spectrum in this band for a PSMB capability, and efforts to harmonise spectrum in

this band for the Asia-Pacific region. For the quantitative analysis, it is assumed that 2 x 5 MHz of spectrum has been allocated for use on the dedicated component of the network. An allocation of 2 x 10 MHz has also been tested as part of a change in the design parameters (table C.10).

Table C.10 **Spectrum allocation**

Cost item	*Central case*	*Lower bound*	*Upper bound*
Spectrum	2 x 5 MHz	–	2 x 10 MHz

Importantly, these values are assumptions and do not amount to a finding or recommendation by the Commission that this spectrum should be used for delivering a PSMB capability.

Traffic scenarios

As discussed earlier and in chapter 4, PSMB traffic has been characterised using a scenario-based approach. This is summarised in table C.11. As part of testing alternative option designs, a lower and upper bound traffic demand and growth rate have also been specified.

Table C.11 **PSMB traffic scenarios**

	Central case	*Lower bound*	*Upper bound*
Dense urban, urban and suburban			
PSMB traffic demand	1.5 Mbps/km^2	1 Mbps/km^2	4 Mbps/km^2
Growth rate	5% pa	2% pa	10% pa
Rural and remote			
PSMB traffic demand	500 Kbps/km^2	200 Kbps/km^2	800 Kbps/km^2
Growth rate	5% pa	2% pa	10% pa

Capital expenditure: number of units

This section discusses how the number of units for certain selected capital expenditure items has been derived.

Radio access network

When there is a dedicated network, new LTE site equipment would need to be deployed to the number of sites required for coverage and capacity.

In practice, existing mobile sites would be leveraged to the greatest extent possible to lower the costs of deploying site equipment. However, it is unrealistic to assume that all mobile carrier sites would have sufficient capacity to accommodate new site equipment — especially where the dedicated network is not being integrated with a carrier's network. For this reason, it has been assumed that some of the sites required for a dedicated network would involve a greenfields build.

As a starting point, it has been assumed that 5 per cent of sites would be newly constructed, with a range from 0 to 15 per cent evaluated as part of sensitivity testing (table C.12).

Table C.12 **Percentage of new versus existing sites**
Dedicated network

	Central case	*Lower bound*	*Upper bound*
Per cent using existing site	95	100	85
Per cent requiring new site	5	0	15

Hardening

As discussed earlier, it is assumed that hardening is required at a proportion of all sites. For commercial options, only those sites required for coverage will be candidates for hardening. For sites within a commercial network, it is assumed that fewer hours of additional battery backup are required at each site, as these sites would likely already have some level of battery backup. For options involving multiple carriers, it is assumed that the ability to use more than one carrier's network would mean that lower levels of network hardening are required. Table C.13 summarises the hardening parameters.

End-user devices

The number of end-user devices has been estimated using the total number of PSA users as a guide.

The Commission sought feedback on the scope of PSA users from participants. There was broad agreement that police, fire, ambulance, state emergency services and marine rescue and coast guard were captured by the terms of reference. Some participants considered that a broader cross-section of personnel should have access to PSMB (chapter 2). For the purposes of the quantitative analysis, it is assumed that police, fire, ambulance, and state emergency services (SES) would be the core users of this new capability.

Data from SCRGSP (2014) indicated that there were approximately 100 000 full-time equivalent public safety officers in Australia (approximately 65 000 police and 35 000 fire, ambulance and SES personnel in aggregate) and 250 000 volunteers across fire, ambulance and SES services.

Translating the number of officers into the number of devices requires assumptions about:

- the number of officers that take up a service and when this occurs within the period of analysis
- the type of device used (commercial handset, a ruggedised PSMB handset or an in-vehicle terminal, or multiple devices)
- the ratio between handheld devices and in-vehicle terminals, and how this differs depending on the type of PSA.

The following assumptions have been made in each category for the purposes of the quantitative analysis (table C.14). The number of users has been calibrated with reference to the number of full-time equivalent officers and it is assumed that volunteers would not be provided with devices.

Table C.13 **Assumed hardening parameters**

Per cent of coverage and capacity sites

	Dedicated		*Commercial (one mobile carrier)*		*Commercial (multiple mobile carriers)*	
	Dense urban, urban and suburban	*Rural and remote*	*Dense urban, urban and suburban*	*Rural and remote*	*Dense urban, urban and suburban*	*Rural and remote*
Additional battery backup	100 (24 hours)	100 (24 hours)	100 (20 hours)	100 (20 hours)	75 (20 hours)	75 (20 hours)
Civil site upgrades (central case)	5	5	5	5	5	5
Civil site upgrades (lower bound)	0	0	0	0	..	..
Civil site upgrades (upper bound)	10	10	10	10	..	..

.. Not applicable

Table C.14 **Number of PSA users and devices**

Variable	*Central case*
Number of users	100 000
Growth per annum in number of users	0
Handheld devices as a percentage of users	50
Ruggedised handsets as a percentage of users	50
In–vehicle modems as a percentage of users	10

Core network items

As noted in section C.5, the number of core network items is generally specified as part of option design. Table C.15 sets out the number of units of each core network item required under each option.

Table C.15 **Number of units for core network items**
By option

Cost item	*1*[a]	*2, 3*[a]	*4*[a]	*1*[b]	*2, 3*[c]	*2, 3, 4*[d]
CoreNational	1	0	0	0	1	0
CoreState	0	0	0	8	0	0
PreferentialAccess	1	1	1	8	2	2
LMRIntegration	1	1	1	8	2	2
OSSBSS	1	0	0	8	1	0

[a] Central case. [b] State-based core networks [c] PSMB core network separate from mobile carrier core network. [d] Multiple carriers.

Augmentation of mobile carrier networks

Table C.16 outlines the central case and upper bound parameters for the proportion of total traffic that is assumed to overflow onto mobile carrier networks under each option. As discussed earlier, the proportion of overflow in rural and remote geotypes is always set to zero per cent, which is equivalent to specifying that no additional sites are required for overflow in these areas.

Table C.16 **Overflow traffic**
Central case and upper bound, per cent

	Dense urban	*Urban*	*Suburban*	*Rural*	*Remote*
Option 1	0	0	0	0	0
Option 2	20 (50[a])	20 (50[a])	20 (50[a])	0	0
Option 3	20 (50[a])	20 (50[a])	100	0	0
Option 4	100	100	100	0	0

[a] Upper bound estimate for testing alternative network design.

In addition, the opportunity cost of using spectrum owned by mobile carriers is apportioned between PSA and non-PSA usage. This apportionment is calibrated with reference to the number of overflow sites and total number of sites owned by mobile carriers:

$$apportionment = \frac{overflow\ sites}{overflow\ sites + other\ mobile\ carrier\ sites} \times 100$$

These values are summarised in table C.17. Because the number of overflow sites varies with the volume of overflow traffic, the apportionment varies between the central case options and for some alternative option designs.

Table C.17 **Apportionment of mobile carrier spectrum to PSA traffic**
Per cent

	Central case	*Network capacity (lower bound)*	*Network capacity (upper bound)*	*Overflow traffic (upper bound)*
Option 1	0.0	0.0	0.0	0.0
Option 2	3.0	2.0	7.3	6.9
Option 3	11.2	7.8	25.0	11.8
Option 4	12.8	9.0	28.0	12.8

In general, this approach will overestimate the proportion of spectrum usage that should be attributed to PSAs. In particular, the apportionments outlined in table C.17 correspond with the assumption that overflow sites (and the spectrum that supports them) are always fully utilised. In principle, this issue could be addressed by weighting overflow sites and other sites in accordance with the intensity of their usage. However, this is impractical to implement, given the lack of data in this area.

Capital expenditure: unit costs

Sourcing accurate and robust values for unit costs is a difficult exercise. In part, this is because it is 'difficult to estimate infrastructure costs beyond 3–5 years due to ongoing technology and capability enhancement' (Ericsson, sub. 10, p. 22). In addition, there is limited publicly available information relating to unit costs and observed market prices may include a markup over the true resource cost.

Table C.18 sets out the assumed unit costs for capital expenditure items, expressed in real terms. For the purpose of the quantitative analysis, it is assumed that real prices remain constant over the evaluation period (that is, zero per cent change in real prices). This is because there is very limited evidence to support how real prices are expected to change over the evaluation period.

Table C.18 **Unit costs for capital expenditure items**
In 2015 dollars

Cost item	*Central case*	*Lower bound*	*Upper bound*
Radio access network			
NewSiteBuildMetro	300 000	150 000	500 000
NewSiteBuildRegional	300 000	150 000	500 000
SiteEquipment	80 000	50 000	120 000
Site hardening costs			
Battery20	10 000	..	..
Battery24	12 000	..	..
Civil	50 000	..	..
Core network and add-ons			
CoreNational	10 000 000	..	..
CoreState	7 500 000	..	..
PreferentialAccess	5 000 000	..	..
LMRIntegration	20 000 000	..	..
OSSBSS	50 000 000	..	..
User equipment			
Handset	800	..	..
RuggedisedHandset	2 500	..	..
IVModem	7 500	..	..
Mobile carrier network augmentation			
RANMNO	80 000	50 000	120 000
CoreMNO	15	..	..

.. Not applicable

Opportunity cost of spectrum

There are two broad approaches to calculating the opportunity cost of spectrum.

- *Market valuation approaches* calculate the value of spectrum using available market information or data as a benchmark. Most commonly, this involves the use of data from previous spectrum market transactions, such as past auction results and spectrum trades in the secondary market involving spectrum parcels in the same or similar band (Access Economics 2010; Grous 2013a, 2013b).
- *Direct calculation approaches* calculate the value of spectrum by reference to the cost and revenue advantages of acquiring spectrum. This is typically done by estimating the cost of other inputs needed to maintain a certain level and quality of output on a mobile network, but without the additional spectrum (NERA and Smith System Engineering 1996; Plum Consulting 2011).

For the purpose of the quantitative analysis, the opportunity cost of spectrum is estimated with reference to market transactions of spectrum in the same or comparable frequency bands. Compared to direct calculation methods, this approach has lower information requirements and is more transparent and objective.

Generally, there is limited publicly available data that can be used to infer the value of spectrum in Australia. Data relating to international valuations of spectrum (such as auction results) are of limited use, given that spectrum is not tradeable across geographic areas and its use is subject to different licencing conditions in different jurisdictions.

- In 2013, spectrum in the 700 MHz band was sold at auction for a reserve price of $1.36/MHz/Pop based on a Ministerial direction; and spectrum in the 2.5 GHz band was sold at $0.03/MHz/Pop based on an ACMA reserve price.
- In their report to ACMA, Plum Consulting (2008) estimated that the opportunity cost of spectrum in 825–845 MHz and 870–890 MHz bands was $1.21–$1.46/MHz/Pop.
- Optus (sub. 18) submitted that the opportunity cost of spectrum in the 900 MHz, 800 MHz and 750 MHz ranges would likely be between $1.00–$1.36/MHz/pop.
- The ACMA Apparatus Licence Fee Schedule specifies that 900 MHz PMTS Class B licences are charged at $3 148 358/MHz, which roughly translates to $0.50/MHz/Pop, given the different lengths of the licences (although it should be noted that longer licences tend to be more valuable as they offer greater security of tenure).

For the purpose of the quantitative analysis, guidance has been taken from these sources to establish an appropriate range (table C.19). The estimates outlined in this table are for the purposes of this quantitative analysis only, and should not be taken as a statement of the Commission's view on the appropriate estimate of the opportunity cost price of spectrum, as this is a matter for the ACMA and the Minister for Communications.

Table C.19 **Spectrum assumptions**

Item	*Central case*	*Lower bound*	*Upper bound*
Price per MHz per head of population	$1.00	$0.50	$1.36
Population[a]	22 872 578	..	..
Apportionment to metropolitan areas	50%	..	..
Apportionment to regional areas	50%	..	..

[a] Estimated resident population as at 31 March 2013. This is the population count used by ACMA for setting the reserve price for the digital dividend auction in 2013. **..** Not applicable

Additionally, the opportunity cost of spectrum has been apportioned between metropolitan and regional areas. This recognises that if a dedicated network only provides partial geographic coverage, the same spectrum bands could be used for other purposes in other areas. The apportionment of 50 per cent and 50 per cent roughly reflects the proportion of the population residing inside and outside of dense urban and urban areas.

Accordingly, the total value of spectrum in metropolitan or rural areas is calculated according to the following formula:

$$Price/MHz/Pop \times Population \times Allocation\ in\ MHz \times Apportionment$$

It is assumed that a spectrum licence would be issued for 15 years; hence, the reported net present value of spectrum also includes one instance of licence renewal.

Timing of capital expenditure

Parameters relating to the rollout of infrastructure and take-up schedules have been calibrated with reference to publicly available sources relating to rollout schedules for other LTE networks (table C.20). Assumptions relating to the length of rollout and asset life were calibrated on this basis and are detailed in table C.21.

Table C.20 **Rollout and take-up schedule**

Approach	*Build time*	*Sources*
Dedicated	5 years	Expected timeframe for Telstra LTE rollout for 99% of population (2011 to 2017)
Targeted hybrid	3 years	Telstra LTE rollout for up to 80% of population (2011 to 2013)
Commercial	2 years	..

.. Not applicable

Table C.21 **Rollout period and asset life spans**
Years

Cost item	*Rollout period (options 1,2)*	*Rollout period (option 3)*	*Rollout period (option 4)*	*Asset life (central case)*	*Asset life (lower bound)*	*Asset life (upper bound)*
Radio access network						
NewSiteBuildMetro	5	3	..	20	..	..
NewSiteBuildRegional	5	3	..	20	..	..
SiteEquipment	5	3	..	8	6	10
Site hardening costs						
Battery20	..	3	2	8	..	..
Battery24	5	3	..	8	..	..
Civil	5	3	2	20	..	..
Core network and add-ons						
CoreNational	1	1	..	8	6	10
CoreState	1	1	..	8	..	..
PreferentialAccess	1	1	1	8	6	10
LMRIntegration	1	1	1	8	6	10
OSSBSS	1	1	..	8	6	10
User equipment						
Handset	5	5	5	3	..	..
RuggedisedHandset	5	5	5	5	..	..
IVModem	5	5	5	5	..	..
Spectrum						
Spectrum	1	1	..	15	..	..
Mobile carrier network augmentation						
RANMNO	..	1	1	8	6	10
CoreMNO	..	1	1	8	..	..

.. Not applicable

Operating costs

Direct network operating costs

As discussed above, direct network operating costs are estimated using expense ratios. Reliable data on expense ratios for LTE networks are difficult to source. SCF Associates (2014) approximated annual operating costs as 15 per cent of the networks' value in operation. The expense ratios, including upper and lower bound estimates, used for the quantitative analysis are set out in table C.22.

Table C.22 **Direct network operating costs**
Percentage of unit costs

Cost item	*Central case*	*Lower bound*	*Upper bound*
Radio access network			
NewSiteBuildMetro	7.5	5.0	10.0
NewSiteBuildRegional	7.5	5.0	10.0
SiteEquipment	7.5	5.0	10.0
Site hardening costs			
Battery20	7.5	5.0	10.0
Battery24	7.5	5.0	10.0
Civil	0.0	0.0	0.0
Core network and add-ons			
CoreNational	7.5	5.0	10.0
CoreState	7.5	5.0	10.0
PreferentialAccess	7.5	5.0	10.0
LMRIntegration	7.5	5.0	10.0
OSSBSS	7.5	5.0	10.0
User equipment			
Handset	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0
IVModem	0.0	0.0	0.0
Spectrum			
Spectrum	0.0	0.0	0.0
Mobile carrier network augmentation			
RANMNO	7.5	5.0	10.0
CoreMNO	7.5	5.0	10.0

Network support operating costs

Network support operating costs include annual site rental costs and the purchase of backhaul capacity to carry traffic between individual sites and some point of interconnection and aggregation.

Site Leasing

The parameters used for site leasing costs are set out in table C.23.

Table C.23 **Site leasing costs**
Dollars per year

Cost item	*Central case*	*Lower bound*	*Upper bound*
SiteLeasingUrban[a]	20 000	15 000	25 000
SiteLeasingRegional[b]	12 500	10 000	20 000

[a] Applies to dense urban, urban and suburban areas. [b] Applies to rural and remote areas.

Backhaul transmission

For the purposes of the quantitative analysis, it has been assumed that backhaul capacity would be leased from the existing commercial market. Developing robust estimates for backhaul transmission capacity is challenging for a range of reasons.

In terms of estimating the *quantity* of backhaul capacity required, mobile carriers and governments currently own and lease capacity on backhaul links for existing networks, including mobile, LMR and other networks (Victorian Government, sub. 28). As a result, the incremental capacity required will depend on the extent to which current backhaul capacity can be reused, the number of users of PSMB, their expected traffic, and the amount of spectrum available (Motorola, sub. 12). It will also fundamentally depend on the topology of the backhaul network in place and where the points of aggregation (and the core network) are in relation to each site.

In terms of estimating *unit costs* of backhaul capacity, there are limited data relating to the incremental resource costs of providing capacity on a backhaul link and how these might differ across the options considered in this study. Regulated prices set by the ACCC provide a guide to carrier pricing of backhaul services. However, these prices may not reflect the prices commercially negotiated in the market, including where capacity is bought in bulk or leased over long periods of time.

Additionally, the unit cost of transmission technology will likely improve with higher capacity of usage. For example, optical fibre transmission has a high initial cost of construction regardless of whether the capacity being used is relatively small. The marginal cost to increase capacity on the fibre by addition of more electronics is likely to be relatively small — hence the unit rate ($/Mbps/km) would decrease the higher the capacity of the link.

As discussed in section C.5, a simplified approach is taken to estimating the cost of backhaul capacity, via a representative per-site cost that captures backhaul capacity from each mobile site back to some point of aggregation, as well as an annualised cost for new backhaul links. This representative per-site cost is calibrated with reference to estimates cited in some publicly available studies on PSMB (Bell Labs 2011; Nokia Siemens Network 2010), as well as draft ACCC regulated pricing (ACCC 2015a).

Per-site backhaul costs are based on the following assumptions:

- on average, backhaul between urban sites requires a link capacity of 75–100 Mbps, and sites are 5–10 km from the relevant point of aggregation
- on average, backhaul between regional sites requires a link capacity of 25–40 Mbps, and sites are 50–100 km from the relevant point of aggregation.

To account for the savings associated with higher usage and existing infrastructure, it is assumed that the cost of backhaul is lower when the PSMB capability is delivered over a commercial network (table C.24).

Table C.24 **Per-site backhaul transmission costs**
Dollars per year

Cost item	*Options*	*Central case*	*Lower bound*	*Upper bound*
BackhaulUrban[a]	1	20 000	15 000	25 000
BackhaulRegional[b]	1	25 000	20 000	30 000
BackhaulUrban[a]	2, 3, 4	14 000	10 500	17 500
BackhaulRegional[b]	2, 3, 4	17 500	14 000	21 000

[a] Applies to dense urban, urban and suburban areas. [b] Applies to rural and remote areas.

It should also be noted that there are difficulties associated with forecasting backhaul requirements into the future, as technologies and costs will likely change over time. As such, while it is assumed that real prices and backhaul requirements are constant over the 20-year evaluation period, this may not be realistic.

C.7 Results

This section presents the results of the quantitative analysis. These values presented should be interpreted as a description of the output from the quantitative analysis, rather than as a true forecast of the cost of delivering a PSMB.

Table C.25 summarises the results of the quantitative analysis for the central case, split by expenditure items.

Table C.25 **Net present value of costs**

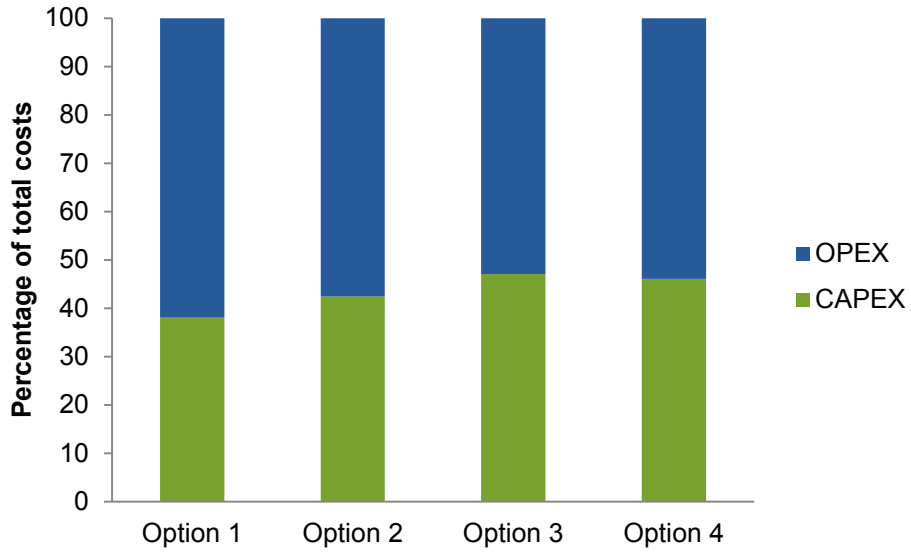
$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	6 151.7	5 132.5	2 904.1	2 201.3
Capital Expenditure				
NewSiteBuildMetro	70.7	60.8	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	1 034.8	942.6	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	18.3	16.7	13.8	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	35.5	146.0	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 241.4	2 092.6	1 321.3	983.9
Operating costs				
NewSiteBuildMetro	59.0	50.7	19.4	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	489.2	445.2	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	73.4	66.8	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	4.0	4.0	4.0	4.0
LMRIntegration	15.9	15.9	15.9	15.9
OSSBSS	39.7	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	16.7	68.7	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	1 048.1	631.1	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	1 048.1	901.5	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	3 910.3	3 039.9	1 582.8	1 217.4

Capital and operating costs

Figure C.6 depicts the division of total costs between capital and operating costs. For all options, operating costs make up the majority of total costs. However, for options involving commercial mobile carriers, operating costs comprise a smaller proportion of total costs. This is because site leasing costs and backhaul transmission costs are lower under these options.

Figure C.6 **Capital and operating costs**
As a percentage of total costs



Data source: Productivity Commission estimates.

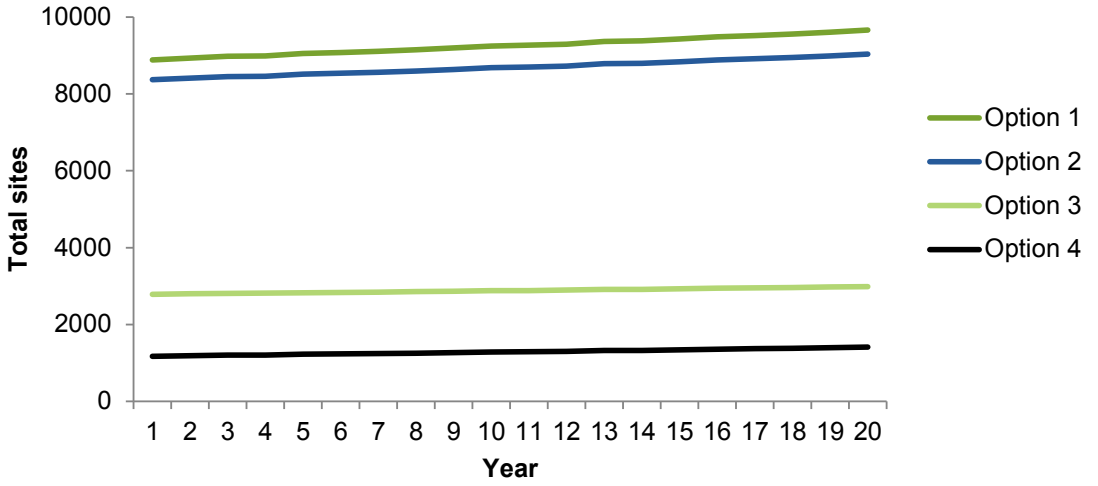
Sites required over time

Figure C.7 depicts the total number of sites required to provide adequate network capacity under each option over the analysis period. This includes sites within both the dedicated network and sites added to mobile carrier networks to meet overflow traffic.

At all times, the number of sites required decreases as the level of mobile carrier involvement in delivering PSMB increases. Furthermore, the growth in the number of required sites is lower for options with mobile carrier involvement, both in absolute terms and as a proportion of total sites. This is because the capacity of a site depends on the quantum of spectrum deployed at that site and because mobile carriers have substantial spectrum portfolios to draw upon.

That said, an upfront investment in the RAN is required under all options in order to provide the additional network capacity required to meet PSMB traffic.

Figure C.7 **Sites required to meet capacity requirements over time**

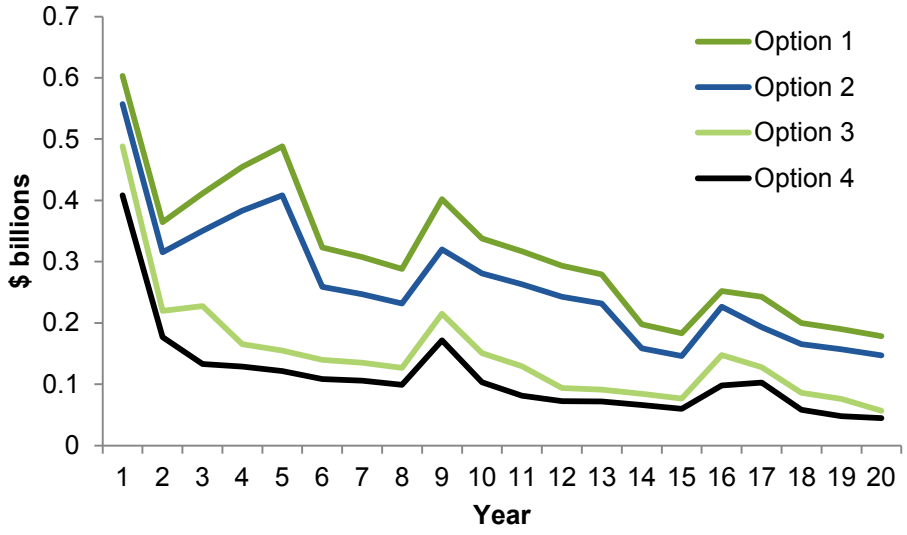


Data source: Productivity Commission estimates.

Costs over time

Figure C.8 depicts the total cost of delivering PSMB under each option, split by year. There is a downward trend in costs over time, as costs incurred further into the future are discounted more heavily.

Figure C.8 **Total costs split by year**



Data source: Productivity Commission estimates.

For all options, costs are 'lumpy' over time due to the periodic replacement of network infrastructure components. However, this should not be interpreted as a representation of when costs would actually be borne by PSAs or governments, as there is uncertainty relating to asset lives. Moreover, the cost to PSAs or governments can be 'smoothed' over time through borrowing or through terms in the procurement contract that specify when costs are to be paid.

C.8 Alternative option designs

This section details the testing that has been undertaken to understand how the results of the quantitative analysis change in response to changes in the design of options.

The results are reported as follows:

- table C.26: for the dedicated option, a separate core network is established in each state and territory
- table C.27: for hybrid options, the mobile carrier network and the PSMB network do not share a core; the PSMB network has its own core network
- table C.28: for the commercial and hybrid options, overflow traffic can roam on two mobile carrier networks
- table C.29: for the dedicated and hybrid options, the upper bound value for quantum of dedicated spectrum is used
- tables C.30 and C.31: for all options, lower and upper bound values for initial network capacity
- tables C.32 and C.33: for all options, lower and upper bound values for network capacity growth rate
- table C.34: for hybrid options, upper bound value for proportion of overflow onto commercial networks.

Table C.26 **Net present value of costs (state-based core networks)**
$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	7 567.9	5 132.5	2 904.1	2 201.3
Capital Expenditure				
NewSiteBuildMetro	70.7	60.8	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	1 034.8	942.6	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	18.3	16.7	13.8	14.3
CoreNational/CoreState	94.4	0.0	0.0	0.0
PreferentialAccess	67.4	8.4	8.4	8.4
LMRIntegration	269.7	33.7	33.7	33.7
OSSBSS	674.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	35.5	146.0	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	3 203.9	2 092.6	1 321.3	983.9
Operating costs				
NewSiteBuildMetro	59.0	50.7	19.4	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	489.2	445.2	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	73.4	66.8	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational/CoreState	44.5	0.0	0.0	0.0
PreferentialAccess	31.8	4.0	4.0	4.0
LMRIntegration	127.1	15.9	15.9	15.9
OSSBSS	317.8	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	16.7	68.7	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	1 048.1	631.1	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	1 048.1	901.5	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	4 364.0	3 039.9	1 582.8	1 217.4

Table C.27 **Net present value of costs (separate core network for PSMB)**
$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	6 151.7	5 343.3	3 114.9	2 201.3
Capital Expenditure				
NewSiteBuildMetro	70.7	60.8	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	1 034.8	942.6	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	18.3	16.7	13.8	14.3
CoreNational	16.9	16.9	16.9	0.0
PreferentialAccess	8.4	16.9	16.9	8.4
LMRIntegration	33.7	67.4	67.4	33.7
OSSBSS	84.3	84.3	84.3	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	35.5	146.0	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 241.4	2 235.9	1 464.6	983.9
Operating costs				
NewSiteBuildMetro	59.0	50.7	19.4	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	489.2	445.2	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	73.4	66.8	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	7.9	7.9	0.0
PreferentialAccess	4.0	7.9	7.9	4.0
LMRIntegration	15.9	31.8	31.8	15.9
OSSBSS	39.7	39.7	39.7	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	16.7	68.7	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	1 048.1	631.1	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	1 048.1	901.5	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	3 910.3	3 107.4	1 650.3	1 217.4

Table C.28 **Net present value of costs (multi-carrier network)**
$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	6 151.7	5 194.5	2 966.1	2 263.3
Capital Expenditure				
NewSiteBuildMetro	70.7	60.8	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	1 034.8	942.6	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	18.3	16.7	13.8	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	16.9	16.9	16.9
LMRIntegration	33.7	67.4	67.4	67.4
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	35.5	146.0	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 241.4	2 134.8	1 363.5	1 026.0
Operating costs				
NewSiteBuildMetro	59.0	50.7	19.4	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	489.2	445.2	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	73.4	66.8	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	4.0	7.9	7.9	7.9
LMRIntegration	15.9	31.8	31.8	31.8
OSSBSS	39.7	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	16.7	68.7	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	1 048.1	631.1	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	1 048.1	901.5	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	3 910.3	3 059.8	1 602.7	1 237.2

Table C.29 **Net present value of costs (upper bound spectrum quantum)**
$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	5 241.7	4 545.1	3 035.9	2 201.3
Capital Expenditure				
NewSiteBuildMetro	46.0	41.1	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	804.3	758.2	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	120.6	113.7	33.1	0.0
Civil	14.2	13.4	13.8	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	527.1	558.8	381.6	134.9
RANMNO	0.0	35.5	146.0	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 211.1	2 121.1	1 453.1	983.9
Operating costs				
NewSiteBuildMetro	38.3	34.2	19.4	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	379.3	357.3	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	56.9	53.6	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	4.0	4.0	4.0	4.0
LMRIntegration	15.9	15.9	15.9	15.9
OSSBSS	39.7	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	16.7	68.7	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	681.7	425.9	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	681.7	608.4	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	3 030.6	2 424.0	1 582.8	1 217.4

Table C.30 **Net present value of costs (lower bound network capacity)**
$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	5 369.4	4 538.2	2 797.7	2 078.4
Capital Expenditure				
NewSiteBuildMetro	54.2	47.7	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	881.2	819.7	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	132.2	123.0	33.1	0.0
Civil	15.6	14.5	13.8	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	284.6	214.0	94.9
RANMNO	0.0	24.3	98.0	114.3
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 045.5	1 914.2	1 237.5	887.5
Operating costs				
NewSiteBuildMetro	45.2	39.7	19.4	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	415.9	386.6	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	62.4	58.0	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	4.0	4.0	4.0	4.0
LMRIntegration	15.9	15.9	15.9	15.9
OSSBSS	39.7	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	11.4	46.1	53.8
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	803.8	494.3	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	803.8	706.1	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	3 323.9	2 624.0	1 560.2	1 190.9

Table C.31 **Net present value of costs (upper bound network capacity)**
$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	10 462.0	8 246.7	3 564.1	2 776.0
Capital Expenditure				
NewSiteBuildMetro	161.3	130.1	26.8	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	1 879.5	1 588.0	254.5	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	281.9	238.2	38.2	0.0
Civil	33.5	28.2	14.4	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	340.5	395.3	295.2
RANMNO	0.0	91.8	386.7	452.4
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	3 318.5	3 017.2	1 751.1	1 425.9
Operating costs				
NewSiteBuildMetro	134.7	108.6	22.5	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	893.1	754.1	120.0	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	134.0	113.1	18.0	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	0.0	0.0	0.0	0.0
LMRIntegration	0.0	0.0	0.0	0.0
OSSBSS	4.0	4.0	4.0	4.0
Handset	15.9	15.9	15.9	15.9
RuggedisedHandset	39.7	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	43.2	182.0	212.9
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	2 394.5	1 351.7	456.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	2 394.5	1 931.0	400.1	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	7 143.5	5 229.4	1 813.0	1 350.0

Table C.32 **Net present value of costs (lower bound capacity growth)**
$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	5 662.8	4 770.1	2 863.8	2 154.0
Capital Expenditure				
NewSiteBuildMetro	60.5	52.7	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	952.4	876.6	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	142.9	131.5	33.1	0.0
Civil	16.7	15.3	13.8	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	29.0	118.4	138.3
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 134.7	2 000.8	1 293.7	951.5
Operating costs				
NewSiteBuildMetro	50.0	43.5	19.4	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	441.4	407.0	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	66.2	61.1	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	4.0	4.0	4.0	4.0
LMRIntegration	15.9	15.9	15.9	15.9
OSSBSS	39.7	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	13.7	56.0	65.4
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	888.9	541.9	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	888.9	774.2	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	3 528.1	2 769.3	1 570.1	1 202.5

Table C.33 **Net present value of costs (upper bound capacity growth)**
$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	7 442.8	6 060.8	3 018.0	2 322.2
Capital Expenditure				
NewSiteBuildMetro	98.6	82.4	23.5	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	1 246.2	1 107.2	222.4	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	186.9	166.1	33.4	0.0
Civil	23.0	20.3	13.8	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	52.0	217.0	253.7
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 517.1	2 323.6	1 395.1	1 067.0
Operating costs				
NewSiteBuildMetro	82.7	69.2	19.6	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	616.1	543.7	104.4	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	92.4	81.6	15.7	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	4.0	4.0	4.0	4.0
LMRIntegration	15.9	15.9	15.9	15.9
OSSBSS	39.7	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	24.2	101.0	118.1
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	1 470.9	860.9	420.0	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	1 470.9	1 229.9	348.1	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	4 925.7	3 737.3	1 622.9	1 255.2

Table C.34 **Net present value of costs (upper bound overflow)**
$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	6 151.7	4 609.7	2 923.8	2 201.3
Capital Expenditure				
NewSiteBuildMetro	70.7	46.0	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	1 034.8	804.3	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	120.6	33.1	0.0
Civil	18.3	14.2	13.8	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	336.3	256.2	134.9
RANMNO	0.0	86.0	155.1	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 241.4	2 008.0	1 336.8	983.9
Operating costs				
NewSiteBuildMetro	59.0	38.3	19.4	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	489.2	379.3	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	73.4	56.9	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	0.0	0.0	0.0	0.0
LMRIntegration	0.0	0.0	0.0	0.0
OSSBSS	4.0	4.0	4.0	4.0
Handset	15.9	15.9	15.9	15.9
RuggedisedHandset	39.7	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	40.5	73.0	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	1 048.1	477.2	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	1 048.1	681.7	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	3 910.3	2 601.7	1 587.1	1 217.4

C.9 Sensitivity testing

This section details the sensitivity testing that has been undertaken to understand how the results of the quantitative analysis change in response to changes in variables and assumptions.

There are a variety of approaches to sensitivity analysis (box C.7). Of these, the partial sensitivity analysis and a modified worst-case analysis were undertaken, on the basis of available information.

While a full risk analysis would provide more comprehensive results, its results would be largely driven by the probability distributions assigned to input values. In other words, the robustness of the analysis is dependent on the accuracy of the assumed distributions, for which data are lacking or insufficient in this case.

Box C.7 Approaches to sensitivity analysis

Depending on the nature and extent of the risk and uncertainty associated with a project, different approaches to sensitivity analysis could be used.

- *Worst-case scenario analysis*. The first step is to construct a hypothetical worst-case scenario by identifying the least favourable plausible outcome for each variable, and calculating results using those values.
- *Partial sensitivity analysis*. If there are a small number of key variables, an analysis of how the results are affected by changes in the most important variables may be sufficient.
- *Full risk analysis*. When there are many uncertain variables, it may be necessary to undertake a full risk analysis (using, for example, Monte Carlo simulation). This involves assigning probabilities to the values of all key variables and assigning covariances for pairs or sets of variables. A probability distribution of the results is then generated through random sampling of the values of the variables. This provides a comprehensive analysis of the potential variability of the results.

Sources: Department of Finance and Administration (2006); PC (2014b).

Partial sensitivity analysis

The partial sensitivity analysis varies the input value of one variable at a time, holding all other values constant. Eleven different variables are varied, using upper and lower bounds, yielding 21 sets of results.

This section presents the results of the partial sensitivity analysis, as follows:

- tables C.35 and C.36: lower and upper bound values for the discount rate
- tables C.37 and C.38: lower and upper bound values for the opportunity cost of spectrum
- tables C.39 and C.40: lower and upper bound values for the cost of site equipment
- tables C.41 and C.42: lower and upper bound values for the proportion of greenfield sites
- tables C.43 and C.44: lower and upper bound values for the cost of greenfield site builds
- tables C.45 and C.46: lower and upper bound values for the proportion of sites requiring civil hardening
- tables C.47 and C.48: lower and upper bound values for asset life span
- tables C.49 and C.50: lower and upper bound values for network operating costs
- tables C.51 and C.52: lower and upper bound values for site leasing costs
- tables C.53 and C.54: lower and upper bound values for backhaul rental costs.

Table C.35 **Net present value of costs (lower bound discount rate)**
$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	8 629.4	7 152.1	3 950.7	2 983.9
Capital Expenditure				
NewSiteBuildMetro	77.1	66.3	24.5	0.0
NewSiteBuildRegional	42.7	42.7	0.0	0.0
SiteEquipment	1 342.9	1 222.7	278.7	0.0
Battery20	0.0	0.0	92.9	128.8
Battery24	201.4	183.4	41.8	0.0
Civil	20.0	18.2	14.6	15.0
CoreNational	20.9	0.0	0.0	0.0
PreferentialAccess	10.4	10.4	10.4	10.4
LMRIntegration	41.7	41.7	41.7	41.7
OSSBSS	104.3	0.0	0.0	0.0
Handset	156.3	156.3	156.3	156.3
RuggedisedHandset	345.8	345.8	345.8	345.8
IVModem	207.5	207.5	207.5	207.5
Spectrum	292.6	327.7	277.4	149.8
RANMNO	0.0	44.3	182.6	213.4
CoreMNO	0.0	3.4	3.4	3.4
Total capital expenditure	2 863.5	2 670.4	1 677.6	1 272.2
Operating costs				
NewSiteBuildMetro	87.2	75.0	27.9	0.0
NewSiteBuildRegional	48.1	48.1	0.0	0.0
SiteEquipment	721.9	656.7	148.5	0.0
Battery20	0.0	0.0	49.6	68.8
Battery24	108.3	98.5	22.3	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	11.2	0.0	0.0	0.0
PreferentialAccess	5.6	5.6	5.6	5.6
LMRIntegration	22.3	22.3	22.3	22.3
OSSBSS	55.8	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	23.7	97.6	114.1
CoreMNO	0.0	1.8	1.8	1.8
BackhaulUrban	1 550.4	933.1	600.1	641.5
BackhaulRegional	1 069.8	748.9	802.2	857.6
SiteLeasingUrban	1 550.4	1 333.0	495.1	0.0
SiteLeasingRegional	534.9	534.9	0.0	0.0
Total operating costs	5 765.9	4 481.7	2 273.0	1 711.7

Table C.36 **Net present value of costs (upper bound discount rate)**
$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	4 604.5	3 864.7	2 240.8	1 706.2
Capital Expenditure				
NewSiteBuildMetro	64.1	55.2	21.6	0.0
NewSiteBuildRegional	36.0	36.0	0.0	0.0
SiteEquipment	823.0	750.1	180.0	0.0
Battery20	0.0	0.0	61.4	85.2
Battery24	123.5	112.5	27.0	0.0
Civil	16.7	15.2	12.9	13.6
CoreNational	14.1	0.0	0.0	0.0
PreferentialAccess	7.1	7.1	7.1	7.1
LMRIntegration	28.3	28.3	28.3	28.3
OSSBSS	70.7	0.0	0.0	0.0
Handset	81.9	81.9	81.9	81.9
RuggedisedHandset	194.0	194.0	194.0	194.0
IVModem	116.4	116.4	116.4	116.4
Spectrum	238.0	266.5	225.6	121.8
RANMNO	0.0	29.4	121.2	141.6
CoreMNO	0.0	2.3	2.3	2.3
Total capital expenditure	1 813.7	1 694.9	1 079.6	792.2
Operating costs				
NewSiteBuildMetro	41.9	36.1	14.2	0.0
NewSiteBuildRegional	23.5	23.5	0.0	0.0
SiteEquipment	348.8	317.7	75.7	0.0
Battery20	0.0	0.0	25.9	35.9
Battery24	52.3	47.6	11.4	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	6.0	0.0	0.0	0.0
PreferentialAccess	0.0	0.0	0.0	0.0
LMRIntegration	0.0	0.0	0.0	0.0
OSSBSS	3.0	3.0	3.0	3.0
Handset	11.9	11.9	11.9	11.9
RuggedisedHandset	29.9	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	12.4	51.1	59.7
CoreMNO	0.0	1.0	1.0	1.0
BackhaulUrban	745.7	449.2	305.8	343.4
BackhaulRegional	521.4	365.0	408.8	459.0
SiteLeasingUrban	745.7	641.7	252.3	0.0
SiteLeasingRegional	260.7	260.7	0.0	0.0
Total operating costs	2 790.8	2 169.8	1 161.2	914.0

Table C.37 **Net present value of costs (lower bound opportunity cost of spectrum)**

$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	6 019.9	4 984.9	2 779.2	2 133.8
Capital Expenditure				
NewSiteBuildMetro	70.7	60.8	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	1 034.8	942.6	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	18.3	16.7	13.8	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	131.8	147.6	124.9	67.5
RANMNO	0.0	35.5	146.0	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 109.6	1 945.0	1 196.4	916.4
Operating costs				
NewSiteBuildMetro	59.0	50.7	19.4	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	489.2	445.2	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	73.4	66.8	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	4.0	4.0	4.0	4.0
LMRIntegration	15.9	15.9	15.9	15.9
OSSBSS	39.7	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	16.7	68.7	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	1 048.1	631.1	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	1 048.1	901.5	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	3 910.3	3 039.9	1 582.8	1 217.4

Table C.38 **Net present value of costs (upper bound opportunity cost of spectrum)**

$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	6 241.3	5 232.9	2 989.1	2 247.1
Capital Expenditure				
NewSiteBuildMetro	70.7	60.8	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	1 034.8	942.6	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	18.3	16.7	13.8	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	353.2	395.6	334.8	180.8
RANMNO	0.0	35.5	146.0	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 331.0	2 193.0	1 406.3	1 029.8
Operating costs				
NewSiteBuildMetro	59.0	50.7	19.4	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	489.2	445.2	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	73.4	66.8	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	4.0	4.0	4.0	4.0
LMRIntegration	15.9	15.9	15.9	15.9
OSSBSS	39.7	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	16.7	68.7	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	1 048.1	631.1	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	1 048.1	901.5	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	3 910.3	3 039.9	1 582.8	1 217.4

Table C.39 **Net present value of costs (lower bound cost of site equipment)**

$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	5 580.2	4 592.5	2 702.2	2 201.3
Capital Expenditure				
NewSiteBuildMetro	70.7	60.8	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	646.7	589.1	137.7	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	18.3	16.7	13.8	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	22.2	91.3	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	1 853.4	1 725.8	1 183.9	983.9
Operating costs				
NewSiteBuildMetro	59.0	50.7	19.4	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	305.7	278.3	64.6	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	73.4	66.8	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	4.0	4.0	4.0	4.0
LMRIntegration	15.9	15.9	15.9	15.9
OSSBSS	39.7	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	10.4	43.0	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	1 048.1	631.1	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	1 048.1	901.5	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	3 726.9	2 866.7	1 518.3	1 217.4

Table C.40 **Net present value of costs (upper bound cost of site equipment)**

$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	6 913.7	5 852.5	3 173.3	2 201.3
Capital Expenditure				
NewSiteBuildMetro	70.7	60.8	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	1 552.2	1 413.9	330.5	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	18.3	16.7	13.8	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	53.2	219.1	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 758.8	2 581.7	1 504.5	983.9
Operating costs				
NewSiteBuildMetro	59.0	50.7	19.4	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	733.8	667.9	155.0	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	73.4	66.8	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	4.0	4.0	4.0	4.0
LMRIntegration	15.9	15.9	15.9	15.9
OSSBSS	39.7	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	25.0	103.1	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	1 048.1	631.1	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	1 048.1	901.5	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	4 154.9	3 270.9	1 668.8	1 217.4

Table C.41 **Net present value of costs (lower bound proportion of greenfield site builds)**

$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	5 949.9	4 948.8	2 861.7	2 201.3
Capital Expenditure				
NewSiteBuildMetro	0.0	0.0	0.0	0.0
NewSiteBuildRegional	0.0	0.0	0.0	0.0
SiteEquipment	1 034.8	942.6	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	18.3	16.7	13.8	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	35.5	146.0	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 131.3	1 992.4	1 298.3	983.9
Operating costs				
NewSiteBuildMetro	0.0	0.0	0.0	0.0
NewSiteBuildRegional	0.0	0.0	0.0	0.0
SiteEquipment	489.2	445.2	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	73.4	66.8	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	4.0	4.0	4.0	4.0
LMRIntegration	15.9	15.9	15.9	15.9
OSSBSS	39.7	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	16.7	68.7	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	1 048.1	631.1	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	1 048.1	901.5	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	3 818.6	2 956.4	1 563.4	1 217.4

Table C.42 **Net present value of costs (upper bound proportion of greenfield site builds)**

$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	6 555.3	5 499.9	2 988.9	2 201.3
Capital Expenditure				
NewSiteBuildMetro	212.0	182.4	69.1	0.0
NewSiteBuildRegional	118.2	118.2	0.0	0.0
SiteEquipment	1 034.8	942.6	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	18.3	16.7	13.8	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	35.5	146.0	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 461.6	2 293.0	1 367.4	983.9
Operating costs				
NewSiteBuildMetro	176.9	152.1	58.1	0.0
NewSiteBuildRegional	98.3	98.3	0.0	0.0
SiteEquipment	489.2	445.2	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	73.4	66.8	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	4.0	4.0	4.0	4.0
LMRIntegration	15.9	15.9	15.9	15.9
OSSBSS	39.7	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	16.7	68.7	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	1 048.1	631.1	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	1 048.1	901.5	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	4 093.8	3 206.9	1 621.5	1 217.4

Table C.43 **Net present value of costs (lower bound cost of greenfield site builds)**

$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	6 050.8	5 040.7	2 882.9	2 201.3
Capital Expenditure				
NewSiteBuildMetro	35.3	30.4	11.5	0.0
NewSiteBuildRegional	19.7	19.7	0.0	0.0
SiteEquipment	1 034.8	942.6	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	18.3	16.7	13.8	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	35.5	146.0	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 186.4	2 042.5	1 309.8	983.9
Operating costs				
NewSiteBuildMetro	29.5	25.4	9.7	0.0
NewSiteBuildRegional	16.4	16.4	0.0	0.0
SiteEquipment	489.2	445.2	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	73.4	66.8	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	0.0	0.0	0.0	0.0
LMRIntegration	0.0	0.0	0.0	0.0
OSSBSS	4.0	4.0	4.0	4.0
Handset	15.9	15.9	15.9	15.9
RuggedisedHandset	39.7	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	16.7	68.7	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	1 048.1	631.1	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	1 048.1	901.5	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	3 864.4	2 998.1	1 573.1	1 217.4

Table C.44 **Net present value of costs (upper bound cost of greenfield site builds)**

$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	6 286.3	5 255.0	2 932.4	2 201.3
Capital Expenditure				
NewSiteBuildMetro	117.8	101.4	38.4	0.0
NewSiteBuildRegional	65.7	65.7	0.0	0.0
SiteEquipment	1 034.8	942.6	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	18.3	16.7	13.8	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	35.5	146.0	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 314.8	2 159.4	1 336.7	983.9
Operating costs				
NewSiteBuildMetro	98.3	84.5	32.3	0.0
NewSiteBuildRegional	54.6	54.6	0.0	0.0
SiteEquipment	489.2	445.2	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	73.4	66.8	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	4.0	4.0	4.0	4.0
LMRIntegration	15.9	15.9	15.9	15.9
OSSBSS	39.7	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	16.7	68.7	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	1 048.1	631.1	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	1 048.1	901.5	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	3 971.5	3 095.5	1 595.7	1 217.4

Table C.45 **Net present value of costs (lower bound proportion of sites requiring civil hardening)**

$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	6 133.4	5 115.8	2 890.4	2 187.0
Capital Expenditure				
NewSiteBuildMetro	70.7	60.8	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	1 034.8	942.6	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	35.5	146.0	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 223.1	2 075.9	1 307.6	969.6
Operating costs				
NewSiteBuildMetro	59.0	50.7	19.4	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	489.2	445.2	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	73.4	66.8	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	4.0	4.0	4.0	4.0
LMRIntegration	15.9	15.9	15.9	15.9
OSSBSS	39.7	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	16.7	68.7	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	1 048.1	631.1	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	1 048.1	901.5	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	3 910.3	3 039.9	1 582.8	1 217.4

Table C.46 **Net present value of costs (upper bound proportion of sites requiring civil hardening)**

$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	6 170.1	5 149.2	2 917.9	2 215.6
Capital Expenditure				
NewSiteBuildMetro	70.7	60.8	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	1 034.8	942.6	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	36.7	33.4	27.5	28.6
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	35.5	146.0	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 259.8	2 109.3	1 335.1	998.2
Operating costs				
NewSiteBuildMetro	59.0	50.7	19.4	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	489.2	445.2	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	73.4	66.8	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	0.0	0.0	0.0	0.0
LMRIntegration	0.0	0.0	0.0	0.0
OSSBSS	4.0	4.0	4.0	4.0
Handset	15.9	15.9	15.9	15.9
RuggedisedHandset	39.7	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	16.7	68.7	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	1 048.1	631.1	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	1 048.1	901.5	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	3 910.3	3 039.9	1 582.8	1 217.4

Table C.47 **Net present value of costs (lower bound asset life span)**
$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	6 433.4	5 376.0	3 003.0	2 253.7
Capital Expenditure				
NewSiteBuildMetro	70.7	60.8	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	1 281.0	1 167.0	272.8	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	18.3	16.7	13.8	14.3
CoreNational	21.0	0.0	0.0	0.0
PreferentialAccess	10.5	10.5	10.5	10.5
LMRIntegration	42.1	42.1	42.1	42.1
OSSBSS	105.1	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	44.2	182.0	212.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 523.1	2 336.1	1 420.2	1 036.3
Operating costs				
NewSiteBuildMetro	59.0	50.7	19.4	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	489.2	445.2	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	73.4	66.8	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	4.0	4.0	4.0	4.0
LMRIntegration	15.9	15.9	15.9	15.9
OSSBSS	39.7	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	16.7	68.7	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	1 048.1	631.1	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	1 048.1	901.5	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	3 910.3	3 039.9	1 582.8	1 217.4

Table C.48 **Net present value of costs (upper bound asset life span)**
$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	5 967.2	4 973.1	2 837.7	2 166.8
Capital Expenditure				
NewSiteBuildMetro	70.7	60.8	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	873.7	795.8	184.4	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	18.3	16.7	13.8	14.3
CoreNational	14.1	0.0	0.0	0.0
PreferentialAccess	7.0	7.0	7.0	7.0
LMRIntegration	28.2	28.2	28.2	28.2
OSSBSS	70.5	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	29.8	122.5	143.1
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 056.9	1 933.2	1 255.0	949.4
Operating costs				
NewSiteBuildMetro	59.0	50.7	19.4	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	489.2	445.2	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	73.4	66.8	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	4.0	4.0	4.0	4.0
LMRIntegration	15.9	15.9	15.9	15.9
OSSBSS	39.7	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	16.7	68.7	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	1 048.1	631.1	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	1 048.1	901.5	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	3 910.3	3 039.9	1 582.8	1 217.4

Table C.49 **Net present value of costs (lower bound network operating costs)**

$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	5 911.1	4 921.4	2 816.5	2 151.3
Capital Expenditure				
NewSiteBuildMetro	70.7	60.8	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	1 034.8	942.6	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	18.3	16.7	13.8	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	35.5	146.0	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 241.4	2 092.6	1 321.3	983.9
Operating costs				
NewSiteBuildMetro	39.3	33.8	12.9	0.0
NewSiteBuildRegional	21.8	21.8	0.0	0.0
SiteEquipment	326.1	296.8	68.9	0.0
Battery20	0.0	0.0	23.3	32.3
Battery24	48.9	44.5	10.3	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	5.3	0.0	0.0	0.0
PreferentialAccess	0.0	0.0	0.0	0.0
LMRIntegration	0.0	0.0	0.0	0.0
OSSBSS	2.6	2.6	2.6	2.6
Handset	10.6	10.6	10.6	10.6
RuggedisedHandset	26.5	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	11.1	45.8	53.5
CoreMNO	0.0	0.9	0.9	0.9
BackhaulUrban	1 048.1	631.1	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	1 048.1	901.5	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	3 669.7	2 828.8	1 495.1	1 167.4

Table C.50 **Net present value of costs (upper bound network operating costs)**

$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	6 392.3	5 343.6	2 991.8	2 251.2
Capital Expenditure				
NewSiteBuildMetro	70.7	60.8	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	1 034.8	942.6	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	18.3	16.7	13.8	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	35.5	146.0	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 241.4	2 092.6	1 321.3	983.9
Operating costs				
NewSiteBuildMetro	78.6	67.6	25.8	0.0
NewSiteBuildRegional	43.7	43.7	0.0	0.0
SiteEquipment	652.3	593.7	137.8	0.0
Battery20	0.0	0.0	46.5	64.5
Battery24	97.8	89.0	20.7	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	10.6	0.0	0.0	0.0
PreferentialAccess	5.3	5.3	5.3	5.3
LMRIntegration	21.2	21.2	21.2	21.2
OSSBSS	53.0	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	22.3	91.6	107.1
CoreMNO	0.0	1.7	1.7	1.7
BackhaulUrban	1 048.1	631.1	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	1 048.1	901.5	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	4 150.9	3 251.0	1 670.5	1 267.3

Table C.51 **Net present value of costs (lower bound site leasing costs)**
$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	5 816.9	4 834.3	2 818.0	2 201.3
Capital Expenditure				
NewSiteBuildMetro	70.7	60.8	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	1 034.8	942.6	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	18.3	16.7	13.8	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	35.5	146.0	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 241.4	2 092.6	1 321.3	983.9
Operating costs				
NewSiteBuildMetro	59.0	50.7	19.4	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	489.2	445.2	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	73.4	66.8	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	4.0	4.0	4.0	4.0
LMRIntegration	15.9	15.9	15.9	15.9
OSSBSS	39.7	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	16.7	68.7	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	1 048.1	631.1	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	786.0	676.2	258.3	0.0
SiteLeasingRegional	291.3	291.3	0.0	0.0
Total operating costs	3 575.5	2 741.7	1 496.7	1 217.4

Table C.52 **Net present value of costs (upper bound site leasing costs)**
$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	6 632.2	5 576.4	2 990.2	2 201.3
Capital Expenditure				
NewSiteBuildMetro	70.7	60.8	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	1 034.8	942.6	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	18.3	16.7	13.8	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	35.5	146.0	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 241.4	2 092.6	1 321.3	983.9
Operating costs				
NewSiteBuildMetro	59.0	50.7	19.4	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	489.2	445.2	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	73.4	66.8	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	4.0	4.0	4.0	4.0
LMRIntegration	15.9	15.9	15.9	15.9
OSSBSS	39.7	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	16.7	68.7	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	1 048.1	631.1	417.4	456.8
BackhaulRegional	728.2	509.8	558.0	610.7
SiteLeasingUrban	1 310.1	1 126.9	430.5	0.0
SiteLeasingRegional	582.6	582.6	0.0	0.0
Total operating costs	4 390.8	3 483.7	1 668.9	1 217.4

Table C.53 **Net present value of costs (lower bound backhaul costs)**
$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	5 744.1	4 872.8	2 688.2	1 964.9
Capital Expenditure				
NewSiteBuildMetro	70.7	60.8	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	1 034.8	942.6	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	18.3	16.7	13.8	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	35.5	146.0	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 241.4	2 092.6	1 321.3	983.9
Operating costs				
NewSiteBuildMetro	59.0	50.7	19.4	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	489.2	445.2	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	73.4	66.8	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	4.0	4.0	4.0	4.0
LMRIntegration	15.9	15.9	15.9	15.9
OSSBSS	39.7	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	16.7	68.7	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	786.0	473.3	313.0	342.6
BackhaulRegional	582.6	407.8	446.4	488.6
SiteLeasingUrban	1 048.1	901.5	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	3 502.6	2 780.2	1 366.8	981.0

Table C.54 **Net present value of costs (upper bound backhaul costs)**
$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	6 559.4	5 392.2	3 120.1	2 437.6
Capital Expenditure				
NewSiteBuildMetro	70.7	60.8	23.0	0.0
NewSiteBuildRegional	39.4	39.4	0.0	0.0
SiteEquipment	1 034.8	942.6	220.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	18.3	16.7	13.8	14.3
CoreNational	16.9	0.0	0.0	0.0
PreferentialAccess	8.4	8.4	8.4	8.4
LMRIntegration	33.7	33.7	33.7	33.7
OSSBSS	84.3	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	263.6	295.2	249.9	134.9
RANMNO	0.0	35.5	146.0	170.6
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	2 241.4	2 092.6	1 321.3	983.9
Operating costs				
NewSiteBuildMetro	59.0	50.7	19.4	0.0
NewSiteBuildRegional	32.8	32.8	0.0	0.0
SiteEquipment	489.2	445.2	103.3	0.0
Battery20	0.0	0.0	34.9	48.4
Battery24	73.4	66.8	15.5	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	7.9	0.0	0.0	0.0
PreferentialAccess	4.0	4.0	4.0	4.0
LMRIntegration	15.9	15.9	15.9	15.9
OSSBSS	39.7	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	16.7	68.7	80.3
CoreMNO	0.0	1.3	1.3	1.3
BackhaulUrban	1 310.1	788.9	521.7	571.0
BackhaulRegional	873.9	611.7	669.6	732.8
SiteLeasingUrban	1 048.1	901.5	344.4	0.0
SiteLeasingRegional	364.1	364.1	0.0	0.0
Total operating costs	4 318.0	3 299.6	1 798.7	1 453.7

Best and worst case scenario analysis

The best and worst case scenario analysis were conducted by varying multiple variables simultaneously, holding all other inputs constant. These variables are:

- the opportunity cost of spectrum
- the cost of site equipment
- the number greenfield sites
- the cost of greenfield site builds
- the proportion of sites requiring civil hardening
- asset life span
- network operating costs
- site leasing costs
- backhaul transmission costs.

The results of the best and worst case scenario analysis are presented in tables C.55 and C.56 respectively.

Table C.55 **Net present value of costs (best case scenario)**

$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	4 212.8	3 458.8	2 115.3	1 725.0
Capital Expenditure				
NewSiteBuildMetro	0.0	0.0	0.0	0.0
NewSiteBuildRegional	0.0	0.0	0.0	0.0
SiteEquipment	546.1	497.4	115.3	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	14.1	0.0	0.0	0.0
PreferentialAccess	7.0	7.0	7.0	7.0
LMRIntegration	28.2	28.2	28.2	28.2
OSSBSS	70.5	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	131.8	147.6	124.9	67.5
RANMNO	0.0	18.6	76.5	89.4
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	1 469.0	1 359.1	978.2	814.0
Operating costs				
NewSiteBuildMetro	0.0	0.0	0.0	0.0
NewSiteBuildRegional	0.0	0.0	0.0	0.0
SiteEquipment	203.8	185.5	43.1	0.0
Battery20	0.0	0.0	23.3	32.3
Battery24	48.9	44.5	10.3	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	5.3	0.0	0.0	0.0
PreferentialAccess	2.6	2.6	2.6	2.6
LMRIntegration	10.6	10.6	10.6	10.6
OSSBSS	26.5	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	7.0	28.6	33.5
CoreMNO	0.0	0.9	0.9	0.9
BackhaulUrban	786.0	473.3	313.0	342.6
BackhaulRegional	582.6	407.8	446.4	488.6
SiteLeasingUrban	786.0	676.2	258.3	0.0
SiteLeasingRegional	291.3	291.3	0.0	0.0
Total operating costs	2 743.7	2 099.7	1 137.1	911.0

Table C.56 **Net present value of costs (worst case scenario)**
$m

	Option 1	*Option 2*	*Option 3*	*Option 4*
Total costs				
Total	9 566.3	8 167.4	4 028.9	2 760.1
Capital Expenditure				
NewSiteBuildMetro	353.4	304.1	115.1	0.0
NewSiteBuildRegional	197.0	197.0	0.0	0.0
SiteEquipment	1 921.6	1 750.4	409.2	0.0
Battery20	0.0	0.0	74.2	103.0
Battery24	155.2	141.4	33.1	0.0
Civil	36.7	33.4	27.5	28.6
CoreNational	21.0	0.0	0.0	0.0
PreferentialAccess	10.5	10.5	10.5	10.5
LMRIntegration	42.1	42.1	42.1	42.1
OSSBSS	105.1	0.0	0.0	0.0
Handset	110.5	110.5	110.5	110.5
RuggedisedHandset	253.5	253.5	253.5	253.5
IVModem	152.1	152.1	152.1	152.1
Spectrum	353.2	395.6	334.8	180.8
RANMNO	0.0	66.3	273.0	319.0
CoreMNO	0.0	2.8	2.8	2.8
Total capital expenditure	3 711.9	3 459.6	1 838.4	1 202.8
Operating costs				
NewSiteBuildMetro	393.0	338.1	129.2	0.0
NewSiteBuildRegional	218.5	218.5	0.0	0.0
SiteEquipment	978.4	890.5	206.6	0.0
Battery20	0.0	0.0	46.5	64.5
Battery24	97.8	89.0	20.7	0.0
Civil	0.0	0.0	0.0	0.0
CoreNational	10.6	0.0	0.0	0.0
PreferentialAccess	5.3	5.3	5.3	5.3
LMRIntegration	21.2	21.2	21.2	21.2
OSSBSS	53.0	0.0	0.0	0.0
Handset	0.0	0.0	0.0	0.0
RuggedisedHandset	0.0	0.0	0.0	0.0
IVModem	0.0	0.0	0.0	0.0
Spectrum	0.0	0.0	0.0	0.0
RANMNO	0.0	33.4	137.4	160.6
CoreMNO	0.0	1.7	1.7	1.7
BackhaulUrban	1 310.1	788.9	521.7	571.0
BackhaulRegional	873.9	611.7	669.6	732.8
SiteLeasingUrban	1 310.1	1 126.9	430.5	0.0
SiteLeasingRegional	582.6	582.6	0.0	0.0
Total operating costs	5 854.4	4 707.8	2 190.5	1 557.2

C.10 Excluded costs

Certain costs are excluded from the quantitative analysis. Generally, this is because there is insufficient information by which to assess the magnitude of these costs or whether the costs would be realised, or because these costs are unlikely to vary significantly between options. It is likely that many of these costs will be substantial but, given the limitations of this study, are very difficult to assess or would be unlikely to alter the ranking of options.

Alternative or supplementary technologies

The cost of alternative or supplementary communication technologies, such as deployables, satellite technology and other non-permanent networks, have not been included in the quantitative analysis. In general, these solutions are used to provide coverage or additional capacity in exceptional circumstances where the permanent RAN network is absent or insufficient. Consequently, the demand for these technologies depends crucially on the frequency, magnitude and location of peaks in traffic demand, for which empirical evidence and robust forecasts are virtually nonexistent.

Moreover, given that, by construction, the permanent network under all options delivers the same baseline level of capacity and coverage, it is unlikely that the cost of alternative or supplementary networks would vary significantly between options from the community's perspective (the costs to specific parties, such as mobile carriers and PSAs, could differ).

Value of spectrum sharing

As discussed above, some options include a dedicated network, which must be supported by dedicated spectrum. In these cases, the opportunity cost for that spectrum comprises part of the total cost of the network.

However, under some options (namely, the hybrid and dedicated options) there is scope for this cost to be mitigated if that spectrum is shared with other users. For example, in periods of low PSA traffic, the spectrum could be used to carry commercial traffic.

In the absence of reliable traffic forecasts for PSAs and detailed information relating to other traffic, it is impossible to predict how much excess capacity there would be in the dedicated spectrum bands, and to what extent that capacity could usefully be shared with other mobile broadband users.

Cost of developing applications

Under all options, the use of the PSMB network will require the development of new applications that meet PSA requirements, including standards relating to security and

interoperability. These costs are likely to be similar under all options and therefore have not been accounted for in the quantitative analysis.

Common organisational-level costs

Common organisational-level costs have been omitted from the estimation of costs. These refer to costs that are common to all areas of a mobile carrier's business, such as management salaries, head-office administration, the cost of operating data centres and backend IT systems.

For mobile carrier networks, these costs are likely to be largely invariant to additional traffic (Ofcom 2006). As a result, the incremental cost of adding PSAs to the network will likely be close to zero. By contrast, some of these costs will form part of the incremental costs of a dedicated network. For example, the cost of establishing a head office will be incurred anew.

However, on a practical level, estimating these costs is difficult due to the lack of publically available data relating to the materiality of these costs. Nevertheless, it is likely that the inclusion of these costs would not change the relative rankings of different delivery options and, if anything, would magnify the cost differences between different options.

Costs of trunk backhaul transmission (including inter-capital transmission)

As noted in section C.5, a simplified approach has been taken to estimating backhaul costs via a representative per-site cost that captures backhaul capacity from each mobile site back to some point of aggregation, based on assumptions about the average distance and level of capacity required. These estimates also factor in an annualised cost for new backhaul links for a proportion of sites to increase the level of geographic diversity.

Some costs associated with backhaul capacity (such as trunk backhaul between major regional centres, and inter-capital transmission) may not be captured by these cost estimates. Given the level of uncertainty associated with how a carrier would structure the topology of its network to deliver a PSMB capability, the analysis has not sought to include these costs explicitly.

Cost of change

The costs of transitioning from current PSA networks to PSMB has been excluded from the quantitative analysis. These costs include the cost of instituting regulatory and governance arrangements, the transaction costs associated with tendering and procurement, and the opportunity cost of developing or changing PSA protocols and practices, including training and other change management.

For the most part, these costs are intangible and hence inherently difficult to quantify. Moreover, these costs are likely to be, in broad terms, common across the delivery options and there is scant evidence as to how these might differ quantitatively between the options.

Externality effects

Except to the extent discussed in this appendix, the external costs and benefits of providing a PSMB capability via different options have been excluded. These include any deterioration in service quality or congestion experienced by commercial mobile broadband customers as a result of adding PSA users to commercial networks. They also include any spillover benefits these customers might experience as a result of upgrades made to commercial networks.

Coverage beyond the commercial carrier footprint

A number of participants submitted that a PSMB capability should, at a minimum, provide an equivalent level of coverage as existing LMR networks. However, as noted in chapter 5 (and earlier in this appendix), the quantitative evaluation in this study focuses on a coverage area roughly equivalent to the footprint of commercial mobile carrier networks.

This is because providing coverage beyond the commercial mobile carrier footprint will require greenfield site builds under all options; therefore, the cost of these extensions is likely to be invariant between options. Moreover, a lack of public information on the coverage footprints of LMR and carrier networks means that it is not possible to robustly estimate the costs of deploying a PSMB capability with an equivalent level of coverage as LMR networks across Australia.

However, using the data available, the Commission has undertaken a limited 'back of the envelope' analysis of how costs would change if the coverage area of the network were extended to match the LMR footprint in Victoria (box C.8). Ultimately, the costs of extending a PSMB capability to areas outside the coverage of mobile carrier networks will depend on the size of the coverage gap between LMR and mobile carrier networks, and on the nature of the geographic areas covered — for example, mountainous areas would have a high cost per square kilometre.

Cost savings from retiring LMR networks

Some participants have indicated that the deployment of a PSMB capability will lead to cost savings as a result of retiring LMR networks (chapter 6). These cost savings have not been incorporated as part of the quantitative analysis for three reasons.

- It is unclear whether or to what extent cost savings from retiring LMR networks will be realised. In particular, states may continue to operate LMR networks until the end of their economic life, especially if the gap between LMR and PSMB coverage is large.
- It is unclear how these cost savings would differ between options. While it is possible that LMR networks could be decommissioned over different timeframes under different options, there is little evidence to indicate what these timeframes are likely to be.
- The terms of reference direct the Commission to consider the best way to deliver a PSMB capability specifically. As such, the Commission's quantitative analysis has not attempted to evaluate the optimal mix of inputs (including communications capabilities) to support PSA operations generally.

Box C.8 Replicating LMR coverage in Victoria

The Commission has developed a 'back of the envelope' calculation of the costs of deploying an LTE network in Victoria to areas within the LMR coverage footprint that are not covered by mobile carrier networks (the 'coverage gap'). This was done based on information provided by the Victorian Government (sub. DR44) relating to the coverage of, and coverage gap between, LMR and mobile carrier networks in Victoria and New South Wales.

The Commission estimates that the costs of providing a mobile broadband capability in the 'coverage gap' would be in the order of 1.15 to 1.8 times more costly than the cost of deploying a PSMB capability in areas of Victoria within the mobile carrier footprint. This is based on a number of key assumptions outlined in the table below.

Parameter	*Range of vales*
Cell radius	10–17 km
Proportion of new sites	50%–90%
New site costs	$300 000-$500 000
Site equipment costs	$80 000
Battery backup (applied to all sites)	$12 000
Civil upgrade (applied to 5 per cent of sites)	$50 000
Site leasing (per annum)	$20 000
Backhaul costs (per annum)	$25 000–$60 000
Network operating costs (percentage of capital costs)	7.5%
Rollout period	2 years

Importantly, the analysis did not assume a particular quality of service and thus cannot be characterised as a public safety grade service. In this sense, the estimated cost increase should be interpreted as a lower bound for the costs of delivering a PSMB capability in those areas.

Moreover, the Commission believes that the costs of matching LMR coverage in most other jurisdictions would be significantly higher than in Victoria, due to its relatively small landmass and the difference between the level of coverage of LMR and commercial mobile carrier networks. For example, the Victorian Government indicated that the coverage gap in New South Wales was an area of about 280 000 km^2, almost 8 times larger than the coverage gap in Victoria.

D Referee report

The Commission engaged Network Strategies Limited to review the quantitative analysis presented in the Commission's draft report. Network Strategies Limited presented the following report to the Commission in November 2015.

Executive summary

The Productivity Commission has been tasked with assessing the most efficient and economical way to deliver a public safety mobile broadband (PSMB) capability to Australia's public safety agencies. To that end, the Commission has developed a methodology and model for comparing the costs of different PSMB delivery options.

The approach used by the Commission in its quantitative framework is consistent with methodologies used for high-level cost models of mobile networks, and is suitable for assessing the relative costs of the various PSMB options.

For this type of analysis the emphasis should be on those costs which differ between the options – it is less important to address those costs which are constant across all options or are not significantly different. The Commission has identified several of these costs and has excluded them from consideration (such as the cost associated with developing PSMB applications) or has used a relatively rough cost estimate (such as the cost of user devices).

We found that in general the Commission's model inputs and assumptions are reasonable for Australian conditions and for the objective of its study. In some instances we have recommended certain inputs and assumptions be reviewed or should be assessed via sensitivity testing. These factors include spectral efficiency, asset lifetimes and unit costs of some network elements. We also suggest that the Commission's report could be strengthened through additional background information on some inputs and assumptions.

The Commission's approach has also been influenced by the information available. Some key inputs – such as traffic demand – are extremely uncertain due to the current lack of PSMB applications and comparable networks. In such instances sensitivity testing is crucial to assess whether the relative costs are affected by the assumed inputs.

1 Introduction

The Productivity Commission is currently undertaking a study into the most efficient and economical way to deliver a public safety mobile broadband (PSMB) capability to Australia's public safety agencies. In its recently released draft report[2] , the Commission compared the costs of different PSMB delivery options, with the analysis based on an economic framework and model developed by the Commission.

The aim of this review is to report on Appendix C of the draft report, Public Safety Mobile Broadband. The report has been prepared for inclusion in the Commission's final report. The assessment addresses:

- the fitness for purpose of the approaches used
- any major omissions from the Commission's analysis
- the clarity of the Commission's exposition
- any other comments that would improve the quality of the appendix.

This review is limited to the Commission's framework, inputs and assumptions. Assessment of the model code and resultant estimates is beyond the scope of this assignment.

Following this Introduction, our report encompasses:

- an overview of the objective for the Commission's analysis (Section 2)
- geotyping (Section 3)
- radio access network dimensioning (Section 4)
- network costing (Section 5)
- excluded costs (Section 6)
- concluding remarks (Section 7).

Although this report was commissioned by the Commission the views expressed here are entirely our own.

2 Background

As noted in the Commission's draft report, a robust and effective mobile broadband capability is a critical enabler for Australia's public safety agencies (PSAs).

Delivering a PSMB capability is complex and involves using scarce and valuable resources, such as radiocommunications spectrum, to further the public interest. To inform

2 Productivity Commission (2015), *Public Safety Mobile Broadband*, draft report, September 2015.

this work and ensure the best path forward, the Commonwealth considers it appropriate to undertake a rigorous analysis of the most efficient, effective and economical means of developing Australia's PSMB capability[3].

In its Terms of Reference, the Commission is required to undertake a 'first principles' analysis of the most efficient, effective and economical way of delivering this capability by 2020, to coincide with the nationally agreed framework to improve government radio communications, including interoperability.

Four specific options for delivering a PSMB capability in areas of Australia where there is existing commercial mobile coverage were investigated:

- **dedicated PSMB capability** – PSAs have access to and control over their own PSMB network and spectrum
- **commercial approach** – PSAs obtain a PSMB service from one or more commercial operators via a contract for service
- **full coverage hybrid approach** – PSAs have a dedicated PSMB network covering the entire commercial mobile network footprint and their own spectrum, plus are able to utilise additional public safety grade network capacity on one or more commercial carrier networks on a preferential basis
- **partial coverage hybrid approach** – PSAs have a dedicated PSMB network covering only metropolitan areas, and their own spectrum. One or more commercial carriers will supply some capacity needs in metropolitan areas (if the dedicated PSMB network is fully utilised), and outside metropolitan areas PSAs would rely on one or more commercial operators for both coverage and capacity.

The Commission notes that there are some areas of Australia that do not have commercial mobile network coverage. It is assumed that the dedicated PSMB network would utilise spectrum in the lower 800MHz band (10MHz of spectrum in this band is being considered for allocation to PSMB use, although a final decision has not yet been made).

The assessment of network costs is based on the incremental opportunity costs for each option, estimated via a bottom-up cost model of the value of the next best alternative use of these resources. The objective of this analysis is to provide indicative cost differences between the various options and to understand the drivers of those differences.

3 Geotyping

Geotyping is a common approach for use in techno-economic modelling of telecommunications networks, both in Australia and worldwide. This enables the model to

3 *Ibid*, page iv.

categorise geographic areas such that areas with similar characteristics – with respect to relevant cost drivers – are grouped into 'geotypes'.

The approach adopted by the Commission, whereby geotypes are defined based on population density, is also commonly used for modelling mobile networks. Furthermore, the five geotypes selected by the Commission – dense urban, urban, suburban, rural and remote – are representative of the categories typically selected in Australian mobile models.

Statistical Area Level 2 (SA2) is a reasonable basis for defining the geotypes as the minimum block size is no smaller than the cell coverage area. It may be helpful to include more detail on the range in size of SA2 blocks by geotype – Box C.1 lists the maximum and minimum size across all geotypes, however this spans an extremely wide range. The comparison of block size against cell size is possibly most relevant for the dense urban, urban and suburban geotypes, as rural and remote block sizes are likely to be many times greater than cell sizes.

In the example in Box C.2 there is a mismatch between the population quoted in the text (3000) and that shown in the diagram (3500).

4 RAN dimensioning

The model's approach for dimensioning the radio access network (RAN) uses two methods, depending on the geotype of the area. For dense urban, urban and suburban geotypes, the number of sites is determined using a bottom-up approach which estimates, for each combination of state / territory and geotype ('state-geotype class'), the number of sites necessary for providing coverage ('coverage sites') and the number of additional sites for capacity requirements ('capacity sites').

In the case of rural and remote areas – where the population distribution, and thus by extension the traffic distribution, is non-uniform – the number of sites is estimated by reference to the number of existing 3G sites for commercial operators in the 850MHz and 900MHz bands. For each state-geotype class the model sets the number of coverage sites to be equal to the maximum number of sites operated by any operator within that area.

4.1 Coverage sites

For each state-geotype class the number of coverage sites is estimated by dividing the total area to be covered by the effective area of each site. Essentially this assumes that all the areas within each state-geotype class are contiguous. It is possible to have a situation such

as illustrated in Box C.3[4], whereby non-contiguous areas are treated as a single area, in which case the number of coverage sites required will be under-estimated.

4.2 Capacity sites

As in the case of coverage sites, capacity sites are calculated for each state-geotype class by dividing the volume of total traffic by the capacity of each site. Again, the model does not capture the benefits of sharing capacity between adjacent areas from different geotypes – less densely populated areas could have spare capacity that can be utilised in areas with higher traffic demand.

No information is provided regarding the assumptions for total traffic calculations, namely throughput per device (TPD), number of devices per square kilometre (ND) and proportion of devices which are online at a given point in time (P), although the use of these parameters is discussed within the draft report[5]. Therefore, it is not possible to undertake a bottom-up analysis of total traffic estimation.

In the case of 'site capacity' calculations the Commission assumes:

- three sectors per site
- a maximum loading factor of 75%
- spectrum allocation of 2×5 MHz (central case) and 2×10MHz (upper bound)
- average cell spectral efficiency as indicated in Table C.9[6].
- As indicated by the Commission the framework applied in its study is in part based on other models of mobile networks including Analysys Mason's mobile network forecasting model, which was recently prepared for the Australian Communications and Media Authority (ACMA) [7].
- The Commission assumes a loading factor (75%) significantly higher than that used by Analysys Mason (60%)[8]. No details regarding the reason for this difference were given in the Commission's draft report.

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4 Productivity Commission (2015), *Public Safety Mobile Broadband*, draft report, September 2015, page 275.

5 Productivity Commission (2015), *Public Safety Mobile Broadband*, draft report, September 2015, pages 281-2.

6 Productivity Commission (2015), *Public Safety Mobile Broadband draft report*, September 2015, page 300.

7 Analysys Mason (2015), *Mobile network infrastructure forecasting model*, June 2015. Available at http://www.acma.gov.au/theACMA/Library/researchacma/Research-reports/mobile-network-infrastructure-forecasting-model.

8 Analysys Mason (2015), *Mobile Network Infrastructure Forecasts (Contracts 13ACMA013 and 14ACMA149)*, updated final report for the Australian Communications and Media Authority, 10 June 2015, page 42.

- Spectral efficiency depends on several factors, including the array of antennas and technology selected (that is, which release of LTE technology has been assumed by the Commission). Following a discussion with the Commission, we understand that the spectral efficiency assumption aims to represent a typical level for a current commercial mobile network, without explicitly specifying the LTE release. Given that LTE Advanced (release 10) technology is already commercially available, the Commission's spectral efficiency assumptions are conservative. Average spectral efficiency for LTE-A[9] is more than double the Commission's assumed values for 2018 (Exhibit 4.1). However given that the assumed demand growth is also conservative, with an annual 5% growth for the central case, the resultant costs are likely to reflect a network with greater capacity and delivering greater demand than that assumed by the Commission.

Exhibit 4.1 **Spectral efficiency in bit/s/Hz**

	Model assumption 2018	*Model assumption 2023*	*LTE-A Release 10*
Downlink	1.60	3.37	3.70
Uplink	0.79	1.66	2.00

Sources: Commission, Network Strategies.

- The assumption of 4% for the annual increase in spectral efficiency also seems to be conservative: it is lower than the 6% used in the Analysys Mason model[10] for years 2018 to 2027.

4.3 Coverage sites in rural and remote areas

The number of sites in rural and remote areas is set to be the maximum number of sites for any operator within that area. We note that there are many factors, not just the number of sites, which can affect the coverage, quality of reception and mobile network performance, including the location of sites in relation to topography, distribution of sites, selection of antenna and transmitter equipment. A more accurate result will be obtained if the modelling is based on actual coverage rather than number of sites, however we recognise that this approach has been largely driven by the information readily available to the Commission. As such, the approach is appropriate for the Commission's very high level analysis, however if a more rigorous costing was required an approach more closely linked to actual coverage would be preferable.

9 Qualcomm (2013), *HSPA+ R7, R8, R9 and R10,* available at http://www.qualcomm.com/media/documents/files/hspa-evolution-enhanced-mobile-broadband-for-all.pdf and Rysavy Research/4G Americas (2012), *Mobile Broadband Explosion,* available at http://www.4gamericas.org/documents/PPT%20-%20Rysavy%20Mobile%20Broadband%20Explosion%202012.pdf.

10 Analysys Mason (2015), *Mobile network infrastructure forecasting model*, June 2015, page 42.

Effective site area

The effective site area (ESA) is defined for each geotype. It is calculated as the product of maximum cell radius (r_G) and a factor which describes how cells overlap (C_O) using the following equation:

$$ESA_G = \pi \times r_G^2 \times (1 - C_O)$$

The draft report contains no information on the assumed cell overlap, however in discussions with the Commission it was stated that in dense urban, urban and suburban areas the value used was 18%. This value is the difference between the area of a hexagon and a circle that fully contains the hexagon – it is common practice in cellular design to represent the radio coverage area of a base station with a hexagon. This is a reasonable assumption for a theoretical high level estimation.

5 Network costing

The Commission's approach estimates the capital and operational expenditure (capex and opex) of delivering PSMB services.

Capex is calculated as the product of discounted units cost and the number of units required in each time period (year). The number of units required each year is also affected by rollout times and the assumed asset lifetimes. Capex items included in the model are:

- radio access network (site and site equipment)
- site hardening (power backup and civil site upgrade)
- core network
- end-user devices
- spectrum
- mobile carrier network augmentation (new sites and core network).

The draft report assumes that all (real) costs are constant over the evaluation period. While some equipment costs are likely to reduce over time, other costs such as labour and site costs are likely to increase. The net effect is unlikely to change the rankings of the various options, although the magnitude of the costs will be affected.

5.1 Radio access network

RAN capex includes site and site equipment costs. The model assumes that new site equipment is required at all sites – both coverage and capacity sites. In the case of new sites a mix of brownfield (co-location) and greenfield site build has been assumed – 5% of sites to be newly constructed while the remaining 95% are co-located in existing sites.

While there was little information in the draft report on site equipment, the Commission provided us with more information on the nature of the associated costs. The costs cover the capex and installation of an eNodeB at a mobile site, including an allowance for mast strengthening. As not all sites would require mast strengthening, this component represents an average across all sites.

Note that in our experience, the cost of collocating at an existing site will be around 60% of that of a new site build.

5.2 Site hardening

The model assumes that a percentage of sites are subject to network hardening. This includes installation of additional battery backups, and civil works to increase physical resilience to protect against failures caused by high winds, fire and floods and measures to improve site security.

The draft report states that only coverage sites will be candidates for hardening upgrades,[11] but this is not consistent with Table C.13 which states that the hardening parameters apply to both coverage and capacity sites.

The model assumes that 5% of the sites are subject to civil upgrades – given that 95% of the sites are assumed to be co-located in existing mobile carrier sites it would be expected that a higher percentage of sites would be subject to civil work.

With regards to battery backup it is assumed that under the two mobile carrier scenario only 75% of the sites will need additional battery backup. While the single mobile carrier option assumes that 100% of the sites are subject to battery hardening there is no apparent justification for the lower assumption (75%) for the two mobile carrier option.

5.3 Core network

According to the Commission, the core network costs are 'ballpark' estimates sourced from confidential discussions with key stakeholders. As such, they are not based on an assumed configuration. We note however that a more precise estimate of core network capital costs will not affect the rankings of the various deployment options.

5.4 End user devices

In estimating the number of end-user devices, the Commission has made assumptions on the number of PSA users that would take up the service, and on the uptake of the various

11 Productivity Commission (2015), *Public Safety Mobile Broadband draft report*, September 2015, page 302.

types of devices (Exhibit 5.1). We note that handset and device costs are constant across all PSMB options and so adjusting these assumptions will have no effect on the cost differences between the different network scenarios. It is likely however that the number of user devices may be under-estimated, which will affect the quantum of the device costs

Exhibit 5.1 **Number of PSA users and devices**

Variable	*Central case*
Number of users	100 000
Annual growth in the number of users	0%
Handheld devices (% of total users)	50%
Ruggedised handsets (% of total users)	50%
In vehicle modems (% of users)	10%

Source: Productivity Commission.

With regard to the number of users, a zero-growth central case is likely to represent a low-end case. The Commission notes that in 2014 there were approximately 100 000 full-time equivalent public safety officers in Australia (police, fire, ambulance and SES personnel) plus 250 000 volunteers. An increasing population over a 20-year time horizon is likely to necessitate an increase in public safety personnel – and hence PSMB users – although it may be possible to achieve some productivity improvements.

The Commission assumes that less than one-third (28.6%) of public safety officers and volunteers would be provided with handsets. Only the aggregate is provided – no information on the mix between public safety officers and volunteers is available.

With regard to in-vehicle modems, a more transparent approach may be to base this on the number of public safety vehicles (rather than the number of users) with an assumed proportion of vehicles that are fitted with modems. An increasing population is also likely to require an increasing number of public safety vehicles.

We note that the cost of LTE handsets – in particular standard commercial devices – is likely to reduce over time, as LTE becomes a more mature technology. We have some recent benchmark information that suggests that the wholesale price of LTE handsets is around USD500 (approximately AUD700 based on an annual average market exchange rate over the past year), which is slightly lower than the Commission's assumption of AUD800.

5.5 Spectrum costs

The Commission's central case assumed spectrum costs of $1.00 per MHz per head of population, with a lower bound of $0.50 and upper bound of $1.36. These assumptions were informed by several different sources, including:

- reserve prices for the 700MHz band at the 2013 digital dividend auction (used for the upper bound)
- estimated opportunity cost for spectrum in the 825-845MHz and 870-890MHz bands from Plum Consulting
- a submission from Optus
- the ACMA's Apparatus Licence Fee Schedule (used to set the lower bound).

We note that with respect to Plum Consulting's estimate, the Commission refers to an incorrect report. Plum Consulting's report on this band was produced in 2011 for the Department of Broadband, Communications and the Digital Economy[12], not the ACMA.

The input assumption should also take into consideration the term for the spectrum licence. The Commission has assumed an asset life of 15 years for the spectrum, which is consistent with the licence term for the first two sources above. However a current estimate of the opportunity cost for spectrum may not be appropriate for the opportunity cost after 15 years. If there is a shortage of mobile broadband spectrum – assuming demand outstrips the availability of suitable new spectrum bands – the spectrum licence renewal price may well be significantly higher than the Commission's assumed price. This would increase the cost of scenarios in which PSAs operate networks using their own spectrum.

Our view is that the upper bound from the Plum Consulting study ($1.46) is probably better suited for an upper bound for spectrum cost, with a value more comparable to the lower bound from this study ($1.21) as the central case. However we recognise that less conservative assumptions for spectrum costs – including the 'constant cost' assumption for licence renewal after 15 years – would not affect the rankings of the PSMB deployment options, but would only increase the costs of the dedicated networks.

Basing the lower bound for the spectrum price on the Apparatus Licence Fee Schedule is likely to understate the potential spectrum costs, even though the fee may have been adjusted for a longer term than the maximum five years for apparatus licences. There is some evidence from spectrum auctions that annualised prices for shorter licence terms are lower than those for longer terms, reflecting the greater value placed by operators on assured tenure. Nonetheless, this value would still be appropriate as a lower bound.

The draft report provides no evidence to support the allocation of spectrum costs to rural and remote areas – 15%, with 85% of spectrum costs being allocated to dense urban, urban

12 Plum Consulting (2011), *Valuation of public mobile spectrum at 825-845 MHz and 870-890 MHz*, report for the Department of Broadband, Communications and the Digital Economy, 15 September 2011.

and suburban areas. The Commission has informed us that the allocation was based on the relative population of these geotypes, which we believe to be a reasonable approach.

We understand that the final version of the model will allocate part of the commercial carrier's spectrum cost to PSAs in cases where increased capacity is required to deliver PSMB services. Without visibility of the proportion of PSA traffic within the carrier's total traffic this would be a difficult task. The Commission has described a pragmatic solution, estimating new sites as a proportion of total sites of a representative carrier, with the spectrum costs allocated to PSAs being this proportion of total spectrum costs.

This approach is likely to overstate the cost allocated to PSAs. If PSMB traffic does not utilise all the capacity upgrade, then the carrier may be able to benefit from the excess capacity by delivering services to non-PSA users. Hence the carrier could utilise a portion of the spectrum that has been allocated for PSMB use.

5.6 Mobile carrier network augmentation

For options involving a commercial mobile carrier network, the Commission's model includes incremental capex required for meeting additional demand that derives from PSA traffic ('overflow traffic'). In the case of rural and remote areas the Commission assumes that there is sufficient excess capacity to meet any overflow traffic. For the remaining areas (dense urban, urban, and suburban) the model assumes that additional traffic on mobile carrier networks is met exclusively through additional site builds.

The Commission provided us with further details regarding the underlying assumptions. Additional site equipment for augmentation is assumed to be co-located on existing sites, and thus no additional site leasing costs would be incurred. Augmentation would occur by upgrading or replacing the NodeB equipment, rather than installing an additional NodeB. In our view, there would be a cost difference between upgrading and replacing the NodeB. In the former, the cost would be expected to be lower than that of a NodeB. Hence if an average cost of augmentation is being used, we would expect it to be lower than the cost of co-locating on a new site. By assuming that mobile carrier augmentation incurs the same cost as a new NodeB, the Commission is overstating the mobile carrier cost – this however will not affect the rankings of the various PSMB options.

5.7 Capital expenditure unit cost

Unit cost assumptions should reflect the characteristics of each geotype. Terrain, distance from urban centres and density of sites are some of the factors which affect the level of investment required for sites – including installation services, infrastructure, equipment and engineering services. In view of this we would expect that the unit cost for sites in dense urban, urban, and suburban areas should differ from equivalent costs in rural and remote areas – the Commission's model currently assumes the same unit cost for

NewSiteBuildMetro (dense urban, urban, and suburban) and NewSiteBuildRegional (rural and remote).

As an illustration, rural and remote sites would incur higher transport and installation costs than sites in dense urban, urban and suburban areas, however this can be offset by lower costs for building permits. The 2007 WIK mobile cost model for the Australian Competition and Consumer Commission (ACCC) [13] did not distinguish between urban and rural areas. We are not aware of any more recent publicly available Australian data on site costs – benchmark data from other countries, such as the Swedish mobile cost model[14], would not be appropriate in this instance.

We recommend that the Commission provides some clarification regarding the core network augmentation unit cost in Table C.17 ($15). This cost should be stated to be per user, with the source being a 2011 Bell Labs paper[15]. Note that the original source is in USD, and the Commission has assumed a 1:1 exchange rate. This is a reasonable assumption for a high-level model.

5.8 Timing of capital expenditure

The model defines a rollout schedule and asset life span for each capital expenditure item. The asset life span defines the period of time for which the asset will be economically feasible for use in a business. Due to rapid technological developments, life span is often less than the physical life of the asset itself. This is reflected in the Commission's assumption where asset life for site and site hardening (civil) cost is set to 20 years, while the asset lives for technical items are set to eight years (core and site equipment), and five and three years (user equipment).

We compared the Commission's assumptions on asset lifetime with information from other models, including:

- the Swedish mobile network model (June 2015 version)[16]
- the Analysys Mason fixed access model developed for the Australian Competition and Consumer Commission (ACCC) in 2009[17] (although we note that the data in this model is now quite old)

13 WIK Consult (2007), *Mobile termination cost model for Australia*, report for the Australian Competition and Consumer Commission, January 2007.

14 Post- och telestyrelsen (2015), *PTS long-run incremental cost model for mobile networks,* available at https://www.pts.se/sv/Bransch/Telefoni/Konkurrensreglering-SMP/SMP---Prisreglering/Kalkylarbete-mobilnat/Gallande-prisreglering/.

15 Bell Labs (2011), *High Level Total Cost of Ownership Comparison: Stand Alone Public Safety Network vs. Public Private Partnership*, September 2011.

16 *Ibid*.

- the Swedish fixed access model (December 2013 version)[18]
- TERA Consultants Unbundled Copper Local Loop (UCLL) and Unbundled Bitstream Access (UBA) services model developed for the Commerce Commission of New Zealand in 2014[19]

With the exception of the 2015 Swedish model, the above models are for fixed access services which include a component for Fixed Wireless Access by means of a mobile network. Our examination of asset lives only considered the information within the wireless components of these models.

The Commission assumes a shorter asset life for site equipment than for these other examples, which would inflate the costs (Exhibit 5.2). We would recommend that the Commission conducts sensitivity testing for asset lives to determine whether this has a significant effect on the results.

Exhibit 5.2 **Asset life span**

	Commission model	*Sweden 2015*	*Sweden 2013*	*Analysys Mason*	*TERA Consultants*
Sites	20	25	12	20	14
Site equipment	8	10	12	12	-
Core	8	8	-	-	-

Sources: PTS, Analysys Mason, TERA Consultants.

5.9 Opex

Two categories of operating expenditures have been included in Commission's model:

- direct network operating costs
- network support operating costs.

Common organisational-level costs were not quantified as part of the analysis (discussed further in Section 6).

17 Australian Competition and Consumer Commission (2009), *Fixed line wholesale services pricing review 2009-2010*, available at http://www.accc.gov.au/regulated-infrastructure/communications/fixed-line-services/fixed-line-wholesale-services-pricing-review-2009-2010/draft-report#accc-draft-report

18 Post- och telestyrelsen (2013), *Hybridmodell version 10.1,* 16 December 2013.

19 TERA Consultants (2014), *TSLRIC price review determination for the UCLL and UBA services - Model specification, documentation, and reference paper*, available at http://www.comcom.govt.nz/regulated-industries/telecommunications/regulated-services/standard-terms-determinations/unbundled-copper-local-loop-and-unbundled-bitstream-access-services-final-pricing-principle/.

Direct network operating costs are estimated for each item that incurs opex via an assumed percentage (7.5%) of its unit capex. In the case of sites and site equipment, the Commission's assumption is within the range assumed by other models. However this assumption is significantly lower than the Swedish core opex, suggesting that these costs may be understated (Exhibit 5.3). In this instance the upper bound used for sensitivity testing may be too low.

Network support operating costs encompass annual site rental costs and the purchase of backhaul transmission capacity. With regard to annual site rental it is not clear if this cost input is only incurred for new sites or whether it also applies for brownfields sites where RAN equipment is co-located on existing mobile operators' sites. In the latter case there would be a saving in leasing costs due to sharing of infrastructure between operators. In any case the Commission's model should include an additional cost input for the leasing cost incurred by an operator co-locating equipment on a third party site.

Exhibit 5.3 **Opex as percentage of unit capital cost**

	Commission model	*Sweden 2015*	*Sweden 2013*	*Analysys Mason*
Sites	7.5%	10%	5%	5%
Site equipment	7.5%	10%	5%	5%
Core	7.5%	20% / 40%	-	-

Sources: PTS, Analysys Mason.

5.10 Other inputs

Social discount rate

Financial results are typically very sensitive to the selection of discount rate. The Commission has used a real discount rate of 7%, consistent with that recommended by the Office of Best Practice Regulation. It has also performed sensitivity testing with assumed real discount rates of 3% and 11%.

While these values may represent a minimum and maximum, they are relatively unlikely to occur, and thus the resultant estimates represent a much wider range than is likely to occur in practice.

6 Excluded costs

The Commission has excluded certain costs from its quantitative analysis. A number of these may have a substantial impact on the overall costs, however where they are unlikely to vary significantly between the various options under consideration, it is not essential that they be included within the Commission's high level analysis of cost differences. These costs include:

- alternative or supplementary technologies
- cost of developing applications
- costs of change.

The remaining excluded costs are discussed below:

- costs of trunk backhaul transmission
- common organisational-level costs
- value of spectrum sharing
- externality effects.

Trunk backhaul transmission

The Commission's simplified approach for estimating backhaul costs may not capture the costs of trunk backhaul and inter-capital transmission. This would mean that the costs of the dedicated PSMB network would be understated.

A commercial mobile network would already include trunk backhaul – the commercial mobile operators may incur incremental costs if its backhaul capacity needs to be increased to allow for the additional PSMB traffic, but these incremental costs are not likely to be greater than the trunk backhaul costs of a dedicated PSMB network.

Therefore, at best the cost differences between the various options would not be significantly affected. Otherwise the cost differential between a dedicated PSMB network and commercial options would widen further.

Common organisational-level costs

We agree with the Commission's assumption that the increase in common organisational-level costs for a commercial mobile operator is likely to be insignificant as a result of the additional PSMB traffic.

In regards to the establishment of a dedicated PSMB network such costs should ideally be included. If detailed bottom-up cost data is not available, these costs are typically estimated in mobile cost models as an overhead based on a percentage of total costs.

Clearly the inclusion of common organisational-level costs will increase the cost differential between a dedicated PSMB network and commercial options. We note that these costs would be higher in the case of separate state networks than for a single national network due to the need to provide this functionality for each separate network.

Value of spectrum sharing

The implementation of spectrum sharing with other users would permit some mitigation of costs for the dedicated PSMB network. However in such a case there would be some overhead incurred as a result of the requirement for co-ordinated management of the spectrum resource.

Allocation of costs between the PSMB network and other users would require detailed knowledge of the relative demand volumes. As noted by the Commission, the level of traffic on the PSMB is unknown, and thus it would be difficult to estimate the capacity available for sharing.

In addition, the value placed on this spare capacity by other users will depend upon the conditions of use. If PSMB traffic has priority over other users, then the value of the spare capacity must reflect that, and so the PSMB operator is unlikely to be fully compensated for the opportunity cost of that portion of the spectrum being utilised by other mobile operators.

Externality effects

The Commission has not included the various costs and benefits due to externality effects within its analysis. Estimation of these effects would be extremely difficult without more detailed information regarding traffic volumes, service characteristics and PSMB broadband applications.

These externality effects would include:

- deterioration of service quality or congestion experienced by commercial mobile networks as a result of adding PSA traffic
- benefits for commercial mobile network customers due to upgrades required for PSA usage
- benefits of PSMB applications to the wider community.

7 Concluding remarks

The approach used by the Commission in its quantitative framework is consistent with those used for high-level cost models of mobile networks, and is suitable for assessing the

relative costs of the various PSMB options. This analysis does not aim to quantify the business case for PSMB – rather it seeks to identify which options would be the most economic to implement.

Clearly for this type of analysis the focus should be on those costs which differ between the options – it is less important to address those costs which are constant across all options or are not significantly different. The Commission has identified several of these costs and has excluded them from consideration (such as the cost associated with developing PSMB applications) or has used a relatively rough cost estimate (such as the cost of user devices).

We acknowledge that the Commission's approach has also been influenced by the information available. Some key inputs – such as traffic demand – are extremely uncertain due to the current lack of PSMB applications and comparable networks. In such instances sensitivity testing is crucial.

We have identified a number of options that the Commission may wish to consider in its modelling and in the final report:

- provide more background on the factors underlying the traffic assumptions, including throughput per device, number of devices per square kilometre, the proportion of devices which are online at a given point in time and the loading factor
- provide more information on the cell overlap factor
- provide more information on the definition, scope and sources of the various cost elements within the report
- review the assumptions for site hardening and clarify which sites are candidates for hardening
- provide more information on the core network components
- review the central case and upper bound values for spectrum cost
- explain the basis for the allocation of spectrum costs to geotypes
- include an assumption for co-locating equipment on existing sites for the purpose of providing additional capacity for serving overflow traffic
- review whether site unit costs for sites in dense urban, urban, and suburban areas should differ from equivalent costs in rural and remote areas
- clarify that the core network augmentation unit cost is per user (Table C.17)
- undertake sensitivity testing for asset lives
- increase the upper bound in the sensitivity testing of core network opex
- clarify whether annual site rental is only incurred for new sites or whether it also applies for brownfields sites where RAN equipment is co-located on existing mobile operators' sites
- include an assumption for common organisational-level costs.

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