AUTOMOTIVE PLASTIC WASTE: VOLUMES ENTERING LANDFILL IN AUSTRALIA AND A STRATEGY FOR REDUCTION

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ABSTRACT

The volume of automotive plastic waste entering landfill created by the collision repair and steel recycling industries is in the vicinity of 200,000 tons per annum. This research analyses this volume with a view to exploring strategies for its reduction. Statistics were gathered onsite from collision repair centres for the measurement of consumable plastic waste, insurance quote centres for ascertaining the percentages of damaged plastic components replaced, and a steel recycling centre for its volumes of generated automotive plastic waste. A national postal survey directed to head teachers of TAFE panel beating sections explored the present depth of knowledge and skill available on the subject of automotive plastic welding and repair training for the collision repair industry. The research indicated that an improvement in industry training would result in only a modest reduction of the total waste stream but the economic benefits could be considerable. A national training policy aimed at up-skilling the collision repair industry in plastic repair skills could create additional fulltime employment for 200 – 300 personnel and offer ongoing saving on insurance repair costs in the vicinity of 35 million dollars per annum. A literature search produced information for a subjective view on the subject of pyrolysis. Pyrolysis could be one potential methodology capable of converting plastic wastes from landfill to useful by-products such as activated carbons and petrochemicals. The findings on pyrolysis were positive and justify further research.

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INTRODUCTION

Background

Global consumption of plastic products currently stands at over 100 million tons per annum and is increasing rapidly. According to Smits (cited in Greenpeace 1999), half of this production enters the waste stream within two years. Plastic waste has become a crucial issue for all countries and governments. The propensity for plastic to continue to replace traditional materials such as metal, glass, timber and textiles is creating a waste stream that is adversely affecting not only the developing countries, but also the developed countries. Plastic waste is now a worldwide problem (Commonwealth Currents, 1995). Scientists and researchers are paying ever-increasing attention to the problem as the availability of landfill repositories is rapidly depleting.

For example, the Center for Manufacturing Research in Tennessee (Porter 1999) has as its mission statement, ‘To develop multidisciplinary R&D and educational programs in plastic recycling to resolve the serious environmental problems associated with plastics waste disposal …’. Its educational goals are directed towards integrating environmental consciousness into the Tennessee Technological University curriculum, thereby improving environmental literacy. The University of Iowa also has a strong research direction towards the problem, particularly in the area of pyrolysis as a methodology for the recycling of automotive plastics.

In Australia, some 95% of solid waste is currently sent to landfill, causing a constant increase in the demand for suitable landfill repositories. An analysis in NSW of municipal solid household waste revealed 46% is putrecibles (decaying organic matter), 24% paper, 26% plastic, glass and metal, with 4% listed as other. (Fletcher, O’Mara & Rane 2004, p.4). Of all waste entering landfill, industrial waste accounts for about 80%. There were 1.5 million tonnes of plastic consumed in Australia in the year 2000, representing a growth rate of some 8%. Half of that volume entered landfill, 11% was recovered / recycled, with the rest remaining in long-term use in areas such as buildings, pipe work or as consumer items. It is now recognised that leaching of waste liquids from landfill poses major environmental problems for groundwater quality (Waste Management and Environment 2002).

As the world’s largest manufacturing industry, and one with an insatiable appetite for plastics, the automotive industry accounts for a large percentage of landfill statistics. Global output of new vehicles is in the region of some 50 million per annum. During the

1990s Americans bought 15 million new cars and trucks per year to replace an attrition rate of some 10 million vehicles (Nadis, MacKenzie & Ost 1993, p.9). In 1989, an estimated 556 million motor vehicles were on the roads worldwide. With escalation, this number could well approach 1,000 million by 2004.

In Europe 3 million tons of Automotive Shredder Residue the by-product of shredding some 14 million cars per annum, enter landfill each year (Recycling International, September 2002, p.18). In Australia there are more than 12.5 million cars currently in use. Around 70% of materials in motorcars can be recycled; the remaining waste enters landfill directly from the steel recycling and vehicle service industries. Reform to waste management within the collision repair industry is a major focus for the Australian Environment Protection Authority (Jackson 2002).

The escalating use of plastic as a material for replacing traditional metals in automotive construction is well documented. Plastic in cars has increased from around 10 kg in the 1960s to as high as 200 kg by the year 2000 (McDonagh 2000). The Ford Motor Company has warned American collision shop owners to prepare for more plastic body panels with "in-mould" colours (Autobody online 2000). Further research supports Ford's attention to future trends of paintless cars with plastic bodies. Mapleston (2000) predicted the production of moulded coloured plastic panels with A class surfaces that eliminates the need for painting would enter production by the year 2003. This has now happened. An example is General Electrics production of in-colour feedstock for injection moulding for automotive panel parts, parts that are now in use in the European manufactured Smart Car, a product of the Daimler Chrysler Corporation in conjunction with the Swatch Watch Company.

The Problem

Plastic constitutes about 28% of the volume of modern vehicle construction. In America a mass of some 20 million injected molded plastic parts, mostly bumpers, finds its way into landfill each year (see Strom 2001, p.1). In NSW it is estimated that 320,000 damaged plastic parts worth about $65m are thrown into landfills each year as a direct result of automotive accidents. This waste stream, some 750 tonnes, is generated on an annual basis (Environmental Manager 2002*)*. Factoring up of this NSW statistic on a population basis for Australia, provides estimates of some 1.3 million damaged automotive plastic parts worth approximately $260 million, and weighing about 3,000 tonnes, are now entering landfill each year.

This estimated 3,000 tonnes of damaged automotive plastic parts is a direct waste stream from automotive collisions. The most prominent contributor is the collision repair industry, an industry that has a present propensity to replace damaged plastic components with new rather than repair. Australian statistics for 1996 record the number of vehicles damaged by accidents within Australia as in excess of 1.2 million (BTRE-Report 102).

A pilot study by the researcher indicated 60% of damaged automotive parts were plastic and, of those vehicles repaired, only one plastic part in 20 was recycled or repaired. The remaining 95% found its way into landfill on a weekly basis via commercial waste removalists. The collision repair industry waste stream is fundamental to this research along with the steel recycling industry. Motor vehicles that have reached the end of their usefulness are used as feedstock by the steel recycling industry where they are crushed and shredded to enable the separation of recyclable metals. The waste by-products of these processes are mostly plastics, a product that is referred to within the industry as Automotive Shredder Residue coupled with collision repair plastic waste represents a significant contributing factor to the overall increasing problem of plastic entering landfill.

At present the volume of automotive plastic waste is constantly increasing due to two significant factors. Firstly, there is a propensity for automotive manufacturers to embrace a new wave of plastic alloys and composite plastics to replace traditional metal panels. Secondly, there is a steady increase in Automotive Shredder Residue waste as the age of automotive shredder feedstock, vehicles that are mostly 15 to 20 years old, rolls on towards today's modern vehicles, vehicles that contain 100 to 150 kilos of extra plastic content per vehicle. Motor vehicle tires, mostly car sizes with composites of plastic blends, also add to the equation.

Each year, 3,000 million tonnes of tyres are produced worldwide (Recycling International, March 2003, pp.17-32). Passenger vehicle tyres are manufactured from mostly plastic composite blends that offer excellent wear characteristics. In the U.S. there is a disposal rate of 240 to 280 million tyres per annum with a recycle rate of only 18%. Radial tyres contain some 4.2kg of steel, a percentage that equates to over 87,000 tons with a reclaim value in the vicinity of US$14 million, all lost to landfill on a yearly basis (Helzer 2004). The problem in Australia is no different.

A review of the above literature highlights the rapidly increasing use of plastic in modern vehicle manufacture and the increasing problems associated with automotive plastic waste disposal within Australia. It supports the rationale for research into automotive plastic waste entering landfill and strategies for reduction.

Research Aims and Objectives

The purpose of this research is to examine plastic waste streams and identify present work and educational practices that are associated with the problems of automotive plastic waste. It aims to test the proposition that improvement is possible in reducing automotive plastic waste by upgrading industry knowledge and skills through education and training. This approach, coupled with research into advancing technology, such as pyrolysis, could favourably impact on formulating a strategy to reduce automotive plastic waste entering landfill.

The project therefore has three primary research objectives:

- To quantify the volume of automotive plastic waste entering landfill by the identification of the major waste streams generated by the collision repair sector and the steel recycling industry
- To quantify the percentage of accident damaged automotive plastic parts presently entering landfill that could be economically recycled, by improvement of work practices through education
- To explore the practicality of recycling automotive plastic waste by the conversion of waste to reusable products, such as activated carbons and petrochemicals with the use of pyrolysis

The findings on pyrolysis could well justify further in-depth research to test if it is a suitable methodology capable of addressing the total issue of the convergence of all types of plastic waste from landfill into useful by-products such as activated carbons and petrochemicals.

Analysis of the above information could contribute to formulating a strategy for the reduction of automotive plastic waste entering landfill within Australia. The research has national and could have international significance.

2.

PREVIEW OF PREVIOUS WORK

Introduction

A two faceted pilot study by the researcher was conducted with a view to obtaining an indication of present work practices and attitudes within the collision repair industry pertaining to automotive plastic part repairs. The first investigated the level of industry knowledge and skill associated with repairing damaged automotive plastic components by repairers, while the second concentrated on the volume of plastic components replaced or repaired as a result of automotive accidents. Although the study was too small for conclusive findings, it demonstrated trends that indicated further research was warranted. The study provided the foundation for the methodology design and tested the practicality of the data collection instruments for this study.

Pilot Study

Interviews were conducted with collision repair proprietors. One hundred and sixteen collision repair proprietors were interviewed at their premises during the normal course of commercial business by the researcher. These in-field interviews were conducted in Adelaide, the South East of SA and Southwest Victoria. Questioning was open-ended and informal. Data were gathered on present work practices and attitudes towards welding and repairing damaged automotive plastic components. No notes were taken during the interviews.

The method of recording was immediate post-interview reflection and an individual assessment with a four-stage rating. The four ratings used were low interest (L) in welding and repairing plastics, medium interest (M) but not repairing plastics at present, high interest (H), equipped with professional welding equipment but needs training and a professional approach (A), actively welding and repairing plastics profitably, equipped with professional welding equipment and an understanding of all aspects of automotive plastic welding and repair.

The findings from these 116 collision repair proprietors were: **L** 47%, **M** 19%, **H** 26% and **A** 8%. The results suggested industry knowledge on the subject of automotive plastic welding and repair was low, and indications derived from the second facet of the pilot study, analysis of automotive accident claim insurance invoices, supported these pilot ratings. The focus here was to assess the total volume of automotive plastic replacement parts used during the repair of accident damage vehicles by recording how many were new as opposed to how many were repaired.

Three insurance companies from two states supplied 28 collision repair invoices for analysis. They were requested to provide invoices on a random selection of detailed repair costs from vehicles less than four years old within a repair costing range of $2,000 to $15,000 per claim. Confidentiality was maintained by the exclusion of the collision repairers' and the insureds' details. Each repair invoice was analysed and the information recorded on data forms for the extrapolation of mean averages.

The major items for analysis were the total number of metal and plastic parts fitted, the total number of plastic parts supplied and fitted and the total number of repaired plastic parts fitted. From the analysis of these 28 claims, the following statistics were recorded:

Total claims costs	$142180
Total parts costs	$67222
Total plastics parts costs	$29323
Total number of replacement parts fitted	658
Total number of metal parts fitted	261
Total number of plastic parts refitted	397
Number of plastic parts replaced with new	383
Number of plastic parts repaired	14

The claims analysis showed more plastic parts than metal parts were fitted. Of the 397 plastic parts refitted, only 14 were repaired (3.5%). These statistics lent support to the in-field survey that had suggested a low percentage (8%) of collision repairers were professionally equipped and possessed the skills to undertake automotive plastic welding and repairs.

The indication that there is a propensity to fit new plastic parts, rather than repair, and the level of plastic welding and repair skills within the collision repair industry, raise three basic questions. Firstly, is it profitable to repair damaged automotive plastics? Secondly, what is the availability of industry training in the latest technological advancements in this area? Thirdly, is there industry apathy towards up-skilling?

Parts Repair Profitability

The question as to the viability of repairing damaged automotive plastic parts being a profitable option as opposed to replacing with new is vindicated by examples from collision repair centres that practise the skills associated with repairing rather than replacing with new. Following are five individual case studies from collision repairers in three different states. The researcher compiled these examples during infield training sessions, delivered as a registered private provider to the collision repair industry.

Collision Repairer, Dalby, Queensland

A repairer quoted and repaired a Honda front bumper bar that was holed, damaged and distorted by collision with a tow bar. The tear was plastic welded, repaired and the bar painted, and the job was completed in one day. When the owner picked up his car, he told the repairer he had been quoted elsewhere and was told the bumper could not be repaired and needed a new replacement. The quote for repairs using a new bumper justified the customer making an insurance claim. As it had been repaired, at a considerable saving he withdrew the insurance claim.

The repairer who lacked the skills to weld and repair plastic and quoted for a new bumper lost the job, and a customer. The repairer who had up-skilled captured a job, a new customer and sold profitable labour. He did not outlay capital for a new part and did not have waste to dispose of. He was paid immediately from the customer and avoided the time lag of insurance claim processes. The insurance company benefited by one less claim to process. The difference in the two options, a new bumper and claim on insurance opposed to paying for a repair, was approximately $400.

Collision Repairer, Nerang, Queensland

During an in-house training program to up-skill panel beating staff in the skills required to effectively repair automotive plastics, the following repair was undertaken during the training program. The front panel of a tradesman's van was being replaced. Upon its removal a plastic heater box was found to be broken. The insurance company was notified and authority to repair received. A photo was taken to validate the damage. The heater box was plastic welded in place and the insurance company charged accordingly.

The benefits of being able to repair in-house through up-skilled tradespeople in this instance were considerable: the continuance of the repair process, no delay, the part not having to be removed and sent away for repairs resulting in a saving of remove and replace charges, no turnaround time lost waiting for the repaired part to be returned, and the customer receiving the vehicle within the timeframe he expected.

Collision Repairer, North Caringbah, NSW

A VW tailgate plastic lock mechanism upon removal was found to be broken. New replacement cost was $450. The part was plastic welded at a charge of $80. The benefits were: no ordering of a new part so no time delay, no capital outlay, a strong hourly charge out rate and a saving to the insurance company of $370.

Automotive Plastic Repairer, Hobart, Tasmania.

A newly established automotive plastic service received an inquiry from a leading insurance company. A new Saab had a minor collision that resulted in a broken plastic locating peg on the air conditioning cooling unit. As the vehicle was new, any repairs would need to be undetectable and guaranteed, otherwise a new unit at a cost $1,245 would be fitted as the vehicle had to be delivered the next day. The part was plastic welded at a cost of $80 (time taken was ten minutes). The repairer profited by enjoying a high hourly rate and the insurance saving was well in excess of $1,100.

Collision Repairer, Annangrove, NSW

During an in-house training program to up-skill panel beating staff in the skills required to effectively repair automotive plastics, the following repair was undertaken during the training program. A near new Nissan sedan had been repaired and finished except for the lower front bumper fibreglass faring that was deemed uneconomical to repair. The new replacement price was $45, however it was on back order due to the part being unavailable. The time wait was estimated to be six weeks. The trainer, as a demonstration, repaired the damaged component in one hour. Whilst the financial reward may seem insignificant, other benefits were realized. The job was completed and able to be delivered, thereby avoiding storage of the vehicle by the repairer for six weeks. The account was finalized and the customer was not subject to the inconvenience of a six-week delay in having repairs effected.

Pilot Study Conclusions

The pilot study demonstrated that the research methodology chosen was appropriate in terms of testing participant involvement, data recording and data analysis. The study was too small for deriving conclusive evidence across the industry, and in any case, was limited mostly to insurance motor vehicle accident claims analysis pertaining to plastic parts. It did not include an assessment of what plastic parts could have been economically repaired, though it did highlight the number of plastic parts damaged, those replaced with new, as well as the percentage repaired.

In view of the findings pertaining to the low percentage of collision repairers interested in automotive plastic welding and repair, research into the training practices in the collision repair industry forms a fundamental aspect of this study. This component, however, will not address the major source of plastic waste entering landfill, namely the waste stream that is created within the steel recycling industry. Any reduction there requires attention towards emerging technology. Pyrolysis could prove to be such a technology.

The evidence presented above lends strong support to the notion that collision repairers who practise automotive plastic welding and repairs when undertaking repairs to today's modern vehicles, practise positive adjuncts to their overall strategy towards efficiency and profitability. If such a strong case exists, why did over 50% of repairers surveyed show little to no interest in the subject of up-skilling staff? Apathy alone is not the sole reason. When the industry's post war-history is examined, cultural practices, shifts in the distribution of work and advances in technology provide some insight.

Collision Industry Historical Review

The Australian economy boomed after the Second World War creating many opportunities for ambitious tradespeople to start their own businesses in the service sector. During the sixties and seventies, many blue-collar workers, clever with their hands and trade skills, founded small businesses. The collision repair industry is such a case. Many present proprietors were the business founders, starting in small premises as one-person operations as all they required were a few hand tools and a rented shed. Little start-up capital was needed, work was plentiful and insurance companies paid reasonable rates. They prospered and grew.

In the early eighties, technological advances in methods of automotive construction and design required new approaches towards vehicle repairs. This trend, coupled with the pressure to upgrade plant, equipment and training, has been relentless and costly for repairers. Today, entry into the industry requires extensive capital expenditure. The return on capital expenditure is low and work is hard to get due to the declining accident rate bought about by safer car construction, safer roads and the enforcement of more stringent driving standards. It can be argued the collision repair industry is at present over-serviced, with more repairers chasing less work, a climate that has promoted the emergence of competitive quote centres owned and operated by the insurance companies. This has fostered the debate as to who actually holds the proprietary rights over a hapless accident victim's damaged vehicle: the insurance company who issues the insurance policy or the collision repairer who repairs the accident damaged vehicle?

The propensity for insurance companies to claim such proprietary rights has resulted in a power shift from collision repairers to the automotive insurance industry. On the whole, insurers now control, delegate and steer crash repair work to repairers of their choice, often based on the repairers' competitive quoting against themselves, a practice that has resulted in suppressed labour costs. As a result the collision repair trade adopted a propensity to fit new parts rather than repair, the reasoning being to take profits from new parts mark-up where possible rather than sell repair labour at competitive and unprofitable hourly rates.

Some insurers realise this and now control the percentage of new parts mark-up by only supplying work to companies who agree, under contract, to set parts mark-up percentages and supply parts invoices upon request for audits. This has eroded repairers' profitability on parts by removing the advantage of mark-ups gained through purchasing power and has further restricted profitability.

The propensity to fit new parts as opposed to repairing has, with the passing of time, led to a decline in traditional trade skills. Some sectors of the repair industry have adopted an attitude of not re-investing in training to upgrade skills as it is seen as un-profitable to quicken labour procedures when the insurance companies enjoy low hourly rates.

Given the constant advancement in technology, present pressure to upgrade knowledge and skill on the shop floor has never been greater. The decision as to what training should be undertaken rests with the proprietors. Collision repair workers are often excluded from opportunities to upgrade their knowledge and skill due to a logjam of information failing to filter through management to the shop floor. This can be due to a combination of reasons, ranging from socio-economic considerations such as planning to sell, planning to close the business, fear that up-skilled workers will want higher wages, to the attitude that they have managed until now so why change, and sheer apathy with no interest in, or understanding of the benefits of up-skilling their workforce. Such perspectives are perhaps understandable when one considers present industry practices, coupled with the proprietors' academic background which is often only basic education.

The danger associated with not up-skilling is highlighted by Brookfield (1986) with his thoughts of professional incompetence when there is a failing to keep abreast of industry developments. The insurance industry realizes, only too well, the escalation of costs associated with the decline of competent tradespeople bought about by collision proprietors adopting a reluctance to take on trade apprentices. They now find themselves offering financial incentives to repairers to indenture apprentices in hopeful anticipation that there will be suitably skilled personnel in the future to repair their accident claim vehicles.

With rapid advancement in technology, big business has often adopted the practice of providing internal training to keep pace with commercial advancement, as it cannot afford to wait for training institutions to catch up. This trend for large industry to take control of workforce education has presented governments with an opportunity to cutback on education funding under the guise of economic rationalization. In July 1994, the then Prime Minister Paul Keating said, at a conference on Australian industry, ‘It is now up to industry to take control of the training agenda’ (Burns, 1995, p.46).

This challenge has been approached by the shift from curriculum-based training to competency-based training, with the formation of Industry Implementation Guides. Implementation Guides created by industry are guides to transition arrangements from accredited courses to qualifications. One implementation guide that was introduced in 1999 and is relevant to this research is the Automotive Industry Retail, Service and Repair Training Package AU99, published by the (then) Department of Education, Training and Employment in Melbourne.

Within this Training Package are: AUR23908A Carry out thermo plastic repair procedures, AUR24823 Fabricate fibreglass / composite material components and AUR24866A Repair fibreglass / composite material components. These standards outline the elements of competency to be achieved and the performance criteria to be met by the individual learner in order to demonstrate competence.

These competency standards are guidelines only and are not supported by curriculum. Curriculum is a matter for individual trainers. Some argue that the curriculum is not the issue, only the ability of a learner to demonstrate competency to meet descriptor outcomes is what is required. In theory, this may be so, however, to up-skill learners there is need for the design and supply of up-to-date training resources capable of reflecting the rapid changes in technology. Sobski (1998, p. 13) argues for the importance of curriculum, based on ‘… a structured learning program’ being available to people wishing to acquire knowledge and skill within a specific area. In support of her argument, Sobski cites an individual trainer’s view as ‘The endorsed part of training packages defines the end point. What we want to know is how the heck we get them there’(p. 14). The political view is this should be left to industry.

There is a propensity for the closure of sections within the TAFE training system, and the panel beating section at the TAFE institute in Mt Gambier is one example. Such closures, coupled with cutbacks to funding by governments, lead to the encouragement of the private provider system within an open training market. Whilst this trend may well suit large business, the question remains over how employees in small businesses will be adequately trained. Small businesses typically have short-term planning horizons. Even with the benefits offered within the Federal Government's Training Guarantee Scheme in the early nineties, '… private companies with payrolls between $200,000 and $2 million, sixty-two percent allocated nothing to training' (Burns 1995, p.37).

On the one hand, there are professionally competent TAFE teachers struggling within a cash-strapped, institutionally based system attempting to catch up with advancing technology as best they can, and on the other, workplace trainers with minimal understanding of and experience with national competency standards attempting to deliver the latest training to industry. The workplace trainer is now becoming one of the fulcrum points for the delivery of industry training.

Many are tradespeople enlisted from within their own workforce and charged with the responsibility of delivering training based on their previous trade experience. These workplace trainers often possess basic training skills at best, as shown in research by Harris, Simons and Bone (2000). Skilled tradespeople do not necessarily possess the training skills required to be competent training presenters or resource designers. The Harris et al. study showed that competency standard training qualifications within the private provider sector was low. 'Only13% of those surveyed had completed a workplace trainer category 1 course, 7% had completed the category 2 course and 10% had completed a workplace assessor training program' (NCVER 2001, p.6).

With pressure on the collision repair industry to retrain not only existing staff but new apprentices as well, and considering the shift from training institutions sharing resources within systemic arrangements to being in competition with each other as well as the private training sector, the impact on the diffusion of knowledge and skill is likely to be marked. This could account for the low percentage of collision repairers competent in automotive plastic welding and repair and justifies research into training practices. To some degree, this research addresses such issues.

Pyrolysis Research

Present work relating to plastic waste stream conversion with the use of pyrolysis is expanding overseas and could prove practical as a methodology for the conversion of plastic waste into useful by-products in Australia. A review of the area indicates a global interest in the subject that covers literature, research, and proposed, as well as working, recycling plants in a number of countries.

Juniper Publications (2002) have produced a comprehensive publication on the subject of pyrolysis titled *Pyrolysis and Gasification of Waste*. The text consists of 633 pages with details of 82 individual pyrolysis processes. The work reviews the industry and the increasing importance of the development of gasification and pyrolysis technologies worldwide. Volume one reviews applications, markets and business opportunities. Volume two describes and analyses processes. This comprehensive subject report is designed for process developers, public policy makers, universities, waste management companies, researchers and investment managers. The price is in the region of 1750 pounds sterling and is supplied with a single user licence CD-Rom.

Pyrolysis is a subject of research within The University of Melbourne (1997) and is detailed within their Research Report as follows:

Thesis in Progress, Doctor of Philosophy

- Low SL Pyrolysis of Moderately Contaminated Mixed Plastic Waste
  Research in Progress, Environmental Engineering
- Pyrolysis of Mixed Plastic MA Connor, GH Covey & SL Low

Conference Publications

- Low SL, Connor MA & Covey GH 1997 Pytolysis of Selected Waste Plastics to Liquid Hydrocarbon Product *Chemeca 97*
- Jebson RS, Chong R & Ozilgen M (eds), *Chemeca 97* Proceedings New Zealand: Institution of Professional Engineers New Zealand.
- Covey GH, Low sl & Connor MA 1997. Small Scale Chemical Recycling of Post Consumer Polymer Waste by Pyrolysis. *Recycling Polymers-Advances in Polymers IV* Proceedings of Recycling Polymers-Advances in Polymers IV, Melbourne: RACI.

An International Workshop on Pyrolysis and Bio-oil (25 November 2002) was sponsored by The University of Melbourne, CSIRO and Monash University. The theme was on Pyrolysis, Production and Properties of Bio-oil. The keynote address was delivered by Professor Tony Bridgewater (University of Aston Birmingham,UK), was titled, “Fast pyrolysis of biomass: Science and technology”. The workshop addressed issues relating to pyrolysis reactors and their use to extract bio-oils from timbers to be used as fuel oil replacements.

Environmental Technology Research Network in the Asia-Pacific Region (ETERNET-APR 2004) lists research projects on Pyrolysis that have been conducted in recent years. Three projects that have been conducted by departments within The Korea Institute of Energy Research are:

- 1991 research by the Waste Resources Utilization Team, Energy and Environment Department, titled "Development of fluidized-bed waste plastics pyrolysis process", with the aim to develop fluidised-bed pyrolysis processes of waste plastic, plastics that are not amenable to landfill.
- 1995 research by the Waste Pyrolysis Research Team, titled "Oil recovery by the co- processing of waste tyre and waste oil", with the aim to develop a process to enable waste tyre and waste motor oil to be simultaneously pyrolysed without causing any environmental problems.
- 1993 research, also by the Waste Pyrolysis Research Team, titled "Study on the development of the combustion technology of gaseous products and tar produced from the waste pyrolysis". The aim was to study pyrolytic gasification experiments on waste tyres, rubbers and synthetic resins with the use of bench scale experimental facilities for the improvement of equipment design.

Extensive research on the problems associated with the recycling of tyres has resulted in a number of pyrolysis projects that indicate the methodology is suitable for tackling the problem. Three examples are:

- Coalite, a Derbyshire UK identity, installed a pyrolysis plant in January 2002 capable of processing 15,000 tonnes of tyres annually, with plans to install a further five units (Waste Watch, 2004).
- Energy Power Resources (UK) is completing its pyrolysis complex by 2004, designed to handle a capacity of 60,000 tonnes of tyres annually to produce enough electricity for 28,000 domestic customers (Waste Watch, 2004).
- The United Kingdom Atomic Energy Authority and Bevan Recycling have completed a tyre recycling plant that uses pyrolysis technology. Mrs Ann Jervis, spokesperson for Bevan Recycling, is cited in the Scrap Tire [sic] News as saying that each ton, 150-175 car tyres, produces approximately 230-270 kg of oil, 400-410 kg of carbon, 130-160 kg of steel and 190-210 kg of gas. Plant production is capable of recycling 500,000 tyres per year (Recycling Research Institute 2002).

The above literature research demonstrates an academic interest on pyrolysis within Australia and lists some other research projects. A further in-depth explanation with a broader report on pyrolysis research is presented in Chapter 4, Presentation of Results.

3
METHODOLOGY

Overview

Several waste streams within the automotive industry contribute to two major flows of plastic waste sent to landfill (see Waste Stream Flow Chart, Figure 1, p.24). Once the waste streams were defined, the approach towards gathering data for analysis was categorised into several areas for investigation: the types of automotive plastic waste, how it is generated, who generates it, present methods of disposal, and the volumes sent to landfill.

A broad approach was adopted for the gathering of data and was based on a solid foundation of the researcher's thorough understanding of the automotive collision repair industry. This understanding enabled a lateral thinking approach towards investigating and identifying strategies for waste reduction to address the problem of automotive plastic waste entering landfill. The methodology was designed to focus on the following aspects:

- identification of automotive plastic waste streams
- infield random sampling to quantify volumes of general consumable plastic waste generated by the collision repair industry
- statistics taken in-field at insurance quoting centres to supply primary and secondary evidence for the measurement of the volumes of damaged automotive plastic parts generated by automotive collisions
- analysis of such data to ascertain present industry plastic repair practices
- identification of the volume of damaged plastic parts replaced with new when they could have been economically repaired
- the present status of industry training and its ability to keep abreast of emerging plastic repair technology
- industry training approaches towards upgrading trainers' knowledge and skill to enable the facilitation of future technology diffusion into industry, and
- identification and suitability of viable recycling practices presently not in use that could be used to form a strategy for reduction of waste

The data for this study have been compiled from research within five different businesses as well as industry education providers. They have been gathered by a combination of in-field work within two states, a national postal survey of industry educators, as well as a literature search on alternative recycle practices for plastic.

Participants and Methods

There were four different groups of industry participants in this research project, three directly and one indirectly associated with the automotive industry. Collision repair centres provided data for the assessment of consumable plastic waste; automotive insurance accident assessment centres provided primary and secondary evidence for the analysis of damaged automotive plastic panels and parts; and head teachers of panel beating in TAFE institutes were surveyed by post for information on present industry training practices. The fourth participant, a steel recycling plant, was subject to in-field empirical research for the analysis of its waste streams associated with the shredding of motor vehicles.

Collision repair centres

Three collision repair businesses were chosen as sites for the analysis of the volume of plastic consumables entering the waste stream. One is established in a country area some 300 kilometres from Adelaide with a staff size of 12 employees. The other two were situated in the Adelaide metropolitan area with staff sizes of about nine and 16 respectively. These three collision repair centres are representative of the average size within the industry and all specialize in automotive insurance claim accident repair work.

Collision repair centres generate a constant waste stream of plastic waste as a by-product of repairing collision damaged automotive vehicles. The plastic waste is mostly empty consumables such as containers, new parts packaging, floor sweepings, used paint residues and plastic panel parts. In city areas, this waste stream enters landfill via commercial waste removal contractors who empty waste skiffs on an average of once a week. Country repairers tend to transport their waste to landfill only three to four times per year as space restriction is not such a consideration as it is with their city counterparts.

The research procedure required three on-site visits to each of the respective collision repair centres. The first visit was to discuss the general nature of the research and seek the respondents' interest and permission for involvement in the research. This visit also included discussions as to the design of the data gathering tools, the methodology for their use and timeframes for sampling, recording and collection.

Once the data gathering tools were designed, the second visit delivered the recording tool to the recipients for testing and discussion. The third visit entailed in-depth discussion on the waste streams and the recording of data on spreadsheets (see Consumable Plastic Waste Analysis, Appendix A).

The recording tools were designed for ease of use and kept simple. The spreadsheet design facilitated the recording of the various individual waste products and an assessment of weight was ascertained by a selection of components weighed on portable scales. The information sought ranged from the listing and analysis of volume of the various waste products to an assessment of their weight and volume over a timeframe of one month.

The overall data analysis involved a combination of the findings from the three collision repair centres that were chosen for the plastic waste analysis. The two main statistics required were the volumes of consumable plastic waste and the number of plastic body components generated by their replacement with new. This evidence was then used to quantify the volumes entering landfill directly associated within the collision repair sector by factoring up the mean to calculate a national estimation.

The statistical findings from the collision repair centres of the number of plastic body components entering landfill generated by their replacement with new, were cross-referenced with the data recorded from automotive insurance accident assessment centres. This was achieved by recording the number of vehicles repaired over a three month period from the collision repair centres and applying the average number of plastic parts recorded on the accident repair invoices for individual vehicles from the automotive insurance accident assessment centres.

Automotive insurance accident assessment centres

Two automotive insurance accident assessment centres provided the venues for in-field assessments of data pertaining to volume of damaged automotive plastic body parts entering landfill generated by the collision repair sector. The centres are located in the Adelaide metropolitan area and are designed for the purpose of customer liaison for insurance claim processing, the assessment of accident repair costs, and the allocation of repairs to individual collision repair specialists. Upon completion of the repairs the vehicles are returned to the centres for repair quality scrutiny prior to customer delivery. The researcher visited both centres for gathering data on several occasions over a number of months.

The handling and use of all collision repair invoice data along with individual owners details is subject to the Financial Services Reform Act 2001. A duty of care for the protection of the identity of individual insurance claimants and individual collision repairers details was a condition required by the insurance company before the research could begin. Full compliance was agreed to and tendered in writing by the researcher.

The vehicles chosen for the collection of data were randomly selected over a period of several months. A number of individual vehicles subject to collision repair claims were pre-assessed for damaged plastic parts prior to repairs being allocated. These were recorded and the vehicle photographed for validation purposes and traceability. After the vehicles were repaired, copies of repair invoices were supplied by the insurance company for analysis and cross-referenced with the plastic damage pre-assessments for the extrapolation of data. The major focus of this component of the research was identifying the percentage of plastic parts that were replaced with new that could have been economically repaired.

The pre-accident assessment provided the opportunity to record details of the various damaged plastic parts and included a calculated assessment of the time required for their effective repairs. This pre-accident assessment of damaged plastic components involved a number of prerequisites - the damaged part had to be capable of being repaired without compromising issues of safety and the repair able to maintain a standard of quality to keep within the ethical guidelines of repairing the vehicle to pre-accident condition, in short, repairs that would be undetectable when finished.

A damaged plastic part deemed repairable during the pre-accident assessment was recorded using a time factor only. When the pre-accident assessment details were cross-referenced with the actual repair invoices, parts that were deemed repairable but were replaced with new were identified. The plastic parts assessed as repairable were subject to a scale of economy based on a repair cost factor of $80 per hour. To be considered as economically viable for repair, estimated repair costs compared to invoiced replacement costs were not to exceed 60%. Recording tools consisted of Vehicle damage pre-repair assessment sheets (see Appendix B) and collision repair invoices.

The vehicle damage pre-repair assessment sheets, when compared with the collision repair invoices, provided a number of aspects for extrapolation onto the Vehicle Crash Quote Analysis spreadsheets (Appendices C, D and E):

- ratio of plastic parts compared with metal parts used in the repair of modern vehicles
- cost of plastic parts compared with metal parts used in the repair of modern vehicles
- identification and validation of the volume of damaged plastic body parts presently entering landfill

- identification of the volume of damaged plastic parts that could have been economically repaired instead of replaced
- extent of profitable recycling opportunities presently being overlooked by the collision repair industry.

TAFE head teachers of panel beating

The head teachers of panel beating within TAFE institutes throughout Australia were selected for a response to a postal questionnaire survey on issues relating to training for the automotive plastic welding and repair industry. The focus was to investigate and evaluate present industry training in TAFE institutes on automotive plastic welding and repairs offered to the collision repair industry.

The respondents' anonymity was assured and the survey process was subject to the University of South Australia's ethical protocols.

The survey was designed to take up as little of the respondents' time as possible by offering multiple answers with tick boxes. The estimated time for completion was in the region of 10 minutes. The survey also offered the recipients the opportunity for deeper involvement, if they desired, through the provision of subjective comments and opinions on several issues (see Survey Questionnaire, Appendix F).

The survey questionnaire was in-field tested for two reasons, firstly, the interest in and suitability of the research, and secondly, the appropriateness of the actual question structure. This testing took place via a face-to-face interview and open discussion with a selected motor trade association training body. A sample questionnaire was constructed, and then presented to the association for critical analysis.

The survey was undertaken by post and contained a self-addressed envelope for the return of the completed questionnaire. The package was addressed to the directors of the various TAFE institutes requesting their permission for the survey to be conducted. If they were in agreement, the questionnaire was then passed onto the respective head teachers of automotive repair and refinishing panel beating sections for their consideration and completion. The survey was voluntary.

The survey questionnaire comprised three separate sections. The first related to the training establishment itself, the second to the training resources used and how they were created or obtained, and the third to the levels of training skills offered on automotive plastic welding and repair. The sections were designed with consideration of respondents' time in mind. Each section contained a series of questions that solicited a response by utilising tick boxes, with a provision for additional comments should the respondents choose to express them.

Anonymity was assured by clearly indicating the questionnaire could be returned without identification. This consideration was extended to entice unbridled opinions on the subject in the hopeful anticipation it would tease out constructive criticism of present policies and practices. Provision for a request from interested recipients of the survey findings was also enclosed, with notification that it could be sent to the researcher separately to maintain confidentiality.

Data analysis consisted of frequency distributions for each of the closed questions (see Appendix F). The results, coupled with the verbatim comments recorded by the head teachers, were then subject to critical analysis in light of the present competency standards on automotive plastic welding and repair training for the collision repair industry. Particular attention was paid to any policies relating to professional development programs for the TAFE training sector that would address issues of technology diffusion within the collision repair industry to improve present work practices (see Appendix G).

Steel recycling centre

Quantifying the volume of automotive plastic waste entering landfill generated by the steel recycling industry was by in-field analysis of the waste stream undertaken at a steel recycling plant in Victoria. The recovery of recyclable metals from the shredding of motor vehicles, and parts that have reached the end of their working life, results in the generation of waste called Automotive Shredder Residue. Random samples taken directly from the Automotive Shredder Residue waste streams during production were analysed by the separation and measurement by hand of plastic content to quantify automotive plastics entering landfill from this source.

The research procedure adopted was to ascertain the percentage of Automotive Shredder Residue generated by the automotive shredding process at the test site by practical in-field volume measurements during plant operation. The material was captured in the bucket of a front-end loader as it spilled from the conveyor belts of the two separate Automotive Shredder Residue chutes over a given period of time. The material was weighed and using calculations of volume over time, measurements were estimated to produce tonnage sent to landfill.

The findings were validated by comparisons with the company’s daily tonnages recorded from their weighbridge statistics of Automotive Shredder Residue as they leave the premises in tip trucks. This tracking measurement is performed by the company for recording the costs associated with its removal to the only designated landfill repository in Victoria for Automotive Shredder Residue, situated at Bacchus Marsh, some 50 kilometres from Melbourne.

Samples gathered from the waste streams were removed from the site and subjected to further hand separation into several different types of material such as plastics, metals and general rubble and dirt. This analysis was recorded in working notes during the operation (see Automotive Shredder Material Analysis, Appendix H). Extrapolations from this chart provided the statistical data for recording as Automotive Shredder Residue Analysis (Appendix I).

The data analysis provided hard evidence which was factored up to derive an estimate of the total tonnage of automotive plastic waste entering landfill within Australia from the steel recycling industry. There are ten automotive steel recycle plants operating automotive shredders within Australia. The output of production within each individual plant is subject to the horsepower size of the shredder. The methodology used for this factoring was to measure the volumes of plastic waste dispatched to landfill from the research site, relate those to the automotive shredder horsepower size, and equate that formula to the other nine recycle companies' automotive shredder horsepower size for the total yield (see Automotive Shredder Residue Landfill Estimates, Table 9).

Pyrolysis Literature Search

A literature search on the general principles of pyrolysis was conducted to investigate its suitability to degrade plastic waste under controlled conditions to produce petrochemical raw materials and other by-products. Central to this investigation on pyrolysis was the search for information on any commercially viable production plants that may presently be in use and commissioned for plastic waste reduction in other countries. The sources used were internet and library research. Particular attention was paid to industry periodicals in an effort to capture the most recent information. The aim was to categorise information into a number of classifications as follows:

- identification of any pyrolysis plants currently in operation that are used for recycling purposes
- evidence that supported the viability that pyrolysis could be a viable proposition for plastic waste conversion into useful by-products within Australia

- information that supported the possibility that pyrolysis could be an effective way of treating PCBs to reduce their collective carcinogenic build-up within land fill
- evidence that supported the viability of an in-depth research project into the use of pyrolysis as a serious methodology for plastic waste management

It was envisaged that an analysis of the above information would contribute to the formation of a strategy for the reduction of plastic waste entering landfill within Australia.

Limitations

Due to time and cost considerations, this research is small in scale. This could create distortions when factoring up the data to national levels. In particular, the data gathered from only one steel recycler could be questioned. Although the sampling was an accurate measurement taken over time from the test site, it cannot be guaranteed other steel recyclers throughout Australia have the same mix of feedstock.

The research was confined to the collision repair and steel recycling industries and did not measure plastic waste from the automotive mechanical service sector, a fact that could be argued to lend support to the notion that the overall findings of automotive plastic waste entering landfill estimated within this research is conservative.

The data gathered from insurance assessment centres was limited to the analysis of 61 claims. This may not represent a large enough number to show a statistical pattern offering evidence of saturation, however the mean of claim costs derived was comparable with the average cost of an insurance claim taken from insurance company statistics.

There could also be limitations relating to the response of the questionnaire survey by the head teachers of TAFE automotive collision repair facilities. Potential problems of reliability may have manifested themselves in the way questions were answered. This could result from respondents' embarrassment in admitting shortcomings in relation to work practices, the reliance on respondents accurately portraying their attitudes and beliefs, or lack of empathy resulting in a lacklustre effort in addressing the questionnaire items. These are aspects over which the researcher has no control.

Although the survey's purpose was to gather a descriptive picture of what is actually happening in the training sector, unintentional bias by the researcher could be possible due to using responses as data for a subjective analysis as to the levels of training being delivered to industry at present. The researcher's view on how it could be improved is also subjective.

Since 2002 a trend has developed to encourage the collision repair industry to repair damaged automotive plastic components. The driving force is the automotive insurance industry which realises the savings to be gained by up-skilling their repairers. As the research data presented has been gathered over a period of time, since late 1999, aspects of it could now be outdated. No research has been undertaken to measure the impact of the Insurance Australia Groups plastic repair index project.

The above limitations do not detract from the overall findings of the thesis. The research clearly identifies volumes of automotive plastic waste entering landfill and suggests practical strategies for its reduction.

4
PRESENTATION OF RESULTS

Waste Streams

Researched plastic waste streams

The two major plastic waste streams from industry targeted for this research project were the automotive industry and the steel recycling industry. Several waste streams within the automotive industry were identified by a combination of industry experience and in-field exploration. These waste streams emanate from two fundamental sources: general maintenance during the life of motor vehicles and disposal when vehicles reach the end of their useful life span. Maintenance and servicing encompasses mechanical spare parts and their packaging, replacement of tyres and batteries, and collision repairs. End of life disposal is mostly through the steel recycle industry. A flow chart, Automotive Plastic Waste Stream, illustrates the sequence of waste flows (Figure 1).

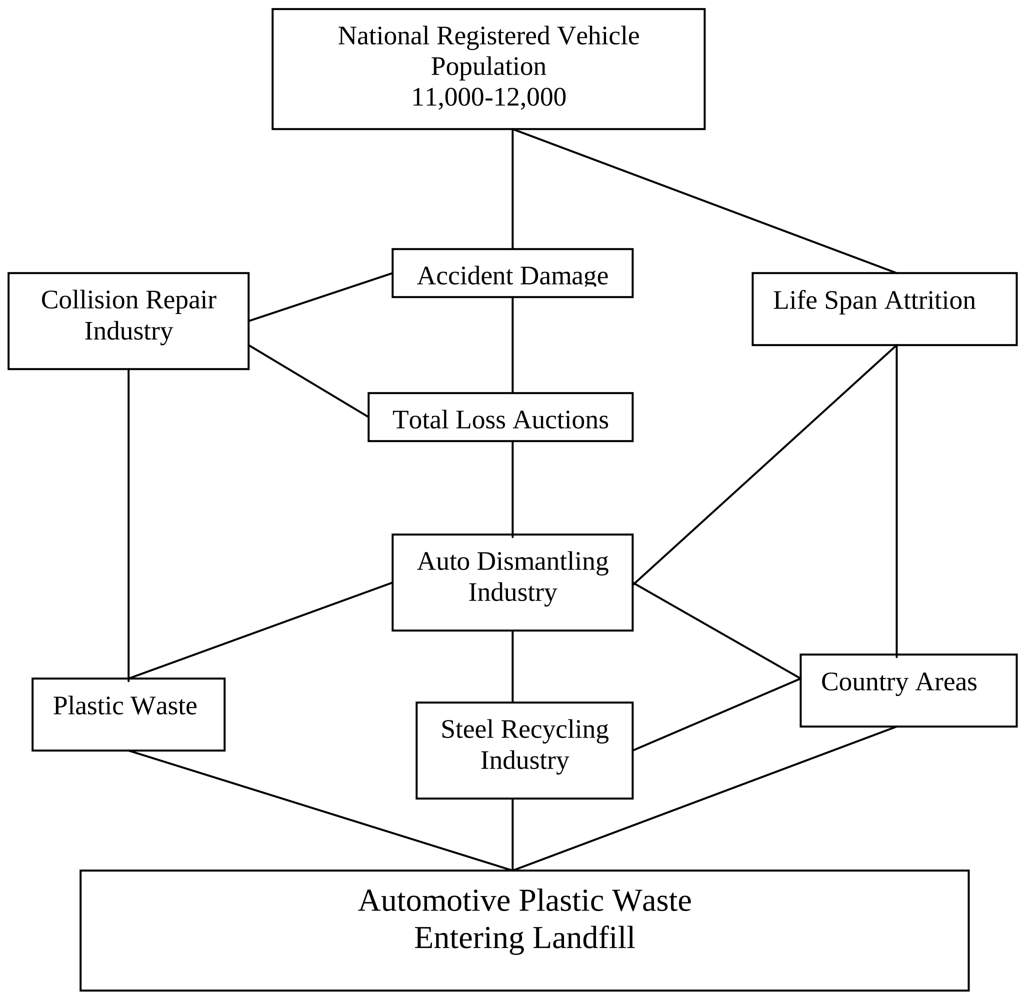

Figure 1: Waste Stream Flow Chart

Mechanical parts and packaging

Plastic packaging is used for protection of new automotive mechanical and panel parts during shipment. It takes the form of plain plastic wrapping film, shrink-wrap, bubble wrap, styrene foams in the form of solid encasement and granulated pellets for loose filling of voids. Some mechanical parts are plastic such as gaskets, pullies, cable housings, electrical fittings, high-tension leads, engine mounts, bushes and spacers. This source of automotive mechanical plastic waste, parts, packaging and consumables directly feeds landfill by rubbish removal services.

Retail service products

Retail outlets such as petrol stations, automotive sections within large retail chains and specialist automotive shops supply products to the private sector for vehicle maintenance and service. In addition to parts and packaging listed above, the activity of maintaining vehicle mechanical condition, the utilization of cleaning products and creative styling products all produce a wide range of plastic waste. Apart from carpets, seat covers, hubcaps and other accessories that find their way into the waste stream, plastic containers are the most concerning. Plastic containers for oils, brake fluids, radiator coolants, windscreen wash additives, battery acids and cleaning and polishing products all have residue left within the containers when discarded. The private sector disposes almost all of this waste through domestic waste removal pickups.

Collision industry parts packaging and consumables

Packaging of collision repair parts is similar to above, however collectively, collision repair plastic waste is possibly the largest contributor. Added to packaging of parts are everyday plastic consumables, ranging from empty plastic containers, adhesives, paint residues from mixing and paint dust from sanding, primer and topcoats deposited in repairs, polyester body fillers dusts and filings created during repair, polyester fillings deposited on damaged parts, sealants, abrasive cloths, polishing and cleaning aids, masking plastic films, and tapes. This source of waste directly feeds landfill by rubbish removal services.

Automotive plastic panel parts

Replacement of automotive damaged plastic panels and parts encompass bumpers and inserts, headlamps park lamps, tail lamps, indicator lamps, grills, radiators, radiator support panels, fans and housings, washer tanks, air cleaners, air duct tubes and fairings, inner guard linings, guards, bonnets, door skins, boot panels, hub caps, body mouldings, interior fittings and trims. This source of waste also directly feeds landfill by rubbish removal services.

Steel recycling automotive shredder residue

Steel recycling is a major global industry with automotive vehicles that have reached the end of their useful life being a major source of feedstock. There are more than 600 car shredders operating worldwide, in Europe there are 224, the Americas 242, Asia 195, the Middle East 7, Africa 11, Australia 10 and New Zealand 2 (Recycling International, September 2001, p.29).

The major feedstock for the steel recycle industry is car bodies and components that have reached the end of their usefulness. The average age of automotive feedstock being processed at present is within a parameter of 10 to 20 years of age, mostly vehicles that contain an average plastic content of some 40 to 80 kilo per vehicle.

The basic operational function of steel shredder equipment is by placing the vehicle on a conveyer belt where it is delivered to and caught between heavy rollers. The rollers compress the feedstock and feed it into the shredder rotor housing. The housing contains a fast revolving drum weighing many tonnes. Attached to the drum are pin hinged hammer plates that smash the feedstock to small pieces as the rollers feed the material over the edge of an anvil. Depending on horsepower size, shredders can process 10 to 200 tons of car bodies per hour. Often these vehicles are still complete, with motors, wheels, tyres and internal trims. The reclaiming process separates ferrous and non-ferrous metals leaving a mixture of waste materials for disposal. It is this waste material that is called Automotive Shredder Residue. In Australia, all Automotive Shredder Residue is sent to designated landfill sites.

Auto parts recyclers

The main feedstock for the automotive recycling industry is smashed vehicles. When storage costs of vehicles in dismantling yards exceeds the potential profitability left within the wreck, these car bodies are either baled, flattened or transported as they are to steel recycling centres and sold as scrap steel. Inherent within this feedstock are various plastics. Other waste from the recyclers goes direct to landfill.

Automotive plastic recyclers

There is a small and scattered cottage industry associated with the collection of automotive bumpers for recycling from the crash repair industry. These are mostly small operations and are highly labour intensive. The separation of thermoset from thermoplastic materials is necessary, as thermosets cannot be remelted. The removal of all metals, such as brackets and mouldings, is a prerequisite. Further separation into the different types of various plastic compositions (20 or so) is needed, as different plastics are not compatible when in a molten state. This is a requirement for on-sale to traditional plastic recyclers for granulating.

The profitability of such exercises is questionable due to the costs of transport and gathering costs, labour costs associated with stripping and finding markets. These markets are limited to plastic recycling companies that are highly mechanised with specialised equipment capable of shredding bumpers and granulating this feedstock for remelting. The material, whilst in a molten state, is then sieved for impurities, pelletised and remixed with blends to conform to marketable specifications.

Polyolefin plastics, the mainstay of material mostly used for plastic bumper manufacture, has a retail price ranging between 90 to 140 cents per kilo. An average bumper weighs approximately 2-3 kilos so new material costs are in the vicinity of $3 to $4 dollars per bumper. Recycled material offers a saving of around 30%, 30/45 cents per kilo. With a window of something in the region of $1.50 per bumper, minus handling, processing, and marketing re-granulated material, not much is left for profit. When compared with the costs of purchasing virgin plastics with guaranteed compositions free from contaminates, the small savings made in purchasing recycled automotive plastic bumper feedstock is not attractive to most plastic moulding fabricators.

Automotive plastic parts exchange services

Exchange headlamp and bumper bar businesses are on the fringe of the collision repair industry and recycle damaged plastic parts as a service industry. This cottage industry is testimony to the inability of the collision repair industry, in general, to come to terms with embracing the knowledge and skills required to weld and repair damaged automotive plastics in house. The exchange headlamp and bumper industry is comprised mostly of small enterprises whose proprietors recognise profitability in others' discarded waste.

National turnover in Australia is small and estimated to be in the vicinity of $20 million. The ratio of waste components required to build exchange parts supplied is approximately 8 to 1. Almost all feedstock within this industry eventually enters landfill, the only exception being a small percentage that enters the general plastic recycling area where it is granulated, mixed with other plastic blends and reused by manufacturers as feedstock.

Country and regional districts

Almost all automotive plastic generated by the collision repair, auto dismantlers and mechanical service industries in country and regional areas enters local landfill.

Private disposal

Private servicing of vehicles accounts for the majority of discarded plastic automotive fluid containers through the residential rubbish removal system. The Environment Minister, the Honorable Dr David Kemp (2004, 18 May, p.8), was cited in *The Australian Financial Review* as drawing attention to the 100 million litres of used oil that is unaccounted for each year. Although the disposal of automotive plastic waste by the private sector was not researched, a percentage of oil containers would be, by association, part of Dr Kemp's statistics.

Discarded car bodies in private hands mostly find their way to steel recycling centres due to scrap steel being in excess of a $100 per tonne. Country and rural areas that lack waste receiving depots dispose of vehicles directly into landfill.

Tyres

Annual production of tyres worldwide is estimated at 3,000 million tons per annum. Of these, Australia accounts for some 17 million (Motor Equipment News, 2000, p.5). Some 45000 truck tyres and 1 million car tyres are retreaded each year. Statistically, 70% of truck tyres compared with only 15 to 20% of car tyres are suitable for retreading. Not all car tyres can be retreaded due to the materials used in tyre manufacture. Unlike trucks, the rubber content is much lower and they contain thermoset plastics such as as butadiene-styrene. Used tyre cases mostly enter landfill as shredded waste with some used for recycling.

Incineration is the most prominent recycling use with 25,000 tons being burnt annually in Queensland and Victoria in cement kilns. Reducing tyres to fine particles, called crumbing, accounts for some 1,000 tons of filler, used in bitumen for roads. Other uses are impact absorption, for areas such as playgrounds, retainer walls and crash barriers. Some recycled products are manufactured into garden hoses. At present, there is a global interest in the methodology of pyrolysis as a process for tackling the problem. Tyres and rubbers account for 16% of Automotive Shredder Residue content.

Collision Repair Data

National statistics

Panel-beaters have adopted a number of descriptors to describe their industry such as Smash Repairers, Crash Repairers, Panel beaters and Collision Repair Centres. The latter is now in vogue and has been bought about by industry organisations' attempts to project a more refined image to the public. Similar policies can be found as the auto wrecking industry now favours descriptors such as Auto or Automotive Dismantlers. National phonebook listings still use Smash Repairers or Panel beaters as industry descriptors.

National statistics for the numbers of collision repair specialists currently in business in Australia were extrapolated from phone book yellow page listings. The total number of collision repairers currently listed for business is 5737 (Table 1). This suggests the Australian population is well serviced, with Britain having a ratio of one repairer for every 4717 vehicles and USA one repairer for every 2453 vehicles, compared with Australia one repairer for every 1925 vehicles (Thomson 2004, p.18).

Table 1: Distribution of Collision Repair Centres in Australia

States/Territories	Number of Collision Repairers	Percentage
ACT	80	1
NSW	1945	34
NT	42	1
QLD	1041	18
SA	494	9
TAS	122	2
VIC	1517	26
WA	496	9
Total	5737	100

Thomson's statistics of one repairer for every 1925 vehicles, when factored out with yellow page business listings, suggest the national registered fleet is in excess of 11 million registered vehicles. A media release by the NRMA (2002, 14 Nov.) claims there were more than 12.5 million cars on Australian roads in 2002.

Work analysis

The collision repair business within Australia is estimated to be a $3.6 billion industry, with vehicle owners paying insurance companies an estimated $4.8 billion for vehicle insurance cover (Thomson 2004, p.18). Insurance Statistics Australia Limited (2003) recorded an average of $2,291 per vehicle per claim due to collision and other accident causes for the year ending 2001. This statistic did not include theft from vehicles or windscreen damage claims.

The collision repair industry is almost entirely owner operated with small work forces from one or two to 20 or so employees. There are a percentage of larger businesses with employee numbers around the 80s, however these super shops represent a minority. The industry draws almost all of its work from automotive accidents. Secondary work sources are body maintenance, auto restoration and presentation for sale of used cars. Most automotive accidents are insurance claims where repairers deal directly with insurance companies. Uninsured third party accident claims, trade and private repairs make up the balance.

Vehicle accident and replacement analysis

Shoebridge (2004, p. 53) reports that the total recorded number of new vehicle sales for 2003 in Australia was 909811, an increase of 10% over 2002. Researchers AC Nielsen predicted that vehicle sales would climb to 950,000 in 2004 whilst automotive consultants Aon Martec, cited by Shoebridge in the same article, were more conservative and predicted 2004 figures to be 925,000. With a national fleet of some 12 million vehicles, and allowing for a 10% increase per annum, the increase recorded in 2003 suggests a national fleet replacement within 10 to 12 years.

For accident analysis, the Bureau of Transport and Regional Economics (BTRE) (BTRE-Report 102) uses insurance company statistics as more crashes appear to be reported to insurance companies than any other organization. Those not reported are either uninsured or under claim excess costs, and therefore are not recorded in insurance company statistics. Estimates of unregistered vehicles on Australian roads by BTRE are 4 - 5%. The Insurance Council of Australia (ICA) estimates that 10-13% of vehicles in Australia are not comprehensively insured.

BTRE holds the view that insurance company statistics underestimate the total number of low-damage crashes. BTRE supports this view by citing supporting data from two large Australian fleets comprising mostly passenger vehicles. For both fleets, collision repairs of less than $2000 in value occur more than twice as frequently as insurance data suggest.

This difference can be explained when consideration is given to the logic of not claiming on insurance when costs of repairs are under excess claim costs. Other factors include reluctance to claim to protect ‘no-claim-bonuses’ or costs of repairs being so small as to not warrant claiming. Given this, the BTRE statistics of the total number of damaged vehicles due to collisions estimated in 1996 at 1,204,352, if based only on insurance statistics can be considered as conservative. Table 2 shows a breakdown of the total number of estimated accident damaged vehicles for 1996.

Table 2: Vehicle Collision Analysis: 1996 (ABS)

Type of Vehicle	Accidents
Cars	1,132,000
Motorcycles	18,222
Rigid trucks	37,800
Articulated trucks	6,780
Buses	9,550
Total	1,204,352

The table shows the accident statistics for motorcycles, rigid trucks, articulated trucks and buses. Collectively, they represent six percent of the total accident rate. No research into the plastic waste associated with these statistics has formed part of this research but would add to the overall findings. Motorcycles for instance are mostly clad in plastic fairings, some kits costing in excess of $6000. These components are the first parts to be damaged when motorcycles are involved in collisions. An assessment of two kilos of plastic per motorcycle damaged by accident is not unrealistic and would equate to the generation of some 36 tonnes of motorcycle plastic waste per annum.

Collision repair consumable plastic waste analysis

In-field research examined the plastic waste generated within three average size collision repair centres, one in a country area some 300 kilometres from Adelaide and the other two within the Adelaide metropolitan area. The core business of all three is insurance company collision repairs.

Both metropolitan businesses used the same process for waste removal which was the emptying of an industrial bin once a week. The bins hold some three cubic metres of un-compacted waste. The country business uses two conventional domestic ‘wheelie bins’ supplied by the local council for weekly removal of small consumable waste, some 1.2

cubic metres, and stores larger waste in stockpiles. The stockpile of plastic bumpers and other large plastic parts is removed to landfill at an average of three times per annum.

A monthly record of the volumes of consumable plastic waste generated by the individual repairers was recorded in-field on worksheets (Consumable Plastic Waste Analysis, Appendix A), added together and averaged. The findings from these data were factored up by the number of collision repair centres within Australia to extrapolate the mean volume of consumable plastic waste entering landfill, and are presented in Table 3.

Table 3: Collision Repair Industry: Consumable Plastic Waste

Location	Kilo’s per month	Kilo’s per year
Repairer 1	140	1680
Repairer 2	93.5	1122
Repairer 3	120.5	1446
Average per repairer	118	1416

National volumes, 5737 repairers @ 1.416 tonnes = 8123.592 tonnes

The general analysis of data relating to the consumable plastic waste was found to be consistent within the three studied businesses and is representative of industry practices and presents an accurate basis for factoring. The consumable plastic waste statistics gathered from the three research sites did not include plastic parts that were replaced with new. Those statistics were gathered at insurance accident assessment centres. Random samplings of plastic part weight calculations were taken and recorded. These statistical data were correlated and averaged to produce a mean for application to the average collision repair statistic of plastic parts waste weight.

Collision repair plastic parts waste analysis

The volume of replaced plastic panel parts, bumpers, grills, headlamp and tail-lamps, radiators, inner guards and sundry other damaged plastic components were recorded at the insurance company assessment centres. This was done by in-field individual assessment of damaged vehicles prior to repairs being effected and then cross-referenced with insurance repair invoices after repairs were completed. Totals of new plastic parts fitted were recorded on the three Vehicle Crash Quote Analysis forms. The findings were factored up by the number of collision repair centres within Australia to attain the mean volume of plastic parts waste entering landfill. The data are presented in Table 4.

Table 4: Collision Repair Industry: Plastic Parts Waste

Crash Quote Analysis	Claims	Plastic Parts
1	28	376
2	7	58
3	26	97
Total	61	531
Average per claim	1	8.7 parts

Total collision repair plastic waste entering landfill

The total volume of collision repair plastic waste entering landfill is the combined total of discarded damaged plastic parts added to the collision repair industry's consumable plastic wastes (see Table 5).

Table 5: Collision Repair Industry: Plastic Waste Entering Landfill

Materials	Tonnes per month	Tonnes per year
National consumable plastic waste	677	8124
National replaced plastic parts	250	3000
Total	927	11,124

Insurance Accident Assessment Centre Data

Parts assessment

Pre-assessments of individual vehicles subject to collision repair claims were assessed for damaged plastic parts. A total of 61 individual assessments were undertaken over three periods. The first assessment period involved 28 assessments in the pilot study over a period of two months from December 2000 to February 2001 (Vehicle Crash Quote Assessment 1, Appendix C). The second assessment period during May 2001 recorded data from seven vehicles (Vehicle Crash Quote Assessment 2, Appendix D). The third assessment of 26 vehicles was recorded during December 2003 to February 2004 (Vehicle Crash Quote Assessment 3, Appendix E). The total number of plastic parts replaced with new, repaired or second hand is recorded in Table 6.

Table 6: Plastic Parts Assessment Data: December 2000 to February 2004

Crash Quote Analysis	Assessments	New	Repaired	Exchange	Second hand
1	28	376	14	7	-
2	7	58	1	3	-
3	26	97	10	6	15
Totals	61	531	25	16	15

When repairs were completed and the repair invoices were submitted for data comparison and analysis, the 61 invoices were analysed to produce statistical data for a single accident. The average claim repair cost for the 61 sample assessments was $3,394. Insurance Statistics Australia provides reports to its members in the form of rolling monthly average indicators extrapolated from gathered data on automotive claims costs, size, frequency and loss ratio. The Insurance Statistics Australia rolling monthly average, as at December 2001, for an automotive collision claim cost was $2,291.

A figure of $2,300 per claim has been used as a basis for an average claim cost for factoring down from $3,394 and has been applied to all the gathered statistical data to represent an average claim analysis. These extrapolations are recorded in Table 7 and are taken from the Repair Analysis Raw Data spreadsheet (Appendix J).

Table 7: Single Accident Average Data (61 infield assessments)

Claim data	Average claim statistics
Claim cost	$2300
Total parts costs	$1055
New metal parts costs	$545
New plastic parts costs	$506
Total new parts supplied	10
Total new metal parts supplied	4 (rounded down from 4.2)
Total new plastic parts supplied	6 (rounded up from 5.8)
Percentage of repaired plastic parts	.27
Exchange plastic parts	.17
Second hand plastic parts	.16

The above data indicate that, on average, there are more plastic parts used than metal parts, the cost of metal compared with plastic is similar, one plastic part is repaired every four claims, one plastic part is supplied from specialist plastic exchange sources every six claims, and one second hand plastic part is supplied every six claims. An average of six new plastic parts are supplied per claim which equates to a repair ratio of one repair for every 24 new plastic parts fitted. This low repair ratio was anticipated, given the findings in the pilot study pertaining to industry repairer attitudes towards plastic welding and repairs.

Accident damage vehicles: plastic repair pre-assessment

Vehicle crash quote analysis number 3 recorded an assessment of 26 accidents with a pre-accident assessment of damaged plastic components deemed to be repairable. Details and assessed repair times were recorded on Vehicle Damage Pre-Repair Worksheets (Appendix B) for comparisons against actual repair invoices submitted by the repairers. Consideration as to economy of scale relating to time, repair, quality and cost factors was paramount. Pre-accident assessments were factored to a charge out rate of $80 per hour.

After the vehicles were repaired, copies of repair invoices were supplied for analysis and cross-referenced with the plastic damage pre- repair assessments for a comparison of recorded data (Appendix C). New plastic parts supplied that were pre-assessed as repairable were subject to comparisons associated with economy of scale utilising the repair cost factor of $80 per hour. The calculated labour cost of repair was compared with the price of the new part fitted to test the economy of the suggested repairs. Analysis of the findings is presented in Table 8.

Table 8: Collision Repair Analysis (26 invoices)

Variables	Findings
New plastic parts supplied	97
Plastic parts assessed as repairable but replaced with new	15
Total assessed repair times of above	13.65 hours
Average assessed repair time per part	.91 hours
Gross savings opposed to supplying 15 new parts	$3147
Less estimated repair costs 13.65 x $80 per hr.	$1092
Estimated savings opposed to supplying 15 new parts	$2055
Average estimated savings from 26 assessments	$79 per claim

An NRMA (2001) media release cites claims manager Paul Pemberton reporting that their repairers repaired some 85,000 vehicles in NSW and the ACT, in a 12-month period from 2000 to 2001. Insurance Australia Group limited (IAG), the flagship for NRMA, SGIO, SGIC, STATE, CGU and NZ Ins, are estimated to control sixty to seventy percent of market share of motor vehicle insurance in NSW and ACT. Factoring up the IAG statistic at a seventy percent base, produces the total number of vehicles repaired in NSW/ACT at some 121,428 per annum. Factoring up on a population basis, the total national assessment for accident vehicles repaired equates to some 346,000 insurance claims per annum.

Difficulty arises when ascertaining an accurate number of motor accident repairs carried out by the collision repair industry due to the number of repairs that are not covered by insurance. This is a statistic that is unobtainable due to research limitations however, by only factoring up insurance statistics and ignoring private repairs, it can be argued the findings are conservative.

With a mean average of six new plastic parts supplied per claim (from Table 7), the total assessment of plastic parts replaced by the collision repair industry equates to some two million new plastic parts fitted to some 346 insurance claims per annum. Using a rounded average of $90 per plastic part, the retail cost is in the vicinity of $180 million per annum. When factored up to the rounded Insurance Statistics Australia statistic of $2300 per claim (Table 7), as opposed to $1804 (Table 8), the possible savings of $79 per claim equates to a figure of $100. This delivers a potential savings on insurance claim costs of $34.6 million per annum. This figure could be attainable through improvement of current work practice skills and attitudes pertaining to the welding and repairing of damaged automotive components.

Collision repairers would also benefit by the creation and sale of additional labour at an average of close to one hour per claim. Three hundred and forty thousand hours at $80 per hour represents a possible national yearly labour sales turnover improvement for the collision repair industry of some $27.2 million. Twenty seven million dollars of additional repair charges would require additional employment of some 200 - 300 tradespeople, fully trained in the specialist skills required for automotive plastic welding and repairs.

Postal Survey Data

TAFE institutes

The aim of the survey was to obtain a broad picture of training delivered by the TAFE training sector in relation to automotive plastic welding and repairs for the collision repair industry. The raw data shown in Table 9 were extrapolated from the returns obtained and transferred to a Survey Descriptive Statistics spreadsheet (Appendix G) for the distribution of scores and general remarks.

Table 9: Survey Raw Data

1. How many teachers in your panel beating section? 1 to 3 (8)   4 to 5 (1) 6 plus (2)
2. Number of students per annum?   1 to 19 (2) 20 to 39 (4) 40 plus (5)
3. Training offered to: Apprentices (11) Adults (3)   Other (3)
4. Is training based on the Automotive Industry Training Package AUR99?   Yes (10)   No (1)
5. Are training resources supplied from an outside source?   Yes (10)   No (3)
6. If yes,   who supplies them?   Curriculum Designers (4)   Product Suppliers (4)
7. If not,   who designs them?   Teaching staff (6)   Other (1)
8. Is there a formal program for updating training resources?   Yes (7)   No (3)
9. If yes, how often?   Per year (1)   No time limit (8)
10. Is there an internal and regular train the trainer program in your institution?   Yes (5)   No (6)

11. How is updated knowledge and skill obtained? Teacher based research (7) Wherever possible (4)

12. Do financial restrictions hamper student training? Yes (5) No (6)

13. Do financial restrictions hamper the upgrading of trainer knowledge and skill? Yes (5) No (6)

14. Is there a formal Automotive plastic welding and repair training program? Yes (10) No (1)

15. If no, is it because: No interest? (1) No funding? (1) No resources? (1)

16. Is it considered an important panel beating skill? Yes (10) No (1)

17. If such a component is delivered, how long is it? 10 hrs + (4) 20 hrs + (1) 30 hrs + (6)

18. Level of training delivered? Subject introduction (2) Basic skills (6) High competence (3)

19. Would a trained student be expected to assess the viability and repair when practical and with confidence: All plastics? (1) Most plastics? (4) Some plastics? (3)

20. In your institution, are teachers confident with knowledge on the subject? Yes (8) No (2)

21. Do the teachers need more knowledge on the subject? Yes (8) No (2)

22. If yes, do they know where to get it? Yes (4) No (4)

23. Is upgraded training knowledge shared with other institutions? Yes (5) No (5)

24. Is there feedback from the repair trade on plastic repair training needs ? Yes (5) No (6)

25. If not, is it because: Not sought? (6) Sought, but not received? -

26. Do you consider there is need for improvement in knowledge and skill to teach plastic welding? Yes (9) No (2)

A total of 38 postal questionnaires were directed to head teachers of automotive repair panel beating divisions at TAFE institutes throughout Australia. Eleven completed returns were received, a response rate of 29%. The returns represented approximately 35 teaching staff delivering training to some 380 students. All of the institutions provided training to apprentices, with three offering additional training to adults and others. All respondents confirmed their training is based on the Automotive Industry Training Package AUR99 with 90% indicating that they considered plastic welding and repair an important panel beating skill. One respondent did not consider it so and the institution did not offer a formal automotive plastic welding and repair training program due to a combination of no interest, no resources and no funding, although the person did not complete the questionnaire and indicated the subject was at least discussed.

The duration of the plastic training module delivery varied, with four institutions offering the program within a time frame of ten hours plus, one at twenty hours plus and six at thirty hours plus. Eight of the 11 head teachers assessed the level of training delivered in their institutions to be at introductory or basic levels. The fluctuations of training times and the basic level of skilled outcomes suggest a mediocre level of tuition and understanding of the subject. Furthermore, only one respondent claimed their training produced a level of high competency attainment that would enable students to assess with confidence the viability of repairing all damaged automotive plastics that are encountered within the workplace.

The survey indicated that most of the training resources are supplied from outside sources, equally divided between curriculum designers and product suppliers. Just over half indicated the curriculum is redesigned or supplemented by teaching staff. Less than half claimed to have an internal regular train the trainer program; seven relied on teacher based research for updating knowledge and skill with the remaining four obtaining it wherever possible. Seven respondents have a formal program for updating training resources, although only one indicated a yearly time frame, while for the rest there was no time limit.

Eight of the head teachers judged that their teachers are confident in the subject; however eight of the respondents also indicated their teachers' need more knowledge on the subject. Half of these considered that their teachers did not know where to get such training even though up-graded training knowledge is shared between the institutions. Nine considered there is a need to improve knowledge and skill to teach plastic welding. Six of the institutions surveyed do not receive, nor do they seek, feedback from the collision repair industry in relation to plastic repair training. Financial restraints were signalled in response to questions 12 and 13, by six of the respondents as a significant factor in hampering student training as well as impacting on upgrading trainer's knowledge and skills.

Provision for general comments within the survey questionnaire (Appendix F) were divided into three sections, the training establishment, training resources, and automotive plastic welding and repair. Response comments are:

Section 1. The Training establishment

- Pre-vocational students and school-based apprentices & trainees as well as regular trainees
- Short courses to upgrade industry skills as required

Section 2. Training resources

- Increasing pressure from institute MGE [sic] to reduce expenditure on plant, equipment, and consumables-Required to be competitive with other RTO's

- Staff development funds are limited and shared throughout the institute
- Would like to send whole team to National workshops however can only send one
- State based material plus locally designed/material to meet local industry needs
- [how is updated knowledge and skill obtained?] Industry liaison, Industry

  Section 3. Automotive plastic welding and repair
- Some vehicles have plastic components that are relatively inexpensive and would be uneconomical to repair. However, some are expensive and could be economically repaired. Insurance Assessors need to ‘Drive” the repair of plastic components-then repairers will repair more.
- With the inclusion of more plastics in modern vehicle technology, more emphasis and content needs to be included in training package modules. Manufacturers must use more repairable and recyclable plastics to begin with.
- There is a lot of information out there on the subject area. Probably the biggest downfall for plastic repairs is the use of combinations of plastics in the manufacturing of these parts
- Every year new plastics come out and constant professional development is needed
- New materials, overseas products and equipment, additional information from vehicle manufacturers
- Most panel shops find it’s cheaper to replace plastic parts than repair

An overall interpretation of the survey findings and general comments suggests there is room for improvement. Although all respondents offer training based on the Automotive Industry Training Package AUR99, only one head teacher judges that training can be considered to match the learning outcomes within the training package competency unit, “AUR23908A Carry out thermo plastic repair procedures”. The significance of lack of funding was also apparent from the general remarks written by respondents. Reference was made to general difficulties, such as lack of funding, stifling the ability to enable competition with Registered Training Organisations and the inability of teachers to organise and attend workshops.

The survey findings provide evidence that a program of teacher workshops could produce an outcome that could positively impact on the level of workplace knowledge and skill pertaining to automotive plastic welding and repairs. The findings also suggest further research into sharing advanced curriculum on the subject could be warranted.

Steel Recycling Centres: Automotive Shredder Volumes

Quantifying the volume of automotive plastic waste entering landfill generated by the steel recycling industry was calculated by in-field measurement and analysis of the waste streams. Calculations were then factored up to estimate national volumes.

There are three internal Automotive Shredder Residue waste streams within the research site visited. The first is created during the actual shredding process and extracts material using a cyclone separator. This material, referred to as flock, is expelled directly to a dump pile. Due to the light nature and small particles within the flock material, measurements were not taken. Observations indicated flock consisted mostly of fine remnants from automotive trim materials such as carpets, foams, hood-linings and seat fabrics amidst other unidentifiable plastics and dust.

The other two waste streams are located further on in the metal separating processes. The second waste stream is the tailings from passing the material through a metal extraction process, which screens off material with a 40mm diameter or less. This waste comprises mostly stones, dirt and a small percentage of plastics. There are small amounts of metals inherent within this waste stream that are uneconomical to retrieve. This waste is collected in Bay 1. The third waste stream is at the end of the separation process. Almost all the material expelled at this point is comprised of plastics and tyre shredding.

Automotive Shredder Residue was measured and analysed from Bay 1 and Bay 5. In both cases the waste was captured in the bucket of a front-end loader as it spilled from the conveyor belts of the two separate waste chutes over a given period of time. The material was weighed and using calculations of volume over time, measurements were estimated to produce volumes of waste from these two sources.

These samples were subjected to further hand separation into several different variables such as plastics, metals, rubble and dirt. This analysis was recorded in working notes during the operation, Automotive Shredder Material Analysis (Appendix H). Extrapolations from this chart provided the statistical data for recording as Automotive Shredder Residue Analysis (Appendix I).

All three waste streams make up the total measurement of Automotive Shredder Residue that is sent to landfill. The company’s tonnage of Automotive Shredder Residue sent to landfill is recorded from weighbridge statistics taken on site as it leaves the premises in tip trucks. The weighbridge statistics were factored up to derive the total tonnage of Automotive Shredder Residue entering landfill within Australia from the steel recycling industry. There are ten automotive steel recycle plants operating automotive shredders within Australia. The output of production within each individual plant is subject to the horsepower size of the shredder. The methodology used for factoring was to measure the volume of plastic waste dispatched to landfill from the research site, relate that to the automotive shredder horsepower size and equate that formula to the other nine recycle companies' shredder horsepower sizes for the total yield. The statistical estimates are listed in Table 10.

Table 10: Automotive Shredder Residue Landfill Estimates for Australia

Steel Recycler	Location	Shredder HP rating	Tons P/W (50hr)	Tons Per Annum
Norstar Steel	Vic	1250	200	10000
Smorgens	Vic	6000	960	48000
Sims Metals	Vic	4000	640	32000
Metal Corp	Qld	4000	640	32000
Sims Metals	Qld	4000	640	32000
Sell & Parker	NSW	4000	640	32000
Sims Metals	NSW	4000	640	32000
Metal Corp	NSW	4000	640	32000
Sims Metals	WA	2000	320	16000
Totals			532000	266000

Research performed by Dr Richard Hooper, from the University of Brighton in the U.K (*Recycling International*, May 2003), produced a detailed statistical analysis of Automotive Shredder Residue. Dr Hooper concluded that the total percentage of plastics and rubber compounds within Automotive Shredder Residue was 60% (see Table 11). Applying this statistic to the estimated total Automotive Shredder Residue sent to landfill within Australia of some 266,000 tonnes per annum, the total volume by weight of automotive plastic (rubbers included) waste entering landfill from the steel recycling industry can be calculated to be around 142,000 tonnes per annum.

Table. 11: Automotive Shredder Residue in the United Kingdom in 2003

Plastics/rubbers		Other	
PP/PE	7	Misc.	17
Dense plastics	23	Metal	7
Foam	14	Textile	4
Tyre	6	Wire	6
Rubber	10	Wood	6
Total	60%		40%

Source: Dr Richard Hooper (*Recycling International*, May 2003).

Pyrolysis

Pyrolysis theory

Pyrolysis is the name of the process for the incineration of organic materials by the application of controlled heat under vacuum to facilitate the absence of oxygen. Decomposition occurs at operating temperatures above 430 deg. C (800 deg. F). There is a growing global interest in the methodology of pyrolysis as a process for tackling the problems of plastic waste (Commonwealth Department of Environment 2001). During the process organic materials are transformed into gases and quantities of liquid and solid residues containing carbon and ash. Gases may be condensed utilising a fractionating tower to produce petrochemical products. Several types of pyrolysis units are available, such as rotary kilns, hearth furnaces or fluidised bed furnaces. These units are simular to incinerators except that they operate at lower temperatures with less air supply.

A typical pyrolysis process involves heating shredded tyres in vacuumed chambers to degrade the feedstock. The decomposition of tyre feedstock produces carbon black 22%, oil 30%, gas 28%, steel 10%, with an inorganic slag/ash of 5% (Commonwealth Department of Environment, 2001). There are a number of experimental pyrolysis plants operating globally, though with varying degrees of success due to cost factors associated with by-products being uncompetitive with virgin materials. Nevertheless, pyrolysis offers some exciting challenges in the quest to overcome the ever-increasing problems associated with plastic waste disposal and the constant demand for raw petroleum products. There are no commercial pyrolysis plants in operation in Australia.

Pyrolysis research

The University of Iowa has a strong research program that focuses on the problem of waste plastics, particularly in the area of pyrolysis as a methodology for the recycling of automotive plastics. The University of Iowa is involved in tackling the inherent problems associated with Automotive Shredder Residue generated by the steel recycling industry. Research such as the Analysis of Plastics Waste from Shredder Operations by Associate Professor Curtis D. Hanson, from the chemistry department, and Kathleen E. Gordon, a waste reduction specialist, are projects that reflect on selected objectives of this research.

The analysis of plastic waste from shredder operations being researched by The University of Iowa focuses on the problems associated with the contamination of Automotive Shredder Residue with oily automotive fluids. They attach to the plastic substrate during the shredding process and pose a problem by leaching when deposited in landfill. This has resulted in the banning of Automotive Shredder Residue from landfill in some states of America causing automotive shredder operations within those states to seek alternative disposal routes or be forced into closing. The identification of oily automotive fluids in Automotive Shredder Residue identified within this research could offer an explanation for some of the missing 100 million litres of used automotive oil unaccounted for within Australia each year (Kemp 2004, p.8).

The research by Hansen and Gordon (2004) focuses on plastic content of shredder material such as polyvinyl chloride (PVC), a thermoplastic that produces hydrochloric acid under ignition, as well as a range of thermoset plastics that are created by the reaction injection molding process. These are mostly urethanes, common materials that are used in the manufacture of automotive parts production. The by-products produced from these plastics by the application of the pyrolysis process will be studied in terms of chemical mechanisms and their relationships to economical recycling potentials.

The research will produce novel methods during pyrolytic recovery by using a laser desorption mass spectrometer to observe reactions as the products are formed. Monitoring in this fashion will provide the opportunity to alter the forming products by optimising temperature and catalytic effects during pyrolysis. Further development may well test the hypothesis that pyrolysis may offer a sound alternative for the conversion of plastic waste from landfill to useful by-products.

The University of Iowa has also undertaken considerable research on the recycling of tyres and the refinement of by-products by also using the methodology of pyrolysis technology. The following three projects are examples:

- A Recovery Method for Tire Bead as Cast Iron Charged Material, by Scott Helzer, Assistant Professor, Industrial Technology, The University of Iowa.
- Production of Condensable Oxygenated Hydrocarbons from Low Temperature Pyrolysis of Scrap Tire, by Curtis Hanson, Department of Chemistry, The University of Iowa
- Expanding the Use of dl-limonene Derived from Spent Automotive Tires. by Kirk Manfredi, Assistant Professor, Department of Chemistry, The University of Iowa.

Recovery Method for Tire Bead as Cast Iron Charged Material researches the potential recovery of metal content from tyres by utilizing improved pyrolysis methodology. An estimated 240 to 280 million tyres are generated in the U.S. each year and total some two million tonnes per year of solid waste. With a present recycle rate estimated at 18%, this biomass of potential resource energy contains some 5/8-22lbs of steel per tyre and equates to 87,000 tonnes of steel, valued at some $14 million entering landfill each year in America.

In this research, the improvement in pyrolysis methodology focuses on the injection of various gases during the reaction to aid in the acceleration of cross-linking processes. The evaluation of the process confirmed that the system being researched promoted embrittlement of feedstock and aided in the destructive decomposition of isoprene polymers. An analysis of recovered steel indicated its suitability for feedstock for gray iron, but due to its brittle characteristics, not suitable for ductile base materials. The improved methodology suggests the process is practical for the recovery of charged wire for use in the manufacture of gray iron. The research also clarified the limitations of pyroletic methodology for tyre recycling (Helzer 2004).

Production of condensable oxygenated hydrocarbons from low temperature pyrolysis of scrap tyre research has perfected a new technique for utilizing the application of pyrolysis within a newly designed chamber. The new methodology economically generates a valuable organic solvent called dl-limonene. This is an improvement on traditional pyrolysis applications that have relied solely on heat being applied to tyres whilst under vacuum in a conventional chamber. This basic approach has proved to be not cost effective due to uneconomical energy requirements (Hansen 2004).

Further research into expanding the use of dl-limonene derived from spent automotive tyres is also being undertaken. The solvent dl-limonene has gained prominence as being environmentally friendly and is used in the electronics industry. The research proposes to isolate and purify dl-limonene into its respective enantiomers as by-products from the recycling process of tyres. Limonene has been traditionally isolated in its optically pure form from biological precursors such as orange peels. Separation of dl-limonene into its d and l forms would value add by being able to be used as precursors for fragrances, flavorings and pharmaceutical compounds. There are a number of uses for dl-limonene ranging from cleaning solvents to fragrance additives for industrial and domestic cleaners (Manfredi 2004).

Pyrolysis projects

With an excess of 3000 million tons of tyres being produced worldwide, global attention to scrap tyre recycling is acute. A recycling plant of Asamer Holding in Gmunden, Northern Austria, was planned to be online by 2003. It intends to process 40000 tons of scrap tyres per year. A similar plant is expected to be operational in England during 2004. It proposes to utilize a patented reverse polymerisation process using microwave energy to breakdown feedstock into carbon black, steel, oil and hydrocarbon gasses, the latter to be used as fuel to meet the plant's electrical needs. Asamer Holding claims the reverse polymerisation process using microwave energy has advantages over current pyrolysis systems due to even heat control and is more effective at lower temperatures. (*Recycling International*. March 2003, p. 32). In Japan, the Seinan Corporation operates a large shredder and treatment plant that incorporates pyrolysis methodology with the use of a Twin-Rec fluidised bed gasification and ash process (*Recycle International*, May 2002, p. 31.)

Waste legislation

Automotive recyclers are now operating in Europe under recycling legislation called the ELV Directive (End of Life Vehicle Directive). Voigt, cited in *Recycling International* (May 2002, p. 27), claims: 'By 2006, the total number of end of life vehicle's available for recycling in the European common market is estimated to be 7.28 million'. Voight further argues that they will most likely be treated in shredders and the 75% metal content comprising mainly iron, aluminium and copper will be extracted. The remaining non-metallic Automotive Shredder Residue, consisting primarily of plastics, glass, electronics and textiles, will be an estimated 1.65 million tons. This will be handled in accordance with the End of Life Vehicle Directive, which demands that 85% by weight will have to be used, recycled or recovered by 2006, and 95% by 2015.

Australia has no present directives in place pertaining to Automotive Shredder Residue entering landfill other than stipulations that designated landfill repositories must be used for Automotive Shredder Residue waste. The presence of low levels of Polychlorinated Bi-Phenyls (PCBs) in Automotive Shredder Residue has been researched and identified by Environmental Consulting Pty Ltd, Oakleigh, Victoria. In the past, PCBs have been used as plasticizers in plastics, automotive paints, hydraulic oils and cooling systems. PCB chemicals are considered cacogenic and are now banned and being phased out from industry (Waste Management in South Australia, 2000).

Polychlorinated Bi-Phenyls (PCBs)

With limited performance data available for treating hazardous wastes containing PCBs, dioxins and other organics (Pyrolysis, 2003), the following research on pyrolysis is also poignant. The US Army Environmental Centre has carried out research in cooperation with the Tennessee Valley Authority and Vanguard Research Incorporated into the destruction of hazardous waste. They have successfully developed and demonstrated the destruction of hazardous and regulated medical wastes using plasma energy pyrolysis as an alternative to incineration. It delivered a destruction and removal efficiency of 99.9999%. This research supports the theory of pyrolysis being used as a possible methodology for approaching the problems associated with PCBs inherent in Automotive Shredder Residue and presently entering landfill in Australia.

5.
DISCUSSION

Introduction

The examination of the research findings is wide and varied due to the scope of the project. Although the following discussion addresses these findings separately, they are dependant on each other for an overall conclusion as to current theories, work practices, and the conduct of the study in relation to a strategy for reducing automotive plastic waste from entering landfill within Australia. Although the discussion highlights research findings that tend to lead towards conclusions, such conclusions will not be drawn in this discussion section but will be reserved for the following conclusions section.

Main findings

The two automotive plastic waste streams subjected to in-depth research were the steel recycling industry and the collision repair industry. The findings clearly defined stable and entrenched work practices pertaining to the creation and disposal of plastic waste within both industries.

The steel recycling industry

The steel recycling industry can be described as secondary mining activity, one that extracts resalable metals from processed feedstock, mainly motor vehicles. The process for the recovery of ferrous and non-ferrous metals is highly mechanised and creates a waste stream commonly referred to as Automotive Shredder Residue. Inherent within Automotive Shredder Residue is automotive plastic waste, a material that accounts for 60% of this particular waste stream. The steel recycling industry produces the most automotive plastic waste within Australia, some 150,000 tonnes per annum. Present practice of disposal is to send the Automotive Shredder Residue to designated landfill repositories, a costly exercise for the industry and one that creates an increasing burden on landfill sites.

The research has established a lack of incentive for the industry to separate plastic from the Automotive Shredder Residue waste streams given there is not an established market for such material. The plastic waste is contaminated with low levels of PCBs, and is a mixture of rubberised materials, thermoset and thermoplastic plastics. Separation of Automotive Shredder Residue to retrieve the plastic content and then further separation into the various plastics suitable for recycling would not be cost effective due to capital outlay and marketability of contaminated plastics. The industry would, however, welcome any cost effective disposable options or alternatives that could result in a saving on tipping fees.

In the long term, pyrolysis methodology may provide a cost effective alternative to present disposal practice.

The collision repair industry

Plastic waste generated by the collision repair industry is a direct result of the repair of automotive collisions and has been approached by researching two distinct variables: one, the actual plastic waste generated as a by-product of the repair process, and two, the analysis and identification of automotive plastic parts that are replaced with new rather than being repaired. Both of these contingents are combined to produce an overall picture of the plastic waste problem within this industry; however, separate investigation enabled a direct focus on the issues relating to a reduction strategy.

Pyrolysis

The biomass of reclaimable energy in the form of petrochemicals and activated carbons are recognised as trapped resources in present plastic waste. Pyrolysis is the only known way to extract these raw materials and therefore has formed part of this research project in the form of a literature search. The search has identified pyrolysis as an exciting and current methodology that is at present the subject of a number of research studies being conducted worldwide, with some projects directing their focus on the problems associated with Automotive Shredder Residue. Current research indicates a positive future for the technology, as it has been shown to neutralise PCBs, offer positive catalytic effects with the introduction of various gases during the process that enrich reclaimed chemicals, and has proven to be a non-polluting method of converting present plastic waste into useful by-products. It would not be an immediate answer to the current problems associated with Automotive Shredder Residue, however the literature search findings do provide for a solid argument that further research into the process is warranted to ascertain the suitability and financial justification for the construction of a pilot plant here in Australia.

The research indicates that there is no short-term solution to the volume of automotive plastic waste generated by the steel recycling industry presently entering landfill. However, the plastic waste stream created by the collision repair industry is another matter. It could be lessened instantly with changes to present work practices and attitudes.

Waste stream

As part of the repair process vehicles are stripped for repair. At this point, the separation of damaged plastic components that are being replaced with new from other waste would be a simple procedure. It is not a present work practice but if implemented could prove to be a cost effective method for automotive plastic waste to be redirected into the general plastic recycling stream, one that is already well established. A time element and product knowledge for separation of the various plastics would be critical as the plastic recycling stream requires unadulterated plastics, stripped of any metals as well as sorted into the various material types.

One reason for this not being practised within the collision repair industry is the lack of financial compensation to the repairers for waste removal. Of the 61 collision repair invoices submitted to insurance companies in this research, at a total repair cost of $207,059, only $38 was awarded for waste removal. Waste removal within the industry is considered at present as an inherent cost of doing business. This is in direct contrast to the automotive mechanical repair sector where a standard practice for charging a waste removal levy applies. Metro Holden, Adelaide, strike it at $4 per invoice. The research confirms that, at present, almost all collision repair plastic waste is sent to land fill mixed with other forms of industrial waste.

Plastic repair practice

The research also identified that present collision repair work practices favour replacement of damaged automotive plastic parts rather than assessment for repair. There are several fundamental factors that contribute to this trend, predominantly a general lack of knowledge and skill by repairers pertaining to the subject and a poor hourly labour rate controlled by the insurance industry. In Victoria, the basic insurance hourly rate has remained at $23 per hour for the last 13 years, as opposed to the increase in insurance premiums of 140% over the last five years (Hudson 2004, p.1).

This supports the collision employers' argument that, with low hourly labour rates, there is no incentive to improve work practices by training staff to repair. Instead, some elect to rely on parts mark-ups to bolster profits. Attitudes such as this create bottlenecks by proprietors or management for the advancement of trade skills as workers are deprived of the opportunity to improve skills. Trades people who have finished their basic training are disadvantaged if they work for an employer who does not embrace a policy of ongoing training. Often the only opportunity to improve skills rests with apprentice or adult training within the TAFE system.

TAFE training

The research has found automotive plastic welding and repair training within the TAFE system to be variable, with the quality of training differing from one institution to the next. Attitudes range from a complete lack of interest towards the subject to it being considered a high priority. There is no evidence of a national policy within the TAFE system that indicates a plan of action for sharing plastic welding and repair curriculum for the advancement of accurate and updated training resources. Instead, it is left to individual institutions to find their own way on what to offer trainees. This situation is fuelled by Government's propensity to encourage a climate of competition between all educational providers. This approach, under the heading of rationalization, expects TAFE to compete with private enterprise. The short-term effect, fuelled by restricting funding, has led to some closures of collision repair facilities within the TAFE sector. The solid underpinning foundation for industry training provided by the TAFE system within Australia is being slowly eroded at a time when technology advancement has never been greater.

Industry training

Registered private providers offer training to the collision repair industry and issue Certificates of Attainment to trainees whom they consider competent based on their interpretation of Training Package requirements. With the subject of plastic welding and repair, the only interpretation of competency is based on the Automotive Industry Retail, Service and Repair Training Package AUR99, competency standard AUR23908A, Carry out thermo plastic repair procedure.

Individual product and material suppliers also offer industry training. They provide training materials that tend to be supplier-specific and structured around the promotion and sale of their own repair systems and materials. Training materials presented in this format, although slanted, do offer industry systems that are practical, but often do not always present the most cost effective repair process as the emphasis is more on marketing their products rather than general subject knowledge. Almost all of this training falls outside the guidelines of the National Training Framework.

Insurance Australia Group (IAG), the largest automotive insurer in Australia, realises the necessity for the collision repair industry to keep pace with changing automotive construction trends and its propensity to use more plastic for parts manufacture. IAG launched a national campaign to assist in training its preferred smash repairers in the skills associated with automotive plastic welding and repairs with a training project called the Plastic Repair Index. With an annual parts bill of some $500 million, $250 million of which relates to plastic parts, its approach to influencing up-skilling of the industry is understandable and, even if modestly successful, equates to massive savings on automotive claim costs of millions of dollars per annum.

The impact of this training program, introduced in mid 2002, has not been measured within this research; however, it highlights the necessity in the present climate for industry to take control of its own training needs. This action by IAG draws attention to the serious difficulties in the TAFE system keeping abreast of industry's current training needs and in turn supports Federal Government policy to shift the balance of the responsibility for industry training to industry itself, a policy that is fuelled by constant cutbacks in TAFE funding and closure of some TAFE apprenticeship facilities.

A strong argument can be mounted for the Federal Government policy in relation to big business taking charge of its own training requirements; however, the effect on cottage industries such as the collision repair industry can be questioned. The reluctance of small business to invest in training is evidenced in the demise of the Federal Government's Training Guarantee Scheme. Many small employers saw it as a burden and, although the effects have not been properly evaluated, the scheme was abandoned (Burns 1995).

Overview

The research has identified stable work practices that identify the predominant automotive plastic waste streams within Australian industry. Yearly, some 200,000 tonnes of automotive plastic waste enter landfill with the predominant contributor being the steel recycling industry with some 150,000 tonnes. Here, the present average age of automotive feedstock being processed is within a general parameter of 10 to 20 years, with an average plastic parts content per vehicle weighting some 40 to 80 kilos per vehicle. Output of plastic waste from the steel recycling industry will increase over the next 10 years by something like 100% due to the increase of automotive feedstock having a higher content of plastic parts. Current vehicles contain from 100 to 200 kilos of plastic parts per vehicle.

In Australia there is no strategy presently available that could reduce this waste stream due to the nature of the waste being contaminated and the cost of separation. Hand separation by manually stripping of plastic parts is not practical due to the massive volumes of throughput (10 to 200 cars per hour) and the high and costly mechanization associated with the industry, not to mention the dangers associated with manual labour hand stripping amongst heavy industrialized equipment.

Long-term though, the advancement of pyrolysis techniques could offer some solutions. Present theories and current research being undertaken around the world on the subject suggests research could be justified as to the viability of the construction of a project plant to test the practicality of such a scheme for Australian conditions.

Automotive plastic waste, on the other hand, could be reduced by an immediate approach to changing established work practices within the collision repair industry. This approach would require changes as to how things are done in two specific areas. The first area is the separation of plastic at collision repair centres so it could enter the plastic recycling stream as opposed to going to landfill. The second is a change in industry attitudes away from replacing damaged automotive plastic components and more towards assessing them with a view to repair.

The research has identified this facet of the investigation as the most practical and profitable approach as a strategy to reducing automotive plastic waste entering landfill. The strategy would have instant benefits to all stakeholders. For example, they could save an average estimate of $70 for insurance companies on every automotive accident repair claim, create fulltime employment for some 300 individuals and offer repairers a remuneration in the vicinity of $80 per hour for labour rates. It would be, however, dependant on the improvement of present industry training policies and practices.

Argument for change

The present volumes of automotive plastic waste entering landfill are constantly increasing and so create a never-ending thirst for more available dump sites. As present landfill sites reach capacity, waste has to be transported further away from its place of origin with the added burden of increasing transport costs. As these costs rise, the costs associated with establishing new recycling options become affordable. The cause and effect of commercial considerations will balance the equation over time but this approach is not a positive strategy due to time lag and the value inherent within waste plastics, the biomass.

Plastic biomass is a rich repository of petrochemicals and activated carbons, materials that are being reclaimed elsewhere with the use of pyrolysis technology. Although the technology can be considered as a new approach for tackling the problem, its impact on the plastic waste issue encompasses not only automotive but all plastic waste. Given the interest and research results that this methodology has attracted overseas for solving problems of plastic waste, further research into pyrolysis could underpin a positive strategy for reducing plastic waste within Australia.

Collaboration on research and development between industry and the education sectors is important to ensure the supply of skilled workers for emerging industries (Whittingham & Ferrier 2000). The research suggests this is sluggish at best. There needs to be changes to the TAFE system to provide a safety net for those workers in industry who suffer from moral exclusion through the lack of small business' approach to training. This can only happen by fostering a greater sharing of training knowledge between institutions on a national level, an attitude that would result in up-to-date uniform training that is available to all. At present, competition within the training sector is counter-productive. It is exposed through this research as self-defeating by the ‘bottling of technology’ rather than the fostering of a climate of technology diffusion, the sharing of knowledge.

The TAFE system needs greater support; a policy of competition is not the answer. Should the present trend continue we could lose a most valued industry training mechanism in Australia. Governments should assist TAFE training to become the yardstick for up-to-date training. At present there is no clear training leader with a reputation others wish to emulate. To expect TAFE to compete with private providers will result in training being reduced to the lowest common denominator. The standards for registered training organizations outlined by the Australian Quality Training Framework permit private providers to operate with only basic qualifications, a Certificate IV from the *Training package for assessment and workplace training* is all that is required. And, a trainer may perform training and assessment without qualifications if under direct supervision of one who holds them. (Australian Quality Training Framework. *Evidence Guide* 2001, Standard 7.4).

Furthermore, continuing research relevant to addressing the issues of upgrading education and training is most important in order to constantly develop the specific skills required for specific jobs and create a workforce that is flexible (Mulcahy & James 2000). Automotive plastic welding and repair is a clear example of the need for industry to up-skill. This research highlights the unnecessary industrial waste of damaged automotive plastic parts that could be economically repaired but enter landfill each year because repair attitudes are not keeping pace with repair technology.

The automotive insurance industry could also assist in bringing about a cost saving change by revising its hourly rates for collision repair labour. Higher labour rates would encourage parts’ repair, and reduce parts’ costs and industry waste. For some time, repairers’ propensity to replace rather than repair has come about by chasing part mark-ups rather than sell unprofitable labour. This has created a more serious and underlying problem for insurers, the disappearance of trade skills from the collision repair industry. Unless arrested, this phenomenon coupled with workshop closures will see the pendulum of power swing back in favour of the repairers. There is a fine balance between economic forces of supply and demand and should insurance companies lose the control they enjoy at present, hourly rates could increase tenfold as insurers find themselves under pressure to fulfill their accident claim obligations.

6
CONCLUSIONS

Outcomes

The research has identified processes that could positively impact on the reduction of automotive plastic waste presently entering landfill within Australia. The findings indicated that improvement is possible in reducing automotive plastic waste by upgrading industry knowledge and skill through education and training. Such an approach, coupled with further research into advancing technology, could favourably impact on reducing automotive plastic waste entering landfill, the creation of employment as well as offering positive financial gains across a wide spectrum of stakeholders.

By examination of the various automotive waste streams, present volumes of plastic content currently sent to landfill were identified as being attributable to distinct and stable work practices within the collision repair industry and the steel recycling industry. In the short-term, immediate benefits of waste reduction and increased profits could be generated by improvement in work practices and educational industry training to upgrade trade skills within the collision repair industry. The steel recycling industry, however, would take a longer timeframe for improvement and would be subject to further research into the benefits of emerging technologies such as pyrolysis.

The research has indicated that the collision repair industry lacks a propensity to keep pace with emerging knowledge and skills associated with the repair of damaged automotive plastics. It revealed practices that tend to replace damaged plastic parts with new rather than repair. Such practices can be attributed to a number of variables that are inter-related. Low hourly labour rates controlled by the automotive insurance industry act as a deterrent in some cases for management to up-skill staff. This creates a social inequity in terms of small employers who can stifle opportunities for their workers to improve their trade skills. To some degree this can be overcome during the apprentice years via a vibrant and up-to-date TAFE system.

Educational Implications

The research identified variability within the TAFE training system. Financial constraints coupled with a policy of competition restrict the sharing of knowledge to develop and update curriculum capable of keeping abreast with industry changes. The TAFE system was found to be variable in its approach to industry training with regard to automotive plastic welding and repair. The TAFE survey indicated individual institute interest in the subject fluctuated from receiving a high priority to no training offered. In particular, the questionnaire identified that over half of the head teachers did not seek feedback from the repair trade. Simply put, it was not sought. This contravenes the Australian Quality Training Framework Evidence Guide for Registered Training Organisations. Standard 1: Systems for quality training and assessment, 1.9 states that a Registered Training Organisation must collect feedback from stakeholders and clients and use the information to review its policies and procedures. Consultation with the major stakeholder, the collision repair industry, should be paramount given the research findings that half of all new parts replaced each year are plastic with a value of some $700 to $900 million. A high priority towards training in automotive plastic welding and repair should be considered as fundamental.

There is a need to improve funding for TAFE training and trainer professional development programs. Privately funded education must be paralleled with the option of a Government funded safety net such as TAFE. The subject matter of this research highlights viability in TAFE curriculum that supports a strong argument for academic research that investigates the shortcomings and limitations of present Government educational policy. Today’s apprentices are the proprietors and managers of tomorrow’s small businesses. They need to be given every opportunity to realize the advantages of industry training. In small business, this can only happen with strong government supported training.

The Collision Repair Industry

The research has identified significant opportunities for the collision repair industry to improve profitability through up-skilling its workforce by adopting a training program to improve knowledge and skill to enable effective plastic repairs rather than replacement with new. This opportunity is supported by calculations that estimate an additional $27.2 million per year in labour charge out rates for repairs could be invoiced by the collision repair industry rather than the purchase of new parts. Other significant benefits for repairing in-house could include:

- Quality control, know the repairs will fit and are correct
- Convenience, in-house repairs, no delays, no sublets (outside repair services)
- Recycling, less rubbish, less parts packaging, less cost for removal
- Competitive quoting, overall cost of repairs less, with more profit
- Greater profits, larger in repairs than new parts markups
- Save capital outlay, less parts purchases
- Reduce debtors ledger, lower charge-outs

- Save administration time, less parts to order and track, less chance of credits
- Create respect, gain the knowledge and skill to repair all modern vehicle materials
- Overseas funds, savings by repair of plastic parts that are imported

For the above benefits to be realized and adopted as an industry standard, the research indicates changes would be needed towards present work practices within the collision repair industry and educational provider attitudes towards working together to create and supply up-to-date training.

Steel Recycling Industry

Research revealed that the major waste stream identified is the steel recycling industry. This industry accounts for some 150,000 tonnes of automotive plastic waste entering landfill each year. Research estimates this will double within ten years, a phenomenon well realized within Europe. This has bought about European legislation, titled End of Life Vehicle Directive (ELV Directive), to restrict automotive plastics entering landfill from the present allowance to only 5% by 2015. This legislation is fueling global research into the problem. No evidence has been found that such research is currently underway within Australia pertaining to the same problem, however it has indicated that various research within a number of western countries suggests pyrolysis offers a variety of solutions.

Pyrolysis

Research of the literature indicates pyrolysis could well be a suitable methodology capable of addressing not only automotive plastic waste but also the conversion of all types of plastic waste from landfill into useful by-products such as activated carbons petrochemicals, and the recovery of small percentages of copper and lead. There seems no reason to assume the methodology would not be suitable for Australian conditions and therefore presents an ideal opportunity to build on research presently in progress overseas.

Summary

The research has shown immediate improvements can be made to the problems associated with volumes of automotive plastic waste entering landfill by addressing the issues of improving work practices within the collision repair industry in association with upgrading industry training by focusing on the TAFE training system. This would benefit all stakeholders. A long-term strategy has been identified as one that could prove to be positive by further research into the methodology of pyrolysis. This could be achieved by building on current research that is presently underway internationally. Such research could well have national (and international) significance.

Future research

The findings support an argument that further research could positively impact on the subject of strategies for automotive plastic waste reduction. Three areas have been identified: education, legislation and technology.

- Educational research into the TAFE system to identify a strategy to improve knowledge sharing on a national level with a view to presenting the latest training technology for the collision repair industry, the impact on institutional training finance cutbacks, and the effects of competing against private providers
- The positive, or negative, effect of introducing legislative action to impact on diverting large plastic components such as bumper bars from landfill modelled on tyre legislation that presently prohibits whole tyres from landfill; and an analysis of the European End of Life Vehicle Directive as to its progress and if such legislation would be suitable for introduction into Australia.
- Research into pyrolysis technology based on overseas research, as a method capable of addressing the total issue of the conversion of all plastic waste from landfill to useful by-products.

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