Cost-orientated Approach to Design and Recovery of Vehicles to meet the requirements for the End-of-Life Vehicle (ELV) Directive

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And funded by:
Engineering and Physical Science Research Council (EPSRC)

In collaboration with:
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Galorath Affiliates Limited
Strategic Environmental Management Limited
Knibb, Gormezano & Partners
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1. Introduction

This report is the concluding document summating the project results from the IMCRC project entitled, "cost-oriented approach to design and recovery of vehicles to meet the requirements for the end-of-life (ELV) Directive", which was undertaken from Oct 2004-Oct 2006. The report contains a brief overview of the research undertaken, the systems developed and the results that were obtained. The appendix contains 4 of the papers produced, which give further insight into the research conducted.

2. Project overview

The project began with two distinct work streams, one focused on developing design methods to assist vehicle manufacturers in facilitating end-of-life recovery, whilst the other considered the end-of-life economics of current ELV processing. The aim of the two work streams was the concept that, by establishing an understanding of closed loop economics, manufacturers could incorporate new design attributes that would assist vehicle salvage operators in the future. The initial project work plan and stakeholder interviews were scheduled with this premise in mind. However, the implementation of the ELV Directive in the UK did not involve the level of financial commitment from the vehicle manufacturers that was expected within the original project proposal. Vehicle manufacturers established "zero-cost contracts" between themselves and the recovery sector, which has seen the responsibility for the achievement of many of the key points of the Directive pass to third party organisations (contracted network providers). This became apparent during the early stages of the project and lead to a reassessment of the initial aims, as vehicle manufacturers had no economic interests in supporting current end-of-life value recovery activities.

As a result the work streams diverged, with the end-of-life economics work stream focused on supporting the decisions made by the vehicle salvage industry (i.e. the economics of dismantling and shredding), and the design work stream providing redesign methods that were not solely base on current recovery economics (i.e. 'design for shredding' and modular design). Despite the challenges the project faced in the initial quarter, the research team responded by re-directing the work stream's focus to collaborate with more appropriate partners. This saw the introduction of a new collaborator (Rozone Ltd) and close working relationships with other prominent businesses (European Metals Recycling Ltd) who were able to provide additional insight and support in light of the Directives transposition. This was followed by a period of intensive data collection, stakeholder interviews and cost modelling (additional detail provided on the following pages) that produced a number of industrial reports, and journal and conference papers on various aspects of vehicle salvage and design costing together with two end-of-life costing systems:

i.) An end-of-life facility costing tool, providing a bespoke costing model for the recovery activities carried out by a particular salvage operator.

ii.) An vehicle analysis and redesign method, based on the dismantling, material and part efficiency, and post shredder separation.

3. The modelling of end-of-life recovery economics

Aim: "To create a cost oriented decision support for the recovery of the most amount of end-of-life value while at the same time meeting the legislative requirements."

Value realisation is obviously dependent on being able to gain an understanding of a salvage facility's ability to understand the economics of its own operation. Recommending additional end-of-life processing activities must also be measured against the costs and revenues of existing processing routes. Only then can an informed judgement be made, supported with an analysis as to its financial viability. Given the relatively recent introduction of approved vehicle treatment facilities within the UK, many operators have little or no detailed understanding of the economic drivers that underpin their industry. Hence, the starting point for the research was to gain an understanding as to how these recovery facilities ran and operated in light of the requirements laid down by the new ELV Directive.

This modelling provided a process map of the dissemination of the vehicle waste as it passes between various recovery agents, and enables the various *direct* and *indirect* costing elements of vehicle reclamation to be highlighted. These costing elements were then used to apply the most appropriate costing techniques (parametrics, analogues, detailed, active based costing, etc.) to the information available and the level of detail required. This cost modelling then made it apparent as to where additional data collection efforts needed to be focused (i.e. vehicle dismantling study, parts resale survey data), or in some instances where radically new costing approaches had to be developed from scratch (i.e. post-fragmentation costing).

As a result of a prolong period of model development a VB.Net application was created that integrated all the various costing approaches into one model, the architecture of which is depicted within figure 1. This software model is designed to allow a vehicle salvage operator the ability to model the value-added processing that their specific facility provides, and to support a number of micro and macro level decisions. At the highest level it can provide insight into that facilities current recycling and recovery levels, and provide a detailed understanding as to a facility's operating costs. This modelling can then be used to provide a break-even analysis for a specific EOL operator based on current material market prices. At the lowest levels it attempts to support decisions such as optimal plastics disassembly (based on mass or value) to facilitate either, pre-fragmentation achievement of the 2015 recycling and reuse target, or identification of profitable plastics assemblies capable of offsetting any direct labour costs incurred. Figure 2 provides a screen-shot from this pre-fragmentation module. Additional micro level support has also considered the cost modelling of post-fragmentation material recovery and developed a separation model to predict the routing of typical material waste streams through a shredding facility (see figure 3). With validation it is hoped that this module will form the basis for process optimisation within a shredding site and highlight optimal waste stream routings. Further details on this work stream can be found in appendix 1 and 2, as well as on the CD demonstration included.

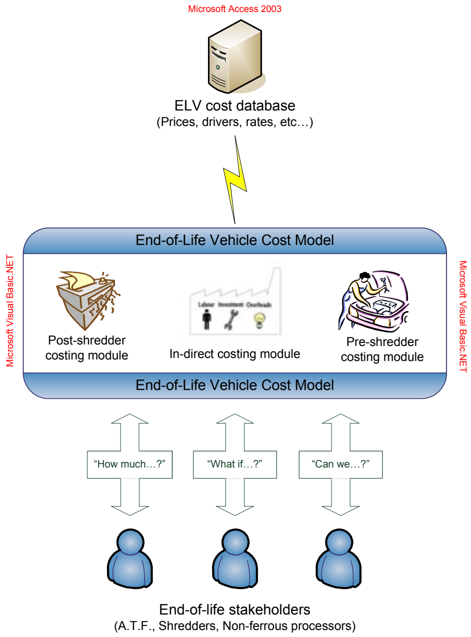

Figure 1, Cost model architecture

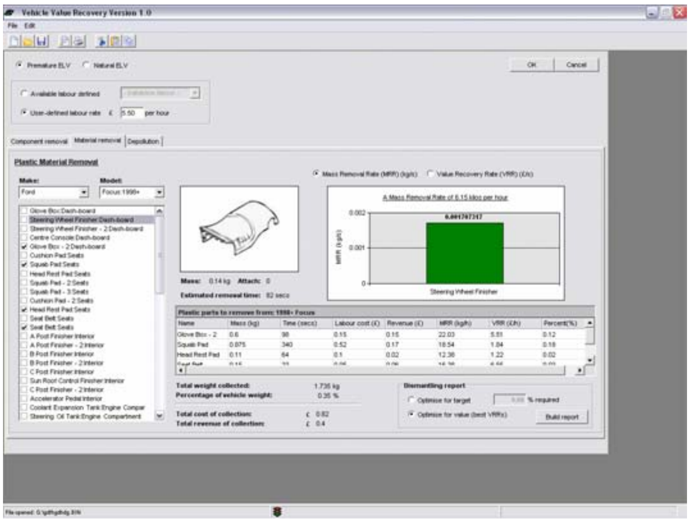

Figure 2, Screen-shot from pre-fragmentation vehicle costing module

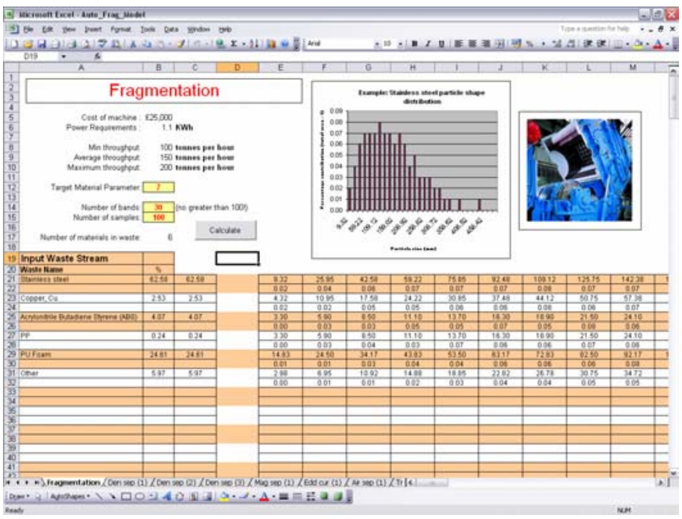

Figure 3, Screen-shot from post-fragmentation waste costing module

4. Design for End-of-Life Vehicle Value

Aim: "The creation of methods by which recovery cost can be analysed through the re-evaluation of design, material use, and manufacturing technique."

Vehicle manufacturers currently base their end-of-life strategy on material blacklisting early in the design process, and Design for Disassembly (DfD) once the vehicles structure has been established. However, these DfD techniques which have been implemented for over a decade, have not resulted in a rise in vehicle dismantling practices and most stakeholders now believe that shredding is the only financially viable way of achieving material recovery targets. Therefore, vehicle manufacturers must adapt their strategy to ensure their DfD methods are implemented earlier in the design process to create a greater structural impact, and that post shredder material streams are analysed and impurities are removed during the design process, to provide greater recovery and value at end-of-life.

The Design for End-of-Life Value methodology attempts to do this by using previous vehicle teardown data to recommend changes to future models before the design process begins. This can be achieved by initially analysing the teardown at either a vehicle or assembly level. Assemblies can be selected for redesign based on their dismantling rate (grams per second), their material efficiency (grams per material) their part efficiency (grams per part), or a combination of all three. Alternatively, the vehicles material content can be placed through a post fragmentation model that simulates post shredder separation processes stipulated by the user, and provides a breakdown of all post shredder material streams. Their current and potential values can then be analysed to identify impurities which can be either replaced within the design or redesigned for pre-fragmentation removal. This concept, termed "Design for Shredding" aims to improve the recovery potential of post shredder material streams by removing impurities either during design or disassembly. Once assemblies are selected, a modular redesign method attempts to group similar materials or functions together to create removable modules. This process uses a set of Design Structure Matrices (DSM's) as shown in figure 4 to analyse the most appropriate modularisation of the assembly. This then outlines high level changes to the structure of the vehicle, that can be implemented early in the design process and that can impact on dismantling time.

A design support tool entitled "DELV: Design for End-of-Life Vehicle" has been developed which is based on the Design for End-of-Life Vehicle Value framework outlined above. Figure 5 displays the material content of the light fraction of a shredded and air separated vehicle. The blue colours in the pie chart represent plastics and rubbers, the red and orange represent ferrous and non ferrous respectively, green represents glass and yellow represents electronic waste. A bar chart also displays the percentage of each material from the vehicle that is within the fraction. Figure 6 shows the value and destination of each material fraction once they have been processed through a generic set of post separation techniques. Out of the nine fractions that are produced only one (the ferrous heavy fraction) is recycled. Each of the other fractions can then be selected to identify problem materials within them. Further details on this work stream can be found in appendix 3 and 4, as well as on the CD demonstrations included.

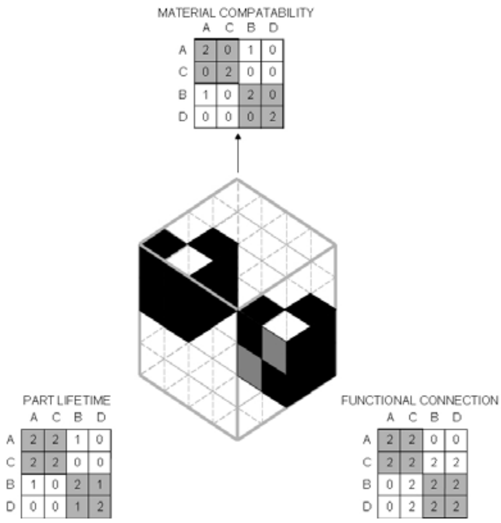

Figure 4, The combination of Design Structure Matrices (DSM's) that create the modularity cube.

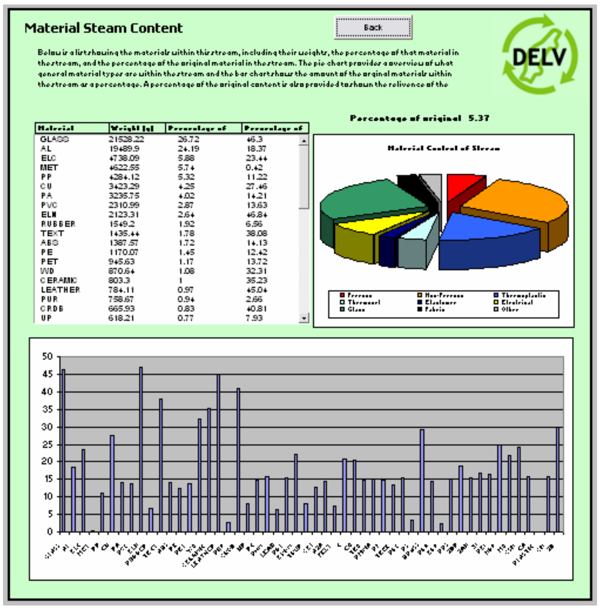

Figure 5, A screenshots of the post shredder analysis of a material stream

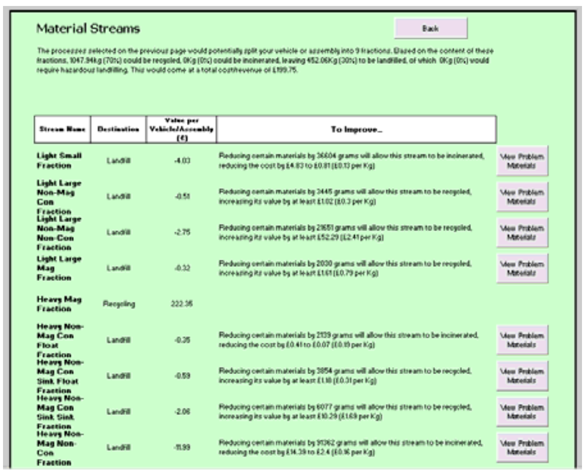

Figure 6, A screenshot of the material stream value analysis

5. Project Results

Listed below are the deliverables achieved during the project, the decision support tools developed, the papers produced over that two year period, and any additional reports and activities conducted.

5.1. Deliverables as outlined in the initial project proposal

- Report on the current state of the art in costing techniques and systems (WP1)
- Develop a database of disassembly and recycling cost factors (WP2)
- Report on the implications of these cost factors on design and end-of-life recovery (WP2)
- A cost model to support 'Design for Eol' (WP3)
- A cost model to support 'Eol Recovery' (WP3)
- A cost orientated decision support system for ELV (WP4)
- Industrial demonstrator model (detailed in section 4.2) (WP4)
- Case report for wider dissemination of research results (WP5)

5.2 Decision Support Tools

- VVR: Vehicle Value Recovery
- DELV: Design for End-of-Life Vehicle

5.3. Papers

Conference papers

- Edwards, C., Coates, G., Rahimifard, S., Bhamra, T., Newman, S.T., Leaney, P. (2005). End-of-Life Recovery of Vehicles in the UK. 4th International Conference on Design and Manufacture for Sustainable Development, Newcastle upon Tyne, July 12th-13th 2005.
- Edwards, C., Bhamra, T., Rahimifard. (2006). A Design Framework for End-of-Life Vehicle Recovery. 13th CIRP International Conference Life Cycle Engineering, Leuven, May 31st-June 2nd 2006.
- Coates, G., Rahimifard, S. (2006). Cost Models for Increased Value Recovery from End-of-Life Vehicles. 13th CIRP International Conference Life Cycle Engineering, Leuven, May 31st June 2nd 2006.
- Coates, G., Rahimifard, S. (2006). Assessing the Economics of Pre-fragmentation Material Recovery. ELV'06, September 20th-21st 2006.

Journal papers

- Coates, G., Rahimifard, S. (2005). Cost Models to support Increased Value Recovery from End-of-Life Vehicles. Proceedings of the Institution of Mechanical Engineers - Part D, Journal of Automobile Engineering (Submitted).

- Edwards, C., Coates, G., Leaney, P., Rahimifard, S. (2006). Implications of the End-of-life vehicle Directive on the vehicle recovery sector. Proceedings of the Institution of Mechanical Engineers - Part B:J, Volume 220.

- Edwards, C., Rahimifard, S. (2006). Design Improvements for Increased Value Recovery from End-of-Life Vehicles. (To be submitted)

- Coates, G,. Rahimifard, S. (2006). Development of Post-fragmentation Waste Stream Processing Decision Support. (To be submitted)

5.4. Additional Reports and Activities

- A dismantling study was conducted on three vehicles at Albert Looms Ltd, Derby in November 2005.

- An Authorised Treatment Facility Survey was sent to approximately 300 ATFs, 35 of which replied.

- A seat dismantling study was conducted in January 2006, comparing a 1993 Ford Escort passenger seat to a 2001 Ford Focus passenger seat.

- Industrial case studies conducted with Holmfield Autos and Albert Looms Ltd in September 2006.

6. Conclusions

It is now clear that the UK will come close to achieving the 85% recycling and recovery target laid down by the directive, and that free takeback has been developed without any direct processing costs to the vehicle manufacturer from 2007. Attainment of the additional 10% to achieve the 2015 recycling and recovery target is still not assured. Short of reviewing the 2015 target, this conformance can only be achieved in two ways:

- Manufacturers need to adapt their designs to suit the current industry shift away from manual vehicle dismantling, more towards large volume automated post-fragmentation separation.

- For the vehicle reclamation sector to improve downstream separation techniques, technology and secondary markets.

Despite the extended producer responsibility that the ELV directive advocates and the inference that manufacturers should have a more active involvement in EOL issues, the "zero-cost" approach adopted within the UK would suggest the latter of these scenarios (downstream improvements) will be the main industry focus over the coming years. Potential pitfalls in placing this burden of conformance with the recovery sector are the consequences of a collapse in the financial drivers that underpin their industry, namely scrap steel prices and the parts resale market. Hence, manufacturers should be aware as to the ramifications this will have in terms of their financial role and responsibilities within ELV reclamation.

Despite the initial drawback created by the transposition of the ELV directive in the UK and its impact on the approaches taken by Vehicle Manufacturers, the project has fulfilled many of the initial aims. The modelling of end-of-life recovery economics conducted by this project provides a platform for many of these ATFs to analyse the benefits of all recovery options and achieve the target for the lowest possible cost. Design for End-of-Life Vehicle Value also provides manufacturers with a design framework based on current and future recovery methods, and promote paradigms such as "design for shredding" which can give an insight into a vehicles recoverability, and how it can be improved.

Finally a subset of results from this research have been selected for two further one year projects funded through the Research Associate Industrial Secondment (RAIS) scheme in collaboration with Rozone Ltd and Galorath International.