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Abstract. The present work aimed at giving a review of the end-of life phase for motor vehicles, providing accurate process modeling, indicating critical aspects, and finally suggesting improvements. For the study, one of the principal dismantler in Sardinia (Italy) was considered. The main innovation is the bottom-up approach to the problem; this was carried out by field observing the process activities and sharing the criticalities identification with the actors. The study has confirmed that the simplicity of disassembling the components and the ease of identification of the different materials to be separated is fundamental for an efficient dismantling of motor vehicles. It is finally crucial that the dismantling processes, being highly complicated, mainly involve the same manufacturers.

Keywords: ELV, End-of-Life Vehicles, Dismantling, Process Modeling.

1 Introduction

According to modern market strategies, the working life of most goods is expected to keep shortening. Consequently, an increasing amount of waste material is conveyed every year to landfill.

In the automotive field, it has been observed that a huge amount of material is produced from vehicles dismantling, still with high market value (e.g. steel, aluminum, glass and plastics). There is thus an economic drive to the efficient reuse of such matter; in addition, most of them should be carefully handled by reason of their potential environmental impact.

In order to effectively address the problem, the common approach of "use and throw" (i.e. disposable) must be overcome: a new policy of reusing and recycling has to start for the rough materials that form worn out goods.

The strict EU regulations on the matter, which have been recently endorsed by the state members, impose a constraint on the fraction to be reused from a dismantled vehicle. For instance, Directive 2000/53 [1] establishes a number of measures to limit unload of refusal, as well as promote recycling and similar reuse of dismantled cars and their components. In such way the total volume of refusal to be discharged can be diminished; moreover the whole life cycle efficiency of motor vehicles is improving, from both the economical and the environmental points of view.

Currently 75-80% of each end-of-life vehicle is recycled or re-used, the vast majority of which is ferrous metal [2]. These are average numbers, if some European countries have already achieved upper standards (Germany, Belgium), others are far to reach the prescribed targets (Italy above all) [3]. Outside the EU, Japan, Taiwan, and South Korea have instituted similar Extended Producer Responsibility (EPR) legislation, which is also becoming increasingly prevalent in North America [4], [5]. In China, despite the huge number of ELVs, quite a large delay in the ELVs policy and legislation exists when comparing to Europe [6], [7].

The European ELV Directive requires a 15-20% increase in recovery from current average levels by 2015. Such improvements need to come from the 20-25% of the vehicle that is not currently recycled, which consists mainly of polymers, rubber, glass and electronic parts. To reach the 2015 targets roughly half of these materials will need to be recoverable or vehicle composition will need to shift toward materials that are already recyclable.

In addition, the Directive 2000/53 states that vehicle manufacturers should design and produce vehicles that facilitate the dismantling, re-use, recovery and recycling of end-of-life vehicles. Carmakers are therefore taking steps to design for recycling and for disassembly. Increasing the level of re-use and remanufacturing will be a key-part of moving toward sustainable vehicle production. Generally speaking, the higher up the process in the hierarchy the more environmentally friendly it is [2].

The dismantlers are main actors of the reverse logistics processes, i.e. the companies that carry out the separation of vehicles into simple components. In order to abide by the latest directives, the dismantlers are nowadays facing pressing needs of re-engineering their organizational processes. On one side the demand of limiting costs, on the other side thrusts for improving the overall recycling efficiency are. Therefore, such companies are forced to analyze their internal organization, finding and solving critical points, possible sources of errors and wastes.

Many studies have been carried out in the last decade, regarding several aspects of the ELV management. Some of them deal with the legislation and its impact on the sector [2], [8]. Other studies more properly concern the ELV management [9]. A number of papers have been published about the ELV processes technologies [10], [11]. Several works concern ELVs market and economics [12], [13], [14]. Finally, a sub-field of research involves the environmental issues and ELVs sustainability [15].

The present work aimed at giving a review of the end-of life phase for motor vehicles. For the study, one of the principal dismantler in Sardinia (Italy) was considered, providing accurate process modeling, indicating critical aspects, and finally suggesting improvements. The main innovation of the research method is the bottom-up approach to the problem; this was carried out by field observing the process activities and sharing the critical aspects identification with the actors.

The paper is structured as follows. In Section 2 a review of the ELV management techniques and of the dismantling approach is given. In Section 3 the ELV scenario in Sardinia is characterized. Section 4 includes a description of the followed methodology and of the adopted tools: process modeling, process sheets, FMECA. In Section 5 the results of the case study analysis are presented, and the major criticalities are summarized. In Section 6 a possible path of evolution is suggested for the considered case study. Finally, concluding remarks are drawn in Section 7.

2 ELV Management Trends

In order to meet the targets of the European ELV, technological innovation can follow two main paths: upstream or downstream of car manufacturing.

Upstream means modify the design for facilitating the ELV processes, i.e. *design for dismantling*. To this end, several car companies have already made agreements with dismantlers. Upstream operating results clearly in a long term path.

Downstream means modify the recycling operations by developing new techniques. Such improvements need to come from the part of the vehicle that is not currently recycled (fluids, polymers, rubber, glass and electronic parts). On one hand, bigger and more efficient recycling plants will be able to handle wastes coming from different industrial fields, not just the ELVs, with large use of automation. An example of large automated dismantling system is represented by CRS (Car Recycling System) [16], in the Netherlands. On the other hand, small specialized companies will be able to manage with currently non-recycled components.

Car material composition has been evolving during the years, with an increasing use of plastics and aluminum, compared to steel and other metals. Some particular components are still critical with regards to ELV recycling: tyres, batteries and catalysts among others. End-of-Life-Tyres or ELTs dismantling is highly complicated because of their webbed structure, which does not allow fusion and for the presence of metals and fibers for reinforcement. However, the huge amount of ELTs (220 million/year in the EU) imposes to find a solution to the problem. Finally, the recovery of catalysts is still developing, even if the interest in the valuable metals herein contained could be the drive for rapid improvements.

3 ELV Scenario in Sardinia (Italy)

The whole car fleet in the Italian region of Sardinia amounts to 959,946 units [17], one third of which within the Cagliari’s district. The 70% of those cars has got a capacity between 800 e 1600 cm^3 (*economy cars*). If you consider the single years of matriculation, a nearly constant amount of new cars was introduced since 1998, about 6-7% of the whole fleet. However, looking at the ELVs for 2007, a peak is evidenced for those matriculated in 1991, which means an average working life of 16 years.

In Sardinia, the dismantlers often operate the essential phases in the ELV process, i.e. drainage and compacting, whereas after the carcass is sent to the rest Italy. Only few of them operate a real dismantling, but keeping for reuse and recycle a small portion of the car components, whilst the rest is compacted and forming the *car fluff.*

When analyzing the process, the first phase (drainage of liquids and hazardous materials) is commonly manual. Afterward, the carcass is made compact by a power press. The car fluff can be ground in Sardinia or shipped to other dismantlers in the rest of Italy, with additional costs. The *car fluff* is anyway sent outside the region, being its amount too small for the sustainability of a dedicated plant in Sardinia.

Some of the dismantlers have direct agreements with one or more car companies. One of them is the analyzed *Case Study* (CS). Despite in the Island there is nearly an absolute lack of recycling plants, the tyres can be conferred for energy recovery or sent to produce acoustic insulator for construction. Oils are transported to two dedicated plants, but only one is able to regenerate the oil. Windscreens are conferred to landfill and the other glass parts remain included into the fluff. In fact, the only company that recycles glass is specialized in bottles and food containers. In a similar way, other plastics are currently recycled, whereas the ELV plastic parts are usually not. Finally, two local companies deal with the recovery of exhaust car batteries.

4 Methodology

4.1 Process Modeling

The analysis of processes, which is key-important for the corrective actions, includes first the identification of the single activities and the process modeling.

The preliminary study was carried out on field, by means of interviews with the process players. Surveys were used to complete this set of information. The followed approach implied that the same people who run the process activities are involved in the analysis (administrative people, workers): with no doubt they know those better.

Flowcharts were chosen for the process modeling, since they represent one of the best tools for the schematic description of processes. Flowchart strength resides in his proper immediacy of direct communication and ease of reading even for non technical readers. When performing process modeling that involves several areas within a company, *functional flowcharts* are more useful for identifying the actors (or groups) responsibilities, also for detecting errors and wastes sources. In addition, the IDEF0 diagrams were thought appropriate for functional modeling, i.e. provide a structured representation of functions, decisions, activities or processes within a system.

4.2 Process Sheets

Process Sheets were filled out for each of the activity in the dismantling process, already identified with the process modeling, and provide the following information: *Phase*: a macro-division of the process, as it appears from the flowcharts; *Activity*: a single operation within the process; *Actor*: the operator who are directly involved in the described activity; *Input*: information/data generated before the single activity; *Description*: summary of the operations performed within the activity; *Time and Duration*: an evaluation of the scheduled time and duration; *Controls*: possible checks done by the operators; *Output*: info/data generated at the end of the single activity; *Criticalities/Errors*: events that could invalidate the effectiveness of the process; *Wastes*: inefficient use of resources and time.

4.3 FMECA

Failure Mode, Effects, and Criticality Analysis (FMECA) is an extension of *Failure Mode and Effects Analysis* (FMEA). In addition to the basic FMEA, it includes a criticality analysis, which is used to chart the probability of failure modes against the severity of their consequences. The result highlights failure modes with relatively high probability and severity of consequences, allowing remedial effort to be directed where it will produce the greatest value.

A FMECA was hence performed, after the required process decomposition into simple activities (i.e. *process modeling*). With the help of the process sheets a list of failure mode was arranged, specifying the possible causes. Those criticalities were grouped into 4 categories, depending on the aspect of the system they affect: *Organizational* (O); *Technical* (T); *Communication and Information* (C); *Layout and Structure* (S). Estimations of the failure frequencies and of their effects on the process were provided and shared with the process players. This resulted into a scale of values: A-*High*: serious, high frequency (can interrupt the process); M-*Medium*: serious, low frequency; B-*Low*: soft, medium-low frequency.

5 Analysis of the *Case Study* (CS)

The *Case Study* (CS) is represented by a dismantling company located in the area of Cagliari, which is the local authorized dismantler of both Citroen and Peugeot. The main activity of such company is car dismantling, but it handles also other wastes, especially hazardous materials. On the whole, the CS deals with: ELVs, ELTs (tyres), plastic packages, ferrous wastes from urban users, electronic equipments, white goods, and more in general metals, paper, wood, plastics.

5.1 The Dismantling Processes

Flowcharts were mainly used for the process modeling. However, for a more compact view is hereby preferred the classical IDEF0 diagram (Fig. 1). The boxes represent the manufacturing functions. The arrows stand for inputs/outputs, controls, and mechanisms.

Cars arrived with proper trucks directly from dealers, retailers or privates. First, all the office procedures are completed: strike off the Public Car Register (PRA); removal of car frame number. Then, an operator is committed of the car and starts securing the car in the drainage area. All recyclable parts and liquids (motor oil, brake oil, refrigerant) are removed; alike hazardous materials pollutants are extracted. Before raising the ELV with the car deck, the operator annotates the frame number, the weight, if catalyzed or not, fuel (gasoline, diesel, LPG) and all data will be later compared with those registered in the office. Each operator is usually committed of two cars at a time. Manual operations follow in this order: removal of fuel tank, catalyst, radiator, oil filter, bumpers, windscreen, seat belt, battery. All former mentioned materials and liquids are recovered. Later tyres are taken off, to reuse if still in working order. The carcass is moved from the drainage to the compacting area, where is made compact by a power press and ground to the final *car fluff*.

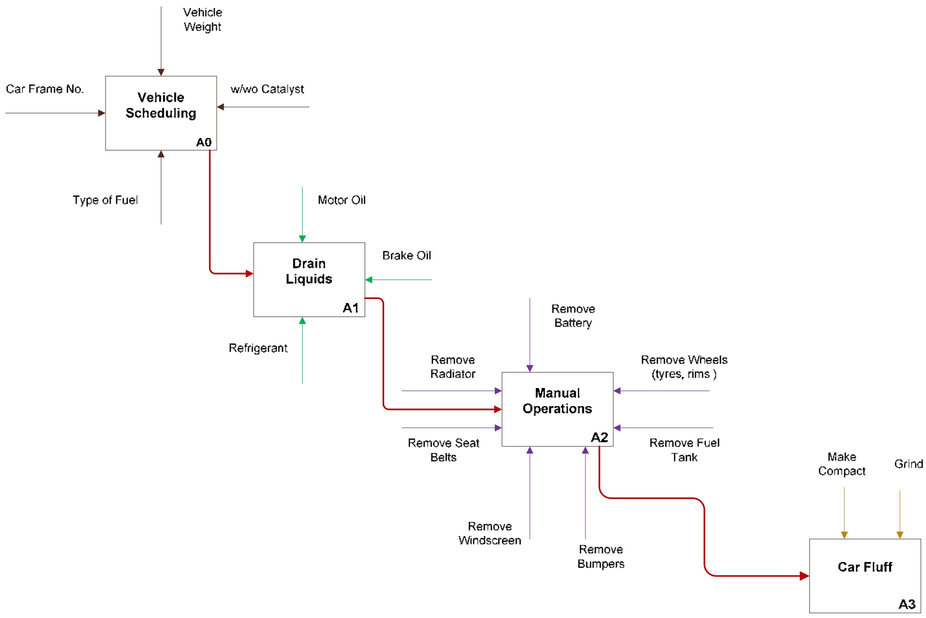

Fig. 1 IDEF0 of the dismantling at WR.

5.2 Main Criticalities

From the FMECA analysis two activities emerge as the most critical (Fig. 2). Operators agree with that outcome, and consistent indications are given by the Gantt diagram of the process. One was found at the beginning of the process, and concerns the *removal of the catalyst*, due to the problematic location and the impossibility of operating in recent cars.

A further criticality is the *removal of the windscreen*. If the windscreen is attached with silicon, it must be crushed and recovery is no more possible basically for the lack in proper devices (e.g. pneumatic cutters).

5.3 Layout

The size and shape of the case study property land impose a definite layout for the dismantling structures and devices. The possibility to relocate both the storage and drainage area in one part of the property was analyzed, but even being the surface adequate, difficulties would be faced in collocating the compacting unit as well as the grinding machine. Reducing working spaces would increase risks for people, also because the administrative center would be closer (noise would be secondary but not least drawback).

On the whole, the present layout is reasonable and meets the company requirements. Moreover, any promising modification should be carefully evaluated since it would affect all the company processes, not only those related to dismantling.

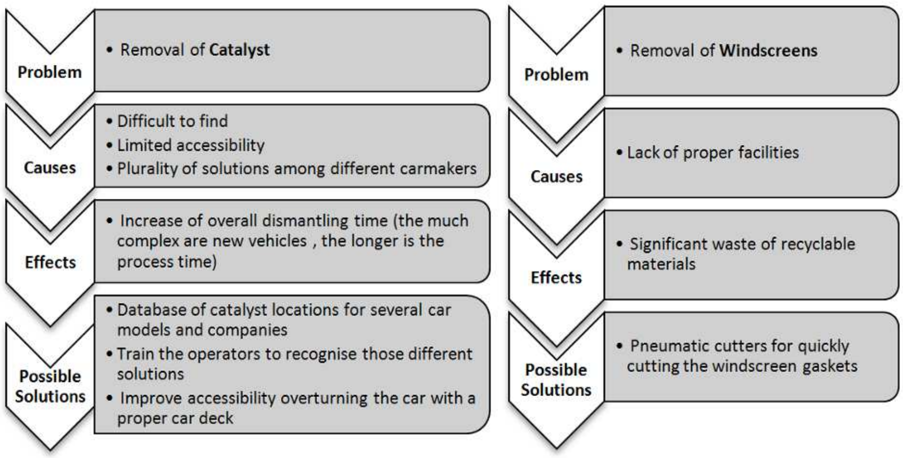

Fig. 2 The two principal criticalities within the analyzed Case Study.

6 Suggestions and Improvements

As a general result, fairly good organizational and technological profiles were observed for the case study, especially regarding the rate of ELVs dismantled (2900 per year). In fact, despite the wide diversity of vehicle to be dismantled (i.e. the various company maker and product model) a standard approach is followed for the process and manual operation do not affect the total dismantling time.

Generally speaking, corrections should be directed toward: *Most critical processes:* those that could affect the whole process effectiveness; *Less efficient processes:* those that do not add value (e.g. delays, redundant docs); *Most ease-to-solve criticalities:* corrections cannot affect the overall equilibrium.

For instance, improvements can derive from the removal of valuable parts (e.g. turbocharger, switchboard), which can be sell as spare parts, whereas are now included in the car fluff. Nevertheless, this would cause the increase in time and warehousing costs. Regarding recyclability, car fluff is the worst element, being composed by plastics, gum, and glass. However, the increase of the plastic fraction will reduce the dismantlers income, which mainly come from metals. Concerning sustainability of ELV, the automatic disassembling would reduce costs, but results feasible only for large companies and small companies will be damaged. A mix of small and large companies is more desirable.

7 Concluding Remarks

The study has confirmed that the simplicity of disassembling the components and the ease of identification of the diverse material to be separated is fundamental for an efficient dismantling of motor vehicles.

It is finally crucial that the dismantling processes, being highly complicated, mainly involve the same manufacturers. For this scope, the flow of information within the dismantling process represents a fundamental feedback for the automotive industry; based on such information, the manufacturers can develop specific actions aimed at improving the overall efficiency and sustainability of the vehicles life cycle since from the early design studies.

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References

1. Directive 2000/53/EC of the European Parliament and the council of 18 September 2000 on end of life vehicles. Official Journal of the European Communities 21 October (2000)
2. Gerrard, J., Kandlikar, M.: Is European end-of-life vehicle legislation living up to expectation? Assessing the impact of the ELV Directive on 'green' innovation and vehicle recovery. Journal of Cleaner Production. 15, 17–27 (2007)
3. EUROSTAT, Environmental Data Centre on Waste, ELVs - Key Statistics and Data. http://epp.eurostat.ec.europa.eu/portal/page/portal/waste/data/wastestreams/elvs (2009)
4. Toffel, M.W.: The Growing Strategic Importance of End-of-Life Product Management. California Management Review. 45(103), 102–129 (2003)
5. Gesing, A.: Assuring the Continued Recycling of Light Metals in ELVs: A Global Perspective. JOM, 56(8), 18–27 (2004)
6. Ming Chen: ELV Recycling in China: Now and the Future. JOM, 57 (10), p. 20 (2005)
7. Ming Chen and Fan Zhang: ELV recovery in China: consideration and innovation following the EU ELV Directive. JOM, 61(3), p. 45 (2009)
8. Edwards, C., Coates, G., Leaney, P.G., Rahimifard, S.: Implications of the ELV Directive on the vehicle recovery sector. J. Eng. Manufacture. 220, 1211–1216 (2006)
9. Mergias, I., Moustakas, K., Papadopoulos, A. Loizidou M.: Multi-criteria decision aid approach for the selection of the best compromise management scheme for ELVs: The case of Cyprus. Journal of Hazardous Materials. 147, 706–717 (2007)
10. Ferrão, P., Nazareth, P., Amaral, J.: Strategies for Meeting EU ELV Reuse/Recovery Targets. Journal of Industrial Ecology. 10(4), 77–93
11. Nourreddine, M.: Recycling of auto shredder residue. J. of Hazardous Materials. A139, 481–490 (2007)
12. Bellmann, K., Khare, A.: Economic issues in recycling ELVs. Technovation 20, 677–690 (2000)
13. Ferrão, P., Amaral, J.: Assessing the economics of auto recycling activities in relation to European Union Directive on ELVs. Technological Forecasting & Social Change. 73, 277–289 (2006)
14. Mazzanti, M., Zoboli, R.: Economic instruments and induced innovation: The European policies on ELVs. Ecological Economics 58, 318–337 (2006)
15. Mildenberger, U., Khare, A.: Planning for an environment-friendly car. Technovation. 20, 205–214 (2000)
16. Car recycling Systems BV. http://carrecyclingsystems.com/ (2009)
17. Automobile Club Italia. http://www.aci.it (2009)