EPS - PROJECT

TITLE: RECY-Car - Market analysis and technical approach of the end of life vehicle waste

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RODRIGO VERBAL

DATE 10/06/2016
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<th>RECY-Car - Market analysis and technical approach of the end of life vehicle waste</th>
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<tbody>
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Abstract

The following project took place in the European project semester in spring 2016 and was settled at the Universitat Politècnica de Catalunya in Vilanova I la Geltrú. This project was initiated by PICVISA, a sub company of the Calaf Group. For example, they are offering some material treatments like sorting of recycling materials. This recycling is for today’s society getting a very important topic because of the environmental pollution and the limited natural resources. But for some specific materials a way to recycle is still missing. The goals of this project were to describe the end of life vehicle recycling and finally solve a specific sorting problem of the company. Therefore, a thoroughly research of the actual literature was done to describe the used dismantling techniques, the materials of a car and reuse possibilities. Also there is an overview of all the different actual sorting techniques which are existing in the market. All these research topics lead to some materials which cannot be sorted at the moment. One of these materials are plastics when they are black coloured. This is also the specific problem of PICVISA. In order to estimate the market for this type of materials, there is a market analysis of the end of life vehicle treatment done. This carried out, that there is a quite huge market for this specific type of materials (50-100 M € in whole Europe). That’s why it seems to be a good idea continue working in this business field. So the next step is a brainstorming which collects several different thoughts to solve the issue and also the criteria to assess them. Then, these criteria are ranked regarding to their importance with an analytical hierarchy process. With this it is possible to evaluate each idea in a decision matrix. This leads to the most proper solution according to the given criteria. In this case the choice was an electrostatic sorting method. In this method, the plastic particles are charged electrostatically, in this use, because of the friction between the single particles (tribo-charging). Because of the electrostatic effects and unequal dielectric constants of the plastics, these materials are charged differently. So it is possible to separate them in a high voltage field. In order to separate several types of plastic, only more of those machines are needed in a row, because there is a tribo-electric charging row among all the plastics.

Key words:

black coloured plastic, dismantling a car, electrostatic sorting, end of life vehicle, market analysis, reuse, recycling, sorting
RECY-Car - Market analysis and technical approach of the end of life vehicle waste

At the Universitat Politècnica de Catalunya in Vilanova i la Geltrú
In the summer-semester 2016

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Company Supervisor
Rodrigo Verbal

Vilanova i la Geltrú, 10th of June 2016
Statutory Declaration

We declare that we have developed and written the enclosed project completely by our self, and have not used sources or means without declaration in the text. Any thoughts from others or literal quotations are clearly marked. The project was not used in the same or in a similar version to achieve an academic grading or is being published elsewhere.
II Acknowledgement

After this four month of work, we want to express our deepest appreciation to all the involved parties:

Firstly, the project group wants to express their sincere thanks to the supervisor Antonio J. Sánchez Egea for his continuous support and the feedback during our project. His guidance helped us a lot. Also we are grateful to the second university supervisor Hernán A. González Rojas.

Beside the university supervisors we also want to express our gratitude to the company PICVISA for defining the project. It was an extraordinary interesting field of engineering, where all the involved parties learned a lot about these issues. This includes also a great thank to Rodrigo Verbal, who was our contact person of the company and also gave us always a very precious and productive feedback.

Furthermore, we want to thank the Universitat Politècnica de Catalunya, especially the Escola Politècnica Superior d’Enginyeria de Vilanova i la Geltrú, for hosting such an international project which was a great experience for all our team members.

Most of the students were supported by the Erasmus + program of the European Union, which enables us to be part of this very beautiful and haunting intercultural experience. That’s why we also want to thank them for this support.

Last but not least we want to thank to our home universities for sending us abroad and the local supervisors in the home countries who took care of us in our home universities:

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Politehnica University of Bucharest, Romania  Prof. Dr.-Ing. Gina Florica Stoica
Tecnologico de Monterrey, campus Mty, Mexico  MDI Valeria Loera
University of Applied Sciences and Arts Coburg, Germany  Prof. Dr.-Ing. Stefan Gast
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<table>
<thead>
<tr>
<th>Family name</th>
<th>First name</th>
<th>Country</th>
<th>Home university</th>
<th>Speciality</th>
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</thead>
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<td>Bourgue</td>
<td>Vincent</td>
<td>France</td>
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<td>Thermal and energy engineering</td>
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<td>María Fernanda</td>
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<tr>
<td>Kelly</td>
<td>Daniel</td>
<td>Ireland</td>
<td>Institute of Technology Sligo, Ireland</td>
<td>Creative Design</td>
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<td>Krapf</td>
<td>Martin</td>
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<td>University of Applied Sciences and Arts Coburg, Germany</td>
<td>Development and management in automotive-engineering</td>
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<tr>
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<td>Politehnica University of Bucharest, Romania</td>
<td>Industrial Design in Mechanical and Mechatronics Engineering</td>
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<tr>
<td>Abbreviation</td>
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<td></td>
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</tr>
<tr>
<td>AHP</td>
<td>Analytical hierarchy process</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASR</td>
<td>Automotive shredder residue</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EG</td>
<td>European Commission</td>
<td></td>
<td></td>
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<tr>
<td>ELV</td>
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<td>Escola Politècnica Superior d’Enginyeria de Vilanova i la Geltrú</td>
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<td>EU</td>
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<td></td>
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<tr>
<td>LIBS</td>
<td>Plasma spectroscopy induced laser</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MIR</td>
<td>Medium infrared thermography</td>
<td></td>
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<tr>
<td>NIR</td>
<td>Near-infrared</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>RAM</td>
<td>Raman spectroscopy</td>
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<tr>
<td>TRA</td>
<td>Tracer incorporation in polymers</td>
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<td>UPC</td>
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<tr>
<td>VIS</td>
<td>Colour analysis by camera or spectrometer</td>
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1 Introduction and Background

1.1 European Project Semester

The European Project Semester (EPS) is an international program, which is mainly created for engineering students, but students from different expertise can also participate in the EPS [1]. This program is settled at the Universitat Politècnica de Catalunya (UPC) and takes place in the Escola Politècnica Superior d’Enginyeria de Vilanova i la Geltrú (EPSEVG). The course is for students from Europe and the whole world [2]. There are native Spanish and foreign students working together in an international multidisciplinary project. The students are divided into small groups and have to work on a project which could be linked to a company. The advantages of this project [2] are that the students get open-minded to a new experience, improve their team working skills and see other ways of working. In this sense, the students are getting used to an international working atmosphere as the same time as they improve different languages skills. This program is the perfect training for the students for their nearly future working career, which could be in an international company.

1.2 Project

Although the natural resources are limited, the growing industrialization and the throwaway mentality of nowadays increase the environmental pollution, which is a very important problem of today’s societies. This makes a good standard of life management necessary because with a good recycling at the end of live of a product, the use of new natural resources and, also the pollution of the environment can be reduced greatly. Recycling is demanded by most of the governments in the world [3], in order to have international agreements which achieve joint goals to reduce the pollution in a worldwide fashion [4]. One big share of the waste is for example caused by end of life vehicles [5]. Just in the European Union (EU) there are 6 280 000 million ends of life vehicles per year (2012) [6], which means a huge amount of waste, but also lots of precious materials which could be recycled. In order to spotlight in this huge field just a little, this project is focused on the recycling of a car and also treats a specific problem in its recycling processes. In this project, there will be a collaboration from a student group (Vincent Bourgue, Maria Fernanda Cruz Rodriguez, Daniel Kelly, Martin Krapf, Andreea Georgiana Preda), two professors from UPC (Hernán A. González Rojas and Antonio J. Sánchez Egea) with a subsidiary company from Calaf Group, which is called PICVISA (represented by Rodrigo Verbal).

This is the first cooperation between the EPSEVG and PICVISA to develop this challenging work. In addition, there were no further researches in former times at the EPSEVG.
1.3 Companies

1.3.1 Calaf Group

In this project, the team is working together with a subsidiary of a local Spanish company called Calaf Group. The Calaf Group was founded in 1964 in a small village called Calaf which is located 90 km in the northwest of Barcelona [7]. The company is still a family-company with 352 employees [8] and today their philosophy is to have several subsidiary companies in different industrial areas. Consequently, Calaf Group managed to have specialties in different engineering-areas and not to bring a negative marketing to the headquarter. Originally this company was focused to build homes in the local area around Calaf. But they soon evolved their focus and diversified their competences to public works, rehabilitation and water supply to several towns. Out of this evolution finally three main sectors of Calaf Group were found: the construction, the industrial company and the service sector. The actual moral concept of the company is to make clear commitments depending on professionalization, specialization and internationalization [8].

1.3.2 PICVISA

PICVISA is a subsidiary company of Calaf Group (headquarter) and was found in 2003 [9]. This subsidiary company is located in Igualda which is between Lleida and Barcelona. The company provides for example innovative solutions for automated sorting machines by using machine vision. There the main activities of PICVISA are software design of machine vision, fabrication and site fixing of the sorting machines and its complementary elements like commissioning [8].

The products of PICVISA are used in specific material recovery facilities for example in the mining, the water treatment and the recycling. So their products also can be used in the recycling process of a car especially in the glass and the plastic sorting. At the moment, there are more than 110 PICVISA machines operating in various countries. Also five different material recovery facilities have been built by PICVISA during the last five years [8].
2 Project Aim

2.1 The aims of the project and the included steps

This project has several aims in order to illuminate the huge and important field of the end of life vehicle. The main goals are with describing how an end of life vehicle is separated into parts, how the used recycling techniques are working and how the materials are recycled. This includes a benchmark analysis of the recycling market, and also tries to solve a special waste sorting problem.

In order to achieve this goals there are different steps to fulfil:

- Detailing the recycling route of an end of life vehicle and the used techniques starting from a whole end of life vehicle up to the small resulting parts
- Finding out if several parts of a car can be reused and how to handle dangerous parts/liquids
- Describe the recycling of the materials of a car with detailing the different types, the properties, the recycling route, the future application possibilities and the hazards. Also materials that cannot be recycled at the moment are also mentioned in this section.

These materials lead the project group to the specific problems faced by PIVISA.

- Benchmark of the car recycling industry
- Considering a technical solution to distinguish between different types of black coloured plastic
2.2 How to achieve the aims

In order to fulfil the main task, the first focus is on doing a thoroughly research and collecting information from the internet, books, articles, and the competitors. To find a solution for the specific problem of the company a brainstorming will create some ideas and criteria to assess them. To define the value (weight factors) of criteria an analytical hierarchy process (AHP) is carried out. With them finally applied, a decision matrix with weight factors will carry out the best solution.

The timeline of the project will be organized with a Gantt chart (the full Gant chart is in the appendix A.4 Gantt chart). Also, a project management software (Trello) is used to keep an overview of the progress of the project and to divide tasks. To document the divided tasks clearly also a responsibility matrix (RACI-Chart) (the full matrix is in the appendix A.5 RACI Matrix) is used.

In order to document all the discussions and decisions in the meetings with the university and company supervisors, meeting minutes are written. They also can be found in the appendix A7 Meeting minutes.

2.3 Deliverables

In the end the project team is going to hand out a report to the company. This report will give an overview of the end of live vehicle recycling and also a description of a way to solve their problem. The overview of recycling maybe finds new business fields for the company, which can gain profit for them in the future. With the solution of the problem they are able to realise the solution and benefit from applying it later.

Completing the tasks will help to reduce the pollution of the environment, because for example more plastic can be sorted, recycled and reused. And there will be no need to burn or landfill this type of waste anymore.

Beside the report, the project team also needs to handout an article, a poster and a video to the university at the end of the project.
3 Dismantling a Car

In order to find out where the specific problem of the company is located the whole recycling process of an end of life vehicle has to be examined. When a vehicle is at the end of its use, it has to pass through several steps to separate all the components and parts to reuse or recycle as much parts as possible from a car. In some of these steps it is possible to find the black coloured plastic materials.

The whole end of life treatment of a car is documented in the standard [10] from the European Commission, which is valid for passenger vehicles and small trucks in the European area. The key points of this law are:

- Quota for the treatment of the end of life materials:
  - Recyclable to a minimum of 85 % by weight per vehicle
  - Recoverable to a minimum of 95 % by weight per vehicle
- The prohibition of harmful substances like lead, mercury, cadmium and hexavalent chrome
- Manufacturers, importers and distributors of cars have to allocate systems to collect end of life vehicles (and used parts from repaired passenger cars)
- Car owners who hand over their end of life vehicles for waste treatment get a certificate of destruction, which is necessary to deregister a car
- The manufactures have to pay (mostly) for the end of life vehicle treatment (usually not the car user)
- Waste treatment centres need to register and get a license of the authority
- Description of the end of life vehicle treatment
- Report to the European commission about the recycling in certain periods

This European law is also the base for the individual laws in the different countries in Europe.

Based on this law several steps need to be followed in dismantling a car. Figure 3.1 gives a short summary of the whole end of life process. Firstly, the removal parts were dismantled, the remaining body is pressed and shredded. Then sorting of the residues takes place. After this the sorted materials and a share of the residue can be recycled with actual methods. Only a small residue, the automotive shredder residue (ASR) is left. These materials are, because of the missing recycling methods or the lack of profit, landfilled or energetically recovered (burned). Table 0.3 in the appendix shows an analysis of the materials shares of the ASR (also called shredder light fraction) right after shredding (with some recyclable materials). In this ASR (the red circle in Figure 3.3) the specific problem of the company is located (detailed explanation is in the section 9.1 Description of the problem).

In the following there is detailed view on all the different steps in the recycling of an end of life vehicle.
Beside the explained law, there also exists an international database (international dismantling information system (IDIS)) for recycling companies. This contains information of more than 20 car manufacturers (73 brands) according to the dismantling and recycling of the single cars. One section, for example treats the plastic. There are all the plastic parts of a car listed which are heavier than 100 g.

This database is also necessary because of the many different parts of a car. Figure 3.2 shows for example all the parts of a Volkswagen Golf III.
According to the law [10] and [14] the main reasons for dismantling of waste parts are:

- Separating functional components in order to reuse them (for example gearbox, engine)
- Removing and save harmful substances (for example: batteries, cooling liquid, oil)
- Gaining recyclable materials (for example: metals, plastics)
- Reduce the residual waste

The dismantle-ability is influenced by [14]:

- The used connection method in the production
- The spatial arrangement and the accessibility of the parts
- The identification marking of the parts

The dismantling techniques can be separated between [14]:

- Non destroying methods (like to screw, to clip)
- Destroying methods (like cutting, breaking, welding)

In order to have an overview of the whole dismantling process, Figure 3.3 shows a flowchart of the selective dismantling, which is the usual way to dismantle a car.

---

**Figure 3.3** Flow process chart of an end of life vehicle [15] [16]
3.1 Dismantling the removal parts

The specific goal for cars is to dismantle all the removal parts in order to have only the chassis left. This reduces the residue after the shredder which is very difficult to recycle because of the mixture of all the different materials (Table 0.3 in the appendix shows the materials shares of the shredder light fraction). The dismantling process is at the moment not done automatically, because there are so many different cars with different sizes and lot of different parts. That’s why dismantling is mostly done by hand and usually in an island-dismantling, what means in several stations. Sometimes it is tried to do it in line but for the same reasons it is difficult to realise [14].

Figure 3.3 showed the single steps in the recycling of an end of life vehicle. In order to dismantle a car several steps are necessary and these steps are now described a little bit more in detail.

First step: Draining the car
This means to remove the liquids (fuel, oil, cooling liquid, breaking fluid, anti-freeze, cleaning liquid), because they are more or the less hazardous (5.7 Liquids) and might cause danger in the further process. This step also includes the removal of the pyrotechnical devices like the airbags or the pedestrian protection. The reason therefore is that an unsafe treatment of these parts would cause several dangers in the later process.

After this there are usually several stations in order to dismantle a car. They are, as already explained, usually done in an island dismantling [17]:

Station 1:
The car is put on a transport car. Then it is possible to dismantle the tires and it can be easily moved during the dismantling process.

Station 2:
In this station, the doors (with extracting of the door covering), the hood, the windows, the seals, and the exterior plastics (like the bumpers) are removed because they are the best available parts.

Station 3:
The next step takes care of the seats because they are now better accessible. So the seat cover, the PUR foam, and the seat frame are extracted and then separated.

Station 4:
Now, there is enough space (no doors, seats) to extract the dash panel (with the cables) and also the interior coverings. This is also the end of the interior dismantling.

Station 5:
Now the car is turned upside down and all the connections from below are solved and the exhaust is removed. Then the car is a turned back.
Station 6:
Then the shocks are solved. Now the body can be lifted by a crane. And the whole powertrain (engine, gearbox, axles) remains on the transport car.

Station 7:
Finally, the remaining parts like cables, the heater, the radiator and the windshield wiper system are removed because they are now accessible.

Then everything is checked. After this the dismantling is finished.

3.2 Press

Press Process begins when all the materials have been removed from the entire vehicle (Figure 3.3). The vehicle stands in a platform to be pressed by a big machine which compresses all the parts to get just a big piece of steel compress in a cube.

Usually waste materials are compressed in order to get adequate sizes for storing, transport and further processes. The press is necessary for bulky, jammed and voluminous metal waste like the body of an end of life vehicle [14].

![Figure 3.4 Overbuilt Car Crusher: (159 tons crushing power, six cars at the same time) [18]](image)

![Figure 3.5 Cars after press process [19]](image)
3.3 Shredder

After the press the remaining material is put in a shredder (Figure 3.3) and is crushed to small pieces.

In a recycling process the shredder is used to [14]:

- Break and destroy the connection of different materials
- Process materials into specific sizes which are suitable for the following steps (like separation, melting)
- Reduce the cost of transport

Crushing the materials uses different mechanical techniques. They are showed in Figure 3.6.

![Figure 3.6: schematic representations of possible shredding techniques](image)

**Comment**: in Figure 3.6 the colour black means: parts of the machine; grey: material to treat

An optimal shredding is reached, when all the connections between the different parts and materials of the waste are broken. The result of shredding are lots of different unsorted parts of materials. According to size of the resulting pieces of material, the shredding processes can be classified (Table 3.1) [14]. This table also shows the used shredder techniques which are used for different types of scrap.

**Table 3.1** Overview of the used shredding techniques (relevant for vehicle waste) [20]

<table>
<thead>
<tr>
<th>Waste material/product</th>
<th>Used shredder</th>
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<tr>
<td>Coarse shredding (d &gt; 100 mm) / middle shredding (100 mm &gt; d &gt; 5 mm)</td>
<td></td>
</tr>
<tr>
<td>Steel/ non-iron scrap</td>
<td>Guillotine cutter, alligator cutter</td>
</tr>
<tr>
<td>Cast iron, Aluminium casting scrap</td>
<td>Jaw crusher, scrap breaker</td>
</tr>
<tr>
<td>Small electric motors</td>
<td>Rotor cutter</td>
</tr>
<tr>
<td>Plastic waste, foam materials, wood waste</td>
<td>Cutting mill</td>
</tr>
<tr>
<td>Vehicle- and Aluminium scrap</td>
<td>Rotor cracker</td>
</tr>
</tbody>
</table>
Whole vehicles, packets of sheets, lead scrap, electric motors | Hammer cracker
---|---

**Fine crushing (grinding) (5 mm > d > 0,1 mm)**

<table>
<thead>
<tr>
<th>Material</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable, connectors, small electronic scrap</td>
<td>Cutting mill, hammer mill (maybe with cryogen treatment in the beginning)</td>
</tr>
<tr>
<td>Fibre composites, laminar structure</td>
<td>Impact mill (maybe with cryogen treatment in the beginning)</td>
</tr>
<tr>
<td>Coatings</td>
<td>Jet mill</td>
</tr>
<tr>
<td>Elastomer, Plastics</td>
<td>Impact mill (maybe with cryogen treatment in the beginning), press cylinder (kollergang), matrix press</td>
</tr>
</tbody>
</table>

**Micro crushing (d < 0,1 mm)**

![Figure 3.7 schematic representations of different Shredders](image)

Figure 3.7 shows the most common shredders.

The shredder for vehicles are dimensioned to be able to shredder compressed and also not compressed cars [14]. The shredding of a car is showed in Figure 3.3. First the cars (if it wasn’t done before) are pressed. After shredding, there is already a first step of sorting showed on the picture: Materials which weight less are blown out by air (Shredder light fraction) (2) and are collected. This way of sorting (density sorting; separation by air) is explained in the section 6 Sorting.

After the shredder the dismantling process of a car is finished.
Example: The Lynx shredder [23]
The feeder pipe allows large chunks of scrap to pass through to the shredding area while a Twin Roll Compression Feeder prevents too much material from hitting the shredder at the same time and clogging the mechanism. A series of huge, rapidly-spinning hammers—powered by a 40 ton, 11 KV, 9 200HP high voltage electric motor—tearing the vehicle into fist sized chunks. The LYNXS can digest 450 cars—roughly 350 tons of material—per hour. It is so big and so powerful; it had to be wired directly into the Welsh national power grid to draw sufficient current.

What comes out of the shredder is "high-density uniform fragmentized scrap" according to the LYNXS site. The machine is capable of handling a wide variety of materials.

![Figure 3.8 schematic representations of a car shredder [22]](image)

![Figure 3.9 Real shredder [24]](image)
4 Reuse of the Parts

As it was told in the section 3 Dismantling a Car most of the parts of an end of life vehicle are dismantled, while many special parts can be reused for selling or in most cases put to good use with the materials that can be reused. In this section, there is a look into the specific areas of the car and the parts that can be reused for them and also can be made to helpful products to benefit towards the environment. The parts can be directly or after a remanufacturing be sold. The parts are usually sold by the dismantling companies. Or from companies which are specialized on the selling of used car parts.

In order to classify the shares of the dismantled and shredded materials Figure 4.1 shows their shares compared to each other. This figure also shows the final treatment of the dismantled and shredded materials.

Comment: This figure shows a quite different amount of the share of dismantled parts than Figure 3.1. But this statistics are out of two different sources: Figure 3.1 is an advertisement of Toyota and no specific country and year of the used numbers are given [11]. Probably it is Japan. Figure 4.1 is a statistic from the German government from the year 2015 and refers to the year 2013 in Germany [5].

![Figure 4.1 Material-shares (according to mass) of the dismantling and the shredded materials and the final treatment](image)

**Figure 4.1** Material-shares (according to mass) of the dismantling and the shredded materials and the final treatment [5]
4.1 Reused Parts

Airbag
The Airbag of a car is wildly recycled and reused while the car is being dismantled. The airbag if not deployed it can be saved and be used in other cars if needs be. The make of airbag modules includes aluminium, stainless steel or mild steel, nylon and plastic, all those can be used for different compounds. The make-up of airbag modules as stated above as made some airbag manufacturers have recycling facilities. Autoliv, an airbag manufacturer, has a recycling facility in Promontory, Utah, where the company cites the ability to recycle 98% of the materials in individual units. [25]

Auto Glass
Most of the glass that is broken would end up in a landfill in former times, but the technologies have improved so glass became easier to reuse for many jobs. Reclaimed auto glass can be transformed into fiberglass insulation, concrete blocks and glass bottles, while the plastic is reused for carpet glue and other applications.

Battery
Car battery is a common recycled part of a car. It can be dismantled and reused for many other helpful services. The battery is separated into plastics and into the lead. The plastics can be melted down and be made to make more bodies for the batteries, while the lead is melted down and put into bars that can be used to make more car batteries. [26] Sulphuric Acid which is in the old car batteries can be reused in many for jobs. They convert it to sodium sulphate, an odourless white powder that's used in laundry detergent, glass and textile manufacturing. This takes a material that would be discarded and turns it into a useful product. The acid can also be reclaimed and reused in new battery products through innovative recycling processes.
Reusing the Parts

Figure 4.2 Life of recycling process of a car battery [26]
Catalysts
A Catalytic converter contains many of precious metals. In recent years the catalytic converter has become popular in the recycling business. The catalytic converter uses a set of catalysts to convert some of the dangerous gases which are produced in the engine of a car. [27] Platinum and palladium, both rare precious metals, are brushed onto a honeycomb-shaped matrix inside the catalytic converter. When exhaust flows by, the metals convert for example carbon monoxide and smog-producing hydrocarbons into carbon dioxide and water. Catalytic converts contain several other metals, including copper, nickel, cerium, iron and manganese. Small amounts of rhodium are also found within a catalytic converter. Rhodium, like platinum and palladium, is very rare and valuable. These three metals can be used for jewellery, electronics and industrial purposes.

Figure 4.3 The process of the end and reuse life of the catalytic converter. [27]
**Mats and carpets**
The mats and carpets that are in a car, can be reused for other cars. Also the textiles that are used can be wildly recycled. Nearly two third of the automobile textiles are for interior trim, i.e. seat cover, carpets and roof and door liners. The rest is utilized to reinforce tires, hoses, safety belts, air bags, etc. It is projected that nearly 45 square meters of textile material is utilized in a car for interior trim (seating area, headlines, side panel, carpet and trunk). According to a survey, the percentage of textile in a motor car amounts to 2 percent of the overall weight of a car. Apart from this, visible textile components, eliminating hidden components such as in tires and composites, hoses and filters; amount to 10 - 11 kg per vehicle in absolute terms. Industrial textiles are largely utilized in vehicles and systems including cars, buses, trains, aircrafts and marine vehicles.

**Oil Filters**
Used oil filters can also be recycled, and must be properly disposed of by law. An oil filter is made of three basic items: paper, steel and plastic. All of these items are recyclable when sent to the proper recycling outlet.

**Rubber hoses**
Some of the rubber hoses can be reused, if they are not too damaged. Just like garden hoses, the rubber hoses from automobiles can be taken to many recycling centres for processing rather than tossed in the trash.

**Tires**
Of course many of the tires that be pulled apart from the car are brought to the landfill and usually burnt but in recent years, tires have been reused for the process of design with gardens and also the recycled tires can be used into rubberized asphalt for highways/motorways.
4.2 Reselling parts

When the car is going to be recycled there are many parts of the car that can in fact be sold for others to put onto or into their car. I will give a list of the many uses that can be resold to people before the whole car is dismantled.

Lights
If the front, lateral and rear of the car’s lights are not damaged they can be put up for selling for other users. Lights are the biggest market for reselling in the car market as many people can break them so easily, when this happens the alternative is used lights as they can end up cheaper.

Bumpers
As the same as lights bumpers are easily damaged in small accidents so recycled bumpers are in the market for people to get repairs for their car as the cheaper price than a new one.

Ignition switch
The ignition switch is a simple tool that be sold after the car has been separated into the parts that can recycle and also resold. Many of the car’s ignition switches are perfectly in good condition when the whole recycle process has taken place, so that is why they can be sold onwards to people that may need them for their own needs.

Radios
Radios can be resold to other if the car is going to get recycled because for many cars fit the standard radio size. The radio is probably the most commonly sold item when the owner of the car is going to recycle their car.

Other reselling parts
According to [14] also the engine, the gearbox, the starter, the electric generator, electric and electronic parts, the radiator, the wheel rims, the tires, the shocks, the tank, the doors, the engine bonnet and the rear lid can be reused.
4.3 Different application of reuse

Several parts (or whole cars) can also be reused in creative ways. Therefore Figure 4.4 (left, middle) shows some reuse applications, which are mostly individual and rare spread. Also some small companies are offering special products out of old parts. One example is swings for playgrounds out of old tires (Figure 4.4 right) [30].

Another quite successful way of reusing old parts from vehicles (trucks, cars, bikes) is for example the company Freitag from Switzerland. This company uses old truck traps to build handbags or backpacks. The makers of these products are made out of old car seatbelts. In the German speaking parts of Europe this bags are quite popular. This company already produces about 300 000 products per year. This means a reuse for example of 300 t of old truck traps, 130 000 car seat belts (and 15 000 bicycle tubes) per year (2015) [31].

But even this quite big Freitag-company has only a very small share of the whole waste materials. So for example the 6-7 million ends of life vehicles per year (2012) in Europe [6] (with the assumption of 4 seatbelts per car) have 24 million seat belts. So this company only uses about 0,5 % of those.

This reuse will probably never be the only final solution of all the end of life vehicle waste. Because there is so much waste (8-9 million t per year (2012) [6]), which would need even more creative ideas. Also some dangerous parts/materials require a special treatment and are not suitable for a commercial reuse. But these creative things can help to reduce the waste at least a little bit.
5 Recycling of the materials

As Figure 4.1 already showed the biggest share of the materials of a car (95 %) are shredded and there is no direct reuse possible. So the shredded materials can be only recycled. Now, in order to have a look on the recycling routes of the different materials firstly it is necessary, to find out the different types of the used materials. In the average, a modern car is build out of round about 30 000 parts [32] and around 40 different materials [14]. And these parts are made out of many different materials. The choice for the material nowadays is often a difficult question in the development of a car. The decision for choosing a proper material is on the one hand of based on suitability of the material, but on the other hand also on the manufacturing process [33]. Therefore, Figure 5.1 shows the different groups of materials and their share according to the mass of a whole standard car manufactured in 2015 [33] [34]. This diagram shows that almost ¾ of the mass from a car is out of metals. Even more than 1/5 is out of plastics, which means thermoplastics and thermostats. Beside these main groups, there are also glass and liquids in a car. The rest of the materials are for example the textile or the leather from the seat or foams in the matrass of the seat or for the soundproofing [34]. The following figure show the material shares of an automobile.

![Material shares of a normal car (according to mass) (Netherlands 2007) [34]](image)
5.1 Metals

Properties
For metals, it is characteristic that they are very good thermal- and electrical-conductors. This material group also have a very high mechanical stability, high ductility, Young modulus and they have a metal gloss. They are never used in technical applications as a pure material. They are usually used in a combination of different elements (alloys) [35].

Different types
Depending on density, metals are usually divided into light and heavy metals [35]. The most used metals in a car are steels, aluminium, copper, zinc, and noble metals like gold, silver and platinum [33].

Use
The main use of the metals are in the body (material mix depending on the material properties), the chassis (more and more light metals are used instead of steel metals), the drive with the powertrain (aluminium, grey cast iron, ceramics, magnesium) [33]. According to reduce the weight of a car, which is a main trend in the automotive industry [33] the use of aluminium increases (10 % in 2012) [36] but still steel is the dominant role (about 61 % in 2015 [33]) (Figure 5.1).

Recycling
Recycling of different metals works more or the less in the same steps, but the used techniques can be different. First there is a shredding and a sorting of the waste materials (this is already explained in the section 3 Dismantling a Car) and if necessary a cleaning. Then, the metals are classified according the level of pollution. After that the single metals are melted and with methods refined. Recycling of metals needs less energy than producing new primary metals and decreases the need of mining [14].

Hazards
Pollution of the waste with for example water, oil, fat or plastics, but also other materials, can cause problems in the melting process or reduce the quality of the recycling products [14]. Also there are several specific dangers according specific types of metals also to human and the environment [37].

Reuse of the secondary material
Because of the very good recycling properties the recycled metals (secondary metals) have the same properties like primary metals [14]. Almost all metals can be reused in the same places like primary materials. At the moment for example more than 98 % of the total steel waste [22] and about 70 % of the total aluminium waste [14] can be recycled.

Comment: Further information (properties, different types, use, recycling, hazards and reuse of the recycled materials) about metals in the automotive industry are given in the appendix A2 Recycling of the materials.
5.2 Plastic

Properties
Plastics are inorganic and produced in synthesis processes. The main elements for plastics are Carbon and hydrogen. But also other elements can be involved. Plastics have (compared with metals) a lower density, a high leaking resistance, a higher damping capacity and a greater influence of the ambient conditions. The properties are heavily influenced by the way of production [35].

Different types
There are three different main groups of plastics: The thermoplastics, the thermostats and the elastomers [38]. There are also thermoplastic elastomers. This is a small group of plastics with properties in between elastomers and the thermoplastics [33]. Each of those groups has many different materials and different properties.

Use
Figure 5.2 shows the used plastic types in the European automotive industry in 2012. This chart shows that most of the used plastics in a car are the thermoplastics.

![Figure 5.2 Shares of used plastics in the European automotive industry of 2012 [39]](image)

In order to locate now the places of the use, Figure 5.3 shows, where the most common plastic types can be found in a car. The bigger one point is, the higher is the use of the specific material in the car is. Therefore, the main use of the plastics is the interior like for example for covers or bars. They are also widely spread in the exterior, like the bumpers or the tires (Elastomers). Also they are used near engine (Thermostats because of the higher resistance against heat) and in the electric as isolators for example of cables [40].
Recycling

The recycling of plastic is more difficult than from the metals. Only most of the thermoplastics can be melted or solved and reused directly. But several additives like colours and fibres which were added in order to improve the properties can cause problems [14]. Also the degradation because of the environment (ultraviolet part of the sunlight, temperature, salt) is reducing the quality of the plastic during its use and so of the later recycled material. The other plastics-types cannot be melted or solved so they only can be grinded, energetically used (burned) or landfilled [35].

Hazards

The grinding stock of elastomers is flammable and can be explode. Also burned or landfilled plastic increases the environmental pollution. Burning of plastics with chloride (like PVC) are causing dangers during the process [14].

Reuse of the secondary material

Depending on the age and type several thermoplastics can be reused in the same parts (mixed with new materials) [14]. The other plastics just can be reused as filling materials or for other applications [41]. Elastomers can be reused for example in athletic grounds, carpets in a car, in the asphalt, as rubber in tires, soles of shoes, or as oil binder. According to [42] in 2013 in Germany 33 % of the plastic waste of a car was recycled, 64 % was energetically reused, and 3 % was landfilled.

Comment: Further information (properties, different types, use, recycling, and reuse of the recycled materials) about plastics in the automotive industry are given in the appendix A2 Recycling of the materials.
5.3 Glass

Properties
Glasses have a special physical constitution of an amorphous solid body. Glasses are made out of sand (quartz), soda and chalk [14].

Different types
There are two different types of glass used in a car. On the one hand you have toughened safety glass and on the other hand composite pane safety glass [33].

Use
Glass in a car is used in the windows: The front- back- and fond- windows are out of glass. Furthermore the sunroof is out of glass. The used type of the window depends [33].

Hazards
The black edge of old cars (built befor 2003) is out of led silicate [14].

Recycling
Problems during the recycling problems are caused by the black colour at the edge of the glasses [14].

Toughened safety glass is shivering into lots of very small parts. This requires a very good sorting technique and is very expensive. In order to recycle the glasses there are several steps [14]:

- Dismantle the windows
- Collecting according to colours, edge layer and function elements
- Delamination of multilayer glass
- Shredding of the glasses
- Separate the metal parts and the coloured glasses
- Transported to the glassworks

Reuse of the secondary material
When the glass is well sorted, it can be reused in the glassworks like new glass [14]. In Germany 84,2 % of all the glass waste (of all sources) was recycled [43].

Comment: Further information (different types, recycling,) about glass in the automotive industry are given in the appendix A2 Recycling of the materials.
5.4 Ceramics

Properties
Ceramics which are relevant for technical use have a very high compressive strength, hardness, wear-resistance, high temperature resistance, a good corrosion resistance, a low density and a very high dielectric constants and good piezoelectric properties [33]. But they also have a low ductility, a complex manufacturing process in the production and in the machining and it is often difficult to combine them with other materials [33].

Different types
There are there different groups of ceramics existing: The silicate-, the oxide- and the non-oxide ceramics.

Use
Ceramics are used as the carrier of the catalytic converter, in electronic applications, as bearing rings, as an isolation sockets in water or fuel pumps, as the valve of an exhaust regulation, as brake discs, in some special cars as a clutch, ignition plugs, heat elements, and as dielectric in electrical condensers, and as piezo elements. [33]. Also ceramics are used as a surface coating [33].

Hazards
Ceramic dust can be dangerous for the lung of humans

Recycling
So far there was nothing found in the literature about the recycling of technical ceramics. But probably the recycling is possible

Reuse of the secondary material
Like the recycling, there was nothing found in the literature. But when the recycling is possible, the reuse also should be possible.

Comment: Further information (different types, use) about ceramics in the automotive industry are given in the appendix A2 Recycling of the materials.
5.5 Textile materials

Properties
The properties are depending on the manufacturing process. So it is not possible to give general information. The main properties are the length of the fibre, the yarn count and the density of the fibre [44].

Different types
Usually the textile materials are separated into synthetic and natural fibre [44].

Use
Fibres are used in seats, for the multilayer folding top of a cabriolet can [33]. Beside this it is also possible to find fibres to strengthen the clutch- and brake lining, for isolation and insulation, for belts, as a filling material in head restraints, as seat cover, to strengthen plastics or in the carcass of tires, the connecting rods, the tank, breaks, and the cardan shaft [44].

Hazards
So far the researches have not carried out any dangers about fibres.

Recycling
The fibre materials are usually blown out in the shredder light fraction, the first sorting step after the shredder.

Reuse of the secondary material
Fibrous materials out of light materials like porous and fibre like the foam from seats or the textile fibre are used in clearing sludge basins for sludge drainage [45].

Comment: Further information (different types, use) about textile materials in the automotive industry are given in the appendix A2 Recycling of the materials.
5.6  Leather

**Definition**
Leather is made out of hide and fells of animals [44].

**Properties**
Leather has a very well optical surface, and high water vapour permeability. That’s why the haptic and feeling are very good. But the material is very expensive and the manufacturing process is difficult. Also the smell can be sometimes a problem [33].

**Different types**
Depending on the animal and the origin part of the leather there are different types [44]. But the use of leather imitates out of polyester and PVC foils are increasing [44].

**Use**
Leather is usually used in the interior in order to design it individually. Because of the high price and the complex process leather lamination is usually only used in higher middleclass and upper-class cars [33].

**Hazards**
So far the research has not carried out any hazards, put in the production of leather there might be used some harmful liquids

**Recycling**
Leather is also blown out in the shredder light fraction after the shredder

**Reuse of the secondary material**
So far research hasn’t carried out any reuse of the secondary material

**Comment:** Further information (different types) about leather in the automotive industry are given in the appendix A2 Recycling of the materials.
5.7 Liquids

Different types
There are different liquids in a car. So for example there are the lubricants with the engine oil, the gearbox oil, the hydraulic oil and the grease. Also there is a fuel which is in the most cases petrol or diesel. A car also has a breaking fluid, and a cooling fluid [46].

Properties
Engine oil is usually a mixture of basic fluids and several additives. The fuels are out of Fuel is usually described by its density and cetane number or octane index. Information more in detail are given in the appendix under A2 Recycling of the materials. The cooling liquid has to be resistant in a huge temperature range (-37 to 109 °C). Breaking fluid has a good viscosity.

Use
Lubricants are necessary for the reliable work of the engine and the gear box. They reduce the friction between movable parts, remove particles and shivers out of the greasing point and sometimes to seal (piston-cylinder in the engine) or to remove/transport heat. The fuel is burned in the internal combustion engine of a car in order to use the delivered energy for driving. The cooling fluid is used as an antifreeze- and corrosion protection in the engine [46]. Brake fluid is used to transmit the braking energy between the main braking cylinder and the breaks of the wheel. It also lubricates the bearings, the valves and the piston [46].

Hazards
The oils and the fuel are hazardous to water. So it has to be collected and transported carefully. Also there have to be arrangements to avoid a burning of the oil [14]. The fuels are flammable, and in a specific concentration and with a spark fuels can explode. Also fuels can pollute the environment and the water

Recycling
The engine oil has to be collected cleaned and refined after the use [14]. Necessary for recycling of the brake fluid is a mono-material collection, a cleaning and a chemical reprocessing [46].

Reuse of the secondary material
Depending on the recycling method the oils can be used as new oils or as heating oil. Otherwise the waste oil is used as reductor in a blast furnace [14]. In Germany 76 % of the whole waste oil was recycled and 24 % was the energetically recovered in 2008 [43]. Because of the pollution old fuel cannot be reused. There is only energetically recovery possible. Braking and cooling fluid can be filtrated, distillate and then usually reused [14].

Comments: Further information (properties, different types, use, recycling, hazards and reuse of the recycled materials) about liquids are given in the appendix A2 Recycling of the materials.
6 Sorting

Sorting (in process technology) means to sort macroscopic solid particles with the use of different physical properties [18]. In order to be able to recycle the materials like it was showed in the previous section (5 Recycling of the materials) a very good separating of all the materials is necessary. As it was already showed there are many different materials in a car and to sort them different sorting steps and techniques are necessary and used. Also the company’s problem (detailed explanation is in the section 9.1 Description of the problem) is a result of the not-existing adequate sorting technique for a specific application.

6.1 Overview of sorting techniques

Table 6.1 shows a general overview of the different methods to sort solid materials. And classifies them according to Schubert [47]

<table>
<thead>
<tr>
<th>Sorting method</th>
<th>Machine</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Density sorting</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Heavy media separation (swim-sink)</td>
<td></td>
<td></td>
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<tr>
<td>1.1 Gravitation</td>
<td>Heavy media separation</td>
<td>Plastics with different densities from metals, alloys of different density</td>
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<tr>
<td></td>
<td>Swim-sink-separator</td>
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<tr>
<td>1.2 Centrifugal force</td>
<td>Sorting-centrifugal</td>
<td>Plastics from metals, Plastics with different densities</td>
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<td></td>
<td>Sorting-cyclone</td>
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<tr>
<td>2 Sedimentation processes</td>
<td></td>
<td>Non-metal-scrap</td>
</tr>
<tr>
<td>3 Herd resort</td>
<td>Shock herd</td>
<td>Plastic from metal, plastic, paper</td>
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<tr>
<td>4 Air separation</td>
<td>Zigzag separator</td>
<td>Cable insulation from copper wire</td>
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<td></td>
<td>Cross-flow separator</td>
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<tr>
<td><strong>Magnet sorting</strong></td>
<td>Drum cobber</td>
<td>Ferromagnetic metals, alloys (iron materials, nickel materials) from metals, plastic, paper</td>
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<tr>
<td></td>
<td>Belt magnetic separator</td>
<td></td>
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<tr>
<td><strong>Eddy current sorting</strong></td>
<td>Eddy-current separator</td>
<td>Aluminium, magnesium from paper, films, plastics, glass, non-magnetic metals</td>
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<tr>
<td><strong>Electro sorting</strong></td>
<td>Electrostatic separator, Corona roller separator</td>
<td>Types of plastic</td>
</tr>
<tr>
<td><strong>Sorting based on mechanical properties</strong></td>
<td>Filter band separator</td>
<td>Films from compact material, packaging, construction waste, bulky waste</td>
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<tr>
<td>Flotation</td>
<td>(pneumatic) flotation cell</td>
<td>De-inking from paper pulp</td>
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<tr>
<td></td>
<td></td>
<td>In future maybe plastics</td>
</tr>
<tr>
<td>Sensor based sorting</td>
<td>NIR-sensor</td>
<td>Plastic materials, glass materials, plastics from metals, PCBs, PVC, paper, wood, construction waste</td>
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<td></td>
<td>Optoelectronic sensor</td>
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<td>Metal detector</td>
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<td></td>
<td>X-ray sensor</td>
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<td></td>
<td>Multi sensorics</td>
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</table>

**Density sorting [14]**

The main density sorting is based on the different densities of solid materials and a liquid with a known density. In order to separate the solid material different options are possible.

- **Swim sink separator**: The solid materials are put in stationary or slow flowing liquid. The solid material with the lower density (than the liquid) swims the one with the higher density sinks. There are different densities possible for the liquid (saline solution, water-alcohol mixture, or heavy liquids) and so different levels of separation.

- **Shock herd**: they have fluted surfaces and are shocked by a powermachine. Because of different inertia the particles of different densities are separated.

- **Air separation**: This is based on the different speeds of particles in a fluid (air or water). So the lighter materials are blown out the heavier materials fall down (Figure 3.8 already showed an integrated air separation in the shredding process)

Figure 6.1 shows the most common density sorting techniques.
Figure 6.1 schematic representations of density sorting methods [21] [14]
**Magnet sorting [14]**

In this sorting process, the magnetic particles are extracted from the non-magnetic ones. Therefore, permanent and electro magnets are used. The best size of the feeding material is 1 - 10 mm (sometimes 100 mm).

**Figure 6.2** schematic representations of magnet sorting methods [21] [14]

**Electro sorting [14]**

Therefore, first an electrical charge of the feeding has to be done. This can be done by polarisation in the electrical field, by tribo-charging (frictional electricity) or in a corona field. The separation is based on different electrical conductivities, and dielectric constants of the particles. Then it is possible to separate the different particles in a high voltage field.

**Figure 6.3** schematic representations electro sorting methods [14]
**Flotation [14]**
Is just used for very small particles within the range of (50 and 300 µm). The particles are put in a suspension and after a blowing in of air in the suspension some particles are adsorbed by the air bubbles. But maybe on time this method can become relevant in the plastic sorting with bigger sizes of the particles in the future.

**Sorting according to different mechanical properties [14]**
There are different mechanical properties used:
- Rebound properties
- Moving properties

Figure 6.4 shows an example of the moving properties.

![Figure 6.4 schematic representation of a sorting method according to mechanical properties [14]](image.png)

**Sensor based sorting**
This is a further development of the sorting by hand. The particles can be identified according to different properties:
- Colour
- Shape
- Fluorescence
- Brightness

The smallest size of the sorting particles depends on the sorting technique and is said between the range of 2 – 10 mm.
In order to realise sensor based sorting six steps are necessary:

- Cleaning of the surface
- Separating of the particles on the band/freefall/conveying trough (no overlapping)
- Accurate identification of the position of the single particles
- Analytical identification of the single particles
- Signal processing and control of the expulsion device
- Material specific release of the single parts by compressed air/mechanical flaps/mechanical rams

Figure 6.5 shows some typical layouts of sensor based sorting machines.

Figure 6.5 schematic representations of sensor based sorting methods [21]
The identification can be done by for example by different methods [21]:

- Optoelectronic
- Spectroscopic
- Electromagnetic

There are several already controlled sensor based sorting techniques. They are showed in the following:

**Metal sorting [48]**

In order to sort metals, the following methods can be used:

- Controlled induction (IND) - *Widely used*
- X-ray
  - Transmission (XRT) - *Widely used*
  - Fluorescence (XRF) - *Widely used*
- Optical emission spectrometry (SEO) - *Widely used*
- Medium infrared thermography (MIR) - *Widely used* (sort plastics too)
- Shape Recognition (FOR) - *Little used*
- Planar magnetic induction tomography (PMIT) - *Starting*

**Plastic sorting [48]**

- medium infrared thermography (MIR) (Widely used) (Figure 6.6)
- nearby infrared spectrometry (NIR) (Widely used)
- colour analysis camera or spectrometer (VIS) (Widely used)

The VIS can also be used for glass sorting. The NIR can also detect wood.

**Figure 6.6** schematic representation of plastic analysed by MIR [49]

**Comment:** The techniques are described more in detail in the appendix A.1.1. Controlled technologies.
Developing techniques [48]

There are also some techniques in the development. And some of them might become interesting in the future:

- Plasma spectroscopy induced laser (LIBS) used for metals, semiconductors, glasses and plastics. (LIBS is a technique of rapid chemical analysis using a short pulse laser to create micro plasma to the surface of the product analysed. The radiation emitted by ionized gas is analysed by optical spectroscopy.) (Figure 6.7)

- Raman spectroscopy (RAM), characterizing the molecular composition and structure of a material. It can especially recognize dark materials.

- Terahertz spectroscopy (THz) can analyse the molecular structure of a product, such as the differentiation of the two isomers.

- Ultrasound (ULT) in development to guide this technology for the detection of dark bodies

- Tracer incorporation in polymers (TRA) can be used for metal and polymers sorting applications.

Figure 6.7 schematic representation of plastic analysed by LIBS [50]

Further information about the developing technologies and notably more about Plasma Spectroscopy Induced Laser (LIBS) stated in this section in the automotive industry are given in the A.1.2 Developing Technologies.
6.2 Techniques which might be able to sort black colored plastics

In general, several of those techniques might be able to separate the black coloured plastic (the problem is explained in the section 9.1 Description of the problem). Maybe using the different densities can be an option, because there are small differences according to the density of different types of plastics. The magnet sorting only can separate metals from non-metals, so this is not usable for plastics. The electro-separation also might be interesting, because there are several electrostatic effects existing in different types of plastic. The mechanical properties are also probably not that interesting because these techniques are usually used to separate films from other types of waste.

Sensor based sorting might be a third interesting method because of the many different available techniques. But the actual controlled techniques cannot be used for sorting plastic when it is black. NIR technique cannot detect any black colour because the infrared waves are not reflected when they interact with black colours surfaces. The same is for colour analysis camera and the MIR (Figure 6.6). But in the last case the research and development are mainly geared towards finding new sorting applications for black coloured plastic and rubber. So in the near future this technique might also become interesting for sorting black coloured plastic.

From the developing technologies of the sensor based sorting maybe TRA, LIBS and RAM might be interesting to solve the problem. But RAM is too expensive at the moment and so only used in laboratories. The others would be efficient, but TRA needs to work with polymers which are made with tracers for this sorting technology. But plastics which are recycled at the moment were produced several years ago. They don’t contain theses tracers. Maybe in future when all the plastics contain this kind of tracers this technology could work. The radiation which is created during the LIBS does not depend on the colour of the subject. This will only depend on the intrinsic properties of the material. LIBS also provides very detailed information about the nature of the material and its composition. Then, LIBS (Figure 6.7) seems very interesting for this application because besides being able to identify the different families of plastics, it is able to quantify the additives, which were added during manufacture. But this technology is still in development. Although it is known for nearly 30 years, the LIBS technology was until recently confined to laboratory use due to its complexity and its cost. But areas for improvement relate mainly to the reduction of time analyzing and processing information, increasing measurement throughput, improving the reliability of measurements, cost reduction. So this technology probably won’t be ready for industrially use in the (near) future.

In order to sum this section up, there are some sorting techniques which are kept in mind, which might be possible to sort the black plastics. This are: density sorting, electro sorting and Sensor based sorting.
7 Materials which cannot be recycled

All the sections so far handle the end life vehicle treatment and showed a lot of different reuse and recycling possibilities. But as Figure 3.1 already showed, there is still a share of materials left which cannot be recycled at the moment. Usually the reason is that there is no recycling method existing so far. Also sometimes there would be a method to recycle, but this way too expensive. So all these materials are usually energetically recovered (burned) or only landfilled. Figure 7.1 shows therefore the treatment of different materials more in detail and which materials are the most difficult ones to recycle and to reuse.

![Figure 7.1 Material-shares of an automobile in 2013 (according to mass) and the end of life treatment of the materials [5]](image)

The hugest part of the not recyclable materials in Figure 7.1 is the shredder light fraction. This is because they have a huge share of the whole mass of the materials. This shredder light fraction is the, according to the weight, the light residue product of the shredding. The main materials of this are: plastics, elastomers, tires and glass and ceramics. In the appendix A2 Recycling of the materials a whole table is given with the most common materials and their shares. The main share of these materials are the plastics according to the table in the appendix [51] the shredder light fraction contains between a plastic share between 35 and 70 %. Those are difficult recyclable materials, because (as it was already showed in the section 5 Recycling of the materials) it is not possible to recycle thermostats and
elastomers because of their chemical composition. As already described these materials are only used as filling materials, for burning or landfilling [14].

Also the recycling of thermoplastics can be impossible at the moment. So for example when they are black coloured. Then it is not possible to distinguish between the different types because actual sorting. Because sorting methods usually work with machine vision in the infrared area and the infrared waves are not reflected by the black coloured plastic. So this material cannot be sorted and recycled at the moment and is also mentioned in Figure 7.1 as landfilling or energetically recovered material.
8 Benchmark

In order to calculate the market volume of the black coloured plastic of a car, first a view on the general car and recycling market (of a car) is necessary. Then, it is possible to calculate the mass of black coloured plastic in a car and finally the market volume. Also there will be an examination of the main competitors of PICVISA.

8.1 National vehicle market

In 2015 the Federal Environment Agency in Germany published an official document about the end of life vehicle recycling in the year 2013 in Germany. One section of this report also treats the national vehicle market:

**Germany (in 2013) [5]:**
- Number of new registered passenger cars: 2,952,431
- Number of registered passenger cars (in total): 43,431,124
- Average age of all registered passenger cars: 8.7 years.
- Average age of end of life vehicles: ≈ 14 – 15 years
- Number of final deregistered passenger cars: ≈ 3,300,000
  - Number of issued certificates of destruction: 500,322
  - Number of registered exports: 1,570,000
  - Number of others: 1,180,000
  (Others: not registered exports, vehicle theft, use on non-public area)

8.2 End of Live Vehicle treatment

This 500,322 really destructed end of life passenger vehicles in Germany in 2013 (8.1 National vehicle market) are dismantled, like it was already showed in the section 3 Dismantling a Car. The following section has a detailed look on the treatments and material shares of reuse and recycling of the material. The different ways of reuse and recycling was already showed in the in the sections 4 Reuse of the Parts and 5 Recycling of the materials.

**Germany (in 2013)**
The before told number of 500,322 destructed end of life vehicles produce a waste of in total 513,106 t [5]. The cars are following the steps which were described in the previous sections. The shares of the material treatment are [5]:

- Material share of reuse: 5,708 t (1.1 %)
- Material share of recycling: 428,721 t (84.2 %)
• Material share of energetically recovery 66 796 t (13.1 %)
• Material share of landfill 7 882 t (1,5 %)

In order to dismantle a car like it was described in the section 3 Dismantling a Car in Germany there are: 1 331 dismantling plants (1 196 of them also treat harmful substances) [52]. In this dismantling plants there are 29 324 t of parts removed [5]. The treatment of these parts is [5]:

• Material share of reuse: 5 843 t (19,9 %)
• Material share of recycling 15 220 t (51,9 %)
• Material share of energetically recovery 6 956 t (23,7 %)
• Material share of landfill 1 305 t (4,5 %)

As it was described in the section 3.3 Shredder the remaining materials are shredded. Therefore in Germany 52 shredding plants for cars are existing [52]. The amount of shredded car materials in Germany is 483 782 t [5]. The treatment of the shredded material is [5]:

• Recycling 417 259 t (86,2 %)
• Energetically recovery 59 925 t (12,4 %)
• Landfill 6 598 t (1,4 %)

Just to have an overview of car-waste compared to all the other types of waste, in Germany are 733 shredder plants/waste cutter which treat all types of waste. Those shredders have an input of 14 596 700 t [52].

The next step in the recycling route of a car is the sorting. This was explained in the section 6 Sorting. But there were no specific numbers for cars found. It is quite likely that after the shredding most of the car waste is mixed with waste from other origins. That’s why the following numbers are so extraordinary big. In Germany there are 1 094 sorting plants (for all types of waste existing). These plants have an input of 24 831 600 t. A small share of these materials are coming from the car waste [52].

The used sorting machines in those plants are from produced from different manufactures. In the following there is a benchmark analysis of the main-competitors of PICVISA. In order to see, if there are any solutions to sort black coloured plastic. And this analysis shows that only one company (RTT Steinert) has developed a new product which is able to sort black coloured plastics with machine vision. But unfortunately they don’t make detailed descriptions how their technique is working.
# 8.3 Manufactures of (sensor based) sorting machines

<table>
<thead>
<tr>
<th>Company</th>
<th>binder+co</th>
<th>MSS</th>
<th>REDWAVE</th>
<th>RTT STEINERT</th>
<th>sesotec (former s+s)</th>
<th>TOMRA (former titech)</th>
<th>PELLENC ST</th>
<th>PICVISA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
<td>Austria</td>
<td>USA</td>
<td>Austria</td>
<td>Germany</td>
<td>Germany</td>
<td>Norway</td>
<td>France</td>
<td>Spain</td>
</tr>
<tr>
<td>Employees</td>
<td>376 (2015)</td>
<td>760 (whole CPG group)</td>
<td>500 (whole BT-group)</td>
<td>300</td>
<td>25 developing NIR</td>
<td>500</td>
<td>201-1 000</td>
<td>1 000 (group)</td>
</tr>
<tr>
<td>Business fields</td>
<td>Comminuting</td>
<td>Screening</td>
<td>Drying</td>
<td>Sorting</td>
<td>Wet-processing</td>
<td>Packaging</td>
<td>Sorting</td>
<td>Mining</td>
</tr>
<tr>
<td>Used sorting techniques for plastic (and glass)</td>
<td>Sensor based sorting:</td>
<td>- contaminations - colours - special glasses (heat resistant/lead glass) - machines can be equipped with a non-ferrous detection Also offering:</td>
<td>- Systems for material conditioning - Turnkey plants</td>
<td>Sensor based sorting:</td>
<td>NIR sorting</td>
<td>Infrared:</td>
<td>Colour Sorting:</td>
<td>X-Ray Fluorescence Technique:</td>
</tr>
</tbody>
</table>

**Sources:** [53] [54] [55] [56] [57] [58] [59] [60] [61] [62]
8.4 Market volume of black coloured plastic

With numbers of 8.1 National vehicle market and 8.2 End of Live Vehicle treatment it is now possible to estimate the amount of black coloured plastic in a car, the profit which it might gain and the total market of black coloured plastics in all the end of life (passenger) vehicles per year.

The share of plastic materials was already told in Figure 5.1. Also the shredder light fraction contains, according to [51], a plastic share is between 35 and 70 %. With assumption (52,5 %) and with the numbers out of [5] there are round about 75 000 t of all the plastic types in all the really recycled (destructed) end of life vehicles in Germany (146 kg/car).

68 000 t of this plastics are actual reused (1 500 t) and recycled (66 500 t) [5]. This means there are 7 000 t (16,6 kg/car) of all different plastics types of a car left (in Germany, 2013) which are not recycled yet. Figure 0.6 [39] in the appendix says on the other hand, that about 80 % of all the plastics in a car are thermoplastics. The thermoplastics are the plastic materials which are usually recyclable (5.2 Plastic) and would gain the most profit (13,4 kg/car). The assumption is now that the plastics which are (at the moment) not-recyclable have the same share of thermoplastics then a normal car. But probably only ¾ of these plastics are black and might be sorted with the new technique (10 kg/car).

The price of recycled-plastic was on the 13th of May in 2016 (depending on the type and country) usually between 0,80 - 2 €/kg [63]. This means for the thermoplastics of a car a gain of 8 – 20 €/car. In Germany with the 500 322 vehicles and the calculated value of black coloured plastic in a car, would be a market of 4 - 10 M €.

In order to calculate now the whole market in the EU, the relevant market for PICVISA, this value is multiplied with the number of really destructed cars. With the number of 6 280 000 end of life vehicles in all the member states of the EU in 2012 [6] the value for this countries can be calculated. The assumption therefore is that the cars in the EU have (according to the used materials) the same share of plastics than in Germany.

Using the same aforementioned assumptions, with use of this data and the used assumptions, there would be a market of 50,2 – 125,6 M € for the black coloured plastic materials of the end of life vehicles. This was estimate for the 28 countries in the European Union.

Comment: This source [6] doesn’t tell anything about the treatment of the end of life vehicles, but it seems to be the number of really destructed cars, because the number for Germany is accords with the number of destructed cars in Germany in 2012 in [64]).
9 Separation of the black coloured plastic

In this section there is first a description of the problem. After that there is going to be a brainstorming, to find several ideas (without being focused on the feasibility) and also the criteria [65] to assess the ideas. Then there will be a decision matrix based on these criteria. This will help to find the best solution. Finally, the chosen solution is going to be described in detail.

9.1 Description of the problem

The whole description of the recycling process of an end of life vehicle leads to several parts and materials which cannot be recycled at the moment (7 Materials which cannot be recycled). Figure 3.1 already showed the whole recycling route of an end of life vehicle and the location of the specific problem of the company in the red circle on this figure. The problem is to separate the plastic waste when it is black, because the actual machine vision methods are not working with this type of material. These machines are using infrared (described in the section 6 Sorting) and those waves are not reflected by black colour. Furthermore, it is not possible to separate the black coloured plastic waste with infrared [66]. The only way to handle with these materials at the moment is to landfill them or do an energetically recovery (burning). With finding a solution hopefully there will be no need to landfill anymore.

9.2 Brainstorming

9.2.1 Find ideas to sort black coloured plastic

The first brainstorming has carried out some ideas to solve this problem (Comment: At the moment it is not clear, if these solutions are feasible):

- Spray an acid on the plastic waste to create a pattern (which is not black) there. Then it might be possible to distinguish them by cameras. Then a separation also would be possible
- Use a hot stick to deform the plastic parts. Thermoplastics are probably going to react in a different way. Then there might be a separation possible
- Solve the (solvable) plastics. Thermoplastics are usually solvable and would be solved. Then they would be separated. And after this the solvent would be boiled and the plastic might remain
- Use electrostatic properties-> Load up the plastics with electricity. Then some plastic types will be loaded positive, others negative. And then there would be a separation between positive and negative parts
• Use different densities to sort different types of plastics and create therefore a sorting application. So the material with the higher density might be separated from the material with the lower density.

In the following three of those solutions will be explained more in detail. The hot stick method and the solving solution are not explained in the following because it is expected, that these methods probably will destroy the plastic.

The acid concept

![Figure 9.1 Sketch of the acid concept: Using an acid to create a pattern](image)

![Figure 9.2 First model of the using acid concept](image)
The density sorting concept
This sorting was already explained in the section 6.1 Overview of sorting techniques. Figure 6.1 showed the idea of this method.

The density sorting is based on the different densities of solid materials. This method would use small differences in of the densities of different plastic types. For example, a swim-sink separation with a liquid of a known density is used. There the particles with a higher density would sink and one with the lower density would swim. So a separation might be possible.

The electrostatic sorting concept
This sorting was already explained in the section 6.1 Overview of sorting techniques. Figure 6.3 gave already examples for electro and electrostatic sorting methods.

In this sorting method different dielectric constants of the different plastic materials are used. In the sorting machine the particles are first charged electrostatically. Some of the particles are (according to the dielectric constants) charged positive, others negative. Then it would be possible to separate these different charged particles in a high voltage field. Figure 9.3 shows the separation in the high voltage field.

![Positive Charges](image)

*Figure 9.3 Electrostatic concept*
9.2.2 Find the criteria to assess the ideas to sort the black coloured plastic

In order assess and rank the ideas to sort black coloured plastic which were found in the previous section several criteria need to be found. This happens in a meeting with the company and with studies of the literature [65]. The criteria are:

- Low costs (of the development, production and use)
- The simplicity of production
- The feasibility of the technique
- If the technique can be combined with machine vision
- The effects on the environment (which should be as low as possible)
- The effect on the plastic which is sorted (this also should be low, because a destroyed plastic cannot be sold and gain any profit)
- A short sorting process
- An accurate sorting process
- The time between a service at the sorting machine (when a check-up of the parts change of parts of the sorting machine is necessary)
9.3 Choice of the proper method to separate black coloured plastic

Those found criteria are now ranked in an analytical hierarchy process (AHP), where the criteria compared pairs according their importance, in order to give them weight factors for the final decision matrix. Figure 9.4 shows the final result of this process and the arithmetic average (on the right) will be used as the weight factor in the following decision matrix. The detailed description of how to do an AHP and the rankings are given in the appendix A.3 Choice of the proper solution to sort black coloured plastic.

![Figure 9.4 Result of the Analytical hierarchy process (AHP)](image)

Finally, all the solutions are ranked according the single criteria (with the weight factors) and the solution with the highest value is the best solution according to the chosen criteria in a decision matrix. The grades are based on the estimations by the team and the company. Figure 9.5 shows the final result of the decision matrix. The method to do this and the single ranks are also explained in the appendix A.3 Choice of the proper solution to sort black coloured plastic.

![Figure 9.5 Decision matrix](image)

Figure 9.5 shows, the electrostatic sorting method has the highest value. This is the most proper solution according to the criteria. That’s why the focus in the following is on this solution.
9.4 The chosen solution: electrostatic separation

9.4.1 Method

As already told in the section 6.1 Overview of sorting techniques the electrostatic separation can be used in order to separate [67]:

- A mixture of electric conductors and non-conductors (metals and plastic)
- A mixture of plastics

For separating the plastics, the method is based on different charging of the plastics when they are put in contact to each other then it is possible to separate the plastics in a high voltage electric field. Therefore, the plastics need to have different electric dielectric constants [67].

This principle has several steps:

Create electric charging on the material

The first step is to create an electric charging on the plastic. This can be done by three methods [14]:

- Charging by friction of the particles when they are put in contact (tribo-charging)
- Polarisation in the electric field
- Charging in a corona field.

But as Table 6.1 already showed, the corona field and the polarisation can only be used for sorting conductors and non-conductors. In order to sort plastic so only the tribo-charging is left.

Figure 9.6 shows the method of the tribo-charging. There is a contact between two different types of plastic. This creates an electron-transfer which leads to different electric charges on the plastic materials.

![Figure 9.6 Schematic representation of the tribo-electric charging of plastics [67]](image-url)
The charging itself depends on the tribo-electric charging row. Table 9.1 shows a row for several types of plastic. With this row it can be predicted which material will be charged positive and which one negative.

**Table 9.1** Tribo-electric charging-row [68] [69]

<table>
<thead>
<tr>
<th>Charging tendency</th>
<th>Plastic type</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>+++</td>
<td>Polyethylene imine</td>
<td>PEI</td>
</tr>
<tr>
<td>++</td>
<td>Polyethylene oxide</td>
<td>PEO</td>
</tr>
<tr>
<td>+</td>
<td>Polyurethane</td>
<td>PUR</td>
</tr>
<tr>
<td></td>
<td>Polymethyl methacrylate</td>
<td>PMMA</td>
</tr>
<tr>
<td></td>
<td>Polycarbonate</td>
<td>PC</td>
</tr>
<tr>
<td></td>
<td>Cellulose acetate</td>
<td>CA</td>
</tr>
<tr>
<td></td>
<td>Polyamide</td>
<td>PA</td>
</tr>
<tr>
<td></td>
<td>Polymacrylnitrite</td>
<td>PAN</td>
</tr>
<tr>
<td></td>
<td>Polystyrene</td>
<td>PS</td>
</tr>
<tr>
<td></td>
<td>Polyethylene</td>
<td>PE</td>
</tr>
<tr>
<td></td>
<td>Polypropylene</td>
<td>PP</td>
</tr>
<tr>
<td></td>
<td>Polyethylene terephthalate</td>
<td>PET</td>
</tr>
<tr>
<td></td>
<td>Chlorinated rubber</td>
<td>RUC</td>
</tr>
<tr>
<td>-</td>
<td>Polyvinylidene chloride</td>
<td>PVDC</td>
</tr>
<tr>
<td>--</td>
<td>Polyvinyl chloride</td>
<td>PVC</td>
</tr>
<tr>
<td>---</td>
<td>Polytetrafluoroethylene (Teflon)</td>
<td>PTFE</td>
</tr>
</tbody>
</table>

The friction can be created by an intensive particle-particle contact or particle-wand contact [67]. Therefore, a mixing drum or a fluidised bed can be used [14]. Also some other possibilities are showed in Figure 9.7.

This charging is creating a Coulomb force in the particles. The literature speaks of a Force between 1 – 7 nC/g plastic. The amount depends on the charging method in step 1 and also on the size of the particles. The fluidised bed is able to create the highest charging of 7 nC/g. Also smaller particles usually can be charged with a higher value [70].
Separation of the black coloured plastic

Separating in a high voltage field

Those different charged plastic types can be now separated during the second step in a high voltage field. The literature [70] speaks of a field 60 kV and 6 mA. Figure 9.8 shows therefore the schematic diagram. So the negative particles are pulled by the positive electrode, the positive materials from the negative one. During the separation there is a coulomb force, the gravity force and maybe a centrifugal force (because of the deviation force) on the particles [67].

Figure 9.7 schematic representations of tribo charging [70]
9.4.2 Requirements for the electrostatic sorting

In order to have a well working sorting and a high accuracy several points need to be followed [67]:

- Clean Material (No dust, dirt, oil)
- Dry material
- Total shredded (separated) material
- Size of the sorting material smaller than 10 mm
- Material with different dielectric constants

9.4.3 Possible separation

The literature [14] already stated, that it is possible to sort these types of plastics:

- HDPE/PP
- PET/PVC
- PVC/Rubber
- PP/PS
- ABS/PMMA
- PVC/PE
- Plastics/very fine metal particles
9.4.4 Parts of the sorting machine

Charging part
For the charging the plastic which needs to be sorted a fluidised bed (Figure 9.8) seemed the best solution.

Sorting pipe
The inner surface of the sorting pipe needs to be out of a conductive material, because in this the high voltage electric field separates the plastic. But on the outside there should be a non-conductive material, because otherwise it would be quite dangerous for the workers which might get in touch to the sorting machine during its use. So the suggestion would be to have a copper surface inside the pipe. Then there should be a layer of steel which is giving the pipe its stability. According to the costs this is much cheaper than copper. And on the outside, there should be a plastic which has very good isolating properties (PVC or IIR). The size of the pipe is depending on the mass of material which needs to be sorted in a specific time. Also if a huge diameter is required, there should be tests first, if a sorting in a huge pipe is possible.

Collecting boxes
The boxes where the sorted material is collected should be made out of plastic, or a specific cotton. The size should be big enough, because otherwise those sacks/boxes need to be changed quite often and the machine has very often brake times.

For the exact material and the size also the companies which are buying the sorted materials should be asked. They have probably already specific standards so it is easier to use them and the plastic company can continue their work like before.

High voltage field
In order to create the high voltage field a generator needs to create this high voltage field of 60 kV and a current of 6 mA. Electrodes which are integrated in the pipe should create there the electric field to the pipe. The material for the conductive parts should be, because of the good conductive properties, copper. For that reason, these parts need an isolation out of IIR or PVC in order to protect the working people.

Figure 9.9 and Figure 9.10 are showing first idea of a electrostatic sorting machine. There you can see the fluidised bed (1), where the plastics are put in and the particles are charged like it was described in 9.4.1 Method. Then they fall in the sorting pipe (2), where they are sorted during a free fall because of the high voltage field. The separated particles are collected in two different boxes (3).
Figure 9.9 First idea of an electrostatic sorting machine (sideview)

Figure 9.10 First idea of an electrostatic sorting machine (isometric view)
9.4.5 Sorting several plastic types

The idea which was described so far is in this one step just possible to sort the plastics in a positive and a negative charged part. So after this first step there is just a half of positive charged plastic particles and one half of negative charged particles. This is already a first separation and for a mixture of only two different plastic types.

But when there are more different types of plastic in the heterogeneous waste-mixture, this one step is not enough. The idea is now to separate these first sorted materials in a second sorting division again, which has the same layout then the first machine. Because of the tribo-electric charging row (Table 9.1) it should be possible to sort the plastics again to separate further plastics.

This step needs to be done as often until all the materials are separated. The literature listing 11 often used types of plastics in a car [38] and [40]. These materials present 15 different modules and it would be possible to sort 16 types of plastic.
10 Outlook

10.1 Future work

The next steps would be to do a detailed calculation of the solution and then to build a small prototype which should spotlight, that this technique is feasible and it is possible to sort these types of plastic. When this is successful a detailed construction of all the parts of the machine with a detailed dimensioning and defining the exact materials would be the next step. This was, because of the extraordinary huge research part, not possible to do during this project. But at least some guidelines are now already given. When this is done a first prototype can be built. With this it is possible to check if the solution is really working like estimated and if the amount of sorting material can be sorted in reality. Furthermore, some conclusions can be made for the production while building the prototype. If this is successful, there can be thoughts how to continue with a production.

Also the sorting machine likely needs some pre-treatment modules. But this is depending on the type of waste. So if there is a wish to sort really polluted (oil, dust, other materials) waste there would be a need for some pre-treatments. So for example, a shredding section to cut the waste down and to separate the connections, a magnet sorting (which is already existing in PICVISA) to extract metals and, cleaning section to remove the pollution (oil, dust) and a drying section are maybe needed.

A when the black coloured plastic sorting machine is finished another goal might be to combine it with the already existing machine vision machines of PICVISA. So first in the machine vision machine the coloured plastics are sorted out and only the black ones are remaining. These materials fall one level down into the electrostatic sorting machine. With this PICVISA would be able to offer a full sorting plastic machine. Figure 10.1 shows therefore a first idea. There are the plastics first sorted by a machine vision sorting. There the coloured plastics are blown out into the blue box. Where they are already sorted. The black coloured plastics are not detected and not blown out they remain on the conveyor and fell into the electrostatic sorting machine.
This recycling method is not restricted for only black coloured plastics. It would also be possible to sort other colours. So when the technique is getting cheaper it also might replace already established techniques because of some reasons like the cost, the accuracy or the speed of sorting. So there might be an even higher market potential for this technique in the future.

Also the market is not only restricted on car-waste-plastic. It is also possible to sort plastics of other origins (other waste plastic, or even in the production of plastic). So the market might increase for these types of machines.

(Figure 10.1 schematic representations of the combination with a PICVISA machine)
10.2 Recycling of vehicles in the future

It is always hard to have a look in the future and try to estimate its developments. But probably there are several trends in the present which are continuing and likely be some of the biggest drivers in the future. So in the following there are forecasts tried for the vehicle market, because this market influences the amount of material which needs to be recycled, the future cars, because their composition influences the required sorting techniques and also the laws because they are the guidelines for the end of life vehicle treatment.

Vehicle market
The car market in Europe, which is one of the main origins of the waste materials for PICVISA, is more or the less saturated. So likely there won’t be more cars in this market. Maybe the number of cars might decrease on the other hand a little bit in Europe because of new alternative offers like for example car sharing or better public transport systems in the urban areas. But at the moment there is no successor-technology of car itself conceivable, so in the foreseeable time there always will be cars on the street and those cars will get old and will need an adequate end of life treatment. For these reasons the market of end of life vehicles probably won’t disappear.

Vehicles
There are for example plans (which are already starting tried to realise) for a better marking of the parts in a car during the manufacturing process. This should make the recycling simpler because the identification of the material is easily possible. Also there are intentions to separate different materials, which are not or only difficult to separate in the later recycling, already in the construction. This also might reduce the effort in the sorting in the future a little bit. But on the other hand there is often a try to use new innovative materials in car. These materials might require a more intensive sorting. There is also a tendency to use more electric engines in the car, and this makes (at the moment) the use of some dangerous materials (for the batteries) necessary. So this will also be a very important point in the future end of life vehicle treatment. So there are opposing trends but probably sorting will still be an important part of recycling.

Laws
In the future the recycling laws probably will increase even more and will require even higher recycling rates of vehicles and also other parts of the trash. That’s why the importance of the sorting likely won’t decrease. In all likelihood it will increase.
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<td>Figure 0.7</td>
<td>Place of the plastic application in a car [40]</td>
<td>XLI</td>
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<td>Place of the plastic application in a car [14]</td>
<td>XLIII</td>
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<td>Result of the Analytical hierarchy process (AHP)</td>
<td>LXV</td>
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A Appendixes
A.1 Sorting [48]

A.1.1. Controlled technologies

1: X-ray transmission (XRT)
- Uses the principle of fluoroscopy heavy metals (detect the material at the atomic level)
- Suitable for the detection of metals
- Can also recognize a material whose molecule contains specific atoms (e.g. bromine atoms, for the detection of flame retardants).
- Does not detect bottles filled with water and does not differentiate between different molecules of brominated additives.
- Used in laboratory, portable and continuously.

2: X-ray fluorescence (XRF)
- Uses the principle of sending X-rays on the waste to be analysed.
- Excites the atoms, which in turn emits radiation X "secondary" then this spectrum is analysed by a spectrometer.
- Is used mainly for the fine analysis of the composition of metal alloys and for the sorting of alloys containing metals with different contents.
- Allows for quantification of the total mass of each metal content (lead, mercury, cadmium, chromium VI).
- Can also recognize and measure other heavy atoms such as bromine.
- Is usable in laboratory, portable and continuously.

3: Induction "controlled" (IND)
- Uses the principle of induction sorting is to create a magnetic field with coils, in which is going to sort waste.
- .9% purity on plastics and refined copper.
- Is used on systems continuously.

3a: The planar magnetic induction tomography (PMITs) 3 is a variant of the controlled induction:
- Allows to recognize and sort ferrous metals (including steel) and nonferrous small calibre continuously.
- Fills the gap related to the resolution of 25 to 50 mm of traditional inductive sensors.
- Can also be applied to the extraction of metals from shredder residue (in combination with an eddy current system) in the RDF in wood waste and used glass.

4: Optical Emission Spectrometry (SEO)
- Meets the needs of the metallurgical industry (control, production, inspection of raw materials, waste sorting).

- Is based on the quantitative measurement of the optical emission spectrum from atoms or molecules stimulated to high levels of energy, to determine the concentration of the analyse.

- Constitutes the reference technique for elemental analysis (by weight composition) of solid metal samples, both alloys, of steel or products containing unwanted non-metallic inclusions.

- Is frequently used for iron base / steel, aluminium, copper, nickel, zinc and lead.

- Is a destructive method. It is used in laboratory and portable.

5: Near Infrared Spectroscopy or Near infra-red (NIR)

- Is based on the analysis of a reflection spectrum whose signature reveals the structure of molecules.

- NIR is widely used to sort an increasing number of materials, including:
  - Polymers between them
  - Fibrous (paper, cotton, textile)
  - Inert
  - PVC
  - Others chlorinated

- Is commonly used in combination with an eddy current separator to achieve a complete sort of blends multi materials (eg packaging).

- Will "see" metals, brominated flame retardants, dark, black objects (especially parts containing carbon black) liquid (full bottles) and waste in the form of ribbons.

- Is studied to expand its scope in sorting new materials (plasters.).

- Can be used in laboratory, portable and continuously.

6: Medium Infrared Thermography (MIR)

- Uses the principle of analysing the difference of temperature of an object before and after illumination by a source MIR, then the sensor detects heat dissipation depending on the material and thickness of the material.

- Is recent according to industrial terms.

- Provides a sorting material in response paper and board according to their weight. The MIR also recognizes the "non paper" as the same black plastic and ELA.

- Is in progress to be able in the near future to identify new sorting applications (plastic and black rubber, plastics containing brominated flame retardants), the spectrometer miniaturization and reduction of the measurement time.
7: Colour Analysis Camera or Spectrometry (VIS)

- Mains two different sensor technologies:
  - Colour camera system coupled to a prism, which takes measurements on primary colours (red, green and blue) according to their intensity.
  - The spectrometer, which analyses the entire visible spectrum and allows get more selective and more accurate results than the colour camera.
- Is well suited to sorting plastics by colour (eg PET), cartons, paper and glass.
- Is improving about signal processing, to better discriminate the materials according to their colour.
- Can be used in laboratory, portable and continuously.
- Is widely used in the industry.
- Is a proven solution; the number of applications is steadily increasing.
- Is used for sorting PET crystal bottles for recycling "bottle to bottle" and sorting of metals and polymers in the milled electronic cards.
- Could be combined as required (NIR + induction, NIR XRT + ...).

8: Pattern Recognition (FOR)

- Has been the subject of recent developments, such as recognition of son and cables in a mixture of metal objects and sorting the heads of cartridges silicone mastic (the latter being a poison for recycling HDPE).
- Is made and is increasing about sorting rates, on the treatment of very high data volumes and stabilization of shape criteria.

Table 0.1 Table about the overview of controlled technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Level of development</th>
<th>Detection</th>
<th>Continues portable laboratory (C,P,L)</th>
<th>key developments (R&amp;D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-ray transmission (XRT)</td>
<td>Widely used</td>
<td>Sensing the material at an atomic level. Well suited to metal detecting. Recognizes certain specific atoms such as bromine (detection of flame retardants).</td>
<td>L/P/C</td>
<td>Detectors &quot;multi energy&quot; to improve identification of metals having similar densities.</td>
</tr>
<tr>
<td>Method</td>
<td>Application</td>
<td>L/P/C</td>
<td>Notes</td>
<td></td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>------------------------</td>
<td>----------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>X-ray fluorescence (XRF)</td>
<td>often used to analyze the elemental atomic composition and mass concentration of each element.</td>
<td>L/P/C</td>
<td>Sorting Efficiency and Expansion to new applications.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Detailed analysis of the composition of metal alloys and sorting of alloys containing metals with different contents.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>controlled induction (IND)</td>
<td>Widely used to distinguish metals from other materials.</td>
<td>C</td>
<td>Sorting of ferrous and non-ferrous (cascading sorting machines).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>More selective and more flexible than Eddy Current sorting technology.</td>
<td></td>
<td>Sort of small metal parts and fine &quot;non-ferrous&quot; in packaging from the collection in the compost shredder residues of WEEE and ELV.</td>
<td></td>
</tr>
<tr>
<td>planar magnetic induction tomography (PMIT)</td>
<td>Starting to sort ferrous metal conductors (including stainless steel) and non-ferrous.</td>
<td>C</td>
<td>Cleeped.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Suitable for sorting of small pieces of metal in the bottom ash.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extraction of metals from shredder residues (in combination with an eddy current system)</td>
<td></td>
<td>In the RDF in wood waste and used glass.</td>
<td></td>
</tr>
</tbody>
</table>
| **optical emission spectrometry (SEO) (Wide used)** | **Elemental analysis (mass composition) of solid metallic samples (alloys, steels, products containing inclusions not undesirable metal).** | **L/P** | • Low levels Analysis  
• Improved accuracy and detection limits. |
| **Nearby infrared spectrometry (NIR) (Wide used)** | **Recognizes materials (polymers, them, paper, wood)** | **L/P/C** | Recognition black products - Extension of the scope to sort of new material. |
| **medium infrared thermography (MIR) (Used quite often)** | **Sorting paper and board according to their weight.**  
**Sort of "non paper" as plastics, metals and ELA.** | **P/C** | • New sorting applications (Plastic and black plastic rubbers containing retardants brominated flame)  
Miniaturisation  
• Reduction of measurement time |
| **colour analysis camera or spectrometer (VIS) (Wide used)** | **Sorting plastics by colour (eg PET), cartons, paper, glass, some metals.** | **L/P/C** | Improved signal processing. |
| **Shape Recognition (FOR) (little used)** | **Recognition of son and cables in a mixture of metal objects, silicone cartridges etc.** | **P/C** | -Increase Sorting rates  
-Ability And data processing speed  
-Stabilisation Shape criteria. |
A.1.2 Developing Technologies

11: Plasma Spectroscopy Induced by Laser (LIBS)

- Rapid chemical analysis
- using a short pulse laser
- create a micro plasma on the surface.
- Radiation emitted ionized gas
- Analysed by optical spectroscopy. Provides very detailed information (not only on the nature of the material, also on its composition)
- Confined to laboratory use due to its complexity and cost. It was used as a complementary technology in XRF, the NIR and Raman.
- Is operable to metals, semiconductors, glasses, biological tissue, insulation material, plastic. For example, to bronze waste, it can determine the purity of the piece studied.
- Had a detection limit for heavy metals is of the order of ppm.
- Is able to recognize the light atoms (unlike XRT), recognize brominated derivatives (unlike NIR) and differentiate different types of brominated additives (unlike XRT).
- Also has advantages over X-ray fluorescence, which shows some limitations on lighter elements and from the spark spectrometry (SEO) which can cause fouling of the electrodes problems on some materials.
- Had a controversial ability to perform an analysis of the interior of the product being sorted (stratigraphic analysis of a material). For some experts, the LIBS is primarily a surface sensor.
- Areas for improvement relate mainly to the reduction of time analysing and processing information, increasing measurement throughput, improving the reliability of measurements, reduction of costs (especially sensors) and miniaturization. The sorting line is also one of many R & D objectives.

12: Tracers Incorporation into the polymers (TRA)

- Needs of a pré-incorporation of small amounts of "tracers" in manufactured polymers, which are easily detectable by sorting systems once the product has become waste.
- Mains several option because technological options for the detection and sorting of waste containing tracers are relatively open, either in the choice of process type (magnetic, X-ray fluorescence, UV fluorescence, IR, neutron activation magnet) or at the choice tracer (iron and its oxides, rare earths, coumarone derivatives ....).
- Is used for metal sorting applications in biology and medicine. It is not used industrially for sorting waste.
R & D aimed at improving the speed and quality sorting of polymers contained in ELVs using a signature with tracers detected by sorting spectrometry (XRF or UV) and extend this sort of technology to other polymeric materials and other industries such as WEEE and packaging.

May be useful for sorting of waste ground, the marking of parts no longer recognizable.

Will not emerge before 20 or 30 years, while others believe the emergence of industrial horizon a decade. In addition, account must be taken of the service life

13: Spectroscopy Terahertz (THz)

- Is a fine detection technique based on the emission of a wave whose frequency is between 0.1 and 10 THz.
- Is Non-destructive and can analyse the molecular structure of a product, either in reflection or in transmission. The characterization of the products can reach a very fine level, such as the differentiation of the two isomers (molecular structure).
- Is already used and have already some medical and security application.
- Is used in certain airports for the detection of dangerous products. No leads have been identified in the area of waste sorting.
- Was unexplored until recently because of the absence of sources and detectors. R & D focuses on the stability and accuracy of emission sources (the quantum cascade lasers often require extremely low temperatures and do not provide good spectral purity).
- Had an horizon of development for waste sorting applications seems to be the medium / long term.

14: Ultrasonic (ULT)

- Is used industrially for sorting in the food industry but not for sorting waste.
- Will probably in the near future be able to detect dark bodies and for the production of high purity polyolefin from waste.

15: Raman Spectroscopy (RAM)

- Is a non-destructive technique for characterizing the molecular composition and structure of a material.
- Is limited to laboratory applications
- Could open up avenues for recognition dark materials and multilayer bottles.
- Had an usage cost still being very high.
- Had no vision of continuous waste sorting application yet.
<table>
<thead>
<tr>
<th>Technology</th>
<th>Horizon Development</th>
<th>Detection</th>
<th>Continues portable laboratory (C,P,L)</th>
<th>key developments (R&amp;D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>plasma spectroscopy induced laser (LIBS)</td>
<td>Short / medium term</td>
<td>Nature of material and composition: metals, semiconductors, glasses, organic fabrics, insulation materials, plastics, etc. May perform an analysis of the interior of the product being sorted (stratigraphic analysis of a material) but this is controversial.</td>
<td>L/P</td>
<td>• Reduced analysis time and information processing.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Increased measurement speeds,</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>• Improved reliability measures,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Reduced cost sensors,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Miniaturization,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Tri online</td>
</tr>
<tr>
<td>tracer incorporation in polymers (TRA)</td>
<td>Horizon emergence : 5 à ... 20 ou 30 ans</td>
<td>Technology used for metal sorting applications in biology and medicine. Not used industrially for sorting waste.</td>
<td>L</td>
<td>Improve the speed and quality sorting of polymers contained in ELVs Extension to other polymers and other industrial sectors such as WEEE and packaging (especially for sorting of shredded waste).</td>
</tr>
<tr>
<td>Terahertz spectroscopy (THz)</td>
<td>Moyen/long terme.</td>
<td>Analysis of the molecular structure of a product. The characterization of the products can reach a very fine level, such as the differentiation of the two isomers. Existing applications are mainly medical and security (airports) for detection of dangerous products. No application in the field of waste sorting.</td>
<td>discontinuous (Security gates)</td>
<td>Improve the stability and accuracy of emission sources.</td>
</tr>
<tr>
<td>Method</td>
<td>Tri in the food industry</td>
<td>Production of high purity polyolefin from waste.</td>
<td>Detection of dark bodies</td>
<td></td>
</tr>
<tr>
<td>------------------------</td>
<td>---------------------------------------</td>
<td>-------------------------------------------------</td>
<td>--------------------------</td>
<td></td>
</tr>
<tr>
<td>Ultrasound (ULT)</td>
<td>Not used for waste.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raman spectroscopy (RAM)</td>
<td>Characterizing the molecular composition and structure of a material. No continuous waste sorting application.</td>
<td></td>
<td>Recognition of dark materials and multilayer bottles.</td>
<td></td>
</tr>
</tbody>
</table>
A2 Recycling of the materials

Table 0.3 Material shares of the automotive shredder residue (ASR) (= shredder light fraction) [51]

<table>
<thead>
<tr>
<th>Material</th>
<th>Material share (according to mass)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastics</td>
<td>25...40 %</td>
</tr>
<tr>
<td>Elastomer, Tires</td>
<td>10...30 %</td>
</tr>
<tr>
<td>Wood, cellulose material</td>
<td>3...8 %</td>
</tr>
<tr>
<td>Fibres, material for upholstery</td>
<td>5...16 %</td>
</tr>
<tr>
<td>finish, undercoating</td>
<td>3...5 %</td>
</tr>
<tr>
<td>Glass, ceramic</td>
<td>10...16 %</td>
</tr>
<tr>
<td>Metals</td>
<td></td>
</tr>
<tr>
<td>• Iron</td>
<td>5...15 %</td>
</tr>
<tr>
<td>• Copper</td>
<td>1...3 %</td>
</tr>
<tr>
<td>• Aluminium</td>
<td>2...3 %</td>
</tr>
<tr>
<td>Others (rusts, sand, dust)</td>
<td>2...5 %</td>
</tr>
<tr>
<td>Harmful substances</td>
<td></td>
</tr>
<tr>
<td>• Carbon hydride</td>
<td>2 %</td>
</tr>
<tr>
<td>• PCB</td>
<td>10...25 ppm</td>
</tr>
<tr>
<td>• Dioxins, Lead, Nickle, Cadmium</td>
<td></td>
</tr>
</tbody>
</table>

A2.1 Metals

Characterized by [35]:

- Being very good thermal- and electrical conductors
- Very high stability, ductility and metal-gloss
- Never used as a pure material, always used as Alloys
- Are divide [35]:
  - Light metals (density less than 5 kg/dm³)
  - Heavy metals

Main use [33]:

- Body (material mix depending on the material properties)
- Chassis (more and more light metal is used instead of steel metals)
- Drive with the powertrain (Aluminium, grey cast iron, ceramics, magnesium)
Steel materials

It is the dominant material in the automotive parts. (61% of the whole mass from a car is out of steel (Figure 5.1) [33].

Definition

- Not one specific material
- Many materials with different compounds and properties
- No common way to define steel
- According to DIN EN 10020:2000-07 [71]: Steel is a material which is mainly out of iron with share of carbon is less than 2,06% and other materials as alloy.

Properties

Same properties of steel are [72]:

- Density (7,85 kg/m$^3$)
- Elastic modulus (190-210 GPa).
- Others are depending on the sort.

Different types

There are several different groups of steel used in a car. Figure 0.1 shows for example several of those steels, which are often used in a car, and classifies them according to total elongation and tensile strength [73] [33].

![Figure 0.1 Different high strength steels, their elastic limit and the total elongation [74]](image)
The Steel types are:

- Micro alloyed steels [33]
  - Steel index LA
  - Developed since the 1970s
  - Alloying materials: usually vanadium, titan and niobium
  - Used in the raw-building of a car.
  - Yield strength: about 500 GPa.

Bake hardening steels [33].

- Steel index B
- very ductile under room temperature
- Material is heated in lower level after production -> increase the yield strength while having a quite high ductility

Interstitial steels [33]

- Steel index Y
- Are produced in a way to avoid the interstitial admission of alloying materials.
- Alloying materials: Manganese, silicon and phosphor
- Very suitable for deep-draw,
- Very constant allocation of the plasticity.

Multiphase steels [33]:

- Dual phase steels (index X)
- Complex phase steels (index C)
- TWIP steels (index T)
- Martensite phase steels
- Ultrahigh strength steels
- Low level of plasticity which -> gives some limits in the manufacturing process.
- High strength is caused by a structural hardening.
- As the structure there is a second phase,

The use of the different steel materials
Figure 0.2 shows the body of a car and is a good way to represent, when and where the different strength types of the steels are used. Mainly, these steels are used in crash critical areas which have to fulfil high requirements in the case of a crash. So for example the front wings have to absorb a lot of energy in the case of an accident. But the most strengthen steels are used in the door beams and the pillows of the cabin, because especially in the case of a side crash there is no space to absorb the crash energy like the whole front area of an in a front crash [33] [75].

For other parts which are not that critical in the case of a crash like the rear seat pan or the drip moulding are nowadays often made of lighter materials. If for this parts still steel is used, than usually softer steels. Also in other parts of the car steel is used.

Hazards of steel

- Very high temperatures of production (1300 and 1500 °C) [14]
- Unwished pollutions (water oil, fat, water and flammable materials) are causing several dangers under the very high temperatures [14]
- Sometimes parts of the melt are thrown out of the melting pot [76].
- Can lead to conjunctivitis, choroiditis and retinitis in the human body [77]

Recycling of steel
- Recycling rate of iron: More than 98 % [22]
- Recycling several times not reduces the quality of the steel [35]
- Advantages [14]:
  - Decreases the mining of steel.
  - reduces the environmental pollution extremely
- Depending on the level of the pollution of the metal waste: Difficulty of recycling increases [14].
- Contamination of the iron with copper and zinc reduce the plasticity of recycled steel greatly [22]
- Sulphur reduces the quality of the recycled steel extremely [14]
- Wanted alloys. (nickel, manganese, and molybdenum) [14]
- After sorting and cleaning [14]:
  - Classify according to classes
  - Maybe second cleaning step
  - The mixed metals are melted and the melt is cleaned (refinement). (Sometimes already enough)
  - Heavily polluted: physical techniques:
    - Evaporation,
    - Distillation and condensation (for several times)
    - selective oxidation and reduction

**Where to reuse the material**

No loss of quality [22]

Reused in the same parts where the former parts were used, like body, the chassis, the drive and the powertrain [33].

**Cast Iron**

**Definition**

- Variation of the steel materials
- Difference to steel is: cast iron contains more than 2 % of carbon [71].

**Properties** [35]

- Relatively cheap
Manufacturing process is easy to handle [35]:
  - Lower casting temperature,
  - Good mould filling ability
  - Low contraction while cooling down
- High compressive strength
- Good damping behaviour
- Failsafe running functions
- Tensile strength between 100 and 1400 MPa [33] [35]
- Cannot be forged because of the high carbon share

**Different types**

Classified because of the different shape of the solidified carbon (Figure 0.3) [35]

- Lamellar-graphite
- Spherical graphite
- Vermicular graphite
- New development: Austenitic cast iron (ADO [35].

![Figure 0.3 Shapes of the solidified carbon in cast iron (lamellar-, spherical-, vermicular- graphite) [35]](image)

**Use**

- Components with an extensive shape [35].
- Lamellar-graphite cast iron: Brake disc, engine block [8].
- Spherical graphite carbon cast: differential housing, the con-rod, axle journal, fly wheel or the crankshaft [8].
- ADI: axle casing, wheel hub, the gear rim, the crankshaft [33].

**Hazards, Recycling, Reuse of the secondary material**

Same as the steel.
Nonferrous Metal

Aluminium

Definition

- Bounded as an oxide or a mixed oxide [35]
- The main material to create aluminium is bauxite [35]
- For technical uses are important [35]:
  - Wrought alloy
  - Casting alloys

Properties

- Density: 2,6-2,8 kg/dm$^3$ (three times lower than steel) [35]
- Melting point: 660 °C (pure) [35] 935-1215 °C (alloys) [78].
- Tensile strength of the alloys: 35 - 290 MPa [35]
- Yield strength: 95-410 MPa [35]
- Tensile strength: 150 - 300 MPa [35].
- Very durable in terms of climatic- and salty conditions [35].
- Good formability and good free-cutting properties [35].
- Surface is very well looking
- High electrical and thermal conductivity [35].

Different types and classification

Usually aluminium is available as a wrought alloy or as casting alloy and divided into different groups according to the principal alloying element (Table 0.4).

Table 0.4 Groups of the aluminium alloys [78]

<table>
<thead>
<tr>
<th>Alloy group</th>
<th>Principal alloying element</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1xxx</td>
<td>Unalloyed Aluminium</td>
<td>Purity of 99.0% or Greater</td>
</tr>
<tr>
<td>2xxx</td>
<td>Copper</td>
<td>Heat Treatable Alloys</td>
</tr>
<tr>
<td>3xxx</td>
<td>Manganese</td>
<td></td>
</tr>
<tr>
<td>4xxx</td>
<td>Silicon</td>
<td>Low Melting Point Alloys</td>
</tr>
<tr>
<td>5xxx</td>
<td>Magnesium</td>
<td></td>
</tr>
<tr>
<td>6xxx</td>
<td>Magnesium and Silicon</td>
<td>Heat Treatable Alloys</td>
</tr>
</tbody>
</table>
Casting alloy [33]:

- Good cast properties: responsible share of silicon (5-20 %)
- Different composition.
- Most common casting alloys:
  - Aluminium-silicon (AlSi)
  - Aluminium-silicon-magnesium (AlSiMg)
  - Aluminium-silicon-copper (AlSiCu)
  - Aluminium-zinc-magnesium (AlZnMg)

Use

- Increased in the last years (in 2012 10 %) [36]
- Most in the chassis (high-strength and high-viscous alloys are used) [33].
- Bogie grinder [33].
- Drive wheel carcass [33].
- Nodes of a space frame body [33].
- Door frame this [33].

Hazards

- Polluted same as like the one of steel
- Salt scum in the melting (no landfill allowed) [14].
- Effects on health [79]:
  - Dementia
  - Damage of the central nervous system.
- In the environment [79]
  - Bad for animals
    - Losing weight
    - Getting lung problems
  - Aluminium can destroy the roots of trees. [79].

Recycling
- Production of secondary aluminium only needs 1/20 of the energy than primary aluminium would need [14]
- Easy to separate from other types of scrap [14]
- No loss of quality [14]
- Recycling rates in total from about 70% [14].
- Like steel the recycling depends on the level of pollution [14]
- Figure 0.4 shows the process. [14].
- Secondary aluminium has a share of 51% of the production of new aluminium in Germany [80]
- Residues like the salt scum and the waste gas have to be treated in separate steps [14]
- Problems during the recycling [14]:
  - Different quality from the casting alloys
  - Silicon hard to remove (very noble according to electrochemics).

![Diagram](image)

**Figure 0.4** The steps in recycling aluminium [14]

**Reuse of the secondary material**

- No quality loss of the recycled material.
- Used in the same products like primary aluminium.

**Magnesium**
Properties

- Density from only 1.74 kg/dm³ [35]. It is lowest density of all the common used metals.
- Young’s modulus amounts 45 000 MPa [35]
- Yield strength 40 MPa (pure) 80-160 MPa (alloys) [35]
- Tensile strength 165 MPa (pure) 150-250 MPa (Alloys) [35].
- Not so resistant to heat and corrosion
- Contact corrosion causes several problems.
- But Magnesium has also very good moulding properties. [33]

Different types [33].

- Cast material (for example MgAl9Zn1HP, or MgAl5HP)
- Alloys of other metals [33].

Use

- Complex parts with a variable thickness of the walls (built with cutting methods)
- Casting parts [33]:
  - Parts in the seats,
  - The rim
  - The carrier of the control panel
  - Steering wheel carcass.
- Very ductile and resistant magnesium cast materials: sump or valve lid [33].
- Tries to use magnesium sheets in the car. [33] [81]

Hazards

- Magnesium dust is easily flammable [33]
- Assumptions: Magnesium is carcinogenic, mutagenic or teratogenic to the human body. [82]
- Others hazards comparable to aluminium recycling [14].

Recycling

- Most of the recycling already takes place in the aluminium recycling ) [14]
- To recycle the magnesium basic materials the huge affinity to oxygen is used [14]
- The melting process is quite similar to the aluminium process (Figure 0.4) [14]

Reuse of the secondary material

- Like the other metals
Zinc

Properties

- Zinc has very good flow properties [33]
- A low melting point from about 419 °C [33]
- Temperature of ebullition of 916 °C [14].
- This allows a very high freedom of construction. [33]
- Can be combined with galvanic deposited surfaces to create very good surfaces [33].

Different types

- Zinc die-casting [33]
  - Standards: EN 1774 and EN 12844)
  - Alloying elements: aluminium, copper and magnesium. (zamak)
- Also galvanized steel sheets (with zinc coatings) (protects the steel against corrosion) [33].

Use

- Car contains about 10,2 kg of zinc [83]
  - Half of it (4,9 kg) are casting zinc materials.
  - 3 kg are used on steel as a protection against corrosion
  - 0,5 kg are used as a activator in tires [33]. (to make the tire more resistant against temperature, pressure and chemical and physical treatments.)
- Very complex parts with very thin walls [33]
- The well looking parts [33]
  - Door handles
  - Trim elements.

Hazards [84]

- The human body can handle zinc quite well
- Too much zinc it still can cause health problems
  - Cramps in the stomach
  - Irritation of the skin
  - Pancreas.
  - Danger for unborn children

Recycling [14]

- Low temperature of ebullition is used.
• Separation of zinc by distillation (with highly reduced atmosphere in order not to oxidate zinc steam)

**Reuse of the secondary material**

In the same parts like primary copper
Copper

Properties [85].

- Very high electrical conductivity from 58,8 S/m
- The density amounts 10,50 kg/dm³
- After silver the best electric conductor (under room temperature).
- Because of the cheaper price copper is the favourite material for massive parts

Different types [85]

- Unalloyed copper
- Alloyed materials
- Also used as alloying material for several other materials

Use

- In a modern middle class car round about 20-25 kg of copper is used [85] [45].
- The main use (14-15 kg) is in the main wire harness [85].
- 5,5 kg is used in the engine [85].:
  - 3,2 kg in the as nonalloyed Copper in the generator,
  - Starter,
  - Cooling module
  - Cables
  - The other copper in the engine is used as an alloying element
- About 0,5 kg used in the heating-cooling aggregate [85].
- The other material is spread in other part as pure and alloyed copper [85].
- If increase the use of hybrid vehicles: the use will increase [85].

Hazards

- Problems during melting [14]:
  - Wire isolation of PVC
  - the flame retardant
  - Contact with a high copper concentration during a longer period [86]
    - Changes on the nose and the mouth of humans
    - Maybe also reduce the intelligence

Recycling
- Reduces the need of energy compared to primary copper of about 60 - 65 % [85].
- Like steel other metals, the complexity of the recycling increases with the amount of pollution [14].

**Reuse of the secondary material**
- In Germany already 43% of the new copper produced is out of secondary copper [85]
- In the same parts

**Noble Metal**

**Properties** [33]
- Very noble according to electrochemist.
- Very high durability against corrosion and oxidation.
- Very high contact safety

**Different types** [33]
- Silver
- Gold
- Ruthenium
- Rhodium
- Palladium
- Osmium
- Iridium
- Platinum

**Use** [33].

**Gold**
- Contacts of an airbag are gilded
- Contact of printed circuit boards (PCB) in integrated circuits are gold wires used

**Silver**
- Conductive layers of PCB tracks
- Relays

**Platinum, palladium and rhodium**
- Catalytic converter
Appendixes

Others:

- Several sensors
- Wheel speed sensor,
- Air cooler,
- Lambda oxygen sensor [33]

Hazards

- Like all the metals pollution can cause several problems
- Gold can cause irritation of the skin and allergic reaction [87]
- Silver salts are dangerous and lead to death (more than 2 g). Silver can also create allergic reactions, skin irritations and problems with the breathing [88]
- Platinum is rare and heavily dangerous but platinum can increase the toxicity of other dangerous materials. Only the platinum salts can become dangerous for human. Platinum is collected by the roots of plants. But the effect of this is not clear [89].
- Rhodium dust is flammable and can burn. But it is very rare, that’s why there is almost no effect of it to the environment or human [90].
- Palladium is hardly absorbed by the human body. But it can irritation of the skin, the eyes and the breathing. [37]

Recycling [14]

- Thermal treatment (separate them from the organic materials)
- Collected in copper or in lead castings (separate contamination from the noble metals).
- Electrolysis (to create the noble metals) [14].

Reuse of the secondary material

- Very good possible.
- Reused in the same places
A.2.2 Plastics

Figure 0.5 shows, plastics can be classified according to their general properties.

![Classification of plastics](image)

**Figure 0.5 Classification of plastics** [41]

![Shares of used plastics in the European automotive industry of 2012](image)

**Figure 0.6 Shares of used plastics in the European automotive industry of 2012** [39]
Thermoplastic

Properties

- Classified according to their physical structure. [41]
- Molecular chains are not cross-linked [41]
- Different types [41]
  - Amorphous
  - Practically crystalline
- Start to melt when they reach a specific temperature [41]
- Thermoplastics show a plastic flow and a relaxation [41]
- Molecular chains slip off under high temperatures and strain [41]
- Thermoplastics are meltable as often [41]
- Low to middle tensile strength, elongation at break and stiffness [41]

Table 0.5 Different thermoplastics, their properties and use in a car [38]

<table>
<thead>
<tr>
<th>Name of the plastic</th>
<th>Abbreviation</th>
<th>Properties</th>
<th>Use in a car</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polypropylene</td>
<td>PP</td>
<td>• Cheap material</td>
<td>• Bumpers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Good stability,</td>
<td>• Wheel arch liner</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Chemical resistance</td>
<td>• Air filter housing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Guide channel</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Container</td>
</tr>
<tr>
<td>Material</td>
<td>Description</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Polyurethane (PUR)               | • Elastic with a low thermal conductivity  
                                 | • Good damping properties                                                    |
| Acrylonitrile butadiene styrene  | • Can be galvanized  
                                 | • Good stability                                                            |
| Polyamide (PA)                   | • Resistant to temperature and age,  
                                 | • Good endurance strength and stiffness  
                                 | • Low gas permeability                                                      |
| Polyvinyl chloride (PVC)         | • Weather resistant  
                                 | • Cheap  
                                 | • Hardly inflammable  
                                 | • Good haptic                                                              |
| Polyethylene (PE)                | • Cheap  
                                 | • Chemical and ageing resistant,  
                                 | • Good stability                                                            |
| Polyoxymethylene (POM)           | • Stable to chemical  
                                 | • Abrasion resistant  
                                 | • Impact resistant  
                                 | • Low tendency to creep  
                                 | • Heat resisting                                                          |
| Polymethyl methacrylate (PMMA)   | • Transparent  
                                 | • Scratch resistant  
                                 | • UV resistant  
                                 | • Stress cracking resistant                                                |
| Polycarbonate (PC)               | • Impact resistant  
                                 | • Transparent  
                                 | • Uv resistant                                                             |
| Polyethylene terephthalate (PET) | • Tensile strength  
                                 | • Stiffness  
                                 | • Barrier effect                                                           |
| Polybutylene terephthalate (PBT) | • Stiffness  
                                 | • Thermal resistant  
                                 | • Good electric isolation  
                                 | • Dimensional stability                                                    |

**Different types**

- Separated into different classes (according to their kind of polymerization) [41].
- The fat types are the most common ones in the automotive industry [39]:

---

**Appendixes**
Appendixes

- Polyolefin: PE, PP, PB-1, PIB, PTFE, UHMWPE
- Vinyl-connections: PVC, PVCD, PVDF; PS; PVAC; PVAL; PVK; PVE
- Others: PA; POM PMMA; PUR
- Ionomere: SAN ABS; ASA; SB

Hazards

Beside a wrong end of live treatment (burning, landfill) which can pollute the environment, the researches haven’t carried out anything.

Recycling

In order to recycle plastic there are three different ways possible

Several problems which are making recycling of plastics to difficult process [14]:

- Oxidative degeneration (from oxygen in the air, UV-light) during the use of the plastic reduces the quality of the plastics (can be intensified when other materials (metals, waste) is mixed to the plastic
- Also different types of plastic are not compatibility to each other.
- There are only a few possibilities to clean the materials without destroying them. So for example colour materials and additives cannot be separated.
- There are so many different types of plastic with different additives, reinforcements, colours

For thermoplastics the right of the 3 ways of recycling (Figure 0.8) is usual [14]:

![Figure 0.8 Place of the plastic application in a car [14]](image)
• clean thermoplastics (without reinforcements and coatings) can be put directly back in the production of new thermoplastics

• The others:
  o Shredded
  o Cleaned
  o Sorted
  o Mixed plastic types remaining (sometimes already be reuseable)
  o To separate them in total
  o Selective resolution (use of different ways of solving)
  o Cleaning
  o Solution from the remaining,
  o Solvent is boiled away,
  o Pure plastic powder is remaining.
  o For several types of plastic: a solvent and according to it, the temperature is known.

**Reuse of the secondary material** [14].

• ABS out of a radiator grill
  o Cleaned
  o Shredded
  o Possibility to mix it with new ABS in order to reuse it in new radiator grills

• PA 66 out of a radiator tank can be used as secondary PA [14].

• PP out of bumpers and battery boxes are mixed (after shredder, sorting, cleaning) and can be used for wheel house liners [14].

**Elastomer**

**Properties** [41].

• Chemical classified: conjugated double bonds

• Wide-meshed plastics

• Over the glass temperature: getting elastic, but don’t start to flow

• Mixed type:
  o Thermoplastic elastomer (TPE)
  o Classified between the thermoplastics and the elastomers
  o Multi-phase plastics
Areas of elasticity like an elastomer in which meltable amorphous thermoplastics are added

- TPEs are meltable
- Getting more and more important in automotive applications

Advantages (compared to elastomers)
- Less weight
- Easier manufacturing process (like a thermoplastic)
- Lower price

- Elastomers are not meltable.
- Molecular chains of elastomers cannot slip off.
- A low stiffness and tensile strength.
- Elongation at break is good in combination of a rubber-like elasticity.
- This materials show a plastic flow and relaxation

**Different types [91]**

TPE: EPR (EPM), SBS, TPE

Saturated elastomers: FCM, EPDM, ACM, VMQ, VMSI

Non-saturated elastomers: IIR, NR, BR, SBR, NBR, AM

**Use**

- Seals [92]
- Cable coating [92]
- Very important for the damping: [92]
  - Additional springs in the chassis
  - Bump stops
  - Shock absorber mounting or
  - Torque arms.
- SBR, BR and IR: in the tires
- IIR: cable isolation
- NBR is the standard rubber: different types of sealing.
- EDPM is used in order to absorb energy body parts in the critical areas [91]
  - Spoiler
  - Bumpers
  - Cable isolation.
- TPEs convoluted rubber gaiter of axles and drive shafts [33].
Hazards

The grinding stock is flammable and can be explode [14].

Recycling [14].

- Recycling is difficult:
  - Not meltable
  - Not solvable.
- Keeping the structure is only possible, when the plastics are grinded.
- This material is mixed to new material
- Problem of the tire recycling: exactly resulting grinding stock is always different (because of the different compounds of different tires)

Reuse of the secondary material

- Adding to new materials [93]
- Depending on the size of the grinding stock [93]:
  - Athletic grounds (old rubber and PVC),
  - Carpets in a car,
  - In the asphalt,
  - Rubber in tires, soles of shoes
  - Oil binder
- Most of the old tires round about 45 % is just energetically reused [14].

Thermosets

Properties [41]

- Classified according to the process parameter pressure.
- Close-meshed amorphous plastics.
- Do not flow.
- Reaching a softening temperature (glass temperature): just softening
- Not possible to melt thermosets.
- Molecular chains of thermosets cannot slip off (Like the elastomers)
- High tensile strength, stiffness and an elongation at break.
- Only show a small/no plastically flow and relaxation.
- These plastics are heat-proof

Different types
Two different types [92].
  - Fibre-reinforced thermosetting resin
  - Thermosetting moulding material

Thermosets are for example UP, EP, PF, UF, MF, PI, SI, CF, MPF, RF, DAP; PDAP [41]

Use [92]

- For small parts (with a higher heat treatment)
  - In the motor
  - In the lights.
- Fibre-reinforced thermosetting resins: some body parts: the engine bonnet, the hatch door and the mudguard.
- Thermosetting moulding material: the break piston, the toothed belt disc and several housings (crankshaft, window lifter, pumps) the is used.

Hazards

Beside a wrong end of live treatment (burning, landfill) which can pollute the environment, the researches haven’t carried out anything.

Recycling

- Limiting the recycling ways of thermosets [14]
  - Close-meshed cross-linking,
  - Insolvability
  - Brittleness
  - Thermosets don’t flow => not possible to melt them for recycling [41].
- Just can be shredded and mixed to new materials [14].

Reuse of the secondary material

- In primary thermosets [14]
  - Used up to 80 % of filling materials
  - Up to 30 % old thermosets
A.2.3 Glass

Properties [14]

- Special physical constitution of an amorphous solid body.
- Glasses are made out of quartz sand, soda and chalk

Different types [33]

There are two different types of glass used in a car:

- Toughened safety glass
- Composite pane safety glass.
  - Build out of three layers
  - Between the two panes, there is a polyvinyl butyral (pvb) film.
  - The pbv film keeps in case of a break of the window, all the splitter together in the glass.
  - Sometimes a metal oxide layer integrated:
    - For a heating of the window
    - As an antenna

Use [33]

- Used type of the window depends
- Glass in a car is used in the windows:
  - Front window
  - Back window
  - Fond windows
  - Sunroof

Hazards

The black edge of old cars (built bevor 2003) is out of led silicate [14].

Recycling [14]

- Problems during recycling:
  - Black colour at the edge of the glasses.
  - Toughened safety glass shivers into lots of very small parts.
  - Requires a very good sorting technique and is very expensive.
- Several steps recycle the glasses there are several steps to do [14]:
  - Dismantle the windows
Collect them according to colours, edge layer, function elements
- Delamination of multilayer glass
- Shredder the glasses
- Separate metal parts
- Separate coloured glasses
- Transportation to the glassworks

This way of recycling is very expensive and not profitable. But according to the laws which are demanding recycling rates, it should be done.

**Reuse of the secondary material**

When the glass is sorted, it can be reused in the glassworks like new glass [14].
A.2.4 Ceramics

Properties [33]

Ceramics which are relevant for technical use have a:

- Very high compressive strength
- High hardness
- High wear-resistance,
- High temperature resistance
- Good corrosion resistance
- Low density
- Low ductility
- Complex manufacturing process
  - Production
  - Machining
- Difficult to combine with other materials.
- Very high dielectric constants
- Good piezoelectric properties

Different types

Silicate ceramics like china, cordierite, mullite and steatite [33].

Oxide ceramics This are monophasic and out of one component metal oxides on the basis of aluminium, magnesium, titan or zircon or mixed oxides out of aluminium titanate or lead zirconated titanate

Non oxide ceramics are produced on the basis of carbon, silicon, nitrogen, boron

Use [33]

- Silicate ceramics: carrier of the catalytic converter
- Oxide ceramics: electronic applications:
  - Isolators,
  - Knock- and distance sensor
  - Lambda oxygen sensor
- Non oxide ceramics:
  - Bearing rings
  - Isolation sockets in water or fuel pumps
  - Valve of an exhaust regulation
Appendixes

- Sometimes used as brake discs and in some special cars as a clutch
- As a surface coating: put on a metal part to improve the resistance against temperature and wearing
- Ignition plugs
- Heat elements
- Dielectric in electrical condensers.
- As piezo elements.
  - Deformation elements to trigger the airbag and the seat belt tightener
  - Ultrasonic sensors for the parking
  - Piezoelectric fuel injectors in diesel common-rail-ignition-system,
  - Accelerating sensor

Hazards, Recycling, Reuse of the secondary material

Up to now the researches haven’t carried out anything about technical ceramics, but recycling should be possible.
A.2.5 Textile materials

Properties [44].

- Depending on the manufacturing process.
- Not possible to give general information
- The main properties:
  - Length of the fibre,
  - Yarn count
  - Density of the fibre

Different types [44]

- Natural fibre.
  - Natural fibres can come from
    - Plants
    - Animals
    - Minerals
  - Natural fibres are: cotton, kapok, hemp, linen, ramie, flax, ramie and coco
- Synthetic fibre
  - Are based on polymers.
  - Synthetic fibres are: polyamide, aramid, polyester, polyurethane, polyacrylcs, polytetrafluoroethylene, pvc, polyolefin, glass fibre (inorganic), carbon fibre (inorganic)

Use [44]

- Natural fibre:
  - Cotton: in seats, seat cover [33]
  - Linen and hemp: to strengthen the clutch- and brake lining.
  - Kapok: isolation and insulation
  - Ramie: belts.
  - Coco is used as a filling material in head restraints
  - Cotton can be used as seat cover
  - Polyester fibre: multilayer folding top of a cabriolet can
- Synthetic fibre:
  - Dominant synthetic fibres in a car
    - Polyester fibre
    - Polyamide fibre
Polypropylene fibre.
  o Aramid: in airbags, to strengthen plastics or in the carcass of tires [44].
  o Polyamide: to strengthen tires.
  o Polyolefin: to strengthen plastics
  o Glass fibre: strengthen plastics.
    ▪ Interior covers
    ▪ Body parts
  o Carbon fibre
    ▪ More and more getting used because of the (good light weight properties)
    ▪ To strengthen plastics (cfk).
    ▪ Several body parts
      • The connecting rods
      • The tank
      • Breaks
      • The cardan shaft

Most of the natural fibre are nowadays replaced by synthetic fibre [33].

Hazards

Up to now the researches haven’t carried out any hazards.

Recycling

Blown out in the shredder light fraction

Reuse of the secondary material

Fibrous materials out of light materials like porous and fibre like the foam from seats or the textile fibre are used in clearing sludge basins for sludge drainage [45].
A.2.6 Leather

Properties

- Made out of hide and fells of animals [44].
- Very well optical surface [33]
- High water vapour permeability [33]
- Very good haptic and feeling [33]
- Very expensive [33]
- Difficult manufacturing process [33]
- Smell is sometimes a problem [33].

Different types [44]

- Depending on
  - The animal
  - The origin part of the leathers.
- Leather imitates out of polyester and pvc foils (increasing; cheaper than natural leather).

Use [33]

- In the interior: to design it individually.
- Only used in higher middleclass and upper-class cars:
  - High price
  - Complex process

Hazards, recycling, reuse of the secondary material

Up to now the researches haven’t carried out anything about hazards, recycling and the reuse of leather.
A.2.7 Liquids

Lubricants

Different types [46]

Usually there are several different types existing in a car:

- Engine oil (normal engine oil, fuel-efficient engine oils, inlet oils)
- Gearbox oil
- Hydraulic oil
- Grease

The engine oil can be classified in the society of automotive engineers (sae)-classes. This classification is based on the viscosity.

- Properties [46]
  - Engine oil is usually a mixture
    - Basic fluids
    - Several additives.
  - Basic fluids mainly define the properties of the oil:
    - Viscosity (also under temperature influence),
    - Resistance against oxidation
    - Adaptive responding behaviour.
  - The basis of the engine oil are different carbon hydrates.

Use [46]

- For the reliable work of the engine and the gear box
- Reduce the friction between movable parts
- Have to remove particles and shivers out of the greasing point
- Sometimes have to seal (piston-cylinder in the engine)
- Remove/transport heat

Hazards [14]

- The oils are hazardous to water
- Has to be collected
- Transported carefully
- There have to be arrangements to avoid a burning of the oil.
Recycling

- Engine oil collects during its lifetime several other materials [46]:
  - Unburned carbon
  - Friction particles.
- If the waste oil has no loss of quality [14]:
  - Only pouted with water, abrasion and mud,
  - Reconditioning with a solid-fluid sorting (sedimentation and filtration) is enough.
- More polluted waste oils [14]
  - Have to be refined.
  - Process is more or the less comparable to the refinement of crude oil
  - Used methods:
    - Sulphuric acid method
    - High pressure hydrogenation method
    - Extraction with compressed propane are used.
- Most of the waste oils are reprocessed to heating oil [14]:
  - Need to fulfil requirements of heating oil => the waste oil needs to be reprocessed
  - Separation of:
    - Water
    - Additives
    - Metal compounds

Reuse of the secondary material [14].

Depending on the recycling method:

- As new oils
- As heating oil.
- As reductor in a blast furnace
Fuel

Different types [46].

For a normal (European) car with an internal combustion engine there are two main different types of fuels:

- Diesel
- Gasoline.
- But beside this there are several alternative fuels usually rare fuels (in Europe):
  - Natural gas (cng)
  - Liquid petrol gas (lpg)
  - Compressed natural gas (cng)
  - Ethanol (e85) (en 51625)
  - Methanol fuels
- Usually made out of crude oil.
- Alternative diesel can be made for example out of
  - Sugar cane
  - Rape
  - Wheat
- Normal European diesel usually is a mixture out of:
  - Classical diesel
  - Rap oil

Composition [46]

- Hydrocarbons
- Several added additives (improve the properties)
- Diesel
  - Out 300 different hydrocarbons
  - Most of them: alkane.
- Petrol is a mixture of
  - Reformate
  - Olefins
  - Pyrolysis-petrol
  - Soparaffins
  - Butane
  - Alkylate
Alcohols

- Diesel [94]:
  - Minimum requirements: are regulated in EN 590:
    - The boiling range is between 250-360 °C.
    - The minimum cetane number amounts 51
    - Density 0.820-845 kg/m^3 (at 15 °C)
- Petrol [95]:
  - Minimum requirements: are regulated in EN 228:
    - Three different types of petrol in Europe (according to the octane index):
      - At least 98: super-plus
      - At least 95: super
      - At least 91: normal fuel
      - The boiling point of all the three fuels amounts 210 °C
      - Density 720-775 kg/m^3 (at 15 °C)
  - Leaded fuel was abolished in 1996 in Germany [46].

Use

The fuel is burned in the internal combustion engine of a car in order to use the delivered energy for driving.

Hazards

- Are flammable
- In a specific concentration and with a spark fuels can explode
- Can pollute the environment and the water

Recycling [14]

- Old fuel is polluted
  ⇒ Cannot be reused.
  ⇒ Only energetically recovery possible.

Reuse of the secondary material [14]

Energetically recovery
Cooling fluid

Composition [46]

- Usually (in non-arctic areas) water and antifreeze are mixed in a 1:1 rate.
- Antifreeze:
  - 93% of the whole cooling fluid.
  - 7% are corrosion inhibitors.
- Antifreeze material: a type of glycol (monoethyleneglycol)
- Corrosion inhibitors:
  - Benzoate/nitride
  - Nitride-amine-phosphate-free inhibitors (nap)
  - Silicate-free inhibitors (oat)

Properties [46]

When there is a 1:1 water: antifreeze rate,

- The boiling point: 109 °C
- Start to freeze: -37 °C
- Solidification point: -47 °C
- Density 1.110-1.145 kg/m³

Use [46]

In the engine:

- Antifreeze
- Corrosion protection

Hazards, recycling, reuse of the secondary material

So far the research hasn’t carried out this topics.
Brake fluid

Properties [46]

- Good viscosity up to -40 °c.
- High boiling temperature (otherwise steam bubbles in the breaking system => would reduce the breaking pressure)

Different types [46]

- Can beased on
  - Glycol
  - Silicon.
- Glycol fluids:
  - Out of polyglycol-ether
  - Hygroscope
  - Absorbs water
  - Avoid a dangerous steam building in the breaking system.
- Silicon fluids:
  - Out of silicon oil.
  - Cannot absorb water
  - Compressibility higher
  - Solved air is higher

Use [46].

- Glycol fluids are the typical brake fluid of a car.
- To transmit the braking energy between
  - The main braking cylinder
  - Breaks of the wheel.
- In addition to this the brake fluid also has to lubricate:
  - The bearings
  - The valves
  - The piston

Hazards

Up to now the researches haven’t carried out any hazards.

Recycling

Necessary for recycling is a mono-material collection, a cleaning and a chemical reprocessing. [46]
Braking and cooling fluid can be filtrated, destilated and then usually reused [14].

**Reuse of the secondary material** [14]

When it is recycled well it can be reused like the former braking liquid
A.3 Choice of the proper solution to sort black coloured plastic

This is the detailed description of the section 9.3 Choice of the proper method to separate black coloured plastic

In order to rank the ideas and make a choice for one solution first the relevant criteria need to be collected. This happens in a meeting with the company and with studies of the literature [65].

The criteria are:

- Low costs (of the development, production and use)
- The simplicity of production
- The feasibility of the technique
- If the technique can be combined with machine vision
- The effects on the environment (which should be as low as possible)
- The effect on the plastic which is sorted (this also should be low, because a destroyed plastic cannot be sold and gain any profit)
- A fast sorting process
- An accurate sorting process
- The time between a service at the sorting machine (when a check-up of the parts change of parts of the sorting machine is necessary)

AHP

In order to rank those criteria, an AHP is done. In this all the criteria are listed in the columns and the lines. Then the line is always compared to the column. When the criteria of the line is more important than the column it gets a value between (1 and 9) depending on the level of importance. Figure 0.9 gives therefore an explanation and Figure 0.10 shows the result.

<table>
<thead>
<tr>
<th>Intensity of importance</th>
<th>Definition</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equal importance</td>
<td>Two activities contribute equally to the objective</td>
</tr>
<tr>
<td>3</td>
<td>Weak importance of one over another</td>
<td>Experience and judgment slightly favor one activity over another</td>
</tr>
<tr>
<td>5</td>
<td>Essential or strong importance</td>
<td>Experience and judgment strongly favor one activity over another</td>
</tr>
<tr>
<td>7</td>
<td>Demonstrated importance</td>
<td>An activity is strongly favored and its dominance demonstrated in practice</td>
</tr>
<tr>
<td>9</td>
<td>Absolute importance</td>
<td>The evidence favoring one activity over another is of the highest possible order of affirmation</td>
</tr>
<tr>
<td>2, 4, 6, 8</td>
<td>Intermediate values between the two adjacent judgments</td>
<td>When compromise is needed</td>
</tr>
<tr>
<td>Reciprocals of above nonzero</td>
<td>If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.</td>
<td></td>
</tr>
</tbody>
</table>
As Figure 0.10 shows the cost is most dominant criteria because for example it is higher importance than the simplicity of the production. Because a cheaper product is more important than the way of production, the feasibility and simplicity. Also a cheaper product is of course better than just the combination with machine vision. Also the low cost in total is better than the time between to services.

The simple way of production has only a few bigger importance than the time between the machine service.

Of course the technique needs to be more feasible than the simple way of it. Because when it is not feasible a simple and fast sorting technique is senseless.

Also the effects on the environment are a strong argument, because with heavy effects the machine might not work sustainable and also maybe not get an admission. So this is more important than the simple way of the production or the combination with machine vision.

Also the effects on the plastic should be as low as possible because the sorted plastic will be resold. And a destroyed plastic would create a lower or maybe no profit. That’s the reason why this criterion is more important than the simple way of production and the combination with machine vision.

The sorting accuracy is also important for the selling of the sorted materials. Because the higher the purity is the higher the price will be

The service time of the machine during the use also influences the marge of the sorting company. Because the longer and more often a machine stops the higher are the loses of profit. Also a service usually cost money because of the technicians or the parts which need to be replaced. That’s why this criterion is a little bit more important for than the way of production and the combination with machine vision.

---

**Figure 0.9** Explanation of the ranking of the Analytical hierarchy process (AHP) [96]
In the next step all the empty spaces are getting the value \( \frac{1}{\text{value}} \) of the inverted space:

\[
\frac{1}{\text{line 5 column 2}} = \frac{1}{\text{line 2 column 5}}
\]

and then the sums of each column are calculated.

Now each value in all the spaces are divided through the sum of the whole column in order to norm the values. Then the sum and the arithmetic average of each line is calculated. This arithmetic average is finally used as weight factor in the decision matrix.
Finally, all the solutions are ranked in the single criteria. The higher the value is the better is the fulfillment of the criteria. To get the final score of one solution the value of the criteria is multiplied with the weight factor all the values are summed up. The solution with the highest value is the best solution according to the chosen criteria.

**Acid solution**
The acid solution is the only solution which can be combined with machine vision (Figure 9.2). That’s also the reason why the production would be easy for PICVISA, because they are already producing these sorting facilities based on machine vision. But it is not sure if this solution really is able to separate the plastic and how accurate it will be. This technique is also not very simple because different types of acid and maybe also different levels of temperature would be needed to create a pattern. Furthermore, the acid might destroy the plastic and reduce the profit which can be gained. Creating a pattern will take some time, so the sorting speed is not very high. Also the acid might have a bad influence on the machine and might destroy parts soon, which makes a service often necessary.

**Electrostatic separation**
The costs in total might be higher than the acid solution, because it is a complete new machine, which is not combinable with machine vision. In the literature there are already some sorting rates documented which are speaking from a high accuracy. Also the sorting time (during a freefall) is very fast. Also there is no destroying of the plastic or a bad influence on the environment because of a chemical. Only the electricity might cause problems with the environment. Also the wearing of the machine is much lower than in the acid solution.

**Density**

**Figure 0.12 Result of the Analytical hierarchy process (AHP)**

<table>
<thead>
<tr>
<th>Category</th>
<th>Low cost (in total)</th>
<th>Simple way of production</th>
<th>Feasibility of the technique</th>
<th>Simplicity of the technique</th>
<th>Combination w. MV possible</th>
<th>Low effects on Plastic</th>
<th>Sorting accuracy</th>
<th>Sorting Time</th>
<th>Time between machine-service</th>
<th>Arithmetic average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low cost (in total)</td>
<td>0,327</td>
<td>0,119</td>
<td>0,206</td>
<td>0,238</td>
<td>0,194</td>
<td>0,348</td>
<td>0,351</td>
<td>0,228</td>
<td>0,14</td>
<td>0,21</td>
</tr>
<tr>
<td>Simple way of production</td>
<td>0,065</td>
<td>0,024</td>
<td>0,008</td>
<td>0,01</td>
<td>0,007</td>
<td>0,017</td>
<td>0,023</td>
<td>0,011</td>
<td>0,009</td>
<td>0,03</td>
</tr>
<tr>
<td>Feasibility of the technique</td>
<td>0,065</td>
<td>0,119</td>
<td>0,041</td>
<td>0,143</td>
<td>0,003</td>
<td>0,348</td>
<td>0,023</td>
<td>0,015</td>
<td>0,14</td>
<td>0,15</td>
</tr>
<tr>
<td>Simplicity of the technique</td>
<td>0,065</td>
<td>0,119</td>
<td>0,014</td>
<td>0,048</td>
<td>0,151</td>
<td>0,039</td>
<td>0,039</td>
<td>0,015</td>
<td>0,084</td>
<td>0,09</td>
</tr>
<tr>
<td>Combination w. MV possible</td>
<td>0,036</td>
<td>0,071</td>
<td>0,288</td>
<td>0,007</td>
<td>0,022</td>
<td>0,017</td>
<td>0,017</td>
<td>0,011</td>
<td>0,006</td>
<td>0,01</td>
</tr>
<tr>
<td>Low effects on Environment</td>
<td>0,109</td>
<td>0,167</td>
<td>0,014</td>
<td>0,143</td>
<td>0,151</td>
<td>0,116</td>
<td>0,351</td>
<td>0,228</td>
<td>0,196</td>
<td>0,15</td>
</tr>
<tr>
<td>Low effects on Plastic</td>
<td>0,109</td>
<td>0,119</td>
<td>0,206</td>
<td>0,143</td>
<td>0,151</td>
<td>0,089</td>
<td>0,119</td>
<td>0,38</td>
<td>0,196</td>
<td>0,09</td>
</tr>
<tr>
<td>Sorting accuracy</td>
<td>0,109</td>
<td>0,167</td>
<td>0,206</td>
<td>0,238</td>
<td>0,151</td>
<td>0,039</td>
<td>0,023</td>
<td>0,076</td>
<td>0,196</td>
<td>0,09</td>
</tr>
<tr>
<td>Sorting Time</td>
<td>0,065</td>
<td>0,071</td>
<td>0,008</td>
<td>0,016</td>
<td>0,108</td>
<td>0,107</td>
<td>0,017</td>
<td>0,011</td>
<td>0,038</td>
<td>0,15</td>
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<tr>
<td>Time between machine-service</td>
<td>0,047</td>
<td>0,024</td>
<td>0,008</td>
<td>0,016</td>
<td>0,065</td>
<td>0,023</td>
<td>0,039</td>
<td>0,025</td>
<td>0,006</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
A density machine is probably not as complex as an electrostatic sorting machine, because there are almost no electronic devices needed. But to find exact liquids to separate plastics because of their small difference in density is probably impossible. This also has a bad influence on the sorting time and especially on the accuracy.

As Figure 9.5 the electrostatic sorting method is the most proper solution to the criteria. That’s why the focus in the following is on this solution.
### A.4 Gantt chart

<table>
<thead>
<tr>
<th>RECY-Car</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>CW:</td>
<td>7 8 9 10 11 12 14 15 16 17 18 19 20 21 22 23 24 25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reeding/collecting information (need for next part)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Aim/Goals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepare project scope presentation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Introduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dismanteling a car</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reuse of parts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recycling of materials</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check MT report</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepare MT defence</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benchmark of the competitors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main problem: distinguish the black plastic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Checking/finishing the report</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepare final defence</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Important Dates for the Project

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>18. March</td>
<td>Project Agreement (students&amp;companies)</td>
</tr>
<tr>
<td>27. Apr</td>
<td>Submission midterm report</td>
</tr>
<tr>
<td>3-4. May</td>
<td>Midterm defences</td>
</tr>
<tr>
<td>10. June</td>
<td>Submission Final Report (students to supervisor)</td>
</tr>
<tr>
<td>20-21 June</td>
<td>Final Project Defences</td>
</tr>
</tbody>
</table>
A.5 RACI Matrix

<table>
<thead>
<tr>
<th>TASK DESCRIPTION</th>
<th>Maria Fernanda</th>
<th>Martin K</th>
<th>Andrea Preda</th>
<th>Vincent</th>
<th>Daniel Kelly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reeding/collecting information (need for next part)</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Project Aim/Goals</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Prepare project scope presentation</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Introduction</td>
<td>I</td>
<td>I</td>
<td>R</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td>Dismanteling a car</td>
<td>R</td>
<td>I</td>
<td>I</td>
<td>R</td>
<td>I</td>
</tr>
<tr>
<td>Reuse of parts</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>R</td>
</tr>
<tr>
<td>Recycling of materials</td>
<td>I</td>
<td>R</td>
<td>I</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td>Benchmark of the competitors</td>
<td>I</td>
<td>R</td>
<td>I</td>
<td>R</td>
<td>I</td>
</tr>
<tr>
<td>Check MT report</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Prepare MT defence</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td><strong>Main problem:</strong> distinguish the black plastic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Checking/finishing the report</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Prepare final defence</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
</tbody>
</table>

A.6 WBS Structure

[Diagram of WBS Structure]

- Describe how to dismantle a car at the moment
- Reuse of parts
- Recycling of the materials (for each material):
  - Airbag
  - Battery
  - Tire
- Benchmarking:
  - Market analysis: Competitors of Calaf Group
- Special problem:
  - Separate the black plastic from the other materials
  - Brainstorming (collect solutions)
  - Ranking (to find the best solution)
  - Describe chosen the solution
# A7 Meeting minutes

## EUROPEAN PROJECT SEMESTER – PROJECT MEETINGS

### MEETING MINUTES

<table>
<thead>
<tr>
<th>Project Team:</th>
<th>RACY-CAR PROJECT</th>
<th>Meeting facilitator:</th>
<th>Antonio Sánchez</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of Meeting:</td>
<td>24/02/2016</td>
<td>Time:</td>
<td>11:30-12:15</td>
</tr>
<tr>
<td>Minutes Prepared By:</td>
<td>45 min</td>
<td>Location:</td>
<td>Politechnical University of Vilanova</td>
</tr>
</tbody>
</table>

### 1. Meeting Objective

Weekly meeting

### 2. Attendance at Meeting

<table>
<thead>
<tr>
<th>Name of student</th>
<th>University</th>
</tr>
</thead>
<tbody>
<tr>
<td>María Fernanda Cruz Rodríguez</td>
<td>Tecnologico de Monterrey, campus Mty, Mexico</td>
</tr>
<tr>
<td>Andreea Georgiana Preda</td>
<td>Politehnica University of Bucharest, Romania</td>
</tr>
<tr>
<td>Martin Krapf</td>
<td>University of Applied Sciences and Arts Coburg, Germany</td>
</tr>
<tr>
<td>Daniel Kelly</td>
<td>Institute of Technology Sligo Ireland</td>
</tr>
<tr>
<td>Vincent Bourgue</td>
<td>Ecole Superieure d’Ingenieur de Reims (ESI Reims), France</td>
</tr>
</tbody>
</table>

### 3. Decisions, Issues, Notes

<table>
<thead>
<tr>
<th>Topic</th>
<th>Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>We speak about the best day for weekly meetings.</td>
<td>All</td>
</tr>
<tr>
<td>If we copy something on the internet:</td>
<td>All</td>
</tr>
<tr>
<td>• We make references</td>
<td></td>
</tr>
<tr>
<td>• Use numbers</td>
<td></td>
</tr>
<tr>
<td>• But it’s better from the book -&gt; Bibliography</td>
<td></td>
</tr>
<tr>
<td>If we make our photos in programs, we don’t need references.</td>
<td></td>
</tr>
<tr>
<td>About the dismantle:</td>
<td>Antonio</td>
</tr>
<tr>
<td>• The battery is not recyclable.</td>
<td></td>
</tr>
<tr>
<td>For the Easter we have holidays one week 21-27th March.</td>
<td>Antonio</td>
</tr>
</tbody>
</table>

### 4. Actions

<table>
<thead>
<tr>
<th>Action</th>
<th>Owner</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>We try to find some example for appendixes</td>
<td>All</td>
<td>16.03.2016</td>
</tr>
<tr>
<td>Describe different part of car:</td>
<td>All</td>
<td>02.03.2016</td>
</tr>
<tr>
<td>• Which is recyclable/reused</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Which is not.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 5. Next Meeting
### Project Team: RACY-CAR PROJECT

<table>
<thead>
<tr>
<th>Date of Meeting:</th>
<th>24/02/2016</th>
<th>Time:</th>
<th>11:30-12:15</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Minutes Prepared By:</th>
<th>45 min</th>
<th>Location:</th>
<th>Politechnical University of Vilanova</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Date:</th>
<th>02.03.2016</th>
<th>Time:</th>
<th>14:00</th>
<th>Location:</th>
<th>Politechnical University of Vilanova</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Objective:</th>
<th>Weekly meeting</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Meeting facilitator:</th>
<th>Antonio Sánchez</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Documents to prepare/bring:</th>
<th>Thinking about solution for the black parts.</th>
</tr>
</thead>
</table>
MEETING MINUTES

Project Team: RACY-CAR PROJECT
Meeting facilitator: Antonio Sánchez
Date of Meeting: 02/03/2016
Time: 14:15-14:45
Minutes Prepared By: 30 min
Location: Politecnical University of Vilanova

1. Meeting Objective
Weekly meeting

2. Attendance at Meeting
Name of student                University
María Fernanda Cruz Rodríguez  Tecnologico de Monterrey, campus Mty, Mexico
Andreea Georgiana Preda        Politehnica University of Bucharest, Romania
Martin Krapf                   University of Applied Sciences and Arts Coburg, Germany
Daniel Kelly                   Institute of Technology Sligo Ireland
Vincent Bourgue                Ecole Superieure d’Ingenieur de Reims (ESI Reims), France

Name of supervisors
Antonio Sanchez                UPC Vilanova

3. Decisions, Issues, Notes

<table>
<thead>
<tr>
<th>Topic</th>
<th>Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Go to the company</td>
<td>All</td>
</tr>
<tr>
<td>• Set Appointment with the company: 16/03/2016</td>
<td></td>
</tr>
<tr>
<td>• Take a camera to take many pictures</td>
<td></td>
</tr>
<tr>
<td>• Tell Antonio</td>
<td></td>
</tr>
<tr>
<td>• Ask about the problem</td>
<td></td>
</tr>
<tr>
<td>• Prepare the questions</td>
<td></td>
</tr>
<tr>
<td>Idea to solve the problem:</td>
<td>Antonio</td>
</tr>
<tr>
<td>• Acid creat different pattern of degration =&gt; seperation</td>
<td></td>
</tr>
<tr>
<td>• Don’t tell the company!! (Maybe patent)</td>
<td></td>
</tr>
<tr>
<td>• Collect more informations about it</td>
<td></td>
</tr>
<tr>
<td>Project agreement</td>
<td>Antonio</td>
</tr>
<tr>
<td>• General summary</td>
<td></td>
</tr>
<tr>
<td>• Everyone has to sign</td>
<td></td>
</tr>
<tr>
<td>Report:</td>
<td>Antonio</td>
</tr>
<tr>
<td>• Overview (parts of the car, Separate material, how recycle)</td>
<td></td>
</tr>
<tr>
<td>• Then black plastic thing</td>
<td></td>
</tr>
<tr>
<td>Antonio has knowledge of software</td>
<td>Antonio</td>
</tr>
<tr>
<td>• Catia, Solidworks, NX, LaTex</td>
<td></td>
</tr>
<tr>
<td>• Can show the projectgroup</td>
<td></td>
</tr>
</tbody>
</table>
### Introduction in LaTex
- Texmaker to get Latex
- mikTex to get Packages

### 4. Next Meeting

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>09.03.2016</td>
<td>14:00</td>
<td>University of Vilanova</td>
</tr>
</tbody>
</table>

**Objective:** Presentation of CALAF Company

**Meeting facilitator:** Antonio Sánchez

**Documents to prepare/bring:** Try LaTex
EUROPEAN PROJECT SEMESTER – PROJECT MEETINGS

MEETING MINUTES

<table>
<thead>
<tr>
<th>Project Team:</th>
<th>RACY-CAR PROJECT</th>
<th>Meeting facilitator:</th>
<th>Antonio Sánchez</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of Meeting:</td>
<td>09/03/2016</td>
<td>Time:</td>
<td>10:45-11:15</td>
</tr>
<tr>
<td>Minutes Prepared By:</td>
<td>30 min</td>
<td>Location:</td>
<td>Politecnical University of Vilanova</td>
</tr>
</tbody>
</table>

1. Meeting Objective
Weekly meeting

2. Attendance at Meeting

<table>
<thead>
<tr>
<th>Name of student</th>
<th>University</th>
</tr>
</thead>
<tbody>
<tr>
<td>María Fernanda Cruz Rodríguez</td>
<td>Tecnologico de Monterrey, campus Mty, Mexico</td>
</tr>
<tr>
<td>Andreea Georgiana Preda</td>
<td>Politehnica University of Bucharest, Romania</td>
</tr>
<tr>
<td>Martin Krapf</td>
<td>University of Applied Sciences and Arts Coburg, Germany</td>
</tr>
<tr>
<td>Daniel Kelly</td>
<td>Institute of Technology Sligo Ireland</td>
</tr>
<tr>
<td>Vincent Bourgue</td>
<td>Ecole Superieure d’Ingénieur de Reims (ESI Reims), France</td>
</tr>
</tbody>
</table>

3. Decisions, Issues, Notes

<table>
<thead>
<tr>
<th>Topic</th>
<th>Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Agreement</td>
<td>Antonio</td>
</tr>
<tr>
<td>• Proposal needs to be described better</td>
<td></td>
</tr>
<tr>
<td>• Toni added some things</td>
<td></td>
</tr>
<tr>
<td>• Group has to do:</td>
<td></td>
</tr>
<tr>
<td>• Change the logo</td>
<td></td>
</tr>
<tr>
<td>• Write more to the points 1+2 (about recycling/company)</td>
<td></td>
</tr>
<tr>
<td>• Use “Track changes” in Word</td>
<td></td>
</tr>
<tr>
<td>• Update timeline</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>To distinguish the polymers</th>
<th>Antonio</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Acid</td>
<td></td>
</tr>
<tr>
<td>• Describe</td>
<td></td>
</tr>
<tr>
<td>• Check possibility</td>
<td></td>
</tr>
<tr>
<td>• Which chemical</td>
<td></td>
</tr>
<tr>
<td>• Hot stick</td>
<td></td>
</tr>
<tr>
<td>• Distinguish Thermoplastics and thermostables</td>
<td></td>
</tr>
<tr>
<td>• Temperature?</td>
<td></td>
</tr>
</tbody>
</table>
## Report:
- **State of the Art:**
  - Car parts: which are how recycled
  - How do they dismantle a car
  - Which technologics do they use
- **Later:**
  - Black plastic problem

## Contents of the first presentation to Rodrigo
- **State of the art:**
  - Parts of the car
  - Technologics
  - Benchmark (companies and fields)
  - No solutions for distinguish black plastics

### 4. Actions

<table>
<thead>
<tr>
<th>Action</th>
<th>Owner</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final Version of the Projectagreement (until weekend)</td>
<td>Students</td>
<td>13/03/2013</td>
</tr>
<tr>
<td>Look for a termin with Rodrigo in April</td>
<td>Students</td>
<td>16/03/2016</td>
</tr>
</tbody>
</table>

### 5. Next Meeting

<table>
<thead>
<tr>
<th>Date: 16.03.2016</th>
<th>Time: 9:30</th>
<th>Location: Infront of the University of Vilanova in order to go to Calaf group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objective:</strong></td>
<td>Visit CALAF Company</td>
<td></td>
</tr>
<tr>
<td><strong>Meeting facilitator:</strong> Rodrigo Cabal</td>
<td><strong>Documents to prepare/bring:</strong> Questions to the company Camera</td>
<td></td>
</tr>
</tbody>
</table>

EUROPEAN PROJECT SEMESTER – PROJECT MEETINGS

MEETING MINUTES

<table>
<thead>
<tr>
<th>Project Team:</th>
<th>RACY-CAR PROJECT</th>
<th>Meeting facilitator:</th>
<th>Antonio Sánchez</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of Meeting:</td>
<td>30/03/2016</td>
<td>Time:</td>
<td>12:30-13:30</td>
</tr>
<tr>
<td>Minutes Prepared By:</td>
<td>60 min</td>
<td>Location:</td>
<td>Politechnical University of Vilanova</td>
</tr>
</tbody>
</table>

1. Meeting Objective
   Weekly meeting

2. Attendance at Meeting
   Name of student       | University                          |
   Andreea Georgiana Preda | Politechnica University of Bucharest, Romania |
   Martin Krapf           | University of Applied Sciences and Arts Coburg, Germany |
   Daniel Kelly           | Institute of Technology Sligo Ireland |
   Vincent Bourgue        | Ecole Superieure d’Ingenieur de Reims (ESI Reims), France |

3. Name of supervisors
   Antonio Sanchez       | UPC Vilanova                        |

4. Decisions, Issues, Notes
   Topic                        | Owner |
   Discussing the manuscript   | All   |
   • Antonio sends his comments to the students |
   • First page: Add Logo of the Project |
   • Abstract maybe name as forework |
   • Materials |
   • Point 7 (discussing the basis for a sorting plant) already given in the text before |
   • Point 1 and 2 (introduction, project aim) extend the actual versions: |
     • Why |
     • Market |
     • How much recycled how much landfill |
   • Point 3: Describe step by step (Maria already received a overview) |
   • Point 5 for the Materials |
     • Describe the material |
       • Properties |
       • where/why used |
       • hazards |
       • Way of recycling (maybe find standards) |
     • Where reused |
## Timeline until midterm report/presentation

- **5.4:** 1,2,3 (introduction, project aim, dismantling a car)  
  - Antonio
- **12.4:** 4,5,6 (reuse of parts, recycling of materials, benchmark)  
  - Antonio
- **19.4:** cohesion of the text
- **Midterm report:**
  - 25.4 to Antonio
  - 27.4 final submission

## Timeline after midterm:

- **Black plastic**
- **Improve 1-6**

## Content of the midterm report/presentation

- **Chapters 1-6**
- **Outlook on possible solutions**

## Asking Rodrigo

- **Presentation for Rodrigo 20.4 (1-6)**
- **Asking for the wanted informations in the benchmark**

## Deviding the parts

- **1-2 Introduction + Project Aim**: Andreea
- **3 Dismateling a car**: Maria/Vincent
- **4 Reuse of the parts**: Daniel
- **5 Recycling of the materials**: Martin
- **6 Benchmark**: Vincent/Martin

## Sign Project Agreement for Maria at Neus

- Antonio

### 4. Actions

<table>
<thead>
<tr>
<th>Action</th>
<th>Owner</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Writing the manuscript 1,2,3 (introduction, project aim, dismantling a car)</td>
<td>Students (Andreea, Maria, Vincent)</td>
<td>05/04/2016</td>
</tr>
<tr>
<td>Writing the manuscript 4,5 (reuse of parts, recycling of materials)</td>
<td>Students (Daniel, Martin, Vincent)</td>
<td>12/04/2016</td>
</tr>
<tr>
<td>Sign the project agreement</td>
<td>Maria</td>
<td>asap</td>
</tr>
<tr>
<td>Contact Rodrigo</td>
<td>Antonio</td>
<td>06/04/2016</td>
</tr>
<tr>
<td>1. Set an appointment (20.4)</td>
<td>Antonio</td>
<td>06/04/2016</td>
</tr>
<tr>
<td>2. Asking for the wanted informations in the benchmark</td>
<td>Antonio</td>
<td>06/04/2016</td>
</tr>
<tr>
<td>Sending feedback on the manuscript</td>
<td>Antonio</td>
<td>31/03/2016</td>
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</table>

### 5. Next Meeting

- **Date:** 06.04.2016  
  - **Time:** 12:30  
  - **Location:** Politechnical University of Vilanova
- **Objective:** Weekly meeting
- **Meeting facilitator:** Antonio Sanchez  
  - **Documents to prepare/bring:** Manuscript topics 1,2,3
EUROPEAN PROJECT SEMESTER – PROJECT MEETINGS

MEETING MINUTES

<table>
<thead>
<tr>
<th>Project Team:</th>
<th>RACY-CAR PROJECT</th>
<th>Meeting facilitator:</th>
<th>Antonio Sánchez</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of Meeting:</td>
<td>07/04/2016</td>
<td>Time:</td>
<td>14:15-14:45</td>
</tr>
<tr>
<td>Minutes Prepared By:</td>
<td>30 min</td>
<td>Location:</td>
<td>Politechnical University of Vilanova</td>
</tr>
</tbody>
</table>

1. Meeting Objective
Weekly meeting

2. Attendance at Meeting

<table>
<thead>
<tr>
<th>Name of student</th>
<th>University</th>
</tr>
</thead>
<tbody>
<tr>
<td>María Fernanda Cruz Rodríguez</td>
<td>Tecnologico de Monterrey, campus Mty, Mexico</td>
</tr>
<tr>
<td>Andreea Georgiana Preda</td>
<td>Politehnica University of Bucharest, Romania</td>
</tr>
<tr>
<td>Martin Krapf</td>
<td>University of Applied Sciences and Arts Coburg, Germany</td>
</tr>
<tr>
<td>Daniel Kelly</td>
<td>Institute of Technology Sligo Ireland</td>
</tr>
<tr>
<td>Vincent Bourgue</td>
<td>Ecole Superieure d'Ingénieur de Reims (ESI Reims), France</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name of supervisors</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Antonio Sanchez</td>
<td>UPC Vilanova</td>
</tr>
</tbody>
</table>

3. Decisions, Issues, Notes

<table>
<thead>
<tr>
<th>Topic</th>
<th>Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manuscript:</td>
<td></td>
</tr>
<tr>
<td>• Add to the manuscript:A part between recycling of materials and benchmark (link) with non recycled materials</td>
<td></td>
</tr>
<tr>
<td>• Style:</td>
<td></td>
</tr>
<tr>
<td>• Calibri 11</td>
<td></td>
</tr>
<tr>
<td>• Space between lines: 1.5</td>
<td></td>
</tr>
<tr>
<td>• Set reference; and more in detail</td>
<td></td>
</tr>
<tr>
<td>• Part 3:</td>
<td></td>
</tr>
<tr>
<td>• Add pictures of the parts from a car</td>
<td></td>
</tr>
<tr>
<td>• Sorting:</td>
<td></td>
</tr>
<tr>
<td>• Describe the techniques summary</td>
<td></td>
</tr>
<tr>
<td>• According to the separated materials</td>
<td></td>
</tr>
<tr>
<td>• Table in appendix</td>
<td></td>
</tr>
<tr>
<td>• Use solidworks for charts of the machine (what they can, how they work)</td>
<td></td>
</tr>
<tr>
<td>• Toni sends his coments to the students</td>
<td></td>
</tr>
<tr>
<td>Meeting with Rodrigo</td>
<td>Antonio</td>
</tr>
<tr>
<td>Toni tries to contact Rodrigo again</td>
<td>Antonio</td>
</tr>
<tr>
<td>Midterm defence: 4/5/2016 9:45</td>
<td>Antonio</td>
</tr>
</tbody>
</table>
### 4. Actions

<table>
<thead>
<tr>
<th>Action</th>
<th>Owner</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve the manuscript 1,2,3 (introduction, project aim, dismantling a car)</td>
<td>Students (Andreea, Maria, Vincent)</td>
<td>12/04/2016</td>
</tr>
<tr>
<td>Writing the manuscript 4,5 (reuse of parts, recycling of materials)</td>
<td>Students (Daniel, Martin, Vincent)</td>
<td>12/04/2016</td>
</tr>
<tr>
<td>Contact Rodrigo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Set an appointment (20.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Asking for the wanted informations in the benchmark</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sending feedback on the manuscript</td>
<td>Antonio</td>
<td>07/04/2016</td>
</tr>
</tbody>
</table>

### 5. Next Meeting

- **Date:** 13.04.2016
- **Time:** 12:30
- **Location:** Politecnical University of Vilanova
- **Objective:** Weekly meeting
- **Meeting facilitator:** Antonio Sanchez
- **Documents to prepare/bring:** Manuscript topics 1,2,3,4,5,6,7
EUROPEAN PROJECT SEMESTER – PROJECT MEETINGS

MEETING MINUTES

<table>
<thead>
<tr>
<th>Project Team:</th>
<th>RACY-CAR PROJECT</th>
<th>Meeting facilitator:</th>
<th>Antonio Sánchez</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of Meeting:</td>
<td>14/04/2016</td>
<td>Time:</td>
<td>14:15-15:15</td>
</tr>
<tr>
<td>Minutes Prepared By:</td>
<td>60 min</td>
<td>Location:</td>
<td>Politechnical University of Vilanova</td>
</tr>
</tbody>
</table>

1. Meeting Objective
Weekly meeting

2. Attendance at Meeting

<table>
<thead>
<tr>
<th>Name of student</th>
<th>University</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maria Fernanda Cruz Rodriguez</td>
<td>Tecnologico de Monterrey, campus Mty, Mexico</td>
</tr>
<tr>
<td>Andreea Georgiana Preda</td>
<td>Politehnica University of Bucharest, Romania</td>
</tr>
<tr>
<td>Martin Krapf</td>
<td>University of Applied Sciences and Arts Coburg, Germany</td>
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<tr>
<td>Daniel Kelly</td>
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</table>

3. Decisions, Issues, Notes

<table>
<thead>
<tr>
<th>Topic</th>
<th>Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manuscript:</td>
<td>Antonio</td>
</tr>
<tr>
<td>• No general layout</td>
<td></td>
</tr>
<tr>
<td>• Reference missing</td>
<td></td>
</tr>
<tr>
<td>• Length of introduction is good</td>
<td></td>
</tr>
<tr>
<td>• Recycling the material part:</td>
<td></td>
</tr>
<tr>
<td>• Material part too long</td>
<td></td>
</tr>
<tr>
<td>• Just one page each materia</td>
<td></td>
</tr>
<tr>
<td>• The other things in the appendix</td>
<td></td>
</tr>
<tr>
<td>• Missing parts: Toni also looks for information</td>
<td></td>
</tr>
<tr>
<td>• Dismanteling:</td>
<td></td>
</tr>
<tr>
<td>• Picture of the car after each step</td>
<td></td>
</tr>
<tr>
<td>• Pictures of the main removed parts</td>
<td></td>
</tr>
</tbody>
</table>

- Toni already sent the actual version of the manuscript to Rodrigo and Hernan, to get feedback

- Meeting with Rodrigo
  - Toni tries to contact Rodrigo again

- Draw a sketch for the midterm-report/presentation to describe the chemical solution:
  - Which acid
  - Time of degradation
  - With solidworks/NX, etc.
Midterm presentation:  
More pictures less text (explain pictures)  
Toni asks about the tribunal

Abstract for the final report (One page describing the whole project)

First drawing from the idea

Toni has a printer just in case it is needed

Next meetings:
- next on 21.4.2016 (send the things on 20.4.2016)
- if necessary also on 25.4
- and train the midterm presentation infront of Toni and Hernan to improve for the real one

4. Actions

<table>
<thead>
<tr>
<th>Action</th>
<th>Owner</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read, check and improve the report</td>
<td>3 Students</td>
<td>12/04/2016</td>
</tr>
<tr>
<td>Writing Benchmark, Create sketches of the solution</td>
<td>2 Students</td>
<td>12/04/2016</td>
</tr>
<tr>
<td>Contact Rodrigo</td>
<td>Antonio</td>
<td>06/04/2016</td>
</tr>
<tr>
<td>- Set an appointment (20.4)</td>
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<td></td>
</tr>
<tr>
<td>- Asking for the wanted informations in the benchmark</td>
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5. Next Meeting

<table>
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<tr>
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<th>20.04.2016</th>
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<td>Weekly meeting</td>
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<tr>
<td>Meeting facilitator:</td>
<td>Antonio Sanchez</td>
<td>Documents to prepare/bring:</td>
<td>Manuscript</td>
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## MEETING MINUTES

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<tr>
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<td>75 min</td>
<td>Location:</td>
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### 1. Meeting Objective
Prepare the Presentation for Rodrigo

### 2. Attendance at Meeting

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### 3. Decisions, Issues, Notes

<table>
<thead>
<tr>
<th>Topic</th>
<th>Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presentation</td>
<td>Antonio</td>
</tr>
<tr>
<td>• Bring the structure before each chapter</td>
<td></td>
</tr>
<tr>
<td>• Slide 1: Write midterm</td>
<td></td>
</tr>
<tr>
<td>• Slide 2: Add institution Logos</td>
<td></td>
</tr>
<tr>
<td>• Slide 5:</td>
<td></td>
</tr>
<tr>
<td>• No semicolon</td>
<td></td>
</tr>
<tr>
<td>• Sum up technical solution in short words</td>
<td></td>
</tr>
<tr>
<td>• Slide 6: Mark actual week</td>
<td></td>
</tr>
<tr>
<td>• Slide 7:</td>
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<tr>
<td>• Add reference</td>
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</tr>
<tr>
<td>• Sources at the end</td>
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</tr>
<tr>
<td>• Number of picture is missing</td>
<td></td>
</tr>
<tr>
<td>• Slide 8:</td>
<td></td>
</tr>
<tr>
<td>• And drain</td>
<td></td>
</tr>
<tr>
<td>• Reference</td>
<td></td>
</tr>
<tr>
<td>• Watch out time!</td>
<td></td>
</tr>
<tr>
<td>• Slide 10:</td>
<td></td>
</tr>
<tr>
<td>• Explain why</td>
<td></td>
</tr>
<tr>
<td>• Tech details</td>
<td></td>
</tr>
</tbody>
</table>
- Slide 12:
  - Explain that nowadays sth is impossible
  - Shrinken sorting
  - Be able to explain sorting
  - Chart for general part
  - Then go to plastic (most important)
- Slide 18:
  - What compound (if not possible remove!)
  - Short (no sentences)
  - Reuse how reuse
  - Separate reuse recycling
- Slide 22: change reuse to use of recycled material
- Slide 25-27: Goal slide
  - First idea
    - Explain a little
    - Introduction with the problem

**Meeting with Rodrigo**
- Ask questions
- Ask about benchmark
- Take notes

**Midterm report:**
- Send to Toni 24.4
- Discuss 25.4

**4. Actions**

<table>
<thead>
<tr>
<th>Action</th>
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<td>Students</td>
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**5. Next Meeting**

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<tr>
<td>Tbd</td>
<td>Tbd</td>
<td>Politechnical University of Vilanova</td>
<td>Weekly meeting</td>
</tr>
</tbody>
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**Meeting facilitator:**
- Antonio Sanchez

**Documents to prepare/bring:**
- Presentation, Manuscript
# MEETING MINUTES

## 1. Meeting Objective

Midterm presentation

## 2. Attendance at Meeting

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## 3. Decisions, Issues, Notes

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<tbody>
<tr>
<td>Presentation</td>
<td>Antonio</td>
</tr>
<tr>
<td>• Table of icons link with the presentation</td>
<td></td>
</tr>
<tr>
<td>• Forget presentation at the moment (important: report!!!)</td>
<td></td>
</tr>
<tr>
<td>• Nana wants to change the date of midterm presentation with the team</td>
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</tr>
<tr>
<td>• Toni tries not to change the date</td>
<td></td>
</tr>
<tr>
<td>• Questions which cannot be answered: We didn’t handle it yet, we do it later</td>
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</tr>
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---

**Project Team:** RACY-CAR PROJECT  
**Meeting facilitator:** Antonio Sánchez  
**Date of Meeting:** 25/04/2016  
**Time:** 16:00-17:00  
**Minutes Prepared By:** 60 min  
**Location:** Politechnical University of Vilanova
Report:
- Deadline 27.4 23:59
- Tonis main crtic points are in the mail:
- Section sorting:
  - Introduction:
    - What is sorting
    - In our context
    - What to sort
  - Widely used techniques (explain why)
- Material what cannot be recycled
- Final report should contain 50 pages
- Introduction: Split it into Deliverable, Aim; How to achiev
- Title of the project needs a change
- Abreviation: Fill in or leave out
- Set reference
- Give the pictures a Title
- No empty spaces -> remove empty headlines

4. Actions
<table>
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<tr>
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<tbody>
<tr>
<td>Improve the presentation</td>
<td>Students</td>
<td>02/05/2016</td>
</tr>
<tr>
<td>Send the midterm report</td>
<td>Students</td>
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</thead>
<tbody>
<tr>
<td>3/5/2016</td>
<td>Tbd</td>
<td>Politechnical University of Vilanova</td>
<td>Final check of midterm presentation</td>
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Meeting facilitator: Antonio Sanchez
Documents to prepare/bring: Presentation, Manuscript
MEETING MINUTES

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<tbody>
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<td>Time:</td>
<td>14:00-15:45</td>
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<td>Minutes Prepared By:</td>
<td>105 min</td>
<td>Location:</td>
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</table>

1. Meeting Objective
Midterm presentation

2. Attendance at Meeting

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3. Decisions, Issues, Notes

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<tr>
<td>• He asks Neus for it</td>
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<tr>
<td>Report:</td>
<td></td>
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<td>• Order them like in MT-Presentation (Vincent part after Dan and Martin</td>
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</table>

Antonio
### Appendixes

- Benchmarking
  - Check symbol of tons (\(\rightarrow t\))
  - Tons are sometimes missing in the BM
  - Introduction missing
  - Why: Find out quantity of black plastic
  - No separation between glass/plastic

- Summary
  - Abstract
  - Who are we working with
  - What problem
  - What solution

- Appendix:
  - One layout

### Article:

- 4-6 pages
- \(\Rightarrow\) shrink manuscript to a few pages
- Toni already sent a template
- Use only own images
- Abstract:
  - 300-350 words
- Introduction:
  - In the end: focus on this article
- Methodology
- Criteria for choice
- Dismanteling
- Benchmarketing
- Results
  - Market analysis
  - Tech. solution
- Conclusion:
  - Feasible
  - Market analysis
  - Cost

### Poster:

- Toni asks for template
- If there is no, he creates a template
- Pictures only some text
- Background: Only white (not the best printer)

Rodrigo maybe set an appointment to visit a dismanteling company

How to continue: Devide Tasks:
- 1 starts with article
- 3 summary for the solution
- 1 organise Benchmarketing/report

#### 4. Actions
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5. Next Meeting

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EUROPEAN PROJECT SEMESTER – PROJECT MEETINGS

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How to continue: Devide Tasks:
- 1 starts with article
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| Meeting facilitator: | Antonio Sanchez | Documents to prepare/bring: | Manuscript |

LXXXIX
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<td>• Toni didn’t receive answer</td>
<td></td>
</tr>
<tr>
<td>• Delia took some notes and ask Neus on the 18th</td>
<td></td>
</tr>
<tr>
<td>• Template for article/poster</td>
<td>Antonio</td>
</tr>
<tr>
<td>• Midterm feedback</td>
<td></td>
</tr>
<tr>
<td>• Final grade(</td>
<td></td>
</tr>
<tr>
<td>• Who grades</td>
<td></td>
</tr>
<tr>
<td>• How is the grade</td>
<td></td>
</tr>
<tr>
<td>• Weight factors</td>
<td></td>
</tr>
</tbody>
</table>

| Final presentation     |                                 |
| • Preferred date: Second day in the morning | |
| • Toni tries to get this date   | |
| • Midterm presentation was too long | |
| • Less research in the final | |
| • Training:               |                                 |
| • First try 14th of June  |                                 |
| • With Rodrigo 17th of June |                                |

| Article                |                                 |
|• Benchmark             |                                 |
|• Sorting               |                                 |
### Report:
- Benchmark
- Money part is missing
- Category sales is confusing
- Also use the data from Rodrigo
- Add PICVISA
- Maybe possible to combine PICVISA machine with electrostatic solution (two steps)
- Calculate more the black plastic market in total in Europe
- Calculate also budget for the machine (appendix)

### ECO-Design assignments maybe as appendix

### 4. Actions

<table>
<thead>
<tr>
<th>Action</th>
<th>Owner</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ask for feedback of Midterm</td>
<td>Toni</td>
<td>02/05/2016</td>
</tr>
<tr>
<td>Continue report</td>
<td>Students</td>
<td>16/05/2016</td>
</tr>
</tbody>
</table>

### 5. Next Meeting

<table>
<thead>
<tr>
<th>Date:</th>
<th>Time:</th>
<th>Location:</th>
<th>Objective:</th>
<th>Meeting facilitator:</th>
<th>Documents to prepare/bring:</th>
</tr>
</thead>
<tbody>
<tr>
<td>24/5/2016</td>
<td>14:00</td>
<td>Politechnical University of Vilanova</td>
<td>Weekly meeting</td>
<td>Antonio Sanchez</td>
<td>Manuscript</td>
</tr>
</tbody>
</table>
EUROPEAN PROJECT SEMESTER – PROJECT MEETINGS

MEETING MINUTES

<table>
<thead>
<tr>
<th>Project Team:</th>
<th>RACY-CAR PROJECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meeting facilitator:</td>
<td>Antonio Sánchez</td>
</tr>
<tr>
<td>Date of Meeting:</td>
<td>24/05/2016</td>
</tr>
<tr>
<td>Time:</td>
<td>14:00-15:00</td>
</tr>
<tr>
<td>Minutes Prepared By:</td>
<td>60 min</td>
</tr>
<tr>
<td>Location:</td>
<td>Politechnical University of Vilanova</td>
</tr>
</tbody>
</table>

1. Meeting Objective

Weekly meeting

2. Attendance at Meeting

<table>
<thead>
<tr>
<th>Name of student</th>
<th>University</th>
</tr>
</thead>
<tbody>
<tr>
<td>María Fernanda Cruz Rodríguez</td>
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<tr>
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</tr>
<tr>
<td>Daniel Kelly</td>
<td>Institute of Technology Sligo Ireland</td>
</tr>
</tbody>
</table>

3. Decisions, Issues, Notes

<table>
<thead>
<tr>
<th>Topic</th>
<th>Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questions to Neus (from Toni)</td>
<td>Antonio</td>
</tr>
<tr>
<td>• Do students first have to pay for printing or do they first get the money</td>
<td></td>
</tr>
<tr>
<td>• If the article will be published</td>
<td></td>
</tr>
<tr>
<td>Final presentation</td>
<td></td>
</tr>
<tr>
<td>• Meeting with Rodrigo 14th June</td>
<td></td>
</tr>
<tr>
<td>• Final rehearsal 17th June</td>
<td></td>
</tr>
<tr>
<td>Article</td>
<td></td>
</tr>
<tr>
<td>• 4-5 pages</td>
<td></td>
</tr>
<tr>
<td>• Thinking of title</td>
<td></td>
</tr>
<tr>
<td>• Team-members and supervisors</td>
<td></td>
</tr>
<tr>
<td>• Abstract: Summary</td>
<td></td>
</tr>
<tr>
<td>• Introduction: Sorting technique, how to improve the technique, final purpose: market analysis -&gt; new idea</td>
<td></td>
</tr>
<tr>
<td>• Methods</td>
<td></td>
</tr>
<tr>
<td>• Results</td>
<td></td>
</tr>
<tr>
<td>• Conclusion</td>
<td></td>
</tr>
<tr>
<td>• Acknowledgement</td>
<td></td>
</tr>
</tbody>
</table>
### Appendixes

<table>
<thead>
<tr>
<th>Report:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Benchmark: Mark the point of the material which needs to be recycle</td>
</tr>
<tr>
<td>• Appendix as big headline</td>
</tr>
<tr>
<td>• Acknowledgement:</td>
</tr>
<tr>
<td>• People who contribute without taking benefit</td>
</tr>
<tr>
<td>• People at home</td>
</tr>
<tr>
<td>• Organisation which pay for the students (Erasmus)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rodrigo</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Toni send the actual version (24.5) to Rodrigo</td>
</tr>
<tr>
<td>• Rodrigo will come next week or the following</td>
</tr>
<tr>
<td>• Will visit the final presentation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Video</th>
</tr>
</thead>
<tbody>
<tr>
<td>• What feelings about EPS</td>
</tr>
<tr>
<td>• What was good</td>
</tr>
<tr>
<td>• What would you improve</td>
</tr>
</tbody>
</table>

#### 4. Actions

<table>
<thead>
<tr>
<th>Action</th>
<th>Owner</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ask Neus</td>
<td>Toni</td>
<td>02/05/2016</td>
</tr>
<tr>
<td>Continue report</td>
<td>Students</td>
<td>16/05/2016</td>
</tr>
<tr>
<td>Start Article, Poster</td>
<td>Students</td>
<td>24/05/2016</td>
</tr>
</tbody>
</table>

#### 5. Next Meeting

<table>
<thead>
<tr>
<th>Date:</th>
<th>Time:</th>
<th>Location:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tbd</td>
<td>Tbd</td>
<td>Politechnical University of Vilanova</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective:</th>
<th>Documents to prepare/bring:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekly meeting</td>
<td>Manuscript</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Meeting facilitator:</th>
<th>Antonio Sanchez</th>
</tr>
</thead>
</table>
# MEETING MINUTES

<table>
<thead>
<tr>
<th>Project Team:</th>
<th>RACY-CAR PROJECT</th>
<th>Meeting facilitator:</th>
<th>Rodrigo Cabal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of Meeting:</td>
<td>26.02.2016</td>
<td>Time:</td>
<td>12:30-14:00</td>
</tr>
<tr>
<td>Minutes Prepared By:</td>
<td>90 min</td>
<td>Location:</td>
<td>Politecnical University of Vilanova</td>
</tr>
</tbody>
</table>

## 1. Meeting Objective
First meeting with the company

## 2. Attendance at Meeting

<table>
<thead>
<tr>
<th>Name of student</th>
<th>University</th>
</tr>
</thead>
<tbody>
<tr>
<td>María Fernanda Cruz Rodríguez</td>
<td>Tecnologico de Monterrey, campus Mty, Mexico</td>
</tr>
<tr>
<td>Martin Krapf</td>
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</tr>
<tr>
<td>Vincent Bourgue</td>
<td>Ecole Superieure d’Ingénieur de Reims (ESI Reims), France</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name of supervisors</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Antonio Sánchez</td>
<td>UPC Vilanova</td>
</tr>
<tr>
<td>Hernán González</td>
<td>UPC Vilanoca</td>
</tr>
<tr>
<td>Rodrigo Cabal</td>
<td>Calaf Group</td>
</tr>
</tbody>
</table>

## 3. Decisions, Issues, Notes

<table>
<thead>
<tr>
<th>Topic</th>
<th>Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduce himself:</td>
<td>All</td>
</tr>
<tr>
<td>● Students and supervisors introduce themselves</td>
<td></td>
</tr>
<tr>
<td>● Rodrigo Cabal Introduces himself:</td>
<td></td>
</tr>
<tr>
<td>● Subcontractor, not Management</td>
<td></td>
</tr>
<tr>
<td>About the project:</td>
<td>Rodrigo Cabal</td>
</tr>
<tr>
<td>● Aims of the project (view of the company):</td>
<td></td>
</tr>
<tr>
<td>● Study the market</td>
<td></td>
</tr>
<tr>
<td>● Analysing the machines</td>
<td></td>
</tr>
<tr>
<td>● How to introduce a technic to a market</td>
<td></td>
</tr>
<tr>
<td>● Maybe: analys how machines match in other client places</td>
<td></td>
</tr>
<tr>
<td>● Work for a Subcompany of the calaf grup (Picavision)</td>
<td></td>
</tr>
</tbody>
</table>
### About the company:

- In the south of Barcelona
- Got the name from the town
- 3 sectors
  - Construction
  - Industrial company
  - Service
- Family company (contradista)
- Numbers:
  - Equity capital: 28.5 M €
  - Employees: 352
  - Turnover: 82 M €
- Investment only in Engineering (no football-club or other sponsoring)
- 5.-6. Biggest construction company in Catalunya

### Questions to the company

- Starting point:
  - Market studies, how do they today
  - Machine vision (Sensor based sorting)
  - Later: The challenge with the black plastic
- Techniques which are available in the market:
  - Infrared NIR-Sectrum
  - SWIR
  - LIR
  - Color-machine
  - Ultraviolett
- Competitors
  - Glas: Redware (Aut), MSS (US), binder+co (Aut), s+s (Ger), titech (Ger), RTT steinert (Ger)
  - Plastic: TITEC, MSS, RTT, binder, redwave, Pellenc (Fra)

### 4. Actions

<table>
<thead>
<tr>
<th>Action</th>
<th>Owner</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Send a mail to Rodrigo (Mail adress exchange)</td>
<td>Students</td>
<td>28/02/2016</td>
</tr>
<tr>
<td>Look for a date to go to the company</td>
<td>Students, Antonio; Hernan</td>
<td>31/02/2016</td>
</tr>
<tr>
<td>Send informations about the company</td>
<td>Rodrigo</td>
<td>28/02/2016</td>
</tr>
<tr>
<td>Find a rhythm of the meetings with the company (how often a month)</td>
<td>All</td>
<td>31/02/2016</td>
</tr>
</tbody>
</table>

### 5. Next Meeting

<table>
<thead>
<tr>
<th>Date: 16/03/2016</th>
<th>Time: 9:30</th>
<th>Location: Calaf Group, Barcelona</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective: Visit the Company</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Meeting facilitator: Rodrigo Cabal | Documents to prepare/bring: Camera, Questions to the company |
EUROPEAN PROJECT SEMESTER – PROJECT MEETINGS

MEETING MINUTES

<table>
<thead>
<tr>
<th>Project Team:</th>
<th>Meeting facilitator:</th>
<th>RACY-CAR PROJECT</th>
<th>Rodrigo Cabal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of Meeting:</td>
<td>Time:</td>
<td>20.04.2016</td>
<td>9:30-11:00</td>
</tr>
<tr>
<td>Minutes Prepared By:</td>
<td>Location:</td>
<td>90 min</td>
<td>Politechnical University of Vilanova</td>
</tr>
</tbody>
</table>

1. Meeting Objective
Show the midterm presentation to the company

2. Attendance at Meeting

<table>
<thead>
<tr>
<th>Name of student</th>
<th>University</th>
</tr>
</thead>
<tbody>
<tr>
<td>María Fernanda Cruz Rodríguez</td>
<td>Tecnologico de Monterrey, campus Mty, Mexico</td>
</tr>
<tr>
<td>Andreea Georgiana Preda</td>
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<tr>
<td>Rodrigo Cabal</td>
<td>Calaf Group</td>
</tr>
</tbody>
</table>

3. Decisions, Issues, Notes

<table>
<thead>
<tr>
<th>Topic</th>
<th>Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Things to improve for the presentation</td>
<td>All</td>
</tr>
<tr>
<td>• Andreea</td>
<td></td>
</tr>
<tr>
<td>• Names in the first slice</td>
<td></td>
</tr>
<tr>
<td>• Background is necessary to introduce better the end of live cars.</td>
<td></td>
</tr>
<tr>
<td>• Add the date of quantity recycle parts.</td>
<td></td>
</tr>
<tr>
<td>• Headline in project aim.</td>
<td></td>
</tr>
<tr>
<td>• Tools: few word of main function.</td>
<td></td>
</tr>
<tr>
<td>• Fernanda</td>
<td></td>
</tr>
<tr>
<td>• 24 million worldwide (9.5 million in Europe), which date?? How many cars are in the world??</td>
<td></td>
</tr>
<tr>
<td>• Format 2nd slice.</td>
<td></td>
</tr>
<tr>
<td>• 100Kg over 1T.</td>
<td></td>
</tr>
<tr>
<td>• Introduce that latter all those pieces will be reused, reselled or recycled.</td>
<td></td>
</tr>
<tr>
<td>• How is dismantle a car?? By hand?? with machines?? Need backup information.</td>
<td></td>
</tr>
<tr>
<td>• Try to add technical info about press and shredder machines.</td>
<td></td>
</tr>
</tbody>
</table>
• Vincent
  • Format and logo of presentation in all the slices.
  • Introduce better why are we focusing in plastic.
  • Plastic technology will help if you add some pictures to the different technology
  • Add the electromagnetic spectrum. SWAR technology.
  • Need to back up the answer of why you choose one technology.
  • Try to sum up when present because of the time.
  • Just focus in the choose technologies to detect black plastic.
• Daniel
  • It will be interesting to show how many part are reuse per year in general and if it is possible per each part. Need to detail in which year.
  • Reselling??? Quantity???.
• Martin
  • Remember to add references to back up your statements.
  • In main figure add the recycling material in term of percentages about car.
  • When talking about the different material will be nice to add the percentage of this material in the car.
  • Format metal: Hazard.
  • Format in glass.
• First Idea: Andrea
  • Need to be explained clear the steps: surface pattern by a chemical degradation.
  • Future idea will be proposed.
  • A 3D diagram will be self-explanatory.
• Maria Liluia MasPOCH: CCP research center.
• All:
  • Need to add future work.
  • Have a look the format reference.

4. Actions

<table>
<thead>
<tr>
<th>Action</th>
<th>Owner</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve the presentation with the feedback</td>
<td>Students</td>
<td>25/04/2016</td>
</tr>
</tbody>
</table>

5. Next Meeting

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Location</th>
<th>Document to prepare/bring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tbd</td>
<td>Tbd</td>
<td>Tbd</td>
<td>tbd</td>
</tr>
</tbody>
</table>

Meeting facilitator: Rodrigo Cabal
# EUROPEAN PROJECT SEMESTER – PROJECT MEETINGS

## MEETING MINUTES

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<th>Project Team:</th>
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<th>Meeting facilitator:</th>
<th>Antonio Sánchez</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of Meeting:</td>
<td>06/02/2016</td>
<td>Time:</td>
<td>11:10-11:40</td>
</tr>
<tr>
<td>Minutes Prepared By:</td>
<td>30 min</td>
<td>Location:</td>
<td>Politechnical University of Vilanova</td>
</tr>
</tbody>
</table>

### 1. Meeting Objective

Weekly meeting

### 2. Attendance at Meeting

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</tbody>
</table>

### 3. Decisions, Issues, Notes

#### Topic

<table>
<thead>
<tr>
<th>Final evaluation of the team member</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toni suggestion:</td>
</tr>
<tr>
<td>Every team member grades the others privately</td>
</tr>
<tr>
<td>Each member comes to his office alone</td>
</tr>
<tr>
<td>Until 10th of June</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D- sketches still missing</td>
</tr>
<tr>
<td>Review necessary</td>
</tr>
<tr>
<td>Final rehearsal 17th</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Article</th>
</tr>
</thead>
<tbody>
<tr>
<td>3rd language</td>
</tr>
<tr>
<td>Abstract:</td>
</tr>
<tr>
<td>250 words</td>
</tr>
<tr>
<td>About the project</td>
</tr>
<tr>
<td>How to achieve the goals</td>
</tr>
<tr>
<td>No personal situation</td>
</tr>
<tr>
<td>Introduction</td>
</tr>
<tr>
<td>Not our situation</td>
</tr>
<tr>
<td>Final what finally brought to market</td>
</tr>
</tbody>
</table>

| Poster shorter than the article   |

<table>
<thead>
<tr>
<th>Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antonio</td>
</tr>
</tbody>
</table>

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<tbody>
<tr>
<td>Antonio</td>
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<thead>
<tr>
<th>Action</th>
<th>Owner</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review report</td>
<td>Students</td>
<td>07/06/2016</td>
</tr>
<tr>
<td>Add 3d sketches</td>
<td>Students</td>
<td>07/06/2016</td>
</tr>
<tr>
<td>Article, Poster</td>
<td>Students</td>
<td>07/06/2016</td>
</tr>
</tbody>
</table>

5. Next Meeting

| Date:            | 07/06/2016 | Time: | 12:30 | Location: | Politechnical University of Vilanova |
|------------------|------------|-------|-------|-----------|
| Objective:       | Weekly meeting |       |       |           |
| Meeting facilitator: | Antonio Sanchez | Documents to prepare/bring: | Manuscript, Poster, Article |