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IMPROVING PLASTIC WASTE MANAGEMENT SYSTEM IN THE AUTOMOTIVE INDUSTRY

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DESCRIPTION

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Abstract

The main goals of the thesis were defined as the analysis of the environmental impact of the automotive company in the field of waste management and developing proposals for improving plastic waste management system. Current study is concentrated only on plastic waste to make the study results as concrete and achievable as possible.

Today, to make lighter weight and more economical vehicles, plastics are replacing many metal components in automotive industry. In order to achieve the targets of the company´s Green Program, such as waste reduction, it is necessary to increase the plastic recycling rates.

Information in the thesis is gathered in the form of literature review. Literature review is descriptive method based on the EU experience and Finnish achievements. A company level waste management system is described according to the knowledge which was gained during the practical training of the author. In the thesis are discussed three possible scenarios for the automotive company at the moment based on information synthetics. Furthermore, to make them more tangible and achievable analyzing of scenarios is conducted by technical and economic assessment. In agreement with received results, recommendations for improving waste management system were developed.

This thesis showed that there are ways by which the company can control generated plastic waste and get profit from the measures.

Subject headings, (keywords)

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OOO "Automotive company X"

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1 INTRODUCTION

The topic of the thesis is based on the actual need to develop proposals based on the European Union experience for improving waste management system in the automotive industry and using as a case manufacturing company OOO “Automotive Company X”.

The conditions around the topic on the waste management in the automotive industry are seen actual, as, first, despite the wide range of research and the large number of studies in the field of cleaner production, the problem of disposal and waste recycling in the automotive industry remains relevant so far. Second, even if there are quite a number of new technological solutions, the understanding of the problem is determined by an increase in the level of education and the accumulation of industrial waste. Efforts of countries outside Russia are aimed primarily at the prevention and waste minimization and then at reuse, recycling, recover and the development of effective methods of final treatment, and the waste disposal that do not pollute the environment. It would be more eco-efficient to prevent the generation of waste from the stage of production. This can be achieved through the development and implementation of sustainable use of natural resources and the allocation of valuable components from by-products and waste. The waste management approach today is to avoid deposition of a material as long as possible.

The waste management topic of the automotive industry in the city of St. Petersburg and in the Leningrad region is emerging as the industry is rapidly developing from the economic point of view. Every year the number of plants is increasing and consequently the waste, which needs more efficient recycling, is increasing as well. Solely in St. Petersburg and the Leningrad region are about 9 relatively new automotive plants: Toyota, General Motors, Nissan, Ford, Hyundai, Scania, Fiat, Navistar International, Yarovit Motors. The case company OOO “Automotive Company X” generates annually about 9400 tons of waste. Among this waste a liberal share falls on plastic waste.

Today, to make lighter weight and more economical vehicles, plastics are replacing many metal components in automotive industry. In order to achieve the targets of the company´s Green Program, such as waste reduction, it is necessary to increase the plastic recycling rates. The main goals of the thesis have been defined as the analysis of the environmental impact of the “Automotive Company X” in the field of waste management and developing proposals for improving plastic waste management system.

The main objectives of the thesis are as follows:

- Analysis of the environmental aspects at the “Automotive Company X”.
- Analysis of plastic application in the automotive industry in general and using the case company.
- Considering possible ways of plastic recycling based on the European experience.
- To identify measures of improving plastic waste management of the company and their economical assessment.

This thesis is to help identify better ways of improving waste management system of the OOO “Automotive company X” environmentally and economically. Current study is concentrated only on plastic waste to make the study results as concrete and achievable as possible.

The characteristics of the literature sources are the internet, documentation of the company such as Waste generation standard and disposal limits, Environmental Management System and waste management monthly reports; technical reports on international research on plastic waste recycling, press releases on recycling, findings of research centers and pilot projects. This is because the newest possible information and the most relevant information should be adapted in the case company´s situation.

Today it is not so complicated to find information about plastic content of vehicle in general level. The major drawback of study was to find information about what kind of plastics waste are generated especially by the case manufacturing company OOO “Automotive Company X” and what is proportion of plastic waste in rejected car`s parts. Due to the fact that plastic waste is included as mixed garbage except polyethylene and polystyrene, there is no statistical data what kind of plastics is disposed in the case manufacturing company.

The second drawback is that it is difficult to compare experiences in plastic waste management from automotive industry as there is no special legislation or guidance relating to end-of-life vehicles (ELV) in Russia. Although in St. Petersburg exist special organizations for recycling of ELV, they operate only in metal recycling. If the company tends to achieve zero landfill waste, it has to take into consideration plastic waste as well.

The last drawback is that there is no information about waste plastic management of the analogue automotive company in Finland. The Valmet Automotive Oy is the only company that specializes on car assembly and located in Uusikaupunki, Finland. Amount of generated waste and ways of waste management is confidential information of the company. The same situation concerns, most obviously, when any other company outside the Automotive Company X corporation would have been selected. Because of the practical training period in the Automotive Company X, the access to the information was easier for the author than for an external researcher who has no contact with the company. The information which is presented in the thesis is confidential information of the Automotive Company X. Therefore, the real name of the company cannot be published.

2 METHODOLOGY

In this thesis the methodology consists of several parts, which are tightened together. Information is gathered in the form of literature review. Literature review is descriptive method based on the EU experience and Finnish achievements. A company level waste management system is described according to the knowledge which was gained during the practical training of the author. Throughout the thesis will be applied methods of analysis and comparison of gathered information in order to identify better ways of improving waste management system. Furthermore, to make them more tangible and achievable several scenarios will be considered based on information synthetics. Analyzing of scenarios will be conducted by technical and economic assessment. In agreement with received results, recommendations for improving waste management system will be developed.

3 BASICS OF CAR PRODUCTION AND A CASE COMPANY OOO “AUTOMOTIVE COMPANY X”

In this chapter will be presented general characteristics of the Automotive Company X, the environmental policy of the company, company`s Green Program, company´s waste management system and environmental aspects in waste management, in order to show that plastic waste is issue that has to be studied.

3.1 General description of the company

Automotive Company X was founded in 2009. The main activity of the company is assembly and production of 50 000 cars per year (200 cars/day, 10 cars/h).

Assembly is effected from component parts delivered to the facility by motor transport. Manufacturing process includes delivery of component parts and materials to the logistics, body assembly in body shop, body painting and plastic parts painting in paint shop, cars' final assembly in trim & chassis shop and car testing. The main steps of manufacturing process are shown in figure 1.

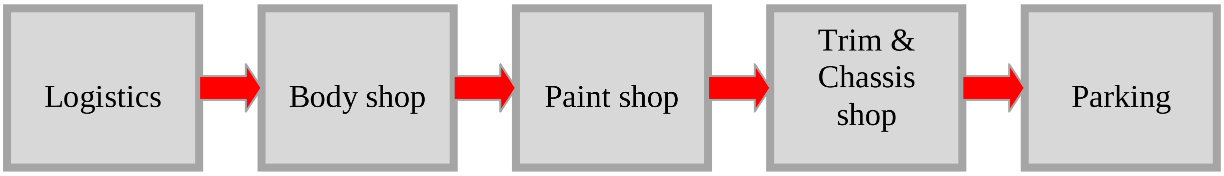

FIGURE 1. Manufacturing process scheme

Operating regime of the company:

- Working days – 250 annually
- Operating regime – three shifts
- Operating shift – 8 hours
- Working hours – 40 hours/week

The company has introduced environmental management system and total quality management system. The company is certified according to international standards ISO 14001 and ISO 9001.

The company does not have its own waste storage or waste disposal facilities. Temporary waste storage sites are arranged on the company's territory. There is a stuff restaurant with an external catering on the territory of the Automotive Company X. The catering company is responsible for the waste management of the restaurant. In the Automotive Company X there is also a medical center, which is operated by an external service provider. The medical center is responsible for its own wastes. (Waste generation standard and disposal limits of the Automotive Company X 2010.)

3.2 Green program of the Automotive Company X

The company has created a medium-term environmental development plan - the so called Green Program which is based on the company's environmental philosophy: symbiosis of people, vehicles and nature. This program ensures that environmental action plans are formulated, that targets and aims associated with the environment are set both for mid-term and for long-term and that every possible effort is made to achieve sustainable improvement goals. The main points of the program are reduction of CO_2 emissions, reduction of harmful impact to the atmosphere, water and soil. Waste management is based on principle of 3Rs: reduce, reuse and recycle. The program follows in waste management so called “zero landfill policy”. The goal is to reduce the amount of waste from their production factories by 2% annually in Japan and by 1% annually worldwide (Environmental policy of the Automotive Company X 2013). The zero landfill policy is originated from the corporation level policy of the company headquarters in Japan. This is why problem is urgent for the Automotive Company X too.

To reach the zero waste goal, the company has to get things running at peak efficiency. Everything the company purchases gets used, everything the company uses is to get used efficiently, and anything left over is still to be used somewhere else. It can sound like a great deal of work, but it can also generate a lot of savings. This policy isn't just about "getting green”, it's a money-saving technique that focuses on cost efficiency, process efficiency, working culture efficiency, and material efficiency. The more waste the company produces, the more the company has to pay for disposal or treatment. The company that produces zero waste pays nothing for waste treatment and minimizes the money to be spent on raw materials. As an extra bonus fewer vehicles shipping waste means a lower carbon footprint and less air emissions. A car production process can still produce some kind of waste (for example scrap metal), but nothing of it can get placed to a landfill. Instead, the zero-landfill company sends the scrap metal to another business that transforms the scrap metal into another product. A great example of this is Volkswagen's Pallet Project which donates used and damaged wooden pallets to community organizations which use them onward for community gardens, student art projects, and inexpensive construction products (Sobolewski 2010).

3.3 Identification of the company´s environmental aspects

According to the ISO 14001 Chapter 3. § 3.6, environmental aspect is an element of an organization's activities or products or services that can interact with the environment (ISO 14001: 2004). Operations may have many environmental aspects, but they may not all be significant.
Assessing the significance of the environmental aspects should be carried out according to certain criteria. The ISO 14004 offers, as an example of significance, a test to use the scale of impacts, the severity of the consequences of impact, the likelihood of occurrence and duration of impact as well as some business factors, such as the cost of reducing the impact, legal lia-

bility, opinion of the stakeholders, the influence on the public image of organization and some others (ISO 14004: 2004).

There are a fairly large number of methods that can be used to evaluate the significance of environmental aspects. However, there is not any universal or preferable method. Therefore, each organization chooses the method that would meet the case of its activity to advantage. It is important that the chosen method should be documented and is not subjected to frequent changes.

The Automotive Company X has their own method to identify significant environmental aspects. Currently, to determine the significance of an environmental aspect of the company, the following procedure is used.

Factor of significance (FS) of each permanent environmental aspect is calculated as follows:

$$FS = P_i \times I_i$$

where P_i is the power of influence of environmental aspect on the environment.

I_i – the intensity of influence of the environmental aspect on the environment.

Factor of significance (FS) of each risk environmental aspect is calculated as follows:

$$FS = EA_p \times I_i$$

where EA_p is the environmental aspect probability.

I_i – the intensity of influence of the environmental aspect on the environment. (Register of significant environmental aspects of the Automotive Company X 2009.)

Existing environmental aspects of the company relating to waste management and current situation of waste management are presented in Appendix 1.

The table shows that the most significant environmental aspects has 12 points and have to be supported by measures for waste reduction, programs, procedure for managing the measure and monitoring. Among significant aspects are risk of generating car parts waste (no metal waste), risk of generating expired chemical materials (paintwork materials, glue, resin, sealant, coagulants etc.), generation of paint slurry and generation of phosphate sludge. Figure 2 represents waste that is disposed to the landfill.

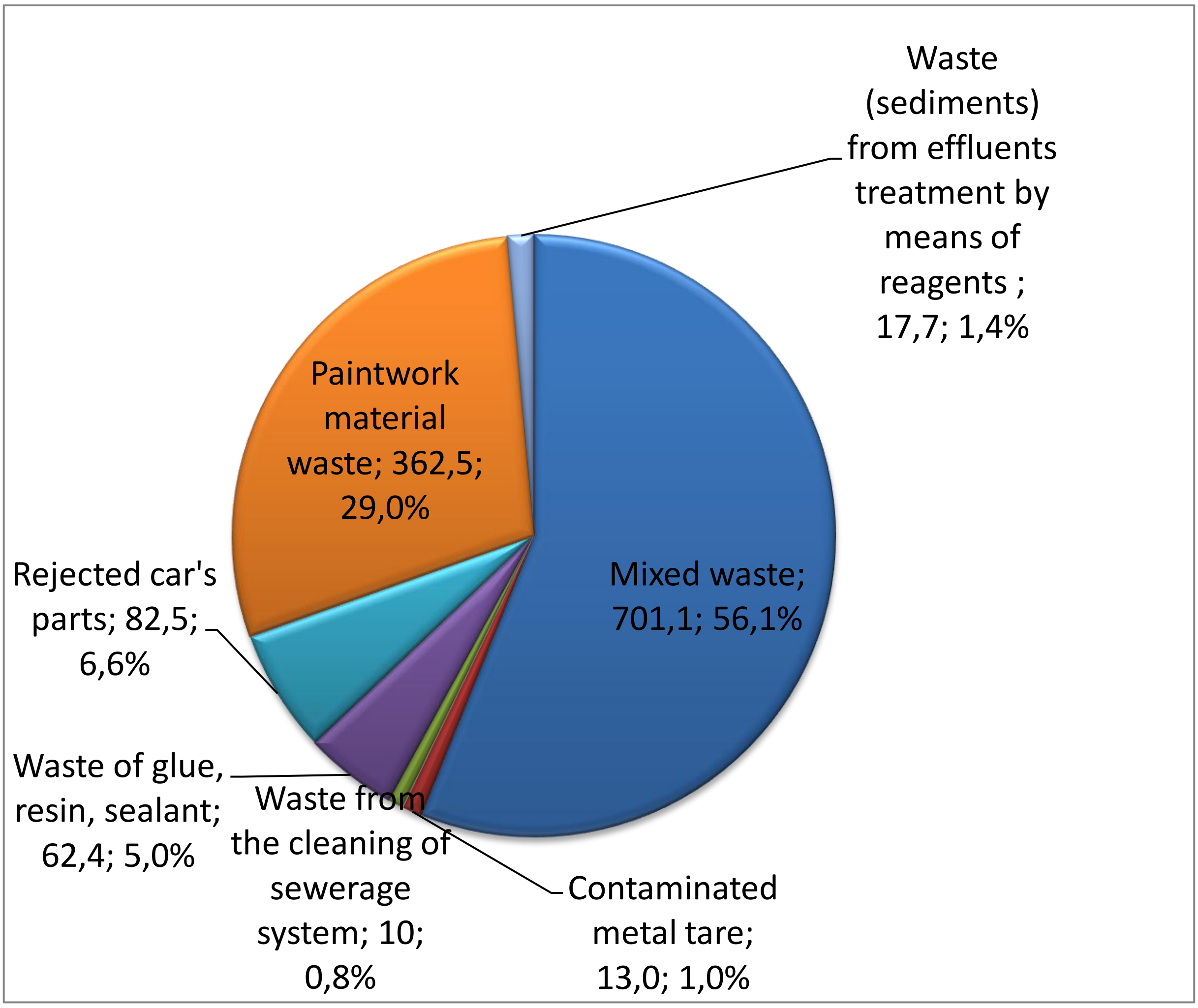

FIGURE 2. Analysis of total amount of waste disposal

The analysis of waste generated shows that a huge amount of waste the company disposes to the landfill is mixed waste (56 %, 701 t/year), e.g. unsorted waste from domestic compartment, contaminated polymer packaging, waste of plywood processing containing binding resin, contaminated metal containers, waste of heterogeneous mixture of solidified plastics, polluted paper bags, wooden packaging (non-returnable containers) made of natural wood (150 t/year), uncontaminated broken glass etc. The next biggest group of waste is paint sludge (29%, 363 t/year). The hazardous wastes are those of chemical waste water treatment, waste of sealants and mastics. The big part of waste belongs to rejected car parts. It is also an issue in waste management that has to be discussed.

4 LITERATURE REVIEW

The chapter will be based on literature review of plastic waste management in the European Union. In order to improve the plastic waste management in the automotive industry it could be reasonable to consider the integrated concept of the EU in waste management, analyze the most common plastics that are used by the field and turned into waste by manufacturing processes. Basics of plastic waste recycling processes will be studied.

Waste management has raised much in recent years. In connection with the study in automotive industry it can be said that the European Union for example has set up some laws to control waste generated in end-of-life vehicles. By example of Finland, as an EU country, will be considered the concept of ELVs and major Finnish companies of plastic waste recycling.

4.1 European benchmarking

Waste management is strictly controlled both on the level of European Union (EU) and on the level of EU member states. The concepts of waste management in the EU are carried out mainly on the basis of EU directives, regulations, instructions and decisions that create a binding legal framework for all EU member states. The main strategic objectives in the field of waste management in the EU are reduction of waste volume by preventing their formation in the process of production, the use of waste in the production process, separation of specific fractions from the waste stream for subsequent use as recoverable material and energy resources, minimization of waste disposed to the landfills.

EU policy on waste management is embodied in the Waste Framework Directive 2006/12/EC. The basic principles of waste management in the EU can be classified as follows:

1. The principle of using a hierarchical order in waste management. Whereas the first option is specified as “reduction of waste at the source to reduce the negative impact on the environment”, the least acceptable option is “waste disposal to the landfills”.
2. The principle of self-sufficiency of the EU member states for recycling and disposal of waste in their country which consists in the fact that any generated waste must be utilized and disposed of in the country where they were formed and not exported to other countries.
3. The principle of the BAT implementation in the enterprises for recycling and waste disposal.

4. The principle of companies (equipment) for recycling and disposal of waste being as close as possible to waste sources.
5. The principle of anticipating measures for prevention of risks to the environment.
6. The principle of producer responsibility, that is, manufacturers of products must be involved in the entire chain of the life cycle of their products including the final stage, that is, the stage of transformation products into waste and taking measures for the collection and utilization of their products that have become a waste.
7. The principle that "the polluter pays" which consists of the fact that the business entities (including producers) responsible for the waste generation are required to cover the costs of recycling and waste disposal. In accordance with the principle, the cost of disposing of waste must be borne by the holder who has waste handled by a waste collector or by undertaking; or by the previous holders or the producer of the product from which the waste came.

The basis of the legal regulations and regulatory standards in the field of waste prevention and handling is the following hierarchy of priorities for waste management and determined in Directive 2008/98/EC:

a) Waste avoidance
b) Reuse of waste
c) Recycling of waste as secondary raw material
d) Waste recovery including waste-to-energy
e) Waste disposal

One of the directions of a European company environmental policy as a solution for the growing problem of consumer waste is the strategy to reduce, reuse and recycle generated waste. But nowadays it is vital that the company should also rethink. Reduce, Reuse, Recycle and Rethink are standards for sustainable development of a company. Each generation needs to rethink the culture created by the previous generation, what can be changed in the manufacturing process for waste reduction, what kind of material should be used for less environmental impact, how our environmental consumer behaviour can be reflected in production process and waste generation, in other words the complete production chain from cradle to grave should be analyzed. (Laseter et al. 2010.)

4.2 Plastics application in automobile industry

Around 76% of the average car, by weight, is composed of metal. On the other hand the metal content has decreased in the last few decades due to the introduction of non-ferrous metals and plastics (Green Vehicle disposal 2013). The following graph shows the average material content of automobiles in 1998.

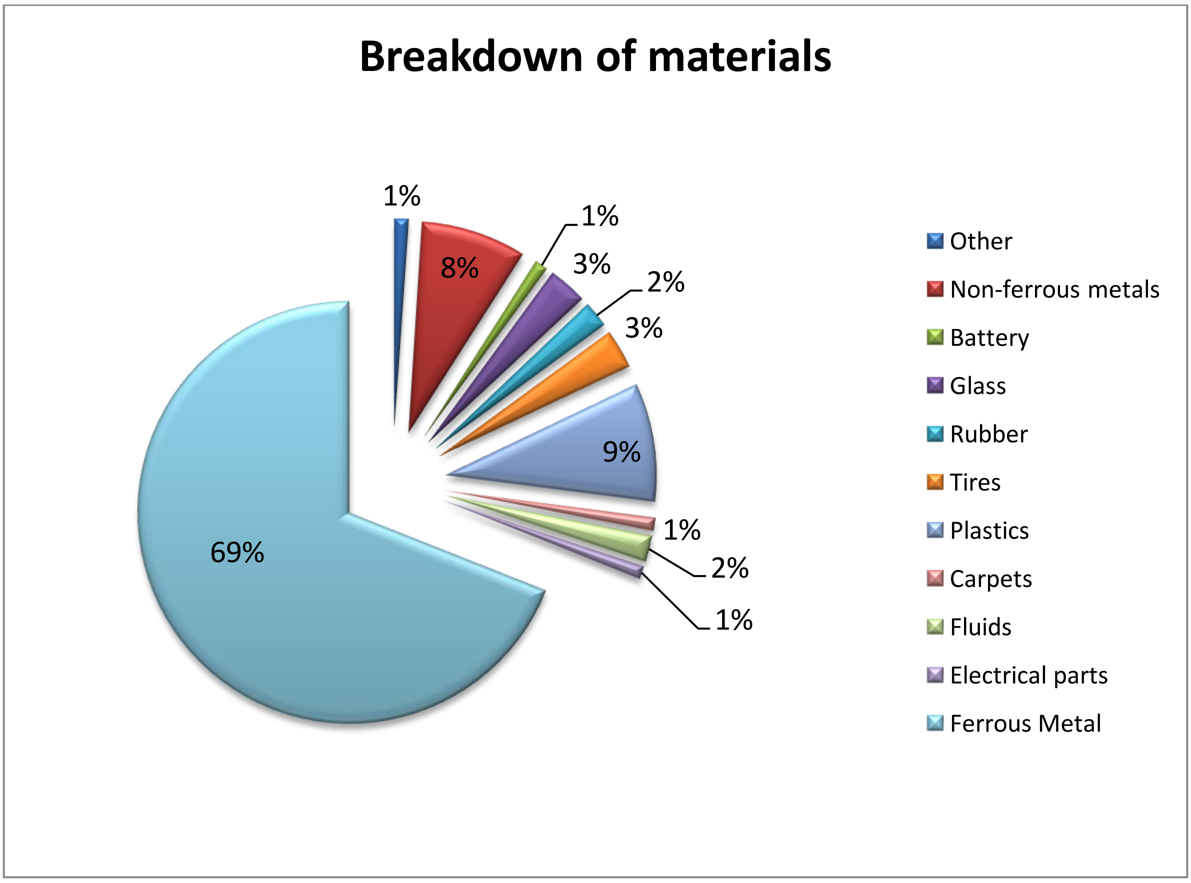

FIGURE 3. Material content of automobiles in 1998 (Green Vehicle disposal 2013)

Polypropylene (PP), Polyethylene (PE), Polyurethane (PU) and Polyvinyl chloride (PVC) are the most common plastic types used in vehicle production. There are also several other types of plastics (Delgado et al. 2007 88). Table 2 shows a list of different types of plastic that are usually applied in vehicle design.

TABLE 2. A list of used plastics in automobile industry (Delgado et al. 2007 89)

Type of plastic	Abbreviation	Application
Polycarbonate	PC	Bumper panel, radiator grilles
Polypropylene	PP	Bumpers, battery case
Polyethylene (high and low)	PE (HDPE, LDPE)	Bumper
Acrylonitrile butadiene styrene copolymers	ABS	Mirror housing, wheel co-vers, front and rear spoil-ers
Polyurethanes	PUR	Arm rest, seat cushion
Polyamide	PA	Wheel covers, fuel tanks, filler flap
Polyphenyles oxides	PPO	Body parts (hatchbacks and mudguard)
Styrene acrylonitrile	SAN	Radiator grilles
Thermoplastic polyolefins	TPE, TPO	Bumpers, dashboard
Polybutylene terephthalate	PBT	Plug connectors
Polymethyl Methacrylate	PMMA	Window visor, taillights headlights
Polyvinyl chloride	PVC	Interiot trim, electrical components, seating

Description of applied plastics will be presented in detail below in this study. Besides the EU legislation, today, exists a large number of quality standards and technical requirements for plastic waste, recyclates and recycled plastic end-uses. They are so called voluntary schemes meaning that it is not compulsory for a product or material to be in conformity with a relevant standard. A list of EN Standards and specifications relevant for waste plastic is shown in table 3.

TABLE 3. Common standards used for recyclates in EU (Plastic Zero – Public Private Cooperations for avoiding plastic as waste 2013 12)

EN 15342	Plastics. Recycled plastics. Characterization of polystyrene (PS) recyclates
EN 15343	Plastics. Recycled plastics. Plastics recycling traceability and assessment of conformity and recycled content
EN 15344	Plastics. Recycled plastics. Characterization of polyethylene (PE) recyclates
EN 15345	Plastics. Recycled plastics. Characterization of polypropylene (PP) recyclates
EN 15346	Plastics. Recycled plastics. Characterization of poly (vinyl chloride) (PVC) recyclates
EN 15347	Plastics. Recycled plastics. Characterization of plastic waste
EN 15348	Plastics. Recycled plastics. Characterization of poly (ethylene terephthalate) (PET) recyclates
prCEN/TR 15353	Guidelines for the development of standards relating to recycled plastics
EN 13430	Packaging. Requirements for packaging recoverable by material recycling
EN 13437	Packaging and material recycling. Criteria for recycling methods. Description of recycling processes and flow chart
ISO 16103	Packaging. Transport packages for dangerous goods. Recycled plastics material
ISO 15270	Plastics – Guidelines for recovery and recycling of waste plastic

According to the Government Decree on End-of-Life Vehicles (581/2004) the amount of waste in automobiles to the landfill in Finland must be reduced to 5% by 2015.

TABLE 4. Finnish utilization requirement in 2006 (Suomen Autokierratys 2013)

Waste management	2006	2015
Reuse and recycling	>80%	>85%
Recovering	<5%	<10%
Utilization in total	>85%	>95%
Final disposal at a dump	<15%	<5%

The overall recycling rate of automotive plastic waste is 9% in the EU (8.5% mechanical recycling, less than 0.5% feedstock or chemical recycling). The corresponding recovery rate represents 20.1% of the total plastic waste in this stream (European Commission DG ENV 2011 86).

Plastics are organic polymeric materials that are widely used and should be recycled more efficiently. Actually they are very problematic when recycling, because plastics are often composed of more than one kind of polymer or there may be some sort of fibre added to the plastic to give added strength. Plastic waste can arise in a business in several different ways, but generally in some form of used packaging or production waste.

Shape of polymer molecules determines its characteristics. There are two types of polymers: thermoplastic and termoset. Thermoplastic polymers can be heated and formed time after time. The shape of the polymer molecules is generally linear or slightly branched. This means that the molecules can flow under pressure when heated above their melting point.
Thermoset polymers undergo a chemical change when they are heated, creating a three-dimensional network. They are forming cross-linked polymers that doesn`t allow to reheat and reform material. They are harder when heated. Comparing these types, thermoplastics are much easier to adapt to recycling. (Lotfi 2009.)

In theory, practically any grade of plastics can be recycled over and over again. In practice, due to contaminants and moisture, plastics can normally be recycled upwards of 10 times. This is a big advantage. In fact the composition of the used plastic should be known precisely. This is not so self-evident that the buyer has all the information from the supplier. The few grades that cannot be recycled are generally supplied to heating plants for energy recovery in district heating systems. This practice is not common in the Leningrad region. There are only a few plants that incinerate sludge from state waste water treatment plants.

Oil is the basic feedstock of plastics. About 4 % of crude oil is used in plastics manufacturing (Suomen Autokierratys 2013). There are obvious advantages of plastic recycling:

1. It can preserves our natural resources by decreasing the demand for virgin materials. Recycling 1 kg of plastics reduces CO_2 emissions by 2 kg compared with using virgin raw material. According to the experience of Finnish recycled company Stena two kg of CO_2 emissions corresponds to the environmental impact from running an electric vacuum cleaner for 34 hours;
2. Energy can be saved and greenhouse gas emissions originating from waste plastic combustion can be reduced;
3. It helps to save money by decreasing disposal costs for the generator and decreasing materials costs for end users;
4. Littering problems originating from plastic waste would also diminish.

There are five factors that are necessary in order for the recycling of plastic to be a successful process. First, the generated plastic waste has to be in a large quantity. The second step is collection of plastic. The third step in the process is sorting and separation of waste. This step depends upon the type of polymers that make up the plastic. To make this process easier plastic products are given codes. The fourth step in plastic recycling is reprocessing which includes the melting process. The process can be accomplished if the polymers have not been widely cross-linked with any synthetics; otherwise the polymers will be difficult to stretch and less pliable. The last step is the production of the melted plastic into new products. To better understand the automobile plastics and right sorting of plastics that are needed to be recycled, there are presented a brief description of different plastic types. (Lotfi 2009.)

Polycarbonate (PC)

Polycarbonates plastic is one of the main plastics used in automotive industry because of versatility, strength, toughness and rigidness. PC is a thermoplastic material that has replaced most of glass applications in vehicles. In addition, they have a flexibility normally associated with the softer, lower-modulus thermoplastics. They can resist heat up to 125 ºC and have resistant to a variety of chemicals. Also, this material can be used in following products such as safety shields, lenses, glazing, electrical relay covers, pump impellers, headlights, interior components. (Go polymers Inc. 2013.)

Polyurethanes (PUR)

Polyurethanes are one of the best foams applicable in the automobile sector. Polyurethanes may be thermosetting or thermoplastic, rigid and hard or flexible and soft with great property variances. Principal applications are in coatings, elastomers and foams. It is used as seats cushions, adhesives and also as insulators in the body of vehicles. Rigid polyurethane foams have become widely used as insulation materials because of their combination of low heat transfer and good cost effectiveness. Because of the light-weight properties the overall weight of vehicles is reduced, which helps to increase fuel efficiency and improve environmental performance. Even though PUR have enormous applications in almost every aspect of human life, this material has disadvantages: poor thermal capability, poor weather ability, flammable and can be attacked by most solvents. (UL IDES Prospector Database, 2012.)

Polyethylene (PE)

Polyethylene (PE) is one of the most widely used plastics. In automobile industry bumpers are made from PE. Polyethylene plastic is characterized by toughness, near-zero moisture absorption, excellent chemical resistance, excellent electrochemical resistance, excellent electrical insulating properties and easy in processing. PE is thermoplastic material. Polyethylene plastics are classified by two types: high-density polyethylene (HDPE) and low-density polyethylene (LDPE). Classification is possible due to density of material and the primary differences are in rigidity, heat resistance, chemical resistance, and ability to sustain loads. Low-density polyethylene plastics are quite flexible, with high impact strength and relatively low heat resistance. They are typically applied in packaging films, extrusion coating of paper, cable coating, injection molding, and pipes and tubing. HDPE is tougher and stiffer than LDPE. It is used for bags and industrial wrappings, soft drinks bottles, detergents and cosmetics containers, toys, jerry cans, crates and dustbins. There are some weak points of PE such as high thermal expansion, PE is subject to stress cracking, material is flammable, has poor temperature capability and low strength. (UL IDES Prospector Database, 2012.)

Polypropylene (PP)

Polypropylene (PP) is the most versatile of the plastic family. Polypropylenes have better resistance to heat and resist more chemicals compared with other thermoplastic plastics. Polypropylenes have negligible water absorption and excellent electrical properties, and they are easy to process. One of the advantages of polypropylene plastic is that PP has an excellent resistance to water and to water solutions, such as salt and acid solutions. They are resistant to organic solvents and alkalis. (Go polymers Inc. 2013.) PP are applied in fibers, filaments and also made into films for packaging, caps and closure. Most of the recycled PP comes from the automotive industry waste. There are parts such as battery cases and bumpers. Usually PP is processed into granular form but in the case of battery recycling there is a problem of lead recovery.

Nissan has started collecting discarded plastic bottle caps from its offices and some other companies in Japan and recycling them as materials for automobile parts. Plastic bottle caps are made from polypropylene, which is also used in many automobile parts. As one way to maximize the use of limited resources mechanisms to recycle materials for use in automobiles were built. In Japan, Nissan dealerships collect damaged bumpers that are discarded after accident and repair them. For bumpers recycling was developed a device that pulverizes the collected bumpers and strips off the coating without the use of chemicals, in a process that is cheaper than the traditional one. Recycled bumper materials are applied in both bumpers for repairs and bumpers for new vehicles. (Nissan Motor Company 2012.)

Recycled PP is used in the automotive industry: for bumpers manufacturing, air-conditioning systems, blowers and valves, flaps and dashboards. In 1990 the company Volkswagen began a developing PP project and recycling project in partnership with Reko (a Dutch recycler of used polymer products) which is specialized in this issue. The recycled PP from bumpers is recovered and used for the manufacture of new ones. PP bumpers from Fiat cars are recycled for the manufacture of the air ducts of instrument board and frames for air filters. Bumpers are granulated and recompaunded for recycled PP manufacture branded as ReFax. Recycled polymer is also used to protect the wheel arches of some FIAT models. French car manufacturer Renault uses polished bumpers made from 100% recycled bumpers material for its model Megan. Australian company Omni Plastics processes bumpers in polymer for floor mats used in Toyota company cars. (La Mantia 2006, 283.)

There are disadvantages of PP: material is degraded by UV, flammable, but fire retarding grades are available, attacked by chlorinated solvents and aromatics, several metals accelerate oxidative degrading and low temperature impact strength is poor. Body parts made of this material are usually manufactured as blends. They can be produced cost-efficiently in the large numbers required by the automotive industry if there are injection-molding plants that are required for manufacturing large parts. (UL IDES Prospector Database, 2012.)

Polyamide (PA)

Polyamides, or they are also called nylon, comprise the largest family of engineering plastics. Characteristically polyamides (nylons) are very resistant to wear and abrasion, have good mechanical properties even at elevated temperatures, have good chemical resistance and low permeability to gases. General purpose nylon molding materials are available for extrusion, injection molding, blow molding, rotational molding, and (for nylon 6 materials) casting or anionic polymerization. Many automotive companies are using this material for the airbags, wheel trims, gaskets, tyres, hoses, ropes and many other items out of the automobile section. There are weak points of the material such as treated by oxidizing agents, attacked by strong acids, shows up high notch sensitivity, very sensitive to UV lights and need stabilizers, they are at risk of losing electrical and mechanical properties at high moisture rate. (UL IDES Prospector Database, 2012.)

Acrylonitrile butadiene styrene copolymers (ABS)

This material is a terpolymer of acrylonitrile, butadiene and styrene. ABS plastics are thermoplastics with high impact strength, ideal for turning, drilling, milling, sawing, die-cutting, shearing. On the basis of ABS plastic are produced polymer composite materials with higher performance and technical characteristics. ABS plastic and its compositions are widely used in the automotive industry. On its basis machine parts are produced. These are panels, frames, dashboards, lining doors, window frames, interior parts, wheel covers, gitters, mirror housings and lights, bumpers. (Go polymers Inc. 2013.)

ABS plastic is recovered from old computer cases, toner cartridges and car parts. The collected material is pelletized and compounded for replacement the original ABS plastic or recycled into products that substitute wooden or steel beams. Hewlett Packard uses 25% of recycled material in their printers DeskJet. Bayer AG also produces recycled ABS plastic for the manufacture of gitters for Volkswagen cars and recycled material consists of 30% of the used gitters. Modern furniture is manufactured by Wharrington International that uses recycled ABS plastic recovered from old cartridges, vacuum cleaner cases, computers and other devices. The company has developed low-pressure casting technology and uses in its products up to 75% of recycled plastic. The material called RECOPOL is used for the manufacture of upholstered chairs, armchairs and tables for cafe. It is also possible to produce large parts, it can be cut, sawn, drilled etc., that is to do everything that can be done with a very dense material. (La Mantia 2006, 287.)

There are disadvantages that cannot be neglected such as limited weathering resistance, flammability with high smoke generation, they have moderate heat, moisture and chemical resistance and relatively high cost that can influence on market demand.

Polymethyl Methacrylate (PMMA)

PMMA is a transparent thermoplastic material often used as a light weight alternative to glass. It is also an economical alternative to Polycarbonate when extreme durability is not required. It is resistant to inorganic acids and alkalis but is attacked by a wide range of organic solvents, has poor impact strength compared to other industrial plastics and scratches easily. Typically the material is applied in viewing ports, furniture accessories, chandeliers and exterior lights of automobiles. (Go polymers Inc. 2013.)

Polyphenyles oxides (PPO)

Poly(p-phenylene oxide) (PPO) or poly(p-phenylene ether) (PPE) are high-temperature thermoplastics. PPO is usually used as a blend with poly styrene (PS). PPO thermoplastics offer properties between common thermoplastic polymers and higher engineering types, e.g. polycarbonates. PPO can be moulded by a range of processes such as injection, extrusion and extrusion blow moulding, thermoforming and foaming. (Go polymers Inc. 2013.)

PPO products are characterized by exceptional moisture resistance, high dimensional and thermal stabilities, good flame resistance, high electrical resistance properties, resistance to radiation and processability by thermoplastics methods. But the material has comparatively high cost. (Lokensgard 2010, 472.)

In the automotive sector PPO is utilized as a solution for automotive interiors. From the material can be made body parts such as hatchbacks and mudguards (Plastic Historical society 2011).

Polybutylene terephthalate (PBT)

Polybutylene terephthalate (PBT) is a thermoplastic polymer that is used as an insulator in the electrical and electronics industries. PBT is resistant to solvents, mechanically strong, has good moisture barrier properties and can be treated with flame retardants to make it noncombustible. PBT is closely related to other thermoplastic polyesters. Compared to PET (polyethylene terephthalate), PBT has slightly lower strength and rigidity, slightly better impact resistance, and a slightly lower glass transition temperature. The material also needs UV protection if used outdoors. PBT is sold in the form of filled and reinforced compounds for engineering applications. Its uses include appliances, automotive, electrical / electronic, materials handling and consumer products. (Go polymers Inc. 2013.)

Polyvinyl chloride (PVC)

Polyvinyl chloride is one of the most widely used plastics and the third-most widely produced plastic, after polyethylene and polypropylene. It is because of its versatility. PVC can be utilized in tough compounds or blended with plasticizers to produce flexible material. Polyvinyl chloride molding compounds can be extruded, injection molded, compression molded, calendered, and blow molded to form a huge variety of products. Tough PVC is strong, difficult to burn, has excellent resistance to most chemicals and organic solvents. Disadvantages include limited thermal capability, higher density compared to other plastics. The polymer is sensitive to UV and requires stabilization. The most important is that thermal decomposition evolves dioxins that are very harmful for health. PVC can be applied for automobile linings, dashboards, cable coverings, flooring, furniture covers, bottles, etc. (Go polymers Inc. 2013; UL IDES Prospector Database, 2012.)

4.3 Plastic waste recycling processes

Today plastics have become useful materials of our everyday life and many of their properties such as versatility, durability and light-weight, contribute to sustainable development. In spite of many advantages of plastics at the end of their useful life, plastics waste may cause a waste management challenge. The major issue is the fact that plastics are often used only once before disposal. The material needs to be recycled.

According to the ISO15270 Guidelines for the recovery and recycling of plastics waste, the selection of methodologies and processes for the management of plastics waste (2008) can be divided into two classes:

a) material recovery (mechanical recycling, chemical or feedstock recycling, and biological or organic recycling);

b) energy recovery in the form of heat, steam, or electricity generation using plastics waste as substitutes for primary fossil fuel resources.

Mechanical recycling

The mechanical recycling process includes material collection, separation of plastics by resin type, grinding and crushing to reduce the plastics' particle size, washing to remove dirt and contaminants, drying, extrusion by heat and reprocessing into new plastic goods.

There are some disadvantages of mechanical process:

1. Mechanical recycling can be applied only for thermoplastics because thermosets cannot be remoulded by the effect of heat.
2. Mechanical recycling of plastics is limited by the compatibility between the different types of polymers. The presence of a foreign material in recycled polymer that is due to bad sorting of plastics may dramatically change the properties and hamper the possibilities to use it in the traditional applications. Although, recycling of plastics without prior separation by resin before remoulding stage produces a material with mechanical properties similar to timber and can replace it in certain applications.
3. Due to effects of temperature, ultraviolet radiation oxygen and ozone most polymers endure certain degradation during their use. Therefore recycled polymers have lower properties and performance than the virgin materials, cannot substitute them and are useful for lesser value applications. (Ylä-Mella 2005 2.)

In spite of listed disadvantages, mechanical recycling is the ideal recovery method for clean or relatively clean plastics waste flows. Sequence of mechanical recycling stages is shown in figure 4.

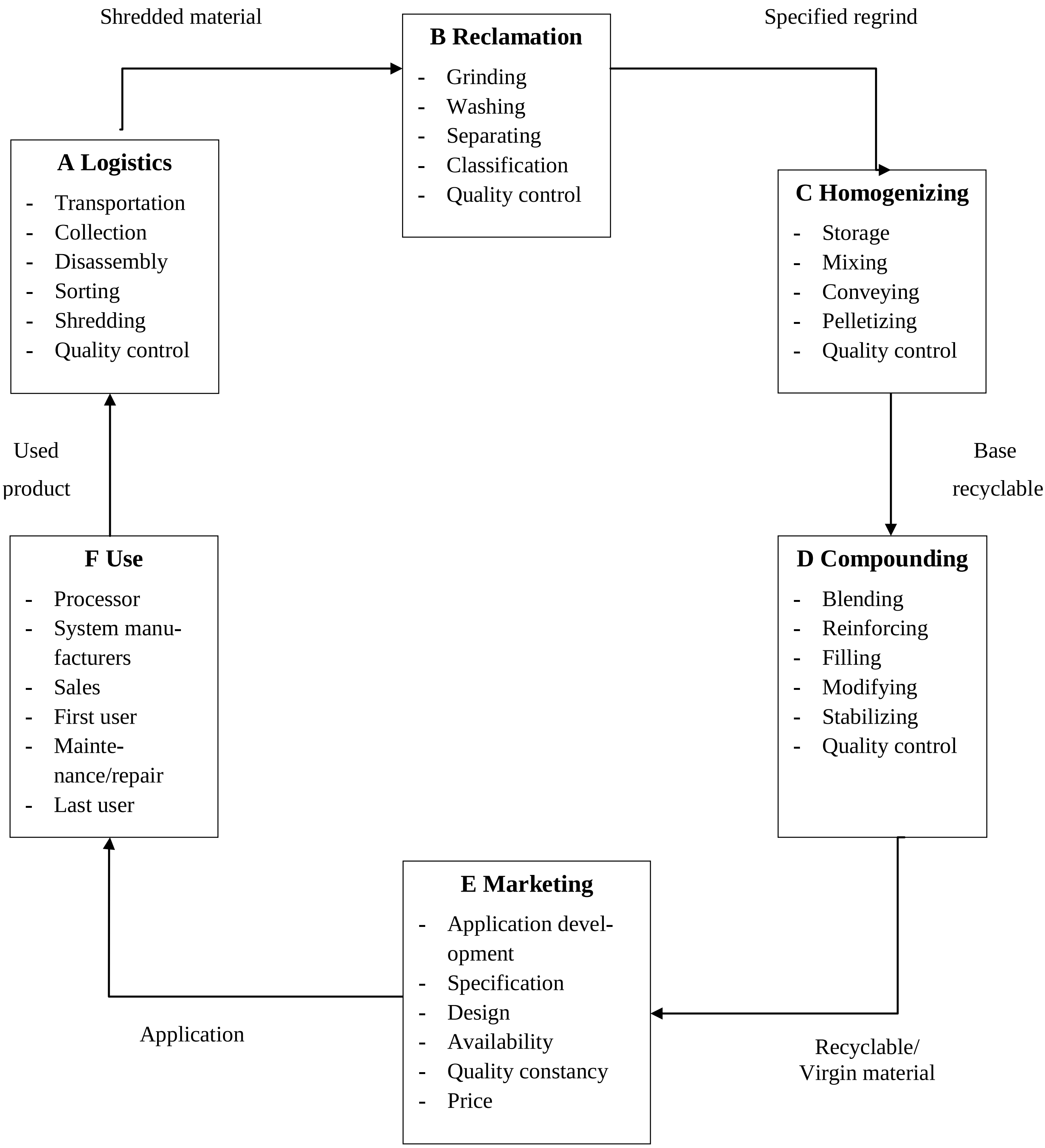

FIGURE 4. Stages in the mechanical recycling of plastics (Ylä-Mella 2005 3)

Plastics waste for mechanical recycling may be offered for sale in the form of bulk waste as it was collected or as sorted waste by efforts of company.

Feedstock or chemical recycling

Feedstock recycling of plastics, also referred to as chemical or tertiary recycling is based on the conversion of polymers using various processes such as heat, chemical, or catalytic agent into their monomeric chemical constituents or into hydrocarbon fractions with further utilization either as polymerization feedstock or in other chemical processes (ISO15270 2008).

The feedstock recycling processes can be classified into three main areas:

1. Recycling to fuels (gasoline, liquefied petroleum gas (LPG) and diesel oils)
2. Recycling to monomers
3. Recycling to industrial chemicals. (Janssen & Santen 1999 27.)

The methods for feedstock recycling of plastic and rubber wastes can be summed up into the following classes:

1. Hydrogenation – the polymer is degraded by the combined actions of heat, hydrogen and many cases catalysts.
2. Gasification – plastic wastes react with oxygen and/or steam to produce synthesis gas (CO and H2).
3. Chemical depolymerization – plastic wastes react with certain agents to yield the starting monomers.
4. Thermal cracking – plastic wastes are decomposed by the effect of heat in an inert atmosphere.
5. Catalytic cracking and reforming – the polymer chains are broken down by the effect of catalyst, which promotes cleavage reactions. (Ylä-Mella 2005.)

Today this type of plastic recycling is under development. A small number of chemical recycling methods have been commercially realized but the interest in more efficient processes is still growing due to the need of polymer waste recycling. According to Aguado & Serrano (1999) and Ylä-Mella (2005) the factors that limit the development of feedstock recycling and determine the profitability of alternative chemical recycling methods are the degree of required separation, the value of the products obtained, and the capital investments in the recycling plants.

Biological recycling

Certain types of plastics waste can be decomposed by aerobic or anaerobic processes.

The main advantage is that there is no need to separate biodegradable contaminants such as foodstuffs or vegetable matter residues from plastics. Although, biodegradation is a viable option for the treatment but cannot be applied to all types of plastics (ISO15270 2008).

Energy recovery

Incineration can be considered as recovery method, as plastic is petroleum based material and could replace the application of other oil based fuels. The major advantage and cost saving is that plastics can be co-incinerated with other wastes or used as source of fuel because of high energy content. Constant reprocessing leads to lesser performance and quality decrease of plastics. If it is no longer economically beneficial to recycle plastics, incineration with energy reclamation will be the economically ideal option. (Ylä-Mella 2005.)

4.4 End – of – life vehicles in Finland

In connection with the study in automotive industry, it can be said that Finland, as an EU country, has a well organized structure for the handling of end-of-life vehicles (ELVs) in accordance with the requirements that are presented in the ELV Directive 2000/53/EC. It is important to take into account that there is no analogue of such kind of regulation in Russia.
The Parliament of Finland adopted Amendment 452/2004 to the Waste Act in June 4th 2004, which introduced producer responsibility to Finnish legislation. The Decree on End-of-Life Vehicles (581/2004) was adopted in June 23th 2004. These regulations enforced the ELV Directive (2000/53/EC) in Finland. The legislation came into force on 1 September 2004. (Suomen Autokierratys 2013.)

In Finland, the average scrapping age of passenger cars is 20.3 years, and the figure is growing each year. The Finnish Car Recycling Ltd is a so-called producer association, which coordinates the collection, treatment and recycling of end-of-life vehicles (ELVs). The recycling system covers the take-back, deregistration, pre-treatment and shredding of ELVs.
Any components that can be reused should be dismantled, provided there is a demand for them. Other parts should be recovered primarily in the form of material and secondarily as energy (Perchard 2004 14).

A press release on the official site on 23th May 2013 said more than 95% of a motor vehicle can be recycled or reused. The owner should take car to a take-back point. The owner is issued a Certificate of Destruction (COD), which ensures that the vehicle can no longer be commissioned to traffic. In accordance with Finnish Car Recycling Ltd. statistic a record number of CODs, 65,058, were issued in 2012. Deregistration of a vehicle will automatically terminate the annual vehicle tax and the statutory motor liability insurance. Recycling an ELV is for free to the last owner. (Suomen Autokierratys 2013.)

The recycling partners of Finnish Car Recycling are Kuusakoski Oy, Stena Recycling Oy, Kajaanin Romu Oy and Eurajoen Romu Oy.The car recycling policy has not been in Finland for long time but is developing tremendously and well organized because both the people and the laws takes it full course.

4.5 Benchmarking in Finland

While in the Leningrad region exist about 9 automotive plants, in Finland there is only one automotive production plant in Uusikaupunki “Valmet Automotive” that was built in 1969. The plant has an annual capacity of 30,000 cars per shift. With a three-shift operation, the capacity of the Uusikaupunki plant can be increased to over 100,000 vehicles annually. The personnel totals 900, working in headquarters, technical center and vehicle manufacturing and manufacturing engineering facilities. The Uusikaupunki facility contains technical center, body shop, paint shop, final assembly, quality and logistics areas and two test tracks. The site area is 210 hectares with 9 hectares under roof.The Uusikaupunki plant is located close to the harbor on the South - West coast of Finland, with frequent and fast sea transports between Finland and the continental Europe. (Valmet Automotive 2013.)

Metso is a global supplier of technology and services in the process industries, including recycling. In the manufacturing process, waste is a constant issue and more firms are looking to process their own waste on site prior to recycling or disposal. To handle this type of industrial operation, Metso offers one of the market’s most powerful fine-shredders. Effective, reliable and with low operating costs, it produces high quality results with greater efficiency and profitability for the operator. (Metso 2013.)

Kuusakoski Inc. is the Scandinavian leading industrial recycling company that specializes on scrap metal recycling. The company has more than 100 worldwide locations, of which 20 in Finland. In addition to Finland Kuusakoski operates in Russia, Estonia, Lithuania, Poland, Sweden, Denmark, the UK and USA, China and Taiwan. CC Petromax is a subsidiary company of Kuusakoski. Petromax specializes on industrial and domestic waste recycling, collection and recycling of electrical and electronic devices, metal recycling, car recycling and supplies industry with recycled material. There are subsidiaries in Saint Petersburg, Moscow region in Lobnia, Vyborg, Gatchina. (Kuusakoski Inc. 2013.)

Another most widely famous company in Finland is Stena Recycling that is part of the Stena Metall Group. Stena Recycling has a large network of recycling plants and a total of nearly 200 facilities in Norway, Denmark, Sweden, Finland and Poland, where waste from throughout society is converted into new materials. (Stena 2013.)

5 PLASTIC MANAGEMENT AT THE AUTOMOTIVE COMPANY X AND DEVELOPMENT OF MEASURES FOR IMPROVEMENT

Based on the Waste generation standard and disposal limits and waste management monthly reports of the Automotive Company X, the analysis of plastic waste management was done. In the table 5 the current material flows of plastics management are presented.

TABLE 5. Plastics management at the OOO "Automotive company X"

Waste	Quantity, t/year		Type of polymer material
	Recycling	Disposal	
Waste of polymer material (contaminated packaging)	-	1,375	LDPE, HDPE, PP
Waste of polymer material (offcuts and scrap of adhesive film)	-	0,312	PE
Hard plastics waste	-	5,6	mixed plastics
Complex combined waste (rejected car`s parts)	-	82,5	PP, PE(HDPE), ABS, PA
Polyfoam waste	165,5	144,4	Extruded polystyrene foam
Polyethylene waste in the form of film	238,2	-	PE
Polystyrene (polyethylene) waste	62,8	6	PS
Waste of complex combined composition in the form of products, equipment devices not included in other items (iron-	-	2,5	HDPE

[continues]

barred plastic containers)			
PET, bottles, plastic cups		withdrawn, unsorted and included into garbage from domestic compartment of an enterprise	PS, PP, PET

It is obvious that significant amount of waste belongs to polymers´ category. Automotive Company X delivers their polyethylene, polystyrene waste to an external company for recycling. Polymer waste material from packaging is not accepted by recycling companies due to substances' toxic content and that is why it is disposed to the landfill. Another, but not the least of the factors, is that plastic bottles and cups are included as unsorted garbage from domestic compartment of organization and sent to the landfill as well. The monthly generated amount of plastic waste is not huge, but according to the sustainable waste principles, it should be sorted and sent to the recycling companies.

Evidently, a huge amount of rejected car`s parts, about 83 tons, is generated annually in the manufacturing process. It is not possible to analyze how the plastic waste could be managed as there is no accurate data what kind of plastic waste is generated. But, the European Union data of plastic consumption in automotive sector is available from the year 2001.

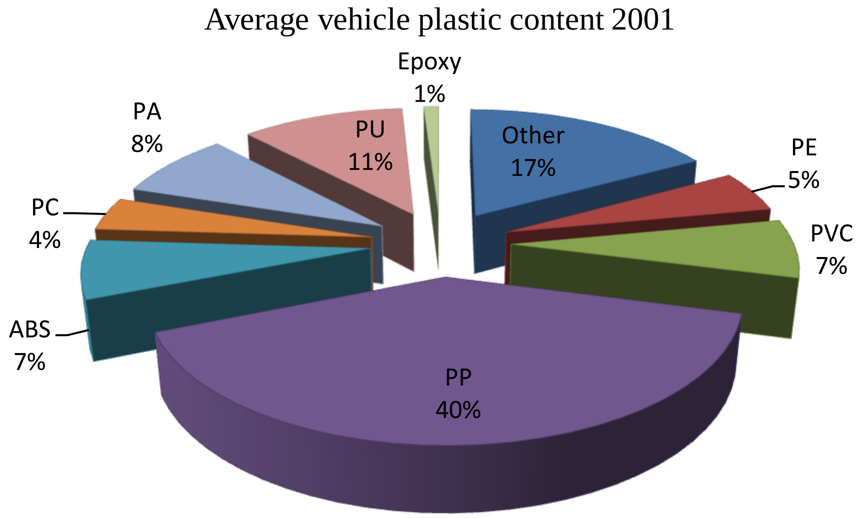

FIGURE 4. Average composition of plastic content in 2001 European cars (Delgado et al. 2007 88)

Those data can serve as a guidance for determining the most common polymers and percentage of them. Based on the European statistics it can be assumed that rejected car`s parts include about 40% of PP, 25% of PA, 20% of ABS and 15 % of PE.

There are issues that should be considered and solved for improving waste management of the company. To solve the problem there are three possible scenarios which the author has formulated and they will be tested below in the study:

- Scenario 1: more thorough sorting of plastic waste by type classification and shipping to recycling companies;
- Scenario 2: collection of generated plastic waste and crushing it by shredder;
- Scenario 3: collection of plastic waste and granulating that is for processing to recyclable material.

6 ECONOMICAL ASSESSMENT OF MEASURES

The goal of technical and economic assessment is to prove suitability, possibility and necessity of suggested measures. The assessment in this study will be based on a study guide (Technical and economic assessment of measures for diploma projecting) that was developed by Ivanovskaya in 2010.

6.1 Scenario 1

As it was mentioned above pure polyethylene and polystyrene are delivered for recycling. Other types of plastic waste are not sorted and are disposed to the landfill. Plastic waste issues could be handled by establishing and running a special sub-management system as a part of the general waste management.

Plastics can be sorted by hand according to their recycling code. In 1988, the Society of Plastic Industry has developed a resin identification codes to sort different types of plastic waste. The coding system helps to identify the different types of plastic. Figure 5 shows classification of plastic codes which would be applicable in Automotive Company X (Ryedale District Council 2013).

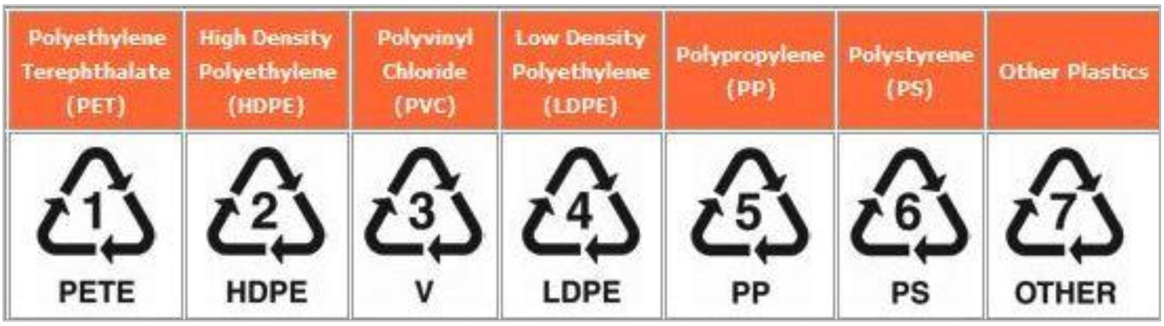

FIGURE 5. Plastic recycling codes (Ryedale District Council 2013)

According to the European commission report “End-of-waste criteria for plastic waste for conversion” waste plastic can be collected in three main ways:

- Mono-material collection: waste mixed plastic is collected separately from other types of recyclables such as metals or glass. The waste plastic can be collected as mixed plastic or by specific plastic types.
- Multi-material collection: waste plastic can be collected together with other dry recyclable waste such as metals or glass, but separately from the remaining components of waste such as food.

Mixed municipal solid waste collection: the plastic waste is collected together with the remaining components of waste. Separation of dry recyclables such as metals, plastics and glass is possible, but often recyclables are contaminated and require further treatment. (Joint Research Center of European Commission 2013 47.)

Sorting plastic waste means separation of the plastic waste itself into the different plastic polymer categories. This is very important due to the fact that for plastic materials recycling into useable polymers, a pure stream of polymers must be obtained. Inefficient sorting makes recycling impossible and leads to economically non-feasible process. In some cases the mix of plastic polymers may even result in safety or health risks. Mixture of PVC and PET, for example, leads to the release of hydrochloric gases if melted at temperature more than 200 ºC, or can seriously decrease the purity of the final product when melting the PET polymers. (Joint Research Center of European Commission 2013 47.)

Material sorting is usually conducted at Material Recovery Facilities (MRF), which then sell the sorted plastics materials to different recyclers. All recyclers have different requirements for the properties of the plastic waste. The company that generated plastic waste could also sort the waste even more efficiently and then sell the material to recycling companies. The foreseen environmental and economic benefit would be bigger even if the amount of waste to be sold were smaller. Recycling companies that are located in Saint-Petersburg are listed in table 6.

TABLE 6. Plastic waste recycling companies in Saint-Petersburg (Solid waste recycling 2013)

Contact information	Material type is accepted
Integratsiya Pererabotki Polymerov Address: Irinivskiy prospect,1 Website: http://polimerspb.ru Tel.: +7 (812) 600-64-78 E-mail: o.polimer@yandex.ru	HDPE, LDPE
Kondor Address: Kommuna Str, 67, A3 Webpage: http://kondor.pro Tel: +7(901) 301-16-80 E-mail: kondor-plastik@mail.ru	HDPE,LDPE,PP,PS
Plastic redemption center Address: Kommuna Str.,67 Webpage: prplast.narod.ru Tel.: +7 921 324 56 05 E-mail:: prplast@yandex.ru	HDPE, LDPE,PP
Region Project Address: Mineralnaya Str., 13A Webpage: http://www.region-proekt.spb.ru Tel.: (812)-963-6629, 312-2779 E-mail: info@region-proekt.spb.ru	PET, HDPE, LDPE, PP, PS
OOO «Replastiko» Adress: Tsvetochnaya Str., 18 Webpage: http://www.replastico.ru/ Tel: 8 965 783 43 03 E-mail: roman@replastico.ru	LDPE, HDPE
OOO «StekloReserv» Adress:Gromov Str., 4, office 327 Storehouse: Murmanskoe highway, 2 Webpage: http://steklorezerv.ru Tel: (812) 244-14-98; 8 (921) 943-37-87 E-mail: info@steklorezerv.ru	PET

[continues]

OOO "Formoplast" Address:Piskarevkiy Prospect, 63 K. Webpage: http://plasticplus.spb.ru Tel: +7 (812) 299 299, 8 (921) 959 77 17 E-mail: plast_plus@mail.ru	HDPE, LDPE, PP,

There are only four companies that are able to recycle PP that is the main plastic material of vehicles. The major polymer materials that can be recycled are HDPE, LDPE, PP and PS as the main plastic content in modern vehicle is represented by PP, PV, ABC, HDPE, LDPE, PA and others. In table 7 the average prices of materials are presented by example of Kondor company.

TABLE 7. Average sales prices of polymer material (Group of companies Kondor)

Type of polymer	Price, RUB/kg	Supplementary conditions
LDPE	30 and more	Price depends on contamination grade, waste plastic volume etc. and customer specific negotiations
PP	12-25	
HDPE	12-20	
Waste film	8-14	
Different type of tare	3-8	

Referring to the table 7 above, average sales prices of polymer material and approximate percentage of plastic waste in rejected cars parts can be assessed by the profitability of selling sorted waste plastic. Results are presented in the table 8 below.

TABLE 8. Approximate annual waste polymers sales

Type of plastic waste	Unit	Price per a unit	Percentage, %	Quantity, kg/year	Total profit, RUB
PP	RUB/kg	18	40	66 000	1 188 000
PA	RUB/kg	15	25	41 250	618 750
ABS	RUB/kg	15	20	33 000	495 000
HDPE	RUB/kg	15	15	24 750	371 250
Total			100	165 000	2 673 000

The table is based on the approximate data. Nevertheless, waste sorting is profitable according to the presented calculation.

In the territory of the Leningrad Region exist companies for end-of-life vehicle recycling, such as OOO ”Boston-m”, OOO “MetalGroup”, group of companies “Recycling materials” . But process is currently operating only for metal parts recycling, not for plastic recycling. One of the reasons is the wide variety of polymer types and additives used. Another reason is that the established practices of recycling are based on initial shredding and subsequent separation of mixed streams. Thirdly, end-of-life vehicles are still dismantled by small companies that are not capable to recycle plastic waste.

If the company wants to make plastic waste as a profitable operation they need to develop and implement a whole management system. To get started the company should organize special tanks for plastic waste collection. The staff should be trained for this special task as they should carry out a visual inspection of each plastic item separately. The staff should also be trained for potential types of contaminants that may be included in the plastic waste and on material components or features that let recognize the contaminants. And, the procedure of recognizing contamination should be documented under the management system.

As mentioned above plastics can be collected by sorting them according to the plastic types. If there is no code on polymer material it is possible to apply simple tests to distinguish common types.

- The water test: after adding a few drops of liquid detergent to water put in a small piece of plastic and sees if it floats.

- Burning test: hold a piece of the plastic in a tweezers or on the back of a knife and apply a flame.
- Fingernail test: can a sample of the plastic be scratched with a fingernail?

  Results of the tests are presented in table 9.

TABLE 9. Tests for plastic type identification (The Schumacher Center for technology and development 2012)

Test	**PE**	**PP**	**PS**	**PVC***
Water	floats	floats	sinks	sinks
Burning	blue flame with yellow tip, melts and drips	yellow flame with blue base	yellow, sooty flame - drips	yellow, sooty smoke, does not continue to burn if flame is removed
Smell after burning	like candle wax	like candle wax but less strong than PE	sweet	hydrochloric acid
Scratch	yes	no	no	no

*To confirm PVC, the sample is touched with a red-hot piece of copper wire and then held the wire to the flame. A green flame from the presence of chlorine confirms that it is PVC (Vogler 1984, 40).

Plastic waste can also be collected by the groups of thermoplastics and thermosets. To determine if a plastic is a thermoplastic or a thermoset, should be taken a piece of wire which is heated below red heat and pressed it into the material. If the wire penetrates the material, it is a thermoplastic, if it does not it is a thermoset.

There are advantages that company can receive implementing the above measures:

- Company does not need to pay fee for landfill disposal
- Company receives money from selling waste plastic
- Improving waste management system
- Green image

Measures proposed in Scenario 1 do not require significant costs and they are recommended for the implementation in the company. The scenario will provide substantial savings because of waste disposal reduction and income because of selling sorted plastic waste and consisting with the environmental policy of the enterprise and the Green Program. Environmental management development improves the competitiveness of the company in the market as well as preserves the environment, public health and raw materials.

6.2 Scenario 2

Scenario 2 consists of the following: collecting the generated plastic waste and crushing it by shredder. The steps are described below.

Step 1. Determination of equipment capacity

To select the crushing machine it should be defined the capacity of equipment that is needed. The volume of plastic waste of rejected cars parts (M) is 82,5 ton annually. As the company is going to expand the productivity in the course of year by two times, it might be supposed that the waste amount will increase by two times as well. So M is 165 t/year. The capacity is assessed according to the following formula:

$$N = \frac{M}{K}$$

where M - total waste mass

N – equipment capacity

K - index of machine utilization (0,6 - 0,8)

$$N = \frac{165}{0{,}6} = 275\,\frac{t}{year}$$

Step 2. Equipment selection

Thereto was selected as a demonstrative crushing machine manufactured by the Chinese company Zerma machinery & recycling technology CO. LTD. The equipment supplied by OOO “Bazent” that is specialized on crushing equipment delivery and is located in Saint-Petersburg. The main characteristics of equipment are presented in table 10 and supported by figure 6.

TABLE 10. Technical characteristics of GSH 350/500

Crusher	GSH 350/500
Rotor diameter (mm)	350
Rotor width (mm)	500
Drive capacity (kW)	22
Capacity, kg/h	300
Rotor knifes (rows)	3 or 5
Stator blades (rows)	2 or 3
Screen size (mm)	>6
Effective working area (mm)	460 x 516
A (mm)	1820
B (mm)	1600
C (mm)	740
D (mm)	1650
E (mm)	520
F (mm)	775
G (mm)	1280

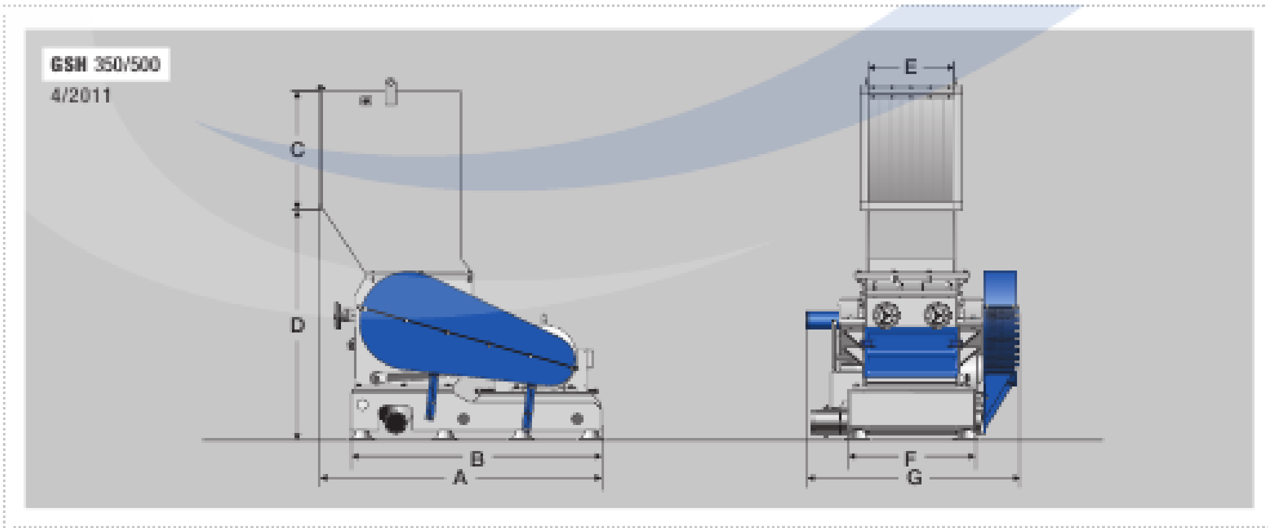

FIGURE 6. GSH 350/500 (Zerma machinery & recycling technology CO. Ltd. 2013)

Because of the size of equipment there is no need for a separate building. It could be placed in the logistics department.

Step 3. Investment assessment

TABLE 11. Equipment purchase

№	Name of equipment	Brand, model, capacity	Quantity	Price, RUB
1	Crusher	GSH 350/500	1	574 000
	Total			574 000

TABLE 12. Total estimated investment

№	Cost type	Cost, RUB	Notes
1	Equipment purchase	574 000	-
2	Transportation and procurement costs	86 100	15% from Equipment cost (Table 11)
3	Installation work	57 400	10% from Equipment cost (Table 11)
4	Balancing and commissioning	86 100	15% from Equipment cost (Table 11)
5	Engineering and consulting work	28 700	5% from Equipment cost (Table 11)
6	Obtaining the necessary permits	30 000	-
	Total	862 300	-

TABLE 13. Planned budget of capital expenditure on construction

№	Cost type	Cost, rub	Notes
1	Equipment investments	862 300	-
2	Normalized circularity assets	129 345	15% from Total estimated investment (Table 12)
	Total	991 645	-

Step 4. Assessment of operating cost of processing 1 ton of plastic waste

TABLE 14. Operating costs of processing plastic waste

№	Expense item	Unit	Quantity	Cost per unit, RUB	Overall costs, RUB/year	Notes
1	Electricity	kWh	22	2,97*	130 680	
2	Auxiliary materials	kg/year	-	-	34 440	6% from equipment cost
4	**Total variable costs per 1 ton of plastic waste (TVC)**				165 120	
5	Salaries	RUB/month	10 000	-	120 000	-
6	Labor tax	RUB/month	3 450	-	41 400	34,5 % from sala-ries
7	Standard fixed costs	RUB/month	2 000	-	24 000	20% from salaries
8	Overhead costs	RUB/month	1 500	-	18 000	15% from salaries
10	**Total fixed costs per 1 ton of plastic waste (TFC)**				203 400	
11	**Total operating costs (TOC)**				368 520	

* Committee Decree in electricity rate in St. Petersburg 19.12.2012 № 559

Total operating costs of processing of 165 ton of waste plastic is 368 520 RUB.
Consequently, operating costs (per unit) of processing 1 ton of waste plastic is:

$$C = \frac{TOC}{M},$$

where C – operating costs per unit,

TOC – of processing waste plastic per year,

M – total quantity of generated waste per year.

$$C = \frac{368\ 520}{165}/= 2\ 233{,}5\ \mathrm{RUB/t}$$

Taking into account the industry´s average interest rate of income, which is 20-30 %, the wholesale price (P) can be calculated according the following formula:

$$P = C \times (1{,}2 \div 1{,}3)$$

$$P = 2\ 233{,}5 \times 1{,}3 = 2\ 903{,}5\ \mathrm{RUB/t}$$

This leads to that wholesale price per 1 kg is 2,9 RUB.

Step 5. Assessment of break–even point

Break-even point (BEP) is the point at which profits are zero because total revenues equal total costs. A company operating above the break–even point makes profit but below the point, it makes losses (Dominiak & Louderback 1997, 38).

Any company which wants to make bigger profit, desires to know a break-even point. Graphically, it is the point where the total cost and the total revenue curves meet. BEP can be assessed by follows:

$$\mathrm{BEP} = \frac{\mathrm{FC}}{\mathrm{P} - \mathrm{VC}},$$

where FC – total fixed annual costs,

P - wholesale price of 1 ton of waste plastic

VC - sum of variable costs by producing 1 ton of waste plastic

Variable costs (VC) by producing 1 ton of plastic waste is

$$\mathrm{VC} = \frac{\mathrm{TVC}}{\mathrm{M}}$$

where TVC – total variable costs,

M - total quantity of generated waste per year.

$$\mathrm{VC} = \frac{165\ 120}{165} = 1\ 000{,}7\ \mathrm{RUB/t}$$

Therefore, the BEP calculated as follows:

$$\mathrm{BEP} = \frac{203\ 400}{2\ 903{,}5 - 1\ 000{,}7} = 106{,}9\ \mathrm{t/year}$$

Production value in break–even point (V_{BEP}) is equal to:

$$V_{BEP} = P \times BEP$$

$$V_{BEP} = 2\ 903{,}5\ \times 106{,}9\ = 310\ 369{,}9\ \text{RUB/year}$$

This is unit sales to achieve target profit. To achieve more profit production value can be calculated for maximum volume of waste:

$$V_{BEP} = 2\ 903{,}5 \times 165 = 479\ 077{,}5\ \frac{\text{RUB}}{\text{year}}$$

Step 6. Assessment of profitability of investment on waste reduction (total savings)

The company can get a clear profit by reducing amount of plastic disposal. Waste disposal has a payable fee. According to the hazard class of waste there are different prices/ton:

1st hazard class – 1739,2 RUB/t,

2nd hazard class – 745,4 RUB/t,

3rd hazard class – 497 RUB/t,

4th hazard class – 248,4 RUB/t,

5th hazard class:

mining industry – 0,4 RUB/t,

processing industry -15 RUB/t,

other industries – 8 RUB/t. (Governmental regulation 01.07.2005 N 410.)

If company disposes over the limit, they have to pay the fee five times more. If plastic waste volume of rejected parts exceeds the limit, the calculation is made as follows:

$$F_l = 5 \times (Mi - Mlim) \times N \times Ke \times I$$

where F_l - fee due to excess the limit of waste volume,

Mi – actual mass of waste,

Mlim – limit of waste formation,

Ke – index of environmental situation,

N – standard fee within set limit for 1 ton of waste subject to hazard class.

$$F_l = 5 \times (165 - 106{,}34) \times 248{,}4 \times 1{,}3 \times 2{,}2 = 208\ 367{,}4\ \text{RUB/year}$$

Waste transportation costs

If weight-carrying capacity of track is 6 tons and price per truck is 2 000 RUB, then:

$$F_t = \frac{165}{6} \times 2\ 000 = 55\ 000\ \text{RUB/year}$$

$$F = F_l + F_t$$

$$F = 208\ 367{,}4 + 55\ 000 = 263\ 367{,}4\ \text{RUB/year}$$

Profit = Total sales + Total savings – Total operational cost

$$479\ 077{,}5 + 263\ 367{,}4 - 368\ 520\ = 373\ 854{,}9\ \text{RUB/year}$$

Step 7. Assessment of present value

r is discount rate, it is equal to 20%.

TABLE 15. Present value assessment

Received in the end of the year	Present value factor	Amount to be received	Present value of future receipt
y	$(1+r)^{-y}$	B_y	PV
0	1	- 991 645	- 991 645
1	0,833	373 854,9	311 421,1
2	0,694	373 854,9	259 455,3
3	0,579	373 854,9	216 461,9
4	0,482	373 854,9	180 198,1
5	0,402	373 854,9	150 289,7
6	0,335	373 854,9	125 241,4
7	0,279	373 854,9	104 305,5
8	0,233	373 854,9	87 108,2
9	0,194	373 854,9	72 527,9
10	0,161	373 854,9	60 190,6
Total		2 746 904	575 554,7

The profitable index (PI) is equal to:

$$PI = \frac{NPV}{I_0}$$

where NPV – net present value,

$I_0 -$ total investments.

$$PI = \frac{1\ 231\ 467{,}6}{991\ 645} = 1{,}24\ > 1$$

Which means that project is profitable

PB – pay-off period is determined as following:

$$PB = \frac{I_0}{B}$$

$$PB = \frac{991\ 645}{373\ 854{,}9} = 2{,}65 \text{ year}$$

Scenario 2 is a profitable project. Equipment purchasing requires investment. In the example, investment has a payback period of 2.65 years. Short payback period often suggests a good investment and can be considered by the company as potential option of waste management improvement. In the end the company gets income from selling crushed plastic and profit by reducing amount of plastic transportation and disposal. The average market price depends on type and quality of material and varies within 17-30 RUB/kg (Cleandex 2010).

6.3 Scenario 3

Scenario 3 consists of the following: collecting of waste plastic and granulating that for processing to recyclable material for sale.

Step 1. Equipment selection

It is possible to make pre-selection of equipment as the required capacity was defined above. OOO "Polimermash Service" is a Russian company that specializes in manufacturing equipment for the production of polymers and their processing. The granulating line recommended by the company for plastic material recycling includes rotary crushing machine, rotor-type aglomerator and granulation line (OOO "Polimermash Service" 2013). Detailed information is presented below.

TABLE 16. Characteristics of recycled granules production

Rotary crushing machine	**IRPS 300**
Capacity depending on the material, kg/h	about 200
Rotor diameter, mm	300
Rotor speed at rated power, sec^{-1}(cycle/min)	1000
Quantity of rotor knives	9

Quantity of stator knives	2
Length of rotor (stator) knives, mm	138 (420)
The size of the slot in the metering screen, mm	F8
Clearance between rotor and stator knives, mm	0,1...0,5
Clearance between rotor knives and sidewalls of crushing machine case, mm	0,1
Power of motor, Kw	18,5
Weight, kg	700
Dimention, mm (length, width, height)	1650×1050×880
Rotor-type aglomerator	**AGPS – 600**
Capacity, kW	23,5
Power of electric motor drive shaft of the rotor, kW	22
Electric motor power the fan shaft, kW	1,5
Water consumption, m^3/h	0,05
Diameter of the agglomerator working chamber (internal), mm	586±5
Rotation frequency of the rotor shaft, sec^{-1}(cycle/min)	25 (1500)
The direction of rotor rotation	reversive rotation
Weight, kg	810
Dimention, mm (length, width, height)	1900×700×1600
Granulation line*	**LGPS 63-160**
Size of granules, mm	3 -8
Capacity depending on the material, kg/h	about 130
Power of motor, kW	55
Water consumption, m^3/h	2
Weight, kg	2100
Dimention, mm (length, width, height)	5800 ×1500 ×175

*LGPS 63-160 includes extruder, feed bin, hot pelletizing head, bath, conveyor, centrifuge.

Extruder capacity: 180 kg/h

Recycled granules production: 150 kg/h

Line speed: 108 000 kg/month

Quantity of material: 129 000 kg/month

The following figure 7 is described recycled granules production line.

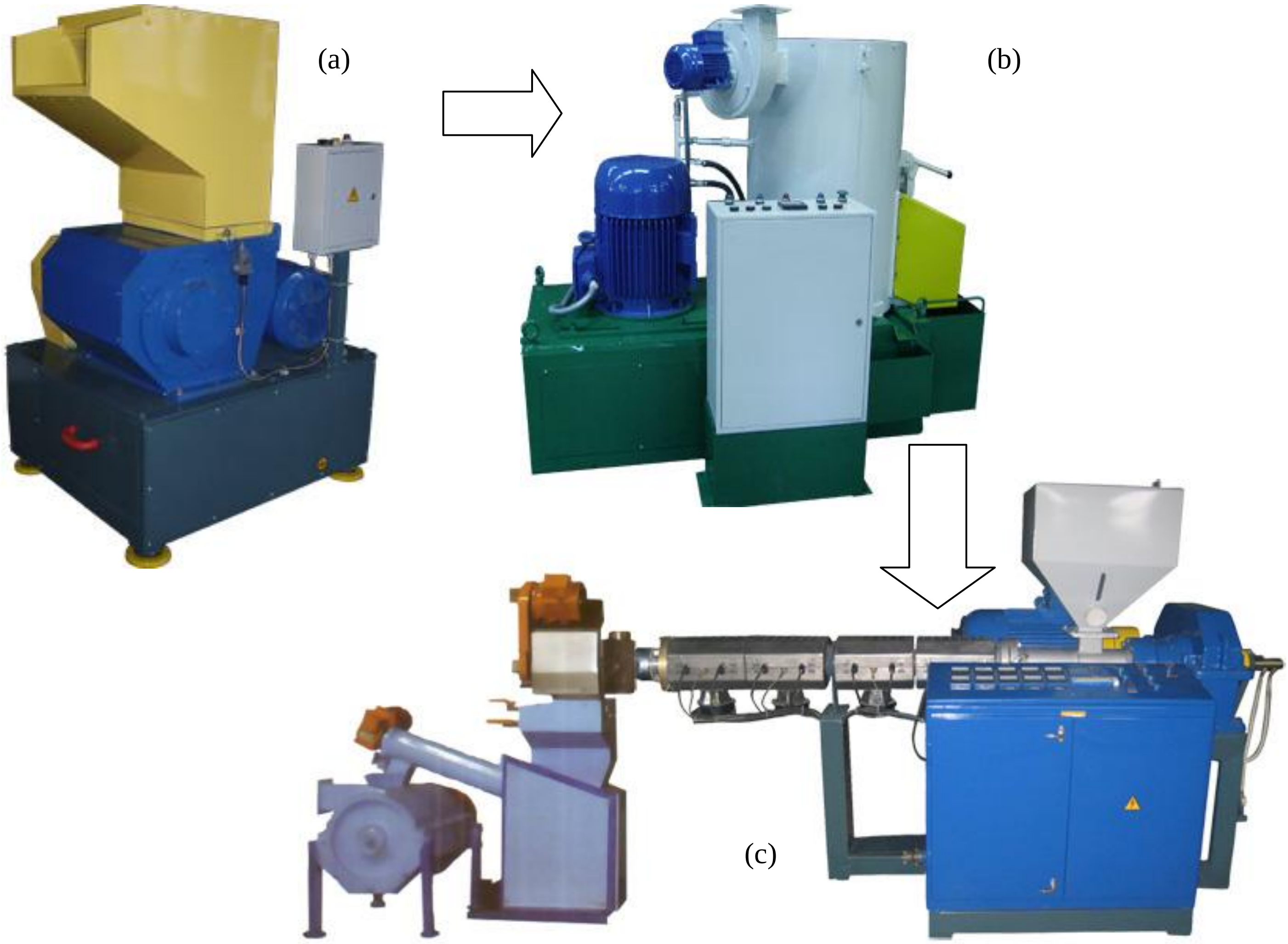

FIGURE 7. IRPS 300 (a), AGPS – 600 (b), LGPS 63-160 (c)

Step 2. Investment assessment

The recycled granules production equipments requires special building, the value of building should be included.

TABLE 17. Value of building

№	Object name	Building area, m²	Cost of 1m³, rub	Object cost, rub
1	Building for plastic recycling	100	6 246, 7	1 249 352*
2	Miscellaneous inputs			124 935**
	Total			1 374 287

*Average building cost in Saint-Petersburg (Design, fabrication and assembly of steel structures 2013)

**Miscellaneous includes costs of site preparation and accounts for 5 % of the building cost

TABLE 18. Equipment purchase

№	Name of equipment	Brand, model, capacity	Quantity	Price, rub
1	Shredding machine	IRPS	1	225 000
2	Agglomarator	AGPS – 600	1	220 000
3	Pelletization line	LGPS 63 – 160	1	1 330 000
	Total			1 775 000

TABLE 19. Total estimated cost of equipment

№	Name of costs	Cost, rub
1	Equipment purchase	1 775 000
2	Balancing and commissioning*	62 125
	Total	1 837 125

* Cost of balancing and commissioning is 3,5 % of equipment cost in accordance to the company conditions.

TABLE 20. Planned budget of capital expenditure on construction

№	Name of costs	Cost, rub
1	Value of building	1 374 287
2	Equipment investments	1 837 125
3	Total	3 211 412
4	Normalized circularity assets	418 711,8
5	Total	3 693 123,8

Step 3. Assessment of operating costs of processing 1 ton of waste plastic

TABLE 21. Operating costs of processing plastic waste

№	Expense item	Unit	Quantity	Cost per unit, RUB	Overall cost, RUB/year	Notes
1	Electricity	kWh	108,5	2,97*	644 490	-
2	Water	m^3/h	2,05	18,70**	76 670	-
3	Auxiliary materials	kg/year	-	-	106 500	6% from equipment purchase
4	**Total variable costs per 1 ton of plastic waste (TVC)**				**827 660**	-
5	Salaries	RUB/month	20 000	-	240 000	-
6	Labor tax	RUB/month	6900	-	82 800	34,5 % from sala-ries
7	Standard fixed costs	RUB/month	4 000	-	48 000	20% from salaries
8	Overhead costs	RUB/month	3 000	-	36 000	15% from salaries
10	**Total fixed costs per 1 ton of plastic waste (TFC)**				**406 800**	-
11	**Total operating costs (TOC)**				**1 234 460**	-

* Committee Decree in electricity rate in St. Petersburg 19.12.2012 № 559

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Total operating costs of processing of 165 tons of plastic waste is 1 234 460 RUB.

Operating costs (per a unit) of processing 1 ton of plastic waste is:

$$C = \frac{TOC}{M},$$

where C – operating costs per unit,

TOC – of processing waste plastic per year,

M – total quantity of generated waste per year.

$$C = \frac{1\ 234\ 460}{165} = 7\ 481{,}6\ \text{RUB/t}$$

Taking into account the industry´s average interest rate of income, which is 20-30 %, the wholesale price (P) can be calculated according the following formula:

$$P = C \times (1{,}2 \div 1{,}3)$$

$$P = 7\ 481{,}6 \times 1{,}3 = 9\ 726\ \text{RUB/t}$$

Leading to that wholesale price per 1 kg is 9,7 RUB

Step 4. Assessment of break – even point

$$BEP = \frac{FC}{P - VC},$$

where FC - fixed annual costs,

P - wholesale price of 1 ton of waste plastic,

VC - sum of variable costs by producing 1 ton of waste plastic

Variable costs (VC) by producing 1 ton of plastic waste is

$$VC = \frac{TVC}{M}$$

where TVC – total variable costs,

M - total quantity of generated waste per year.

$$VC = \frac{827\ 660}{165} = 5\ 016\ \text{RUB/t}$$

$$\text{BEP} = \frac{406\ 800}{9\ 726 - 5\ 016} = 86{,}369\ \text{t/year}$$

Production value in break–even point (V_{BEP})is equal to:

$$V_{BEP} = P \times BEP$$

$$V_{BEP} = 9\ 726\ \times 86{,}369\ = 840\ 029\ \text{RUB/year}$$

This is a unit price for sales to achieve target profit. To achieve more profit, the production value can be calculated for maximum volume of waste:

$$V_{BEP} = 9\ 726 \times 165 = 1\ 604\ 790\ \text{RUB/year}$$

Step 5. Assessment of profitability of investment on waste reduction (total savings)
As were mentioned above, total savings of company includes costs of disposal waste reduction and transportation savings that is equal to 236 367,4 RUB/year.
Profit = Total sales + Total savings – Total operational cost

$$1\ 604\ 790 + 263\ 367{,}4 - 1\ 234\ 460\ = 633\ 697{,}4\ \text{RUB/year}$$

Step 6. Assessment of present value
r is discount rate, it is equal to 20%.

TABLE 22. Present value assessment

Received in the end of the year	Present value factor	Amount to be received	Present value of future receipt
y	$(1+r)^{-y}$	B_y	PV
0	1	-3 693 123,8	-3 693 123,8
1	0,833	633 697,4	527 869,9
2	0,694	633 697,4	439 786,0
3	0,579	633 697,4	366 910,8
4	0,482	633 697,4	305 442,1
5	0,402	633 697,4	254 746,4

6	0,335	633 697,4	212 288,6
7	0,279	633 697,4	176 801,6
8	0,233	633 697,4	147 651,5
9	0,194	633 697,4	122 937,3
10	0,161	633 697,4	102 025,3
Total		2 643 850,2	- 1 036 664

$$\mathrm{NPV} = -1\ 036\ 664 < 0$$

where NPV – net present value,

Which means that project is unprofitable.

The most expensive recycled polymer material is the granular plastic that can be used for industrial production of containers, different car parts, furniture manufacturing and other industries. Such polymer retains the basic characteristics of the starting material, but is produced with a significant lower cost per kilogram. A price varies within 30-40 RUB/kg (Cleandex 2010). Scenario 3 is unprofitable within the company due to the fact that the plant does not generate a huge amount of plastic waste to make a profitable business. The project requires investment for the equipment purchase and special building due to the size of equipment. That is also unprofitable for the company.

7 RESULTS & DISCUSSIONS

This thesis has shown that there are ways by which company can control generated plastic waste and get profit from the measures. In the study above were discussed three possible scenarios for the Automotive Company X at the moment: more thorough sorting of plastic waste by type classification and shipping to recycling companies (Scenario 1); collection of generated plastic waste and crushing it by shredder (Scenario 2); collection of plastic waste and granulating that for processing to recyclable material (Scenario 3).

Measures proposed in the Scenario 1 can be implemented in the company without significant costs. The scenario, which will provide essential savings because of waste disposal reduction and income because of selling sorted plastic waste, is also consistent with the environmental policy of the company and the Green Program. Environmental management conducted according to this scenario would improve the competitiveness of the company in the market as well as would save the environment, public health and raw materials.

Along with the Scenario 1, the Scenario 2 is also a profitable option. The scenario requires investment for crushing machine purchase. But this acquisition would also benefit the company economically and the return of investment would be achieved in a couple of years. The company would also get income from selling crushed plastic and get profit by reducing the amount of plastic transportation and disposal.

Today the Scenario 3 would be unfeasible measure for the company due to the fact that the plant does not generate that much plastic waste to make a profitable business. In spite of the fact that granulated plastic is the most valuable recycled material, a special equipment would be needed for the process and the equipment is a combination of several devices, and, actually, a special building would be needed to maintain the equipment. It is important to remember that one type of equipment cannot recycle all types of plastic material.

On the basis of listed advantages and disadvantages above, today Scenario 1 and Scenario 2 are the better options for the company´s plastic waste management improvement.

Efficient plastic waste management would be created if the materials can be used in the production process. This way the markets are integrated into the materials as such and there is no need to search for buyers. If there is no market for recycled plastics, investment in the sorting and collection is ineffective.

To ensure the successful implementation of the plastic waste management the company should become as the plastic material supplier that meet recycling company´s and customer requirements. As seen above in Chapter 6 it is important to organize a system of more thorough sorting to ensure lower operating costs.

The Automotive Company X follows the same EU hierarchy in waste management as Finnish companies: waste avoidance, reuse of waste, recycling of waste as secondary raw material, waste recovery including waste-to-energy, waste disposal.

The Russian waste management policy is based on principle “pay if you throw”. It means that company has to pay fees for waste disposal volume. It could be an opportunity of the way how to create economic initiative to reduce waste by reusing or recycling. But, in Russia it is easier for companies to pay the disposal fee even though they generated waste over the limits. Still, actions based on the market economy could be used as alternative solutions for decisions making and make them much more attractive for companies. The waste policy implementation could be supported by other acts and regulations such as using pollution taxes and by developing deposit system.

For the proper plastic waste management the entire product life cycle should be covered. If the plastic anyhow ends up to be delivered to landfill, there should be such a channel or service in the landfill at the latest, which takes care of the recycling. Only a multiple approach to plastic waste management involving suppliers, company itself, recycling companies, customers of recycled material and current legislation can create sustainable waste management with zero landfill waste.

8 CONCLUSIONS

According to the environmental aspects analysis a huge amount of company´s waste belongs to plastics category. Except polymer film that is generated from unpacking component parts a significant part of plastic waste falls on rejected car parts.

Today about 9% of the average car, by weight, is made up of plastic. Different plastic types are used in automobile for bumper panels, radiator grilles, body parts, dashboards, wheel covers, fuel tanks, filler flap etc. Currently plastic waste is disposed to the landfill except the above mentioned pure film which company sells for recycling. As stated above plastics can be reused and recycled when there is a ready market for it. According to the EU´s hierarchy in waste management, the reuse has been seen as a better way of managing plastic waste, however, recycling is achievable method for the company. Also, energy recovery could be included at this point when all plastics could be burnt to recover energy.

According to the targets of the company´s Green Program emission of harmful gases such as carbon dioxide (CO_2) are to be reduced. Natural resources would also be saved as extracted raw material can be re-melted, grinded or molded into new forms and zero landfill policy would be resulted. But, unfortunately, recycling is not universal process and simple to merge just like that, there are still many things which should be studied and managed that the all waste types could be utilized as efficiently as possible.

The EU directive on End-of-life vehicles, adopted also in Finland, is an instrument for the right way of waste management. The end of life vehicle, as shown from the European context, indicates a collective contribution from all levels - from engineers to the consumer – how to avoid waste. In Russia, there is no such kind of directive, but there are companies for end – of – life vehicles acceptance. They could accept rejected car parts, mainly consisting of plastics, as possible option. But the recycling process is currently operating only for metal parts, not for plastic ones. One of the reasons is the wide variety of polymer types and additives used. This is the common challenge of the whole industry in the EU as well: the less types, the less problems. Another reason is that the established practices of recycling are based on initial shredding and subsequent separation of mixed streams. Thirdly, end-of-life vehicles are still dismantled by small companies that are not capable to recycle plastic waste.

From the economical point of view efficient plastic waste management can also benefit the company. The waste fee reduction and selling the unneeded material could be economically beneficial. In the study we introduced measures for improvement of the plastic waste management and built three optional scenarios to assess economical potential of the plastic waste management development. The analyses of the scenarios show that as few as more thorough sorting of plastic waste and selling sorted plastic waste would profit the company. Also the company would have savings due to the fee disposal reduction and transportation costs.

Thereby, plastic recycling will benefit the company environmentally and economically.
Based on the finding and conclusions of this thesis, a few recommendations have been made and they are presented in the next chapter.

9 RECOMMENDATIONS

An effective and proper handling of plastic waste would be beneficial for the company. It could be more effective to implement plastic waste management system merged into the overall waste management system. It is reasonable to start plastic waste management implementation step by step. The following list consists of several measures that can be recommended to be taken into the consideration:

- As many polymer materials are generated by the unpacking component part, it is reasonable to change the packaging of parts from one way to returnable in order to reduce polymer materials. The measure would require negotiation with supplier.
- Quite a simple and practical measure would be make employees and suppliers bring back their personal garbage and collect plastic bottles for further recycling.
- To organize special tanks for plastic waste collection on the company´s territory.
- To train the staff for new special waste management task as they should carry out a visual inspection of each plastic item separately. The staff should also be trained for recognizing of types of contaminants that may be included in the plastic waste and on material components or features that let recognize the contaminants.
- To recycle plastic waste back to the plastic raw material.
- It would be reasonable to join forces and start a project with a car company to start collecting plastic waste to be reused or recycled.
- So far the BAT is not well-known. The principle of the BAT implementation in the companies for recycling and waste disposal should be analyzed.
- To make logistical improvement by placing companies (equipment) for recycling and disposal of waste as close as possible to waste sources.

In order to be able to handle plastic waste from automotive industry it is necessary for the company to answer the following fundamental questions:

- What are the main plastic types generated during manufacturing activity?
- How will the sorting of plastic from other material and by types be made?
- How the plastic waste can be recycled in the region?
- Is there a market for plastic waste, recycled material and what price it can be sold?
- What environmental and economical profit company can get implementing the measures?

Based on the above-mentioned, in conclusions, the environmental and economical advantages of improvement plastic waste management and listed questions, for company´s further study can be recommended in a deeper analysis of equipment in the market in order to find the most suitable method for recycling company´s plastic waste. The built scenarios in this study, make a good basement for the comparison of commercial offers. The demand for recycled plastic material has also to be studied to make profitable business. More comprehensive technical and economic assessment of suggested measures should be conducted. It is important to analyze sensitivity of decisions to changes in one or more variables in order to make the right choice. It is so called sensitivity analysis. The selling price, unit variable costs and total fixed costs are possible variables for further studies.

All recommended measures are to help to reduce and handle plastic waste more efficiently in the Automotive Company X as plastic is valuable material in modern vehicle due to the benefits that were discussed in Chapter 2. Thereby, the only contribution in plastic waste management can make savings in environment and natural resources and reduce health risks of the employees.

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APPENDIX 1.

Environmental aspects of the Automotive Company X (Register of significant environmental aspects of the Automotive Company X 2009)

№	Environmental Aspect	Formation place	Value factor	Current situation of waste manage-ment
1	Mercury lamps, luminescent mercury-containing tubes – worked-out and rejected	In all departments Replacing worn-out lamps is performed by the tech-nical service	4*3=12	Transfer to the company for demercurization of lamps
2	Accumulator battery	Replacement units, parts and assemblies Rejected batteries are gen-erated in trim and chasses shop	4*1=4	Transfer to the company for recycling batteries
3	Generation of phosphate sludge	Paint shop (phosphatizing method of body surface)	4*3=12	Phosphate solution moved to a filter press for filtration. The clarified solution returned to the bath, the phosphate sludge disposal to the landfill
4	Generation of paintwork material waste (paint slurry)	Paint shop Application of prime on car bodies, bumpers in spray cabinet, application of surface cover (basic enamel, lacquer)	4*3=12	Waste water passes through hydrofilter and is discharged into the sludge pit. Sludge processing system based on the flotation method. Paint slurry

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№	Environmental Aspect	Formation place	Value factor	Current situation of waste management
				discharged to the landfill
5	Risk of generating expired chemical materials (paintwork materials, glue, resin, sealant, coagulants etc.)	Planning and delivery of components and materials for the production of vehicles in the Department of production control	4*3=12	Landfill diaposal
6	Generation of paper and cardboard waste from stationery activity and paperwork	Paperwork and life activity of departments	3*3=9	1. The greater part is discharged to the landfill 2. Remainder is pressed and sent for recycling
7	Generation of garbage from domestic premises of organisations, unsorted (excluding big-sized)	Paper work and life activity of departments	3*3=9	Landfill disposal
8	Generation of special clothes and personal protection equipment that have lost their consumer qualities	Paper work and life activity of departments/ discarding special clothes	3*1=3	Landfill disposal

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№	Environmental Aspect	Formation place	Value factor	Current situation of waste management
9	Risk of generating car parts waste (no metal waste)	Planning and delivery of components and materials for the production of vehicles in the Department of production control	4*3=12	Landfill disposal
10	Risk of generating metal waste (from car parts)	Planning and delivery of components and materials for the production of vehicles in the Department of production control	4*1=4	Send to the company for recycling
11	Generation of worked-out cartridges waste	Maintenance of office equipment in working condition	3*1=3	Landfill disposal
12	Risk of spillage of construction and domestic waste	Construction work performed by contractors an controlled by Maintenance department	4*3=12	Landfill disposal
13	Generation of domestic food waste	Canteen providing food for company employees	3*1=3	Landfill disposal
14	Generation of sorbent or sand contaminated with oils waste	Shipment of finished products (cars), trucks parking	3*2=6	Landfill disposal

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№	Environmental Aspect	Formation place	Value factor	Current situation of waste management
15	Generation of rubber offcuts	Unpacking of component parts	3*1=3	Landfill disposal
16	Generation of waste: - wooden packing (non-returnable tare) from natural wood - plywood - paper and cardboard - waste of polyethylene in the form of a film - steel scrap - waste of polyfoam - waste of polystyrene	Unpacking of component parts	3*1=3	If paper, cardboard, steel scrap and polyethylene are not contaminated they are sent for recycling, otherwise disposed at the landfill
17	Risk of rejected car's parts generation	Unpacking component parts	3*1=3	Landfill disposal
18	Generation of wiping materials contaminated with oils (with oil content of less than 15%)	Servicing of process equipment in all departments	3*1=3	Landfill disposal
19	Generation of mineral oils (worked-out) Crankcase oil (worked-out)	Maintenance of process equipment in all departments	3*1=3	Send to the company for recycling

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№	Environmental Aspect	Formation place	Value factor	Current situation of waste management
20	Copper scrap and ferrous metal scrap	Maintenance of process equipment in all departments	3*1=3	Send to the recycling company
21	Generation of waste rubber products (rubber dam)	By servicing of process equipment in all departments	3*1=3	Landfill disposal
22	Solid utility waste (sweepings from territory)	Cleaning of the hard surfaces of temporary waste storage areas	3*3=9	Landfill disposal
23	Generation of worked-out propylene glycol waste (Waste containing used non-halogenised organic solvents and their mixtures)	Compressed air generation for industrial purposes	3*1=3	Landfill disposal
24	Waste generation in the repair (rubber)	Compressed air generation for industrial purposes	3*1=3	Landfill disposal
25	Generation of waste (sediments) from effluents treatment by means of reagents	Operation and maintenance of industrial wastewater treatment plant	3*3=9	Landfill disposal

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№	Environmental Aspect	Formation place	Value factor	Current situation of waste management
26	Waste generation from cleaning tanks (lime deposit)	Operation and maintenance of industrial wastewater treatment plants	3*3=9	Landfill disposal
27	Filtration and absorption of worked-out materials not contaminated with hazardous substances (worked-out filter charges), waste (sediments) with mechanical and biological waste water treatment	Maintenance of stormwater treatment facilities	3*2=6	Landfill disposal
28	Waste from cleaning of sewerage system	Maintenance and operation of industrial sewage system	3*2=6	Landfill disposal
29	Generation of oil waste during maintenance and repair of pumps	Maintenance and operation of industrial sewage system	3*1=3	Landfill disposal
30	Waste generation from grease separators containing fats and fat products	Maintenance and operation of sanitary sewage	3*1=3	Landfill disposal

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№	Environmental Aspect	Formation place	Value factor	Current situation of waste management
31	Generation of waste mineral oils – worked-out	Maintenance of fire control system	3*1=3	Sent to the company for recycling
32	Generation of emulsions from oil separators	Replacement units, parts and assemblies	3*1=3	Landfill disposal
33	Waste generation of chips and scrap of ferrous and non-ferrous metals	Metals cold handling	3*1=3	Sent to the company for recycling
34	Generation of industrial waste	Repair and maintenance of process equipment, cleaning of industrial premises	3*1=3	Landfill disposal
35	Generation of scrap metal	Body break test, Body shop	3*1=3	Send to the company for recycling
36	Waste generation from contaminated metal tare (Waste of ferrous metals with impurities)	Control of body geometry	3*1=3	Landfill disposal
37	Generation of surface film from the oil catcher	Shower test (air-tightness test)	3*1=3	Landfill disposal
38	Waste generation from filtration and absorption of worked-out materials contaminated	Production process (all departments)	3*1=3	Landfill disposal

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№	Environmental Aspect	Formation place	Value factor	Current situation of waste manage-ment
	with hazardous substances (air cleaning filters)			
39	Waste from paintwork materials (wiping materials contaminated with paints and oils)	Cleaning hands, bodies, equipment and tools from contamination	3*2=6	Landfill disposal
40	Generation of plastic containers with steel latchings	Application of cataphoresis coating by electrodeposition	3*1=3	Landfill disposal
41	Generation of abrasive cloth waste	Cataphoresis coating grinding, inspection and body polishing	3*1=3	Landfill disposal
42	Waste generation from polishing paste	Inspection and body polishing	3*1=3	Landfill disposal
43	Waste generation (flue cinder)	Welding procedure	3*1=3	Landfill disposal
44	Waste generation of copper welding electrodes	Welding procedure	3*1=3	Landfill disposal