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Storage Method for Parts from End of Life Vehicles' Dismantling Process According to Sustainable Development Requirements: Polish Case Study

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***Abstract*—**Vehicle is one of the most influential and complex product worldwide, which affects people's life, state of the environment and condition of the economy (all aspects of sustainable development concept) during each stage of lifecycle. With the increase of vehicles' number, there is growing potential for management of End of Life Vehicle (ELV), which is hazardous waste. From one point of view, the ELV should be managed to ensure risk elimination, but from another point, it should be treated as a source of valuable materials and spare parts. In order to obtain materials and spare parts, there are established recycling networks, which are an example of sustainable policy realization at the national level. The basic object in the polish recycling network is dismantling facility. The output material streams in dismantling stations include waste, which very often generate costs and spare parts, that have the biggest potential for revenues creation. Both outputs are stored into warehouses, according to the law. In accordance to the revenue creation and sustainability potential, it has been placed a strong emphasis on storage process. We present the concept of storage method, which takes into account the specific of the dismantling facility in order to support decision-making process with regard to the principles of sustainable development. The method was developed on the basis of case study of one of the greatest dismantling facility in Poland.

***Keywords*—**Dismantling, end of life vehicle, sustainability, storage.

I. Introduction

AUTOMOTIVE industry is one of the most influential sectors of economy worldwide. Automobiles are integral part of the current generation's life; however, there is a growing concern over the impact of vehicles through end of life phase, which is referred to management of ELVs [1]. With the increase of vehicles worldwide, it is observed the growth of ELVs' number, what results treatment ELVs as an international emerging problem [2]. Meanwhile, there is a rapidly increasing awareness in industry that today's companies have to seriously consider the impact on People, Environment and Economy, particularly in automotive sector. At the same time, when issues on "*sustainable development*" have been valid globally, the recycling, reuse, recovery or disposal of ELVs have attracted greater attention [3].

ELV is a specified vehicle, which is discarded or is to be discarded by its last owner, what makes that ELV is waste according to the law [4]. As many researches claim, waste from ELV is the issue of a world-wide concern, because of its rapidly growing quantity and special composition of substances, including different toxic substances such as lubricants, acid solutions, and coolants [5]. In the previous work [6], authors proved that ELV should be perceived as a valuable source of materials and used parts. Hence, ELVs' management is significant for resource conservation, environmental protection and economy growth.

Poland is a country with a high potential in ELVs recycling according to the age structure and vehicles' quantity, what was studied in [6]. In Poland, similar to other countries in the EU, ELVs are a major stream of waste[1] [4] which should be managed in the recycling network [7].

In the structure of polish recycling network, the dismantling/disassembling facility (DF) is the only one, that is authorized to manage ELVs. The processes realized in the DF include obtaining vehicles; depollution of ELVs, disassembling and storage of ELVs, spare parts and waste. In the result of all activities realized in DF there are obtained two streams: used parts ready for redistribution as spare parts (reuse scenario) and waste, prepared for recycling or disposal.

DFs are running a specific business, where sell of the used parts is the basic source of revenues. What is more, the reuse scenario is, in the authors' opinion, the best from all ELV's waste management possibilities, from the sustainability perspective. Although there are specific guidelines for some parts storage process, however there is lack of method which would support decision makers in the dismantling facility in the warehouse management area, what could improve their performance.

Taking into consideration all presented aspects, we present a concept of storage method for parts obtained from ELVs disassembling which would consider sustainability issues.

Paper consists of 5 sections. Section II provides information about the DF from the perspective of business specification in Poland. In the Section III, there are presented considerations of reusable parts storage in dismantling facility on the basis of case study. Section IV describes the concept of the proposed method for parts storage. Section V summarizes contributions and directions of future work.

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[1] Every year, ELVs generate between 7 and 8 million tons of waste [8].

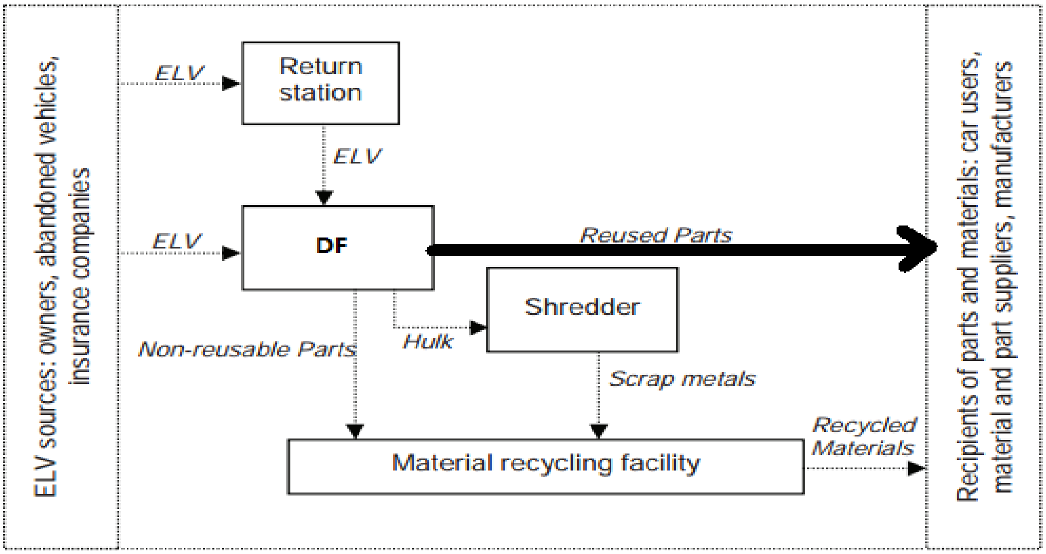

Fig. 1 The participants and the flows in the polish recycling network Source: [9]

II. ELVs Dismantling Facility – Polish Example

A. *Dismantling Facility in the polish Recycling Network*

Polish recycling network is structured according to the guidelines defined in the European Directive 2000/53/EC [7]. It consists of many enterprises involved in ELVs management, what is presented in Fig. 1. As it is presented in Fig. 1, the main entity in the polish recycling network is DF, which obtains ELVs from different sources directly including last owners, insurance companies, public authorities, vehicle return stations as well indirect with the use of return stations. On the 10th May, 2016 Polish recycling network consisted of 1008 DF [10] and 136 return stations [11] In comparison, at the beginning of recovery network creation period (at the end of 2005) those numbers were: 360DF and 50 return stations, what demonstrates that there is a demand for services offered by DF. It is related to the vehicle fleet characteristic in Poland what creates the potential for ELVs recycling (mentioned in the *Introduction* section).

B. *Specific of the Dismantling Facility Business*

In author's opinion, DF is dealing with the same functions as traditionally manufacturing company, including procurement, processing and distribution, what is presented in Fig. 2.

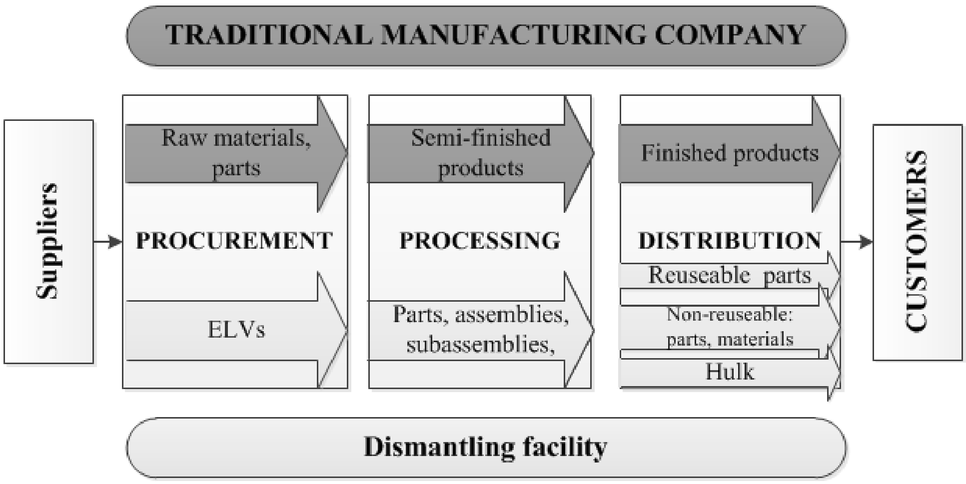

Fig. 2 Comparison of dismantling facility vs traditional manufacturing company

Taking into consideration the specificity of the DF business, there are different material flows as opposed to traditional manufacturing company, where instead of low level of complexity of input stream, there are complex products – vehicles, hazardous for the Environment. Moreover, categories of suppliers and customers of DF are also a difference.

The DF is the only officially approved entity authorized by polish law to ELVs processing. In the light of considerations on ELVs as dangerous waste, the dismantling stations are under constant monitoring and are required to achieve the goals related to the recycling and recovery rates, in accordance to UE guidelines.

The core activities realized in DF are related to the ELV's management including the following operations presented in Fig. 3.

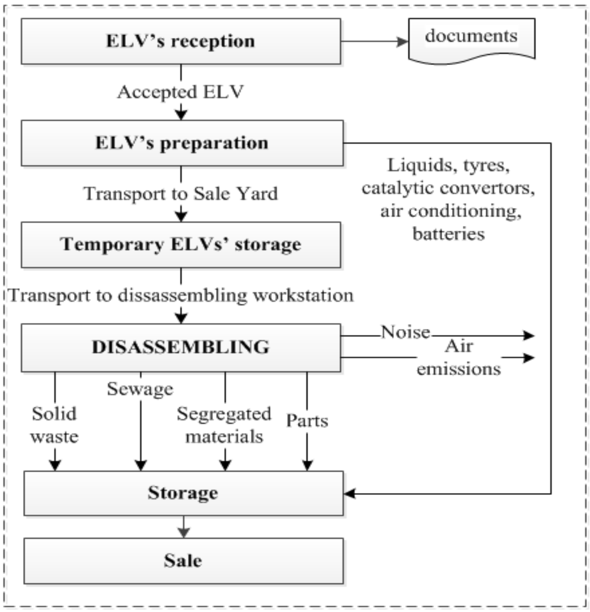

Fig. 3 Core activities realized in DF

In order to process ELVs, DF has to obtain and take supplied vehicles, what results in ELV's reception and development all required documents for supplier. Those activities require additional actions including marketing and ELV's transport from the supplier.

Upon ELV's reception, the ELVs are inspected, drained from fluids (i.e. engine oil, fuel, etc.) and air conditioning, batteries, wheels/tires and catalytic convertors are removed.

Prepared ELV's are placed into *Sale Yard,* where they are temporary stored. Stored ELVs are available for walk-in customers who are able to dismantle only required parts on their own or with Employee's help (ELVs are treated as outdoor warehouse). On the other hand, whole ELVs are disassembled into components after dismantling order, which does not have to be related to the customer's order for part.

During disassembling there are emitted:

- air pollution;
- noise;
- solid waste;
- sewage;
- segregated materials;
- reusable parts.

From the list of presented outputs of disassembly process there are two main flows: *waste* and *reusable parts*, both are stored, what is strictly regulated by law and then sold to customers (individual as well as business) via different distribution channels, mostly direct sale.

DF is relevant entity in sustainability policy realization at the national level, because of the reuse and recycling scenario of ELVs implementation.

In previous work [12], authors have analyzed the DF from the perspective of the social, economic and environmental perspective, what confirms importance of DF for sustainable development. Although a high significance of DF, there are a lot of problems related to the DF business in Poland what was described [13].

We focus on the storage process of reusable parts, due to the importance for the DF considering sustainability issues, what is discussed in the next section.

III. Reusable Parts Storage in Dismantling Facility – Case Study

A. Why to Store Reusable Parts?

Storage process is according to the polish norm, a set of activities related to the stocks' placement on the storage space of the storage building (e.g. in storage equipment) in a systematic way according to the inventory's characteristic and the existing conditions [14].

Reusable parts are all parts, which according to the polish law may be used in the same function as they were designed for. Those parts are used spare parts.

We focused on the reusable parts storage process. It is a result of the value of the reusable parts from the perspective of the sustainability.

First of all, the best strategy for the sustainable development policy introducing is reuse. Reuse is equal to saving natural resources, protecting the environment and saving money, what in a case of the automotive industry is significant (high material – and energy consuming). It brings positives from all sustainability dimensions.

Secondly, used spare parts are the basic source of revenues for DF. In accordance to the research conducted in one of the biggest DF in Poland processing around 1200 ELVs per year [6], authors identified that only metals sale is profitable, although DF are addicted to the price level of the materials which are changing very often and it is poor low. Comparison of the income from spare parts sale and materials sale prove that around 70% of all incomes generate the first group. Taking that into consideration, there should be an emphasis on the storage process realization due to the economic potential.

What is more, the business model of selling used parts is well developed in Poland as well as other post-communist countries in the Europe. It is mainly the result of low salaries and the opportunity to acquire parts which are no longer produced. Those aspects may be considered from the social context of sustainability.

As it was proved, there are many benefits for People, Economy and Environment due to the reusable parts. In order to take the advantage of that it is necessary, in authors opinion to storage parts appropriate.

B. Storage in Dismantling Facility and Traditional Manufacturing Company - Comparison

In the every production company, there is storage. However, in dismantling stations, there are differences resulting from stored and at the same time very different parts.

Therefore, for the comparison analysis there was created a scale in order to verify similarity of the storage process in traditional production enterprise and DF, presented in Table I.

TABLE I
THE COMPARISON SCALE MATRIX

Scale	Explanation
-	There are only differences
0	There are similarities but also differences
+	There are only similarities

The sign "-" in Table I indicates no similarities of storage process in traditional production facility and DF. The "0" means that there are some similarities as well as differences. With the sign "+" there were pointed out only similarities. Authors have compared DF with the traditional manufacturing company with the use of following criteria presented in Table II.

TABLE II
THE COMPARISON FEATURES PRESENT IN STORAGE

Criterion	The presence of the features	Comments
Properties	+	
The shape, dimensions, weight	-	
Packaging unit	-	
Warehouse space	0	
Zoning in the warehouse	0	
Type of storage	0	Adjustments in the rules for mass objects moved by hand. Provisions on objects moving in the type of mechanized work
Internal transport	0	
Warehouse equipment	0	
Labeling locations	-	

In any enterprise, goods should be stored according to their type of store. One of the criteria that should be taken into account are properties of natural products, e.g.: sensitivity to atmospheric conditions, susceptibility to corrosion susceptibility to temperature. In addition, products' group which occur in a manufacturing company and DF, may have aggressive properties e.g.: flammable, explosive, toxic, etc. It is a threat for human life and health as well as for the Environment. It can also be a cause of damage of a storage facility. The described feature occurs in both cases – DF and manufacturing company.

Another issue is number of the assortment stored in a warehouse. In the DF, there is no single assortment. Products stored in DF are diverse in terms of shape, dimensions and weight. In addition, each group of assortment requires proper storage, which is not always easy in real life and made according to the law requirements.

Every product in the traditional production company has a specific shape or before storage, it is packed into the packaging unit. In the case of the DF, parts obtained in the result of disassembly process are stored in the same state as they were disassembled. There is no packaging unit, which would allow to carry out parts easier from the warehouse. Regarding to the storage space in manufacturing company, there can be isolated storage area, surface handling, auxiliary surface, the surface area of communication and design. However in the DF, each part is different (weight, volume), which results in not enough storage area. Moreover, each part requires proper storage. The fulfilment of these conditions is difficult in business reality.

The same problem as above, applies to zones of acceptance, completion and release. There is no possibility of separation specific storage area in DF warehouse. Moreover, sometimes there are no storage areas.

Type of storage is primarily connected with devices with which operations are performed in the warehouse. In manufacturing companies, as well in DF, there is a manual system of warehousing and mechanized one, too.

Manual work, in both companies, is based on the physical strength of a man which performs such tasks as lifting, carrying, packing or filing. All manual operations are in both types of companies. However, in manufacturing company, there are standards applying maximum weight of goods. In DF, in accordance to law, there are requirements of manual handling of goods which are harmful and dangerous.

Considering mechanization of warehousing related to the introduction of machines and mechanical devices by which handmade warehouse operations will be performed mechanically, that issue is subject in one and in the second type of the company. Moreover, in automotive manufacturers, there are an automated job type storage, what is impossible to use in the DF. It is a result of variety of types, shapes and sizes of parts as well as the variety of working methods.

Type of storage is primarily defined by the equipment used in the warehouse. Hardware stores are the technical and organizational measures: means of transport, equipment, tools, installations. Both, manufacturing company and DF use specified means of transport in storage process. In the DF there are used: platform trucks and forklifts trucks. These devices are the most often used, although they are not only used in storage process. However, in manufacturing companies, there can be found carriages designed for use in narrow aisles between the shelves. In contrast to DF, these devices are used only for storage and work for one type of SKU.

Another very important feature that distinguishes mentioned types of enterprise are devices used for storage, which are used in both cases. However, due to the diversity of stored parts in DF, storage takes place primarily on the universal racks. Unfortunately, the weight and appearance of the assortment does not always allow to use this type of equipment (e.g. some goods with very unusual shape). Thus, there are used special station racks. The variety assortment causes the use of pallets, load units, boxes and containers. In addition, in the manufacturing companies, entering and exiting of the products from the warehouse is appropriately tagged. The location of the goods in the warehouse is also known. Each load unit is assigned to a location in the system. In the analyzed DF, there are a lot of different kinds of parts, the storage area is limited and there is lack of addresses location. Information flow is discharged by warehouse's Employees, who knows where the part is regarding to his experience and knowledge.

C. The Specifics of Storage in Dismantling Facility – Case Study

As it was pointed out in *Section II*, one of the core activity in the DF is storage of parts and waste. In accordance to polish recycling law, all reusable parts as well as waste are stored in appropriate conditions, including the following criteria [15]:

- C1: Storage location (*where*?);
- C2: Equipment (*with what*?);
- C3: Mode of storage (*how*?).

The basic requirement is related to the storage location, what is the result of the requirements regarding land use. In the DF there should be separated storage areas for reusable parts, waste and ELVs. The most important issue is to storage reusable parts in the covered object, what is very often not respected due to the increasing quantity of stored parts and limited storage area.

In the analyzed DF, there is used universal equipment, including shelfing racks, console racks as well as special racks (e.g. for glass, doors, etc.). All operations are made by hand, including transport with the exception of movement of engine or transmission, where the forklift is used.

From the perspective of the mode of storage, authors perceived that there is no procedure for storage process. There are no containers for parts which are stored at the shelf. Many of elements are stored direct on the floor, sometimes without required protection and equipment (e.g. palette). Storage area are divided into zones designated for kind of part (e.g. for engines, starters, seats, etc.), although there is lack of formal instructions, what results excess transport and defects of parts (muda). It may cause Employee's overload and in the consequence less efficiency, what may be considered in the sustainability context.

Taking into consideration all presented above information, authors assumed that there is a need for a method supporting decision makers in the DF in the storage process, what could improve DF performance concerning sustainability issues. In order to find a storage method dedicated for specific business of DF, authors have made a literature review with the use of research bases including: SCOPUS, Science Direct and Google Scholar. In the result, authors did not find any example of the work considering reusable parts storage method description.

It leads to development of the storage method for parts (SMEP*)* from ELVs' dismantling process considering sustainability requirements, described in details in Section IV.

IV. SMEP FROM ELVS' DISMANTLING PROCESS

A. Method Description

The presented storage method (SMEP) was prepared with the use of the following research methods:

- systematic literature review according to storage of reusable vehicle's parts;
- observations made in the polish representing of DF;
- interviews with Employees, including company's owner;
- brainstorming.

The basic method used in the research methodology was a case study, of one of the greatest DF in Poland, with about 1200 processed ELVs per year.

The proposed method for vehicle parts storage is intended for use by a disassembly worker, who dismantles ELV into parts and waste. The method is prepared according to two assumptions:

A1. Employee disassembles a vehicle according to the *Disassembly list* (hereafter: *DL*). It contains a list of parts which should be stored. DL should be developed according to the demand analysis for parts or Employee's knowledge about the potential demand, excluding all parts which regarding to the law, cannot be reuse because of security threat in case of their reuse.

A2. Stored parts are clearly marked what makes the element's identification easy.

The SMEP consists of 6 steps presented in Fig. 4.

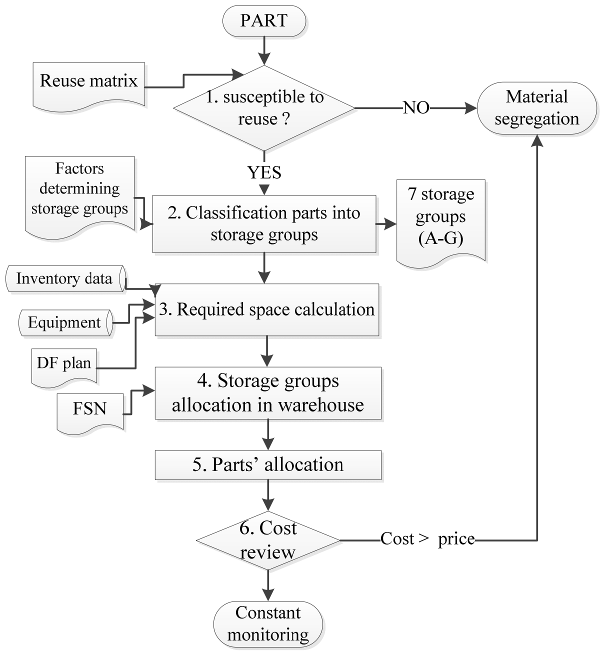

Fig. 4 SMEP procedure

Each of step in the presented procedure is described in the particular subsection.

B. Step 1: Susceptibility to Reuse Scenario Verification

The first stage of the method was to verify susceptibility to reuse scenario. The basic question of that stage is: "*Should part be stored?"*

In order to answer the previous question, authors propose simple tool – *Reuse Matrix* to check if part is able to be stored. The Reuse Matrix is presented in Table III.

There were used only two criteria for determination susceptibility to reuse scenario for part. Authors assumed that Employees will only disassembly those parts which are required according to DL.

TABLE III
REUSE MATRIX

Condition	Id	Value	Description
Efficiency	C1	0	incorrect
		1	correct
Technical Condition	C2	0	damaged
		1	undamaged

To summarize, susceptibility to reuse scenario is the function of two conditions presented in (1):

$$f(s) = C1 * C2 \text{, f(s)} \in \{0,1\} \quad (1)$$

where: f(s)= 1 → part is susceptible to reuse; f(s)= 0 → part is not susceptible to reuse.

Simplicity of the reuse matrix is a result of requirements obtained from the interview with Employees and DF owner. Consequently, only correct and not damaged parts from DL are qualified to storage. Rest of them are intended for material segregation (waste) and they should be placed in the appropriate container.

C. Step 2: Classification Parts into Storage Groups

In the second stage of the procedure, there are identified storage groups of parts intended for storage (result of the first stage of the SMEP).

The basic question of that stage is:" *how to storage?"*. With a view to answer the question, authors used results of observations (possible storage equipment and storage parts in analyzed company) and brainstorming.

Authors have made a brainstorming session with two representatives of the University and three members of DF including the owner.

The first stage of the brainstorming was to determine list of factors for parts classification. In the result there were obtained the following factors (F1-F5), including (Table IV):

TABLE IV
FACTORS DETERMINING STORAGE GROUPS

Factor		Values		
Id	Description	1	2	3
F1	Weight	up to 5 kg	5-30 kg	over 30 kg[2]
F2	Size	a,b,c <0,2 m	a,b,c ϵ<0,2-0,6) m	a,b,c>0,6 m
F3	Shape	Regular	Irregular, but not long timber	Long timber
F4	Content of harmful substances	no	-	yes
F5	Required storage equipment	no	-	yes
F6	Sensitiveness to damages	no		yes

According to the presented results, there were arbitrary defined five important factors. Factor "*weight*" was established in accordance to the law requirements included in [16]. Factors: "*size*" and "*shape*" were distinguished with respect to Employees opinion, who deal each day with parts transport. Factors F4 and F5 were extracted in conjunction with law requirements, particularly "*Required storage equipment*" which may be related to the security of part during storage, separate storage space or container/palette usage).

Each part stored in DF was analyzed with the use of Factors (F1-F5) presented in Table IV. As a result of analysis made by participants of brainstorming, there were prepared following categories of parts (Table V):

TABLE V
STORAGE PARTS GROUPS

Parts	Equipment
engine, transmission	palette with protection, console racks
tire, wheel trim, wheel, rim	separated are with fire extinguisher, racks or stands
drive shaft, pipe, damper, spring, bumper swingarm, gas installation, exhaust, wiper	cantilever racking, hooks, hangers
reflector, navigation, radio,	containers, shelving racks
seats	foiled, console racks
painting elements, glass, including doors, mask,	special racks, spacers between parts
alternator, starter, wheel	shelving racks

In the result, in Table V, there were distinguished 7 different groups of parts with the required equipment.

D. Step 3: Required space calculation

In the third stage of the method, there is estimated required space (m^3) for each of the following groups of parts (A-G). In order to make the calculation, there should be an access to the actual plan of the company, including warehouse area.

The estimation of the space required for the chosen group of parts should be calculated according to (2):

$$S_j = c_j * i_j \quad (2)$$

where: S_j- required space for the j-th group of parts, j={A,B,C,D,E,F,G}; c_j –average space required for one part from *j-th* group; i_j – actual number of parts in *j-th* group (it is acceptable to add 10%).

There should be known the required space in the rack for one part and the information about the number of actual inventory to calculate the total required space. Taking into account the information about the available equipment (particularly rack capacity of stored parts) and the required space for the each group of parts there will be available information about the required area for the j-th group of parts (a_j) in [m^2].

E. Step 4: Storage Groups Allocation in Warehouse

The further two steps (4,5) are directed to obtain the answer for the question "*where to storage*?". The basis is a combined ABC analysis by Gelders and van Looy named FSN analysis [17], where are three types of products: fast moving (F), slow moving (S) and no moving (N) [18]. The FSN analysis is made for storage groups (A-G). There are assigned places in the warehouse according to the rule "*transport distance*

[2] According to [16]

minimization".

Transport distance - t_j is equal to the distance between dismantling workstation and warehouse zone for *j-th* storage group of parts. In practice it is equal to assign groups of parts from the "*F*" category as close as it is possible to the warehouse entrance/exit, in accordance to the warehouse layout.

F. Step 5: Parts Allocation

In the next step, the same analysis (FSN) is used but the purpose is to assign place at rack for each part from the analyzed storage group.

Considering demand on particular parts, there are following guidelines:

- In the middle - parts from the group: F;
- at the bottom: parts from the group: S;
- at the top: parts from the group: N.

G. Step 6: Cost Review

The last stage in the method includes the cost analysis of the storage, repeated each day automatically.

Authors suggest that inventories should be examined in the context of profitability of storage. In practice sometimes parts are stored although their costs are higher than potential income. In the consequence authors recommend cost review of inventories. In the result DF should get the information when the total cost of the part in warehouse is higher than potential income from selling it. In that case there should be made a decision of material segregation, in order to restore a value of part.

The last step is at the same time a direction of further research for authors.

V. Conclusion

Warehouse management and phenomena that occur in each company are treated as one of the most important cells in an field of logistics. Well-organized warehouse processes cause the flow of materials.

Warehouse as the supply chain fulfils a series of functions that need to carry out basic tasks. These tasks are the storage of goods and handling activities.

Warehouse processes also occur in the dismantling facility. Poland is a type of a country, where the potential of sustainable policy realization is related to the recycling network, particularly dismantling facilities which are managing ELVs with the reuse and recycling scenarios. It results in increased demand for services in the field of dismantling and recovery of materials from ELVs, including storage process.

The modern vehicle is made of many different materials with different properties. Disassembled components can also be a source of financial gain. From an environmental point of view, properly conducted storage is more than just a material benefit.

Disassembled parts, due to the different size (the volume), weight, shape, require appropriate storage conditions, what with limited space, is difficult. Comparison of the storage process in traditional manufacturing company and DF, proved that they are different. Moreover analyzed DF has limited financial resources and do not always have the possibility to invest in the warehouse equipment.

Reusable disassembled parts can bring financial benefits for the DF. In order to achieve that, the storage process, as in a typical manufacturing company, should be improved from the perspective of the material flow, to not be a bottleneck. Therefore, the authors have created the concept of storage method for DF called SMEP. This method is aimed at decision support in the process of storing parts. It is not easy to make good decision, what is related to the very large number of removable parts, and large variety of them in order to ensure properly storage for each part.

SMEP method consists of six steps. It aims to bring decision-maker answers to three questions: where, what and how to store reusable parts. Furthermore, the concept also involves an analysis of the cost of the stored parts, what is appealing for the DF.

The presented storage method takes into account the specific of the dismantling facility business as well as sustainability issues.

Unfortunately, this method is only a concept and it require to carry out further studies. These studies should be aimed at the realization of this method even in the form of a program that will help the Employee to decide about storage of parts.

The increase in the number of vehicles in Poland is still growing and therefore dismantlers also gaining in importance. Therefore, the problems of storage process in DF also acquire greater value.

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