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Reverse logistics concept on the example of managing used tires at the Tire Utilization Center

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ABSTRACT

The subject of consideration of the following study is to present the assumptions of reverse logistics in the aspect of sustainable development as a response to the growing ecological requirements resulting from the increased use of natural resources and the increase in the amount of waste. Reverse logistics, assumes the reverse flow of products that have completed their life cycle in order to reuse, use, recover or recycle them. The paper describes the use of reverse logistics assumptions on the example of re-use of used tires by the Tire Utilization Center.

***Keywords*:** Reverse logistics, waste management, recovery, recycling, rubber waste, used tires, Tire Utilization Center

1. INTRODUCTION

Economic development in the world, besides many economic and social benefits, also brings about increasingly large environmental changes. It causes more and more pollution of the natural environment. In connection with this, there is an increased public interest in the threats resulting from this phenomenon. Societies undertake actions in the area of technology, organization and investment to reverse unfavorable actions of economic development. Ecological care is being articulated more and more often in the area of economics, thus ecological problems become an area of interest for contemporary enterprises. Along with the

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aforementioned economic and civilization development, more and more diverse products are manufactured. As a result of the business activity, apart from the desired finished products, also by-products or waste are produced. Their main features are unsuitability at a given time and place and a harmful effect on the environment. [1]

As a result of the growing problem of waste, by-products and useless products, concepts of management and management of these products developed in the economy. Standardized organizational management systems have been introduced to the modern economy in order to multiply beneficial effects for the company's environment. In 1991, the World Economic Council for Sustainable Development initiated, along with other institutions dealing with similar subjects, standardization of environmental management standards. In 1992, the British Institute for Standardization published the Guidelines for an environmental management system, the first environmental management standard and initiated the development of the concept of sustainable development. In the following years in Europe, the Directive introducing the Environmental Management and Audit System, which is a voluntary system, development of principles and forms of action adopted by enterprises to improve the natural environment, was adopted. Also in Poland in 19991, the National Environmental Policy was introduced, and in subsequent years, legal regulations were introduced aimed at eliminating the harmful effects of the country's economic development. All these global actions taken by environmental organizations aim to create a balance between technological progress and environmental protection. [2]

Production enterprises, due to the nature of their operations, may pose a serious threat to the natural environment through the emission of pollutants, including waste. Therefore, there is a need to introduce the concept of sustainable development into the management strategy of modern enterprises. The aim of implementing the principles of sustainable development is better planning and development direction as well as creating economic, social and ecological order. The concept of sustainable development, including in particular the efficiency of raw materials utilization and waste management, is of particular importance for manufacturing companies, whose activity is based on material resources used for manufacturing, technological processes, distribution and sales as well as on after-sales service and end product development and re-use use of materials. The concept of sustainable development of enterprises also includes reverse logistics [3]. Reverse logistics is characterized by the fact that the sequence of activities starts from the moment of consumption, returning to the moment of production to recover value, or the right disposal, in order to reduce the impact on the environment. An important aspect of reverse logistics is the effectiveness of its use in manufacturing enterprises and its economic and non-economic effects. Thanks to it, there can be a significant reduction of emitted waste and pollution, and some materials are directed for re-use. [4]

2. CONCEPT OF SUSTAINABLE DEVELOPMENT IN THE LOGISTIC ASPECT

In the logistics, sustainable development is also reflected, the concept of green logistics has evolved, which deals with minimizing the harmful impact of the flow of goods on the environment while maintaining an appropriate level of satisfying the client's needs. The state, producers and consumers have ever-increasing requirements regarding corporate responsibility in the ecological sphere, therefore companies must take into account this in

their activities and even promote and use as their asset. [5] According to the concept of sustainable development, entrepreneurs should take care of next generations in addition to their profit. They are committed to deliberately using limited natural resources, protecting the environment, using safe and non-hazardous raw materials and production materials. [6]

With the help of logistics it is possible to implement tasks in the field of sustainable development. Sustainable logistics is the process of using environmentally friendly resources and optimizing the production of by-products of their processing in the production process. Sustainable logistics also meets its social goal through economical use of resources and the recycling of useless products, in the interests of ensuring order for future generations. [8]

To build an appropriate strategy for sustainable development in the logistic aspect: [8]

- Identify environmental costs in your organization,
- Determine the area in which you can reduce costs taking into account the reduction of negative factors on the environment,
- Estimate the profits resulting from the introduction of alternative solutions,
- Introduce and control new solutions.

The changing market, as well as the requirements of customers for the quality of products and after-sales service, as well as legal conditions related to environmental protection, mean that products that have been delivered to final customers go back into circulation and need to be developed, therefore recovery logistics is increasingly a more important place in logistic systems. The increasing flows of products have made it impossible to build a logistics system without taking into account the flows generated by recovery logistics. One of the main aspects of reverse logistics is logistics related to waste recycling, which despite the separate infrastructure is an inseparable element of the country's logistics system. [9]

3. CONCEPT OF REVERSE LOGISTICS

As part of the activities based on the principles of sustainable logistics, various concepts have developed that take into account the links between logistics and ecology regarding return flows, including reverse logistics. Reverse logistics is a constantly growing field of scientific and practical knowledge related to the return flow of products from owners to re-users. [10]

Traditional logistics is a process of planning, implementation and control of efficient, cost-effective material flow, inventories in progress, final goods and related information from the place of their creation to the place of consumption in order to adapt to the needs of recipients. [11] Classical logistics is referred to as forward logistics, its essence consists in the flow of goods from the place of extraction, through all intermediate forms, to the final consumer. Reverse Logistics begins, however, where classic logistics ends, it is associated with the creation of added value in the reverse direction in relation to the primary flow in logistics processes. [12]

Reverse logistics is the sum of waste management processes, including damaged products, and information related to these flows, from their origins, to their destination in order to regain their value, by recycling or recycling, or their proper storage in such a way that these flows were economically efficient and minimized the negative impact of waste on the environment. [13]

In reverse logistics, the direction of this flow is reversed, hence it is also referred to as reverse flow logistics. Its main task is to organize the flow of goods that have become unnecessary, post-production residues, packaging, and waste to the place where they will be reused, recycled or disposed of [14]. Return logistics also cover products whose life cycle has come to an end, products whose sales have fallen, withdrawn from the market, products that have lost their properties or have exceeded their shelf life. Products whose life cycle has come to an end are also considered waste. [15]

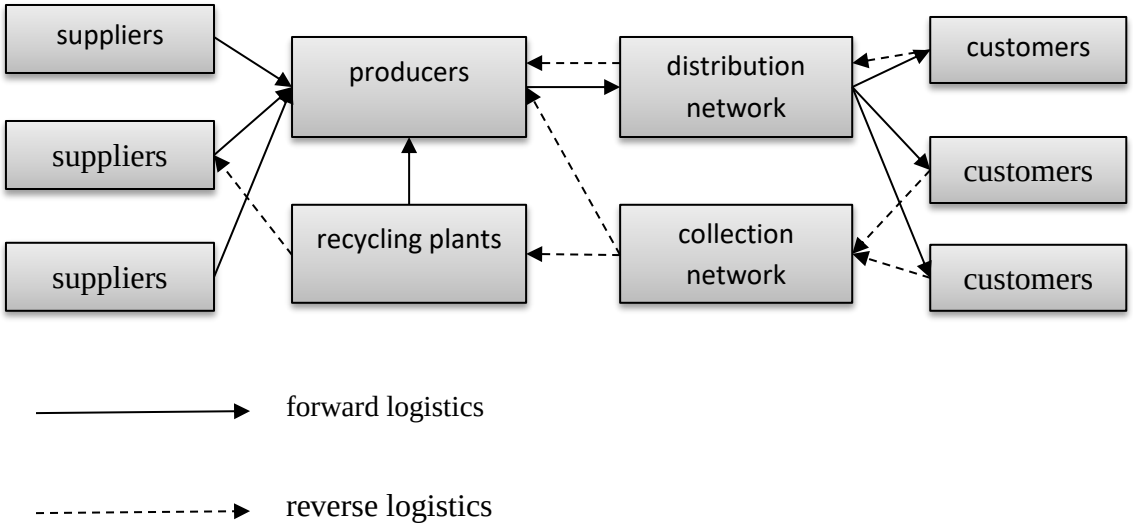

Figure 1. Differences between forward and reverse logistics
[Source: Tibben-Lembke, Ronald S., and Dale S. Rogers. "Differences between forward and reverse logistics in a retail environment." *Supply Chain Management: An International Journal* 7.5 (2002): 271-282.]

Reverse logistics is closely related to the recycling and re-development logistics, which means that it is to strive for the most effective re-use of already used goods. [16]

Re-development and recycling logistics refers to flows: [18]

- damaged goods eg during transport, distribution and restoration of their original properties, reconstruction or utilization,
- goods not matching the order,
- defective goods returned by consumers in the complaint process,
- inventories giving way to new products,
- products that have completed their life cycle,
- used packaging.

In this aspect, reverse logistics deals not only with the flows of waste or useless goods but also with items suitable for further operation after their repair, reconstruction and other replaced, which are not waste. Therefore, the main goal of reverse logistics in the enterprise is the economic goal, minimization of organizational losses due to the re-use of products and maintaining a balance between these activities and social and environmental goals. [17]

The main competence of logistics is recycling, which contributes to the protection of the environment and natural resources. Return logistics concerns several main areas, such as the reverse logistics network structure, interdependencies of many logistics activities, including: transport, storage, product life cycle or IT systems management in reverse logistics as well as legal regulations that protect the natural environment [19]. Reverse logistics networks operate in open reverse logistics systems or in closed systems. In reverse logistics networks, such activities as: servicing and repairing, collection, selection, re-use, renewal or renovation, reprocessing, removal and back-distribution are repeated in Figure 1. [20]

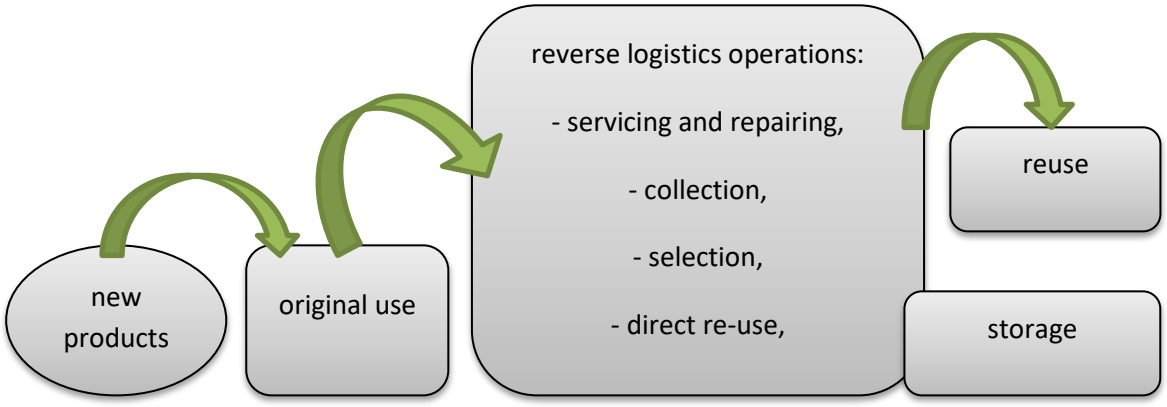

Figure 2. Reverse logistics operations
[Source: De Brito, Marisa P., and Rommert Dekker. "A framework for reverse logistics." *Reverse logistics*. Springer, Berlin, Heidelberg, 2004. 3-27.]

Reverse logistics is different from such areas as waste management, which concerns the main effective and efficient collection, treatment and disposal of waste. Waste management assumes that waste is a product for which there is no new use. The problem of separation of reverse logistics, from many of its related fields, results from the way of understanding the concept of waste. Reverse logistics is applicable to such waste streams where it is possible to recover values from withdrawn products, and where the output is a supply for the new supply chain. [21]

The strategic factors of reverse logistics include strategic costs, general quality, customer service, environmental issues and legal issues. Operational factors include cost-benefit analysis, transport, storage, supply management, regeneration and recycling, and packaging. [22] Reverse logistics activities are aimed not only at solving social and environmental problems, but they can also provide significant financial savings for the company. [23]

4. REQUIREMENTS FOR MANAGING WASTE FROM USED TIRES

The development of the automotive industry causes a growing problem of recycling used tires. The main problem of storing rubber waste is associated with a very long period of

rubber degradation in natural conditions, and thus a significant burden on the natural environment. Rubber compounds used in the production of tires include long-chain polymers that are biodegradable up to 100 years. Therefore, along with the development of the automotive industry, the problem of utilization of used tires is constantly increasing, however, technologies are developed in parallel every year that can significantly support the recycling of rubber waste. [24]

High costs of recycling used tires have resulted in the introduction of appropriate legal regulations requiring the management of rubber waste [25].

In Poland, adopted laws regarding the management of used tires are in line with European Union legislation. As a result of the passed Act on waste of 27 April 2011, a ban on storing used tires from July 1, 2003, and their parts from July 1, 2006, was introduced. On the other hand, the Act of 11 May 2001 on the obligations of manufacturers of certain products and the product and deposit fee imposed on the producers and importers of tires placed on the market the obligation to recover and recycle used tires. The obligation to recycle used tires has also been introduced since 2004 by the "Cleaning Act" of February 7, 2003. The table presents the current levels of recovery and recycling of tires defined in the Regulation of the Minister of the Environment of 29 May 2003 on the annual levels of recovery and recycling of packaging and post-use waste.

Table 1. Applicable levels of recovery and recycling of tires
[Source: Rozporządzenie Ministra Środowiska z dnia 29 maja 2003 r. w sprawie rocznych poziomów odzysku i recyklingu odpadów opakowaniowych i poużytkowych]

Years	2002	2003	2004	2005	2006	Since 2007
Recovering [in %]	25	35	50	60	70	75
Recycling [in 5]	-	-	6	9	12	15

The Act of May 11, 2001 on the obligations of entrepreneurs to manage certain types of waste (including used tires), provides:

- Entrepreneurs subject to the provisions of the Act (producers and importers of tires) are required to achieve appropriate levels of recovery and recycling of used tires.
- This obligation can be carried out alone or through a recovery organization.
- Entrepreneurs and recovery organizations that have not reached the required level of recovery and recycling are obliged to calculate and pay to the marshal's office a product fee calculated separately if the required level of recovery and recycling is not achieved.
- The product charge is calculated as the product of the product fee rate and the difference between the required and achieved level of recovery.
- Recovery level since 2007 at 75% and recycling level at 15%

Table 2. Packaging and products launched into the market and levels of recovery and recycling of packaging waste and post-use products achieved in 2010, 2015-2016
[Source: Central Statistical Office – Environment 2017, Statistical Information and Elaborations, Warsaw 2017]

Tyres	Size of packaging and products launched into the market			Waste exposed to		Achieved level of	
	total	under the obligation of		recovering	recycling	recovering	recycling
		recovering	recycling				
	in thousand tonnes					in percent	
2010	195,1	195,1	195,1	160,3	71,3	82,1	36,6
2015	222,2	217,5	217,5	175,3	47,9	80,6	22
2016	244,7	240,3	240,3	192	77,8	79,9	32,4

According to current standards in Poland, 75% of the recovered tonnage of tires introduced to the market should be properly managed: at least 15% must be recycled, while the rest should be recovered, most often in the form of energy recovery, in which the raw material is converted into energy by means of special combustion for this purpose adapted furnaces, mainly in cement plants. The 2001 Act results in a real solution to the problem of illegal, wild and environmentally harmful tire depots in Poland. Currently, the vast majority of tires that are no longer used, can be recycled. The table presents the number of tires placed on the market in Poland and the levels of their recovery and recycling achieved in 2010, 2015 and 2016. The presented data show that the number of tires entering the Polish market is constantly increasing, but in the years presented, despite the increase in the amount of waste, the recovery and recycling levels required by law have been achieved.

5. THE RETURNING LOGISTICS SYSTEM ON THE BASIS OF THE TIRE UTILIZATION CENTER

With the entry into force, so-called The "product" law started in 2002 in Poland to build a waste management system for car tires. Initially, these works were undertaken jointly by the largest tire manufacturers, operating then in the country, having production plants in Poland, as well as importing new tires to the country, through their companies, established in Poland.

In 2002, Goodyear, Michelin Bridgestone, Continental and Pirelli reached an agreement in this regard and founded the company "Centrum Utylizacji Opon Organizacja Odzysku inc." (CUO), the aim of which was to create a nationwide system of collecting and transporting used tires and carrying out on their behalf the recovery obligation imposed by the "product" law.

In the ecological dimension, one of the main achievements of the Company is a very significant reduction in the amount of littering tires on illegal landfills and the maintenance of the trend of reducing the number of illegal landfill sites and tire dumps.

The center plays a key role in the collection and recycling of used tires in Poland. The CUO company has about 65 percent market share and is the largest organization in Poland that deals with the recovery of used tires. The range of the Company's operations covers the entire country. CUO collects and transfers to recovery about 2/3 of the total collected tires in Poland.

CUO is a representative of Poland in the European Association of Rubber and Tire Manufacturers ETRMA. ETRMA is an international organization associating the world's largest producers of rubber products (including tire manufacturers), as well as companies and organizations that play a strategic role in the European Union in the recovery of raw materials used in the production of rubber products.

ETRMA conducts a series of studies on the scale of production, the demand for synthetic and natural rubber markets as well as recycling, utilization and recovery processes in this sector.

The overriding task of CUO is to solve the problem of used tires, by organizing their collection from exchange points and car workshops, vehicle dismantling stations, municipal enterprises, etc. and subjecting them to recovery and recycling processes. Through its activities, CUO helps used tire owners get rid of rubber waste. The company executes on behalf of shareholders and customers obligations arising from the provisions of the Act of May 11, 2001 on the obligations of entrepreneurs in the management of certain waste and the product fee and deposit fee.

The company also supports city and commune offices for the sake of the environment in their area. Among other things, thanks to the activities of CUO, in a few years the problem of creating illegal dumps of used tires and their illegal repositories was virtually eliminated.

CUO deals comprehensively with the entire logistics process, starting with the collection of tires from:

- service points and tire replacement,
- car workshops,
- car dismantling points,
- municipal offices
- sorting by type to transport to points that subject them to recovery (eg energy) or material recycling.

CUO for authorized entities that will collect the required minimum amount of waste and declare the willingness to transfer used tires, offers the collection of used tires free of charge, providing its own transport. To order a free collection of tires, simply fill out the website and send a completed order form to CUO, and if you need additional information, contact by phone. CUO collects waste from motorcycle pneumatic, passenger, truck and low-speed tires up to 1450 mm in diameter and 450 mm in width. The minimum order quantity is 100 pieces for motorcycle tires, 250 pieces for passenger tires and 70 pieces for truck and low-speed tires.

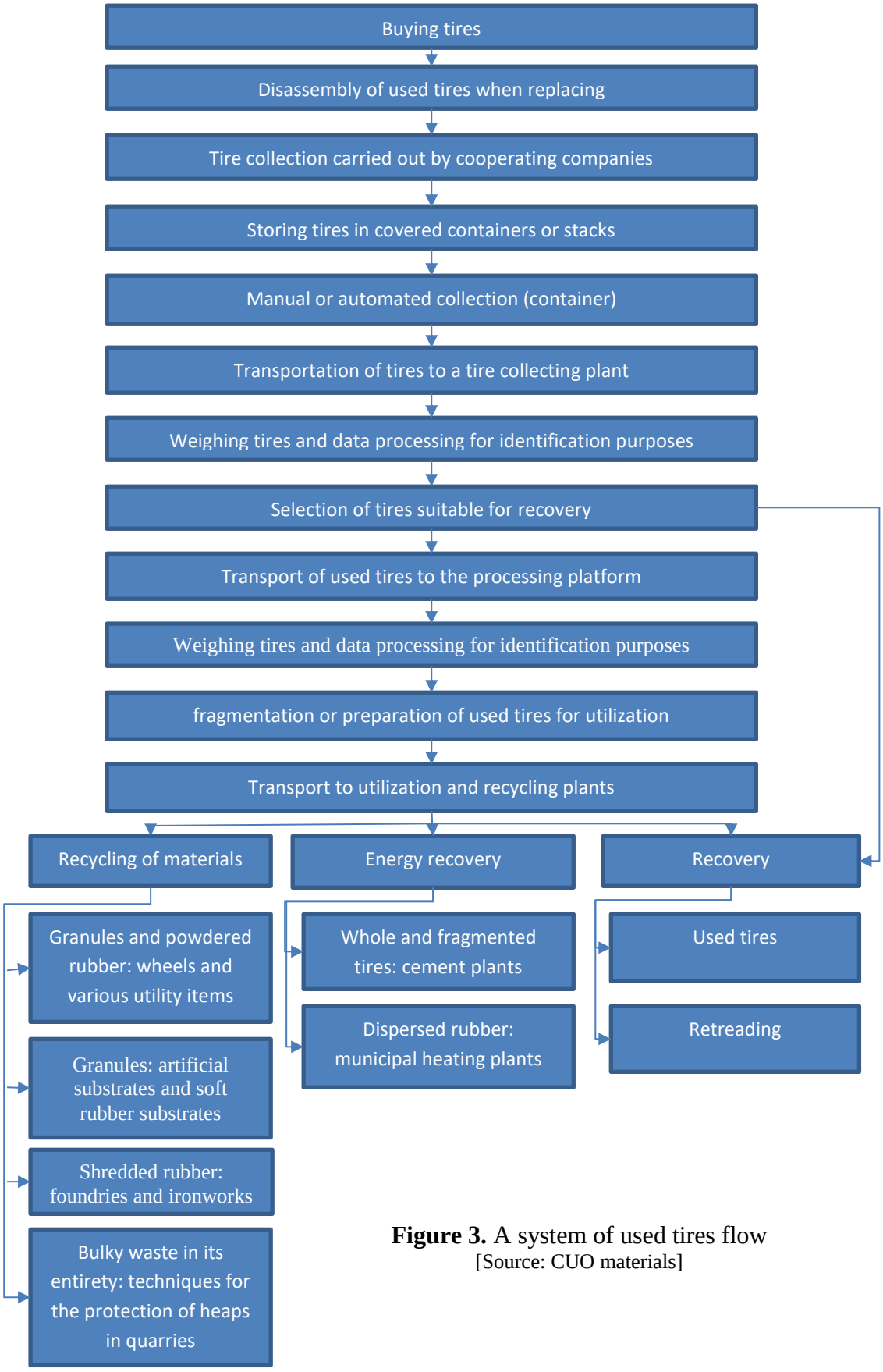

Figure 3. A system of used tires flow
[Source: CUO materials]

The company performs pickup orders from all over the country. After registering in the CUO online system and submitting the collection order, it is immediately forwarded to the logistics operator for execution. The user is obliged to prepare tires for transport as well as to load them on a substituted vehicle. Upon receipt, the tires are converted and a document is prepared, which is a confirmation of the service. Tires are received in an amount not greater than that reported by the user in the order. The tires must retain their shape, be free of rims and must not contain other rubber elements such as inner tubes, protectors, pieces of tires, etc. Tires must not be filled with earth or snow or other elements or substances other than the normal quantity that can penetrate during the storage process. Tires that do not meet these conditions are not picked up. Figure 3 shows the tire flow system.

CUO cooperates permanently with 7 cement plants, 3 recycling companies and 1 heating plant. The company operates through a logistics and transport network throughout Poland. The logistics system built by CUO is:

- Collection, segregation and transport of used tires throughout the country (Agreements with 10 Logistics Operators through tenders in 15 regions)
- Recovery contracts currently signed with 12 entities in the country, carrying out the recovery, including the recycling of used tires (cement plants, heat and power stations, tire recycling)
- Collection at points throughout the country where tire waste is generated (tire service centers, transport bases, dismantling stations for end-of-life vehicles, local self-governments)
- Waste is collected free of charge, through the certificate on the waste transfer card, by entities having appropriate permits for collection and transport of waste
- Disposable collections are possible once the order is placed on the CUO website
- It is possible to cooperate and establish recipients directly with the Logistic Operator

There are several ways to dispose of used tires. Every year, technologies are developing in parallel, which in the future may significantly support material recycling of this waste. The methods of recovery and recycling of used tires are presented below:

a) Recovery - Retreading and use of used tires

According to the Polish law, the recovery is the retreading of tires and the use of used tires, in whole or in parts, for arranging and securing landfills, as well as fenders, that is to protect port quays, to cover race tracks or construction sites along roads, through so-called Bufery. Retreading of used tires gives the possibility of their re-use in the same way. However, only certain tires that are not excessively worn and have no mechanical damage may be used for retreading. This is the most important method of reusing car tires. As a result of cutting a worn tire, a rubber grit is created, which, like material recycling, can be an addition to the rubber mixture from which new tires will be produced. However, research has shown that the use of this waste in the production process of a new tire reduces its lifespan and the cars driving on these tires have higher fuel consumption due to the increase in rolling resistance of such a tire.

b) Burning tires with energy recovery

The vast majority of recovery of used tires in Poland (over 70%) is carried out through energy recovery, i.e. by burning tires with energy recovery. Over 90% of this recovery takes place in kilns in cement plants. Most Polish cement plants have the option of burning entire tires. In addition, some of the tires are burnt in cement plants also in a cut. Tires in the form of granules, mixed with coal dust, also burn some cogeneration plants, and the initial interest in such fuels also manifest in other economic sectors.

Cement plants are the main customers of alternative fuel, and tires can constitute up to 20% of the fuel weight. Cement plants form the main demand side for alternative fuel, which is rubber, because the production technologies in these plants require the use of the highest temperatures in the furnaces. They are much higher than those that arise in the heating furnaces. Therefore, the burning of tires in cement plants is economically more justified - they can be burned in their entirety. It should be emphasized, however, that tires in cement kilns usually constitute 10 to 20 percent. of the total fuel burned. Of course, all production plants must meet stringent standards for the emission of harmful gases, and this is associated with the need to invest in the appropriate infrastructure that prevents the release of tire combustion products into the atmosphere.

Tires are a very valuable fuel because they have higher calorific value compared to hard coal. In addition, as a result of their burning in the cement kiln, no ash is generated, and less harmful gases are emitted compared to coal - mainly carbon dioxide and sulfur dioxide. One tire in terms of calorific value equals one ton of good quality coal.

c) material recycling

A other form of recovery of used tires is, of course, material recycling, i.e. the use of used tires to produce other products, after their preparation, first of all after the separation of steel and textile waste and the fragmentation of rubber waste. In Poland, there are currently two large and several smaller installations for granulating used tires and several plants producing final products from rubber granules, such as circles for junk containers, road safety components, sports object surfaces. Granulates can also be used as asphalt enrichment, vibration damping and sound insulation.

Tire material recycling accounts for approx. 20-25% of the total recovery. During the mechanical grinding process, rubber particles of various sizes are obtained: granules, fine particles, dust. In addition to rubber, steel and textile waste are also obtained. There are two large granulation plants in Poland.

Material recycling is the fragmentation of a car tire. The size of the grinding is left to choose, however, as the fragmentation increases, the costs of the tire processing also increase.

Depending on the fragmentation of used car tires, the following materials can be obtained:

- shreds (300 - 40 mm) and chips (50 - 10 mm) - are used in the construction of tunnels, underpasses, as raw materials used in road construction, etc .;
- granulates (10 - 1 mm) - are the main product resulting from the process of grinding car tires, which is used to build sports surfaces;
- rubber powder (0 - 1 mm or 0 - 0.5 mm) - is one of the components used in the production of, for example, car mats;

- the remaining quantities (according to CEN, about 30% of the tire) are used for the production of various industrial products.

Obtained grit and granulate after adding the appropriate binders are most often used as surfaces of playgrounds, sports fields, and also used as a material for sound absorbing and shock-absorbing coverings. Rubber powder is usually added to rubber mixtures, from which products such as car mats, rubber mats, etc. are made.

The automotive industry has high hopes for using rubber as an admixture in a new type of asphalt surface. Studies carried out in the United States have shown that such a new asphalt exhibits excellent parameters. Vehicles moving on it have 25 percent. shorter braking distance and emit significantly less noise. In the rain, the cars have better grip, and the surface itself has greater durability compared to asphalt produced by traditional methods.

Tire Utilization Center realizes over 50,000. tire pickups per year. It has 25 thousand tire pick-up points registered in the CUO system and implements 7,000 deliveries to cement plants and recyclers every year.

6. CONCLUSIONS

Due to the multitude of newly established enterprises, the growing economic development and thus the increase in the amount of waste and useless products produced, the logistics areas related to the return flows become more important. More and more solutions are being developed in the field of reverse logistics, systems are being implemented to improve the flow of waste and useless products. More and more companies dealing in waste logistics appear on the market, offering comprehensive waste management taking into account ecological and economic factors.

Reverse logistics, which has developed on concepts that combine features of ecology, economics and logistics, is becoming more and more useful. Due to the inseparability of production activities from waste generation and growing environmental awareness, it is important to develop concepts related to waste logistics. Reverse logistics is an important aspect of the company's logistics operations, also because of the desire to reduce the cost of reverse flows.

Thanks to it and technological progress, waste generation is limited and the economy is more efficient and economical. The improvement of the natural environment due to the reduction of the amount of waste deposited is behind the economic consequences. Therefore, reverse logistics is an important element of the modern world, conditioning the balance between the natural environment and the developing economy. Worn tires are an ecological challenge for the modern world.

It is estimated that about 22.5 million tons of tires are produced in the world every year. The Polish tire waste collection systems and existing recovery systems have, so far, allowed obtaining and even exceeding the set levels of recovery and recycling. Tire Utilization Center CUO as the largest organization in Poland dealing with recovery from the market of used tires contributes significantly to the development of tire processing in the country, positively affecting the level of their recovery and recycling.

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