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ANALYSIS OF THE PRINCIPLES OF REVERSE LOGISTICS IN WASTE MANAGEMENT

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Abstract: The goal of mentioned contribution is to moderate the unwanted effects of economics on environment in the form of more purposed economy with material sources from recycling, collection, separation and processing of returnable products. It is a global trend nowadays to lower waste production and to minimize effects on the environment. We are going to deal with effectiveness of partly underground containers in Slovakia and new trends about possibilities of other uses of PET bottles. The article deals with the analysis of whether the level of waste management services is at the required level due to the wide range of services provided within reverse logistics. Article's output is created model of reverse logistics and subsequently analysis of cost effectiveness considering economic aspects entering into the reverse model has been made during its use.

1 Introduction

Reverse logistics is a term for all types of reversely aimed logistically solved motion of goods, waste collection and wrappings from customer to the distributor, possibly producer in order to register a complaint or reuse, recycle or disposal in accordance with the regulations in an ecologically desirable way. Additionally, waste separation, storing of separated waste and wrappings, transportation of waste and wrappings to the users or processors belongs to reverse logistics.

According to Lambert, Stock, Ellram [1]: „reverse logistics deals with removal of waste material, which originates in the process of production, distribution and wrapping of goods. Typically, it is an activity such as securing the temporary storage of these materials, their subsequent removal from the site of disposal, processing, reuse or recycling.

According to the Mesjasz-Lech [2], the most effective method of elimination of waste production and its negative environmental effects is economical waste evaluation. Sizes of flow concerning waste in cities are the main goal of reverse logistics of waste management. Conception of waste-free city needs activities of reverse logistics, because it is not possible to reduce communal waste without proper organisation of waste flows and infrastructure - function of the reverse logistics. Ecologically and economically effective waste flow organisation often encompasses greater region beyond city's borders.

The purpose of reverse logistics in the field of waste management is securing garbage collection, separation, transportation, storage, reprocessing (recycling) and waste recovery, which originates during production, wrapping and distribution of waste while we consider environmental impacts.

General drivers, which most influence waste production not only in Slovakia but on global scale, are mainly population growth and therefore urbanisation, growing concerns among public about the state of the environment, increasingly stringent national and transnational measures and regulations regarding waste and waste management.

Waste and its handling are among the most prominent problems in Slovakia. Country is not able to sufficiently handle it despite of growing pressure from EU through stricter requirements focused on these issues.

Linear economic model is still profound in Slovakia, which consists of entries in the form of mineral resources which are through design and production, transformed into possessions, then are supplied through distribution canals to particular users and used. Waste production is the last part of the chain as a result of consumption of manufactured possessions. This current economic model is based on high difficulty of entries (mineral resources), high rate of possession consumption and associated waste production.

The development of supply chain regulation methods in logistics, including the regulatory framework, has direct and indirect impact on the activities of logistics entities, creation of document flows and the implementation of logistics operations and functions [3].

In response on unsustainable consumer way of living and increasingly significant changes in the environment, EU adopted a package of measures in 2015, presenting recommendations and legislative proposals for the implementation of alternative economic model i.e. model of circular economy. Unlike the linear model, it is based on repeated material returning, components and products back into the production process. There is a constant transformation of production outputs into material inputs, while the main goal of circular economy is to reach the highest possible usability and product value of its parts and at the same time burden the environment as little as possible.

This package of measures was supplemented by specific objectives. In 2018, this goal was complemented especially in the area of recycling and waste prevention. In 2016, 193 countries committed to fight for a better future of our planet together by signing UN Agenda 2030, which comprises 17 goals of sustainable development [4].

In the Slovak Republic, the issue of waste management, the rights and obligations of legal entities and individuals in waste prevention and waste management, responsibility for breach of obligations in the waste management sector and the establishment of a recycling fund and hence retrospective logistics Act No. 223/2001 Coll. on waste in the last version are regulated and observed by the competences of state administration bodies and municipalities.

Act No. 223/2001 Coll. on Waste and on Amendments to Certain Acts defines waste as a belonging listed in the Annex to this Act which the holder discards, wishes to dispose or is in compliance with this Act or special regulations is obliged to discard it [5].

A new Circular Economy Action Plan for a Cleaner and More Competitive Europe was introduced by European Commission in 2020. In the document it is stated that:" despite efforts at both EU and national level, the amount of waste generated is not declining. 2.5 billion of tonnes of waste is generated across the EU from all economic activities, that means 5 tonnes of waste per capita. In addition, every person generates on average half a tonne of communal waste. The segregation of waste production from economic growth will require considerable effort throughout the value chain and in every household" [6]. The document further mentions that the implementation of a sustainable product policy will be a key to make a progress in waste prevention, increasing recycled content, promotion of safer and cleaner waste flows and ensuring high-quality recycling. In addition, as part of a wider set of waste prevention measures, the Commission will present waste reduction targets for preventing the waste production regarding regulation 2008/98/ES [7] for particular flows. All these measures are intended to contribute to the goal of significant reduction of the overall waste generation, namely, to halve the amount of residual (non-recycled) municipal waste by 2030.

Strong dependency on industry is one of Slovak specifics, which prevents its effort to alleviate the pressure on the environment. This is the main reason why Slovakia does not fulfil the requirements from action plans and other legislative EU documents. Slovakia as a whole is at this moment not able to adopt previously mentioned model of circular economy. It creates deviations from EU commitments and also other regional disproportions within the country.

Waste management is an activity aimed at the prevention and reduction of waste production, reduction of its environment hazards and waste disposal in accordance with this act. Waste disposal is collection of waste, waste shipment, waste recovery and waste defusing, including taking care of disposal sites.

Pursuant to § 19, par. 1 of this Act, the producer is obliged to collect created waste, separated by types and to protect them against devaluation, prevent them from being stolen or other undesirable effects and to use created waste as a source of secondary raw materials or energy especially in their own activities. These appointments define the basic obligation for the originators to carry out separate collection of waste [5].

The waste consists of unused materials and auxiliary substances in the manufacturing process, intermediates, malformations and surplus from manufacturing process, used packages and products. The originator of waste is everybody, whose activity waste originates in, or who manages modifications, mixing or other acts with waste, if the result is changing of character or composition. The waste holder is the producer of waste, individual or the legal entity by whom the waste is located. Waste defusing is a waste disposal, which does not harm the environment or threatens human health. Waste recoveries are acts which lead to physical, chemical or biological property changes of the waste. Waste separation is dividing waste by kind or segregation of waste components, which can be, after segregation, ranked as independent kinds of waste.

The purpose of waste management is:

- To prevent waste creation and to limit it mostly by the development of technologies that conserve natural resources; the production of products which, as well as the resulting products, minimize the amount of waste and reduce pollution of the environment as much as possible; the development of suitable methods of defusing dangerous substances contained in waste destined for defusing.
- Waste recovery by recycling, reusing or other processes that enable secondary raw materials to be recovered if waste prevention is not possible.
- To use waste as an energy source, if the material recovery is not possible.
- Eliminate waste in a manner that does not endanger human health and does not harm the environment.

Municipal waste is a waste created by households in the territory of municipality owned by individuals and

waste of similar characteristics created during activities of legal persons or individuals-entrepreneurs and created by municipal activities during cleaning of public roads or open spaces, which are managed by municipality and during maintenance of public greenery, including parks and cemeteries [5].

Paper accounts for about 20% of the mass of municipal waste. Paper can be recycled very well (5-8 times) and can be subsequently composted. When recycling, the paper is pulverized into cellulose fibres and then processed again. In Slovakia we produce 850-thousand tonnes per year. The total annual production of the paper is 800 kg/SR inhabitant. Up to 50% of feedstock is a secondary raw material for paper production. Recycling 100 tonnes of paper saves about 1 hectare of a 100-year-old forest. The paper waste can also produce egg packages, kitchen towels, other packaging, toilet paper, cardboard and other paper products.

Paper packaging can be a part of global food waste solution, which represents up to 1.30 billion tonnes - one-third of food produced globally for our consumption - by minimizing waste and food damaging [8].

The primary function of packaging in all forms, plastic packaging, cans, glass and cardboards is to protect goods during transportation, storage and distribution. They prevent generation of waste resulting from breakage, spoilage and contamination and prolong the life of products. Secondary, but also an important purpose is to provide consumers with product information and to help identifying and distinguishing brands. Minimizing waste, especially food, is a major global challenge. Responsible recycling of waste and packaging paper reduces the amount of waste on landfills.

Glass constitutes to 12% of the total municipal waste mass. It is hygienic, ecologically significant and 100% recyclable. Glass containers can be reused 15 to 75 times. Melting results in losing its properties only insignificantly. According to the ecological ladder, re-use is more of a priority than recycling, because it is more environmentally friendly to use reusable packaging instead of putting it to recycling after use, so passing it back to the store. Glass is biologically inactive material - it does not decompose in nature (or decomposes for up to 4000 years). Sorted glass is processed directly in glassworks (no special processing plants are needed). For correct recycling, it is necessary to carefully sort glass by colour. When recycling glass is handled, it is best to break the glass into as little shards as possible and separate other components (labels or closures) from the glass products.

Plastics account for 7% of the total mass of municipal waste. Total annual production of plastics is 280 kg/SR inhabitant. Plastics are made from crude oil, which is a non-renewable natural resource. Plastics have a relatively small weight but a large volume. They are the worst recyclable material that has the most environmental burden. In nature, plastic bottle is decomposed in 50-80 years, but decomposition of PET bottles takes 400 years. Every minute, people in the world buy a million plastic bottles. One Slovak produces 8.4 kg of waste in the form of plastic bottles per year.

From the economy and ecology point of view, priority is given to recycling, but plastic cannot be recycled indefinitely because it loses its properties. Classified plastics produce various pulps or granules, which are subsequently used in the production of new products.

The packaging industry is the largest plastic producer in Europe. Up to 40% of plastic production in the European market ends in packaging, less in consumer goods and household, construction, automotive or electronics. Europeans dispose 25 million tonnes of plastic waste each year, of which only 30% is recycled.

Metals make up to 4% of the total amount of municipal waste - a much better package is e.g., aluminium, because metal or aluminium cans are a great commodity that can be recycled to infinity. Recycling aluminium cans consumes 95% less energy than their primary raw material production.

Biowaste accounts for 45% of the total amount of municipal waste or waste that goes to the composter, respectively. Recycling of biodegradable waste consists of compost, which results in the formation of a natural fertilizer. Usable in both large and small - in agriculture and in peoples' gardens.

Classed collection is free for citizens of the Slovak Republic. The citizen does not bear the cost of sorting in the local fee for municipal garbage and small construction waste. Financial responsibility for sorted collection is bore by the business entity whose products or packaging ends in communal waste.

By recycling from primary production, we save energy - for each raw material, it represents an energy saving of 97% for plastics, 95% for aluminium, 74% for steel, 70% for paper and 25% for glass.

Innovations focused on smart packaging for products that meet environmental, quality, safety or product identification standards within the logistics chain are currently gaining prominence. Effective operating on the market is not possible without these innovations in the packaging within the integrated innovation process on the market as well as without suitably organized logistics. In the future, this supports the development of products with smart packaging that can be considered as a smart system when it becomes part of a control or feedback mechanism in relation to its usage environment (Improved logistical handling and reduction of logistic costs, control of quality of packaging and contents, improved safety during packaging use, improvements in production of packaging and in reusing and recycling of packaging) [9].

2 Methodology

First feasible step in the research was detailed acquisition and study of basic theoretical knowledge from the literature for the creation of a model of reverse

logistics, which has been applicable to Slovakia. These theoretical models are based on the assumption of a transdisciplinary approach, because limited understanding of reverse models could affect the creation and use of our model in Slovak conditions.

General theoretical models depicting various approaches to reverse logistics from different authors, which decribed Fleischmann [10] in his Quantitative Models for Reverse Logistics and Bloemhof-Ruwaard [11], with collective in their scientific publication Reverse logistics, have been used for the creation of reverse logistics model of waste collection. Authors implemented local specifics which took into account logistic processes and frameworks typical for waste procession in Slovakia (Figure 1).

Secondary material market represents in this model the place, where reverse flow (reverse logistics) happens; from where the waste in the form of material resources goes back into the production process. Their circulation thus radically minimizes the consumption of new material resources and energy needed for the production of new inputs and waste generation is minimized as well as the total costs associated with the production of goods. The most efficient use of resources within the technical and biological reverse cycle is the closure of material flows, ie. constant conversion of production outputs into inputs.

Waste management can be evaluated from the point of view of various indicators and aspects - economic, environmental or social, or qualitative. When creating the model, we dealt with economic factors and evaluation of economic efficiency. Within these evaluations, there are basic models, the authors Soukupová and Struk [12] also describe in their publications. The most commonly used methods for evaluating efficiency of public expenditure are Cost-minimization Analysis (CMA), Cost-effectiveness Analysis (CEA), Cost-utility Analysis (CUA) and Cost-benefit Analysis (CBA). We dealt specifically with Cost-effectiveness Analysis. This consisted of an assessment of two aspects: the effectiveness of expenditure per capita (E_1) and cost-effectiveness of producing one tonne of municipal waste (E_2).

Then the cost efficiency of given expenditure could be expressed as follows (1):

$$CEA = C / E \geq 0 \rightarrow min \quad (1)$$

where C is the environmental protection expenditure, E is the indicator of cost efficiency evaluation.

If CEA ≤ 1, the expenditure is efficient, if CEA > 1, the expenditure is inefficient. Because the criterion is minimizing, it needs to be transformed into maximizing one. Therefore for the construction of EKE criterion we will use the following formula (2):

$$E_E = 1 / CEA = E / C \geq 0 \quad (2)$$

where if EKE > 1, then the expenditure is efficient and EE → max [12].

The data that were analysed and compared in the article were used from the Eurostat database and from the study Analysis of Waste Management in the 8 largest cities in Slovakia [13]. It was an analysis and comparison of data dealing with the areas of municipal waste, expenditure per capita and expenditure on municipal waste production, using statistical methods.

3 Result and discussion

Main goal of reverse logistics is to gain the biggest value from elements, which form backflows, and it is also important to know how to deal with them.

Reverse model of waste collection and recycling in Slovakia is described on the Figure 1. Model was created by authors and comes from general models, which had been created by Fleichmann [10] and Bloemhof-Ruwaard et al. [11].

There are many options how to deal with returned goods. However, actual viability is limited by the intrinsic nature of the product (construction, degree of damage) and, of course, economic criteria- if demand exists for newly acquired materials, parts, whole products in the market. If this is not the case, the products must be stored in a landfill or be incinerated. The goods taken can be divided into categories according to the method of processing, namely [14]:

- Direct rescue – direct usage without any corrections (cleaning, repacking).
- Correction – broken products are repaired into functional condition.
- Recycling – product, or its part, is stripped-down on its basic materials, which are, after processing, used again. Substances, which would otherwise end as a waste, will be used as a raw material.
- Adaptation – requires a considerable amount of work. The product is discarded on parts that are checked, the damaged and worn are replaced by new.
- Upgrade – similar to correction, but with the difference that more work is needed, and the resulting product is of higher quality and value.
- Cannibalization – one or more parts of the product are used to repair another product.

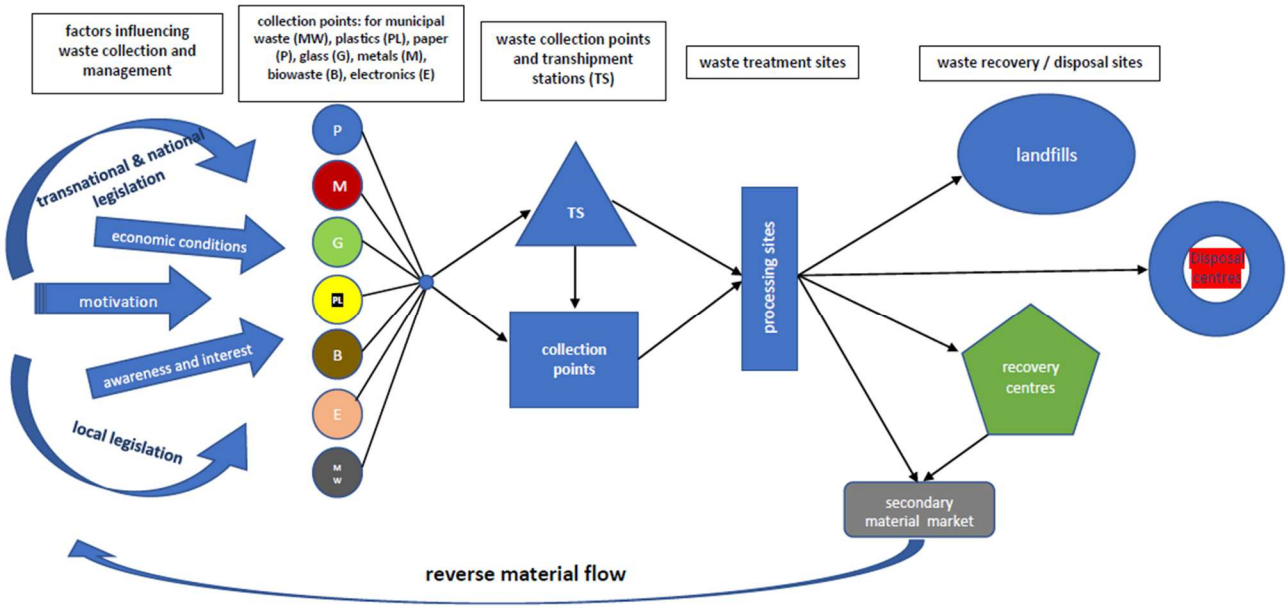

Figure 1 Reverse model of waste collection and recycling in Slovak Republic

Reversely aimed distributional channel represents collection of projects which provide reverse motion of waste and wrappings. Its existence and operation depend on multiple factors, such as country's legislation, economic conditions, motivation, awareness and interest in the solution of waste collection.

Reverse logistics nowadays represents a remarkable part of logistics processes of the company. Under Slovak conditions, it is possible to find ways of its application in an indirect form, especially in the form of waste management.

3.1 Case study: Cost efficiency analysis in the selected Slovak municipalities

Municipalities play a significant and a very important role in waste management. They set their goals in waste management, try to meet them, while spending a substantial part of their budgets on them. For local governments, the most important aspect is considered to be the economic aspect, namely the efficiency of public funds spent on waste management. Therefore, we focused on the Cost-effectiveness Analysis (CEA) in selected municipalities, specifically in the eight largest Slovak cities: Bratislava (BA), Košice (KE), Prešov (PO), Nitra (NR), Banská Bystrica (BB), Žilina (ZA), Trnava (TT) and Trenčín (TN). These municipalities were also chosen because of the availability and completeness of relatively up-to-date data (2019) related to their waste management. The data were drawn from the study Analysis of Waste Management in the 8 largest cities in Slovakia [12].

In 2019, these 8 local governments produced a total of 559,268 tons of municipal waste, which is approximately one quarter of all waste produced in the same year in Slovakia. The average level of waste separation in these cities was almost 41%. The individual data for the above-mentioned eighth municipalities are given in the table below (Table 1).

Table 1 Information about selected municipalities and their waste management

2019	BB	BA	KE	NR	PO	TN	TT	ZA
Population	76147	437725	238757	78353	88464	54696	63751	82867
amount of municipal waste (t)	45070.5	213047.6	97403.3	47382.6	41586.4	28562.8	39717.6	46497.7
amount of MW per inhabitant (t)	0.59	0.49	0.41	0.60	0.47	0.52	0.58	0.56
separation rate	53.37%	31.30%	29.33%	42.00%	39.06%	40.27%	46.55%	43.53%
mixed waste	39%	53%	50%	50%	54%	48%	43%	43%
costs in waste management (€)	3724184	28723806.6	12667724	3869321.7	4791941.2	2305890	3544655	3197723

Source: authors' computation

According to the above-mentioned methodology, we calculated the Cost-effectiveness Analysis (CEA). This consisted of an assessment of two aspects: the effectiveness of expenditure per capita (E_1) and cost-effectiveness of producing one tonne of municipal waste (E_2). The results are shown in the tables below (Table 2 and Table 3).

Table 2 Expenditure per capita related to municipal waste (€)

Municipality	CEAj
Banská Bystrica	48.9
Bratislava	65.6
Košice	53.1
Nitra	49.4
Prešov	54.2
Trenčín	42.2
Trnava	55.6
Žilina	38.6

Source: authors' computation

The average expenditure per capita on municipal waste in the eight municipalities was 50.9€. Expenditures per capita consider the minimization criterion, i.e., the lower the expenditures, the more efficiently they are spent in waste management. The highest expenditures are in the capital Bratislava (65.6€) and the lowest in the city Žilina (38.6€).

Table 3 Expenditure on the production of one tonne of municipal waste (€)

Municipality	CEAj
Banská Bystrica	82.6
Bratislava	134.8
Košice	130.1
Nitra	81.7
Prešov	115.2
Trenčín	80.7
Trnava	89.2
Žilina	68.8

Source: authors' computation

The average expenditure per tonne of municipal waste in the eight municipalities was € 97.9. Expenditures again consider the minimization criterion, i.e., the lower the expenditures, the more efficiently they are spent in waste management, with the highest expenditures in the capital Bratislava (€ 134.8) and the lowest in the city Žilina (€ 68.8). The differences between individual expenditures per capita and expenditures per tonne of municipal waste produced are mainly due to the sale of secondary raw materials, subsidies for certain types of waste and other fees associated with waste management (e.g., legal entities fees).

In order to transform the minimization criteria into maximization, according to the above-mentioned methodology, we calculate the effect of using the effectiveness of expenditure per capita (E_{e1}) and the effect of using the efficiency of expenditure per one tonne of waste produced (E_{e2}). More in Table 4 and Table 5.

Table 4 The effect of using the efficiency of expenditure per capita

Municipality	E_{e1}
Banská Bystrica	0,0204
Bratislava	0,0152
Košice	0,0188
Nitra	0,0202
Prešov	0,0185
Trenčín	0,0237
Trnava	0,0180
Žilina	0,0259

Source: authors' computation

Table 5 The effect of using the efficiency of expenditure on expenditure per tonne of waste produced

Municipality	E_{e2}
Banská Bystrica	0,0121
Bratislava	0,0074
Košice	0,0077
Nitra	0,0122
Prešov	0,0087
Trenčín	0,0124
Trnava	0,0112
Žilina	0,0145

Source: authors' computation

The above calculations show that the highest effect of the efficiency of expenditures used per capita, even per tonne of waste produced is achieved in the city of Žilina and, conversely, the lowest is in the capital of the Slovak Republic - Bratislava.

3.2 Reverse logistics system

Some studies [15] show, that the total cost of the reverse logistics system is largely determined by the cost of transport activities required to collect packaged food waste from the retail stores and ship it to the distribution centres for storage; conversely, the transport cost from the distribution centres to the main facilities contributes to the total cost of the system to a very limited extent.

Recycling is an extensive re-entry of solid, liquid, gaseous waste into the circulation and the re-use of waste energy and heat. Recycling of industrial waste is a backflow into original manufacturing process and gain of secondary raw materials for manufacturing new, other

products. Recycling of consumer goods mean backflow into original manufacturing sector and gaining raw materials for new products. Reverse usage of packages is a reverse move of wrapping packages, i.e., recycling-manufacturing technology.

Recycling is repeated use and product evaluation or a part of the product in the form of material and energy circulation, which: saves primary raw material sources; lowers power consumption by using secondary raw materials; reduces amount of waste, which is necessary to defuse, respectively eliminate; lowers environmental burden.

We can distinguish between several possible scenarios for **waste treatment:** reuse of substances (recycling), thermal treatment and landfill.

In the re-evaluation of the waste, the waste is taken over and transported to a special sorting and processing facility where the material balance of the fractions it consists of is taken into account, taking into account the possibilities of further use as a secondary raw material for the preparation of a new product, respectively their use as auxiliaries.

For thermal treatment, the waste is transported to a special thermal treatment plant (incineration plant) where it is directly incinerated and, most of the time, thermal or electrical energy is generated. This scenario is suitable for residual plastic films and paper. Waste incineration plant means any stationary or mobile technical unit and equipment designed for the thermal treatment of waste with or without the utilization of the combustion heat is generated. It includes the process of combustion by oxidation of waste as well as other heat treatment processes such as pyrolytic, gasification or plasma processes, if the substances resulting from the treatment are subsequently incinerated.

Waste landfilling is characterized by high environmental burden, in which case waste is transferred to a landfill and dumped there without further processing or use. This way of waste destruction is the most unecological one and there is a risk of possible soil or water contamination, possibly air pollution by harmful substances.

The specific chapter are dangerous substances, it is very important when handling them to familiarize the workers with the valid legal regulations in order to ensure proper handling, transportation, storage and disposal in compliance with the safety regulations. By "hazardous waste" we mean any solid or liquid waste as defined in Article 1 par. 4 of Council Directive 91/689 / EEC on hazardous waste.

When we focus on processes of reverse logistics from the point of economic expenses, it is possible to divide these expenses into expenses for recycling, collection, separation, transportation, storage and further waste treatment. Expenses for waste elimination in the form of landfill or waste incineration cause environmental burden, which are hardly quantifiable. The state is therefore trying to regulate by means of orders, prohibitions, taxes, subsidies and other economic instruments. In line with the Slovak Waste Management Program, industrial enterprises should preferably focus on the recovery before disposal, thus gaining a competitive advantage for the future.

Figure 2 shows the share of different economic activities and households in a total waste generation in 2016. In the EU-28 in 2016, 36.4% of the total waste was generated in construction, followed by mining and quarrying (25.3%), manufacturing (10.3%), waste and water services (10.0%) and households (8.5%). The remaining 9.5% generated waste was from other economic activities, mainly services (4.6%) and energy (3.1%) [16].

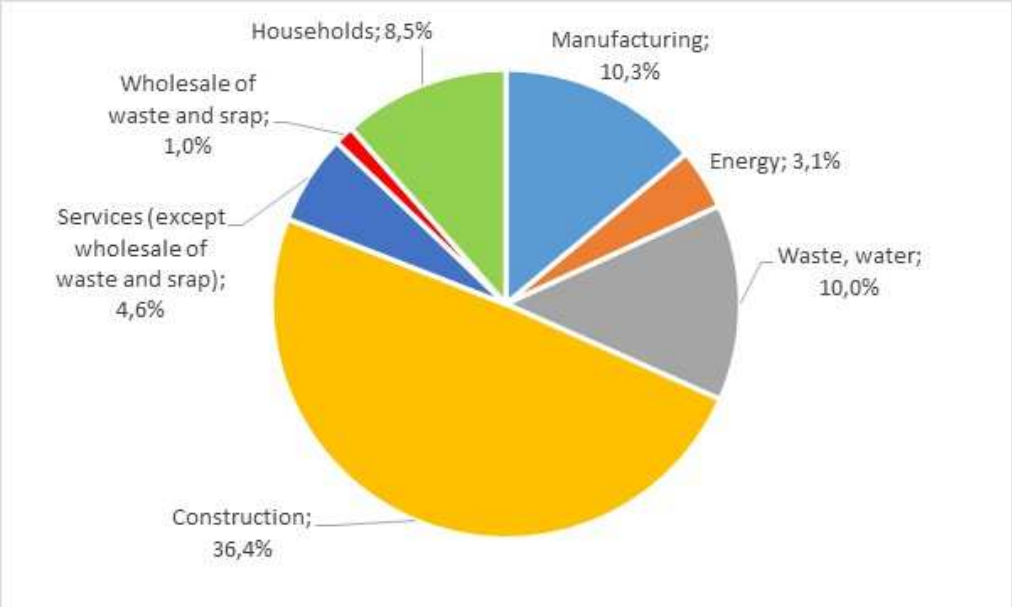

Figure 2 Waste generation by economic activities and households, EU-28, 2016 (%) [16]

The goal of EU waste treatment policies is to reduce the impact of waste on the environment and health and to make EU resources used more efficiently. Proper waste management is a key element in ensuring the efficient use of resources and the sustainable growth of European economies [16].

Each Slovak produces on an average of 321 kg of waste per year. Of this, only about 20 kg is recycled. Every European on average accounts for 475 kg of municipal waste. Of this, about 133 kg is recycled (Figure 3).

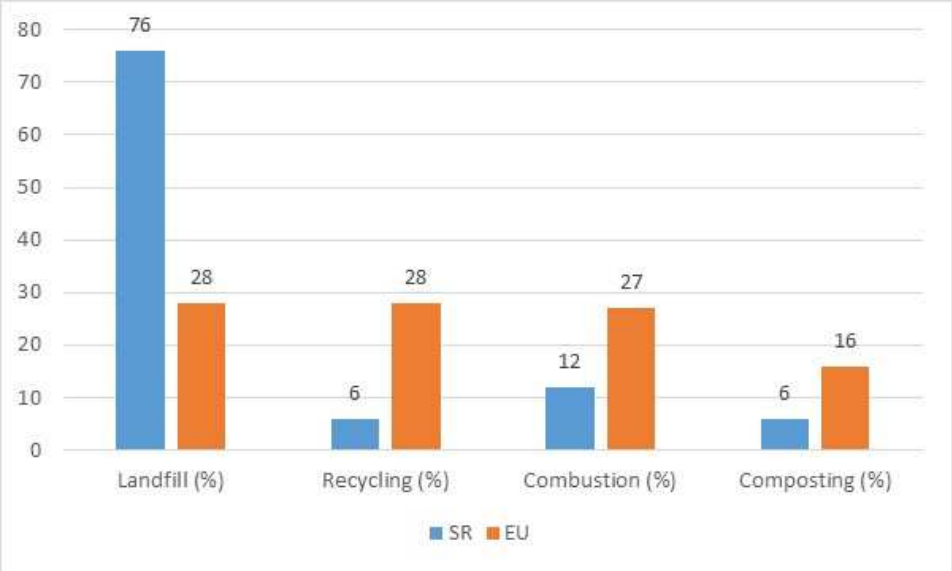

Figure 3 Comparison of waste management with EU countries [17]

Priority goals for waste politics in EU:

- To reduce the amount of created waste.
- To maximize recycling and reusing.
- To limit combustion- burn only non-recyclable materials.
- To gradually remove landfilling of waste, which can be recycled and evaluated.
- To ensure full achievement of waste policy in all EU Member States [16].

Supporting Member states in waste management requires additional efforts. There is a threat that half of them will not be able to fulfil the goal for the year 2020, which is to recycle 50% of communal waste (including Slovakia, which recycled 39% of it in 2019). In order to push political reforms, Commission will organise exchanges regarding circular economy and waste, will intensify cooperation with Member states, regions and cities to make the best use of EU funds. According to a survey conducted by Sensoneo in 2019 [18], Slovakia is among the worst waste managers among OECD countries.

The landfill site is a waste disposal site where waste is permanently deposited on the surface of earth or in the ground. The waste disposal site is also considered to be the place where the waste producer carries out the disposal of their waste at the site of production (internal landfill), as well as the place that was used longer than one year and is used for the temporary storage of the waste. Waste landfill shall not be considered as a facility where waste is deposited for the purpose of its preparation prior to its further transport to a location where it is treated, reclaimed or disposed of, and the time of its storage prior to its recovery or modification does not normally exceed three years or does not exceed one year [5].

Advantages of a landfill: availability, low operating costs and use of methane (only on some landfills). Disadvantages of landfilling include space-related challenges, hazardous landfill gas (forming methane that heats the atmosphere) and the risk of contamination of groundwater. Methane is generated on the landfill and its production is one of the most serious impacts of landfills on the environment. The process of fermentation takes place in communal waste i.e., the biodegradation. It releases landfill gas - methane and carbon dioxide. Some studies say methane has a 25 to 72-fold greater impact than CO2 on global warming. Up to 80-90% of methane is released in the first 10 days, and then it decays in the landfill for the next 30 years. That is why the EU is pushing for a restriction on landfills. An effective solution to this problem in combating waste is waste incineration. In Slovakia, we currently have only two municipal waste incinerators (Bratislava, Košice). For comparison - in the Czech Republic, they have 4 such incinerators, in Austria 12, in Germany 164. Of course, if something burns, it produces hazardous waste, but the combustion of waste is subject to the strictest emission control by all energy producers. Flue gas cleaning is the most expensive of all costs.

At present, we have 125 legal waste dumps in Slovakia. There are 2500 registered illegal landfills, unofficially 7000. While some countries are advancing in the direction of waste disposal and managed to reduce or totally eliminate landfill waste, Slovakia has the biggest amount of waste, which ends in the landfills (Figure 4) and only a small part is recovered. Goal, which we want to achieve, is exactly the opposite.

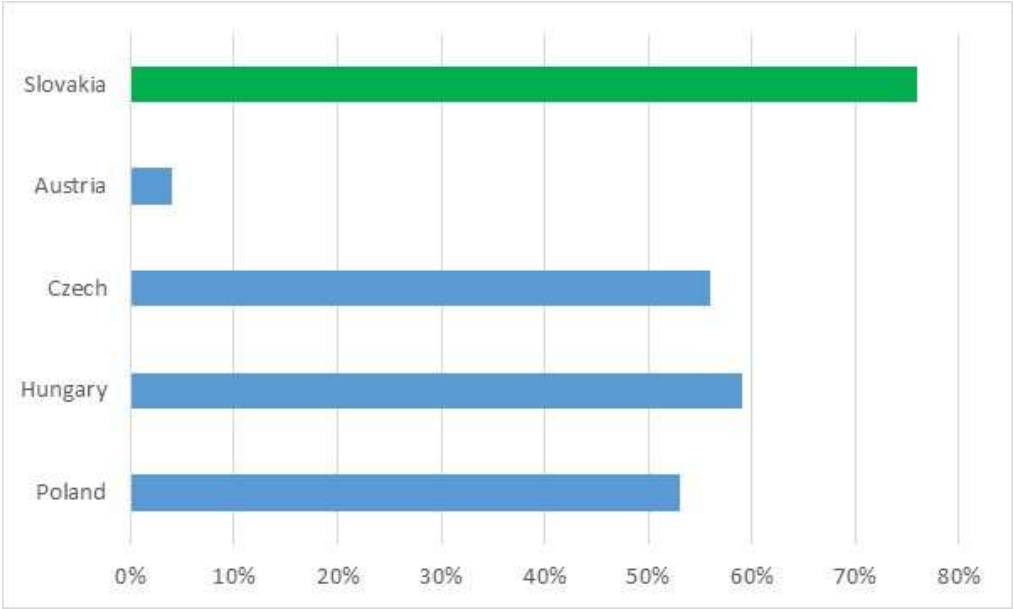

Figure 4 Comparison of municipal waste in landfills [19]

Benefits of combustion: waste reduction, reduces landfilling, energy production that melts into electricity and heat. Among the disadvantages of patio incineration are higher costs, little incinerations and mistrust of citizens.

Of course, it is way of enlightening people, to become more conscious and to conscientiously separate waste. Waste separating, respectively it is further usage of secondary raw materials in production process affects the final product cost- producers have lower expenses, what in the end lowers final costs for consumers.

Waste management is a very wide area for business. In the current state, most towns and villages in Slovakia are also collecting and exporting through standard 110, 120, 240 and 1100 litres collecting containers, which provide space for the collection of mixed, especially municipal waste, and at the same time offer the opportunity to carry out sorted waste collection. However, this situation is inadequate in the light of an evolving living standard, particularly in terms of increasing waste quantities, due to the development of living standards and packaging technology, as the amount of waste is increased especially in municipal waste, mainly in terms of its volume. This creates pressure to increase the number of waste containers, resulting in increased space requirements and the limitation of other necessary functions in a massive housing such as static transport, greenery, and the like.

Global population growth and urbanization increase the demand for additional waste disposal systems, thereby stimulating the growth of the waste market. This developmental impact of the company requires an innovative solution in waste management. The solution to this problem is, for example, the introduction of new systems for a semi-submersible waste collection system using semi-submersible containers. It is a substantially larger container that is embedded in the ground (containers need just a small area, as 60% of the container body is underground). This system saves up to 80% of the area in the collection points and holds up to 6 containers of standard 1100 litres containers in one container. These types of waste containers are most often installed abroad in public places such as shopping malls, airports, office complexes, metro stations and other projects. A very important added function has recently been the implementation of IoT technology in containers in the form of scanners and sensors. Using IoT and data integration, information about waste, its quantity, current condition of containers and their location is collected, and optimal routes for waste collection are selected. Therefore, there is a further reduction in labour costs, fuel, respectively. vehicles.

Main difference, which these semi-submersible waste containers in comparison with the typical ground waste collection have, is an advantage of the location in dedicated places. Therefore, they are a part of permanent infrastructure network with precise location of waste collection, instead of a service dedicated just to particular house/houses using common waste receptacles and standard collection schemes. Planning of this container network can bring significant benefits in logistics of waste management and environmental protection.

For example, in older urban areas, conventional door-to-door waste collection is often challenging due to differences in housing development, topography, climatic conditions, limited space for waste bins and means of transport, as well as frequent accidents at work among waste collection staff [20].

It is expected that the capacity of semi-submersible waste containers market will have reached 1050,1 million $ in 2027 from 796,7 million $ in 2019 [21]. These factors will be reflected in the growth of construction activities around the world, increasing demand on space and increased efficiency of space utilization, order and long emptying intervals, which reduce traffic congestion in cities. The further growth of this segment is also indicated by the increasingly stringent measures of the standard concerning the collection, sorting and waste disposal in European regions.

Benefits of semi-submersible containers can be divided into saving of space, odour reduction, improving of work safety, healthy and safe working environment for the cleaning staff, waterproof and durable construction, only a few moving and breakable parts, adjustable appearance.

Benefits of waste separation can be divided into economic **benefits** (**f**ewer emptying pick-ups, reduced fuel consumption, less emptying personnel), environmental benefits (quiet emptying, aesthetical attractivity encourages cleanliness, reduced CO_2 emissions) and social benefits [22].

Weaknesses of semi-submersible containers:

- The need for an entry building investment.
- Changing the export system (the need to secure a suitable harvesting technique).
- The need to change business and logistics relationships.
- The advantage of a system for concentrated waste production sites.

The 7th Environment Action Programme (EAP) will be guiding European environment policy until 2020: "In 2050, we live well, within the planet's ecological limits. Our prosperity and healthy environment stem from an innovative, circular economy where nothing is wasted and where natural resources are managed sustainably, and biodiversity is protected, valued and restored in ways that enhance our society's resilience. Our low-carbon growth has long been decoupled from resource use, setting the pace for a safe and sustainable global society."

It identifies three key objectives [22] to protect, conserve and enhance the Union's natural capital; to turn the Union into a resource-efficient, green, and competitive low-carbon economy; to safeguard the Union's citizens from environment-related pressures and risks to health and wellbeing.

Slovakia is one of the countries within the European Union characterized by the low eco-innovation index. GDP belongs to key factors enabling effective support for eco-innovation. The failure of global logistics during these days, where the pandemic negatively affected economic growth, replaces local logistics - which is also a positive factor for eco-innovation [23]. Slovakia could use this period to start the positive changes that will have a significant economic, social and environmental impact.

Many professionals and specialists make comment on and assess the system of circular economy as a new phenomenon. According to them, its priority is saving and effective use of restricted natural sources, streamlining of goods production at high effectiveness and lower consumption of sources and low (or even zero) production of emissions. It involves prevention and lowering of waste production and subsequently the sources of polluting materials up to recycling when the sources return to the economic cycle, which has still more urgent practical importance [24].

4 Conclusions

Although reverse logistics as a separate part of the logistics chain has only begun to emerge in recent years, it is an important part of business processes. Under European understanding, its application serves as a tool to mitigate the adverse environmental impacts of the economy and the health of the population. Proper waste management is a key element in ensuring the efficient use of resources and the sustainable growth of European economies. The priority objectives for waste policy in the EU include reducing the amount of waste generated, maximizing recycling and gradually eliminating landfilling.

Main purpose of waste management is to prevent waste production and reduce it mainly by developing technologies for protection of natural resources, production of goods which minimise amounts of waste and reduce environmental pollution as much as possible, development of suitable methods for disposal of hazardous substances contained in waste intended for disposal, waste recovery by recycling, by reusing or other processes, to use waste as an energy source, to eliminate waste in a way that does not endanger human health and does not harm the environment.

Nowadays, and not only in Slovakia, but waste production is also affected by population growth connected with urbanisation. State of the environment is highly topical issue. Increasingly stringent national and transnational measures and regulations regarding waste and waste management are coming to the fore.

The originator of waste is everybody, whose activity waste originates, or who manages modifications, mixing or other acts with waste, if the result is changing of character or composition.

One of the main problems of Slovakia remains low performance regarding waste management, low recycling rate and strong dependency on landfilling. Among OECD countries Slovakia belongs to the 10 worst waste managers. In 2019, Slovak residents produced 2.3 million tonnes of communal waste. Per capita, it is approximately 435

kilograms. Slovakia is currently not able to fulfil the goals, which determined regarding increased rate of waste recycling to 50% in 2020. Currently, this rate is at 39%. Therefore, change in the waste management performance is inevitable. It would be largely dependent on the push of new waste legislation and other fiscal stimuluses. Another significant, not only ecological problem in Slovakia is landfilling. About 50% of waste produced ends on landfills.

At present, we have 125 legal waste dumps in Slovakia. There are 2500 registered illegal landfills, unofficially 7000. Current course shows that Slovakia unfortunately will not get rid of mass landfilling. Even though in March 2019 there was a law change on landfilling fees, which set landfilling prices and defined also it is gradual growth, in comparison with neighbouring countries these fees are still very low. This is also one of the reasons why, in addition to our waste, garbage from nine other countries is imported to Slovakia and also ends up here. We consider it very important that all that responsible will apart from waste management also pay close attention to waste prevention.

Waste separating, respectively it is further usage of secondary raw materials in production process affects the final product cost- producers have lower expenses, what in the end lowers final costs for consumers. Innovations focused on smart packaging for products that meet environmental, quality, safety or product identification standards within the logistics chain are currently gaining prominence. Effective operating on the market is not possible without these innovations in the packaging within the integrated innovation process on the market as well as without suitably organized logistics.

Input factors are important when creating a reverse model, we pointed out in the article the cost-effectiveness with regard to the use of municipal waste. We applied the cost-effectiveness method to cities in the Slovak Republic and then compared the results.

While creating reverse model input factors are important, as we pointed out in the article focused on cost effectiveness considering the use of communal waste. Method of cost effectiveness had been applied on Slovak cities and then the results were compared.

In order to start the discussion about circular economy in Slovakia, economic and legislative motivation for prioritising eco-design, prevention of waste production, its separation and recycling with high added value of output products is essential, both at the citizen level and at the level of companies or institutions.

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