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A comparative analysis of reverse logistics implementation for waste management in Poland and other European Union countries

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Abstract. Reverse logistics represents a current research area, in both theoretical and empirical terms. In Polish practice, reverse logistics refers to a narrow approach within the framework of waste management. Enterprises perceive their success and the source of long-term economic and social benefits in introducing new, pro-ecological solutions at various stages of the supply chain through implementing reverse logistics. The purpose of the article is to present the potential of implementing reverse logistics in view of the growing threats resulting from waste. A multidimensional comparative analysis is used in the study, based on the indicators describing waste management as an important element of reverse logistics for the European Union Member States (the EUROSTAT data). As a result, the EU countries are divided into those placed at the forefront and the ones which cannot handle the level of reverse logistics implementation through waste management. Stemming from the conducted analysis, attention was drawn to the unfavourable position of Poland in the implementation of waste management, which is manifested in the level of reverse logistics implementation.

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INTRODUCTION

Reverse logistics is an up-to-date area of scientific studies regarding both theoretical and empirical approach. In Polish practice, reverse logistics represents a narrow research field related to waste management. Enterprises aim at business success through achieving long-term economic and social benefits by implementing innovative, pro-ecological solutions at different stages of the supply chain, and one of them is reverse logistics. In recent years reverse logistics has been the area of interest for enterprises due to the savings it offers in waste management, but also from the perspective of corporate social responsibility and legislation. The new eco-consumer expects from modern businesses to plan pro-ecological production, to launch only pro-ecological (recycling) packaging on the market, to increase the use of recovered raw materials and relevant components in an enterprise.

Sustainability is not just another buzzword. Consumers genuinely care, and are expecting more from businesses than ever before (*Sustainable Packaging Unwrapped*, 2019, p. 18). This concept of sustainable development is associated with the activities and practices of businesses to achieve environmental sustainability (Naz et al., 2020, p. 2). Over one third of consumers are more willing to purchase products representing the environmentally friendly brands (Gawinowski, 2020).

Reverse logistics has become an important area for all organizations due to the growing environmental concerns, legislation, corporate social responsibility and sustainable competitiveness. Reverse logistics refers to the sequence of activities required to collect the product used by a consumer for the purpose of reuse, repair, re-manufacture, recycle or dispose of it. A careful review of literature shows that the research addressing the issue of reverse logistics is now at the evolving phase and the issues related to adoption, implementation, forecasting product performance, outsourcing, reverse logistics networks of secondary market perspective, and disposition decisions have not been thoroughly examined (Agrawal, et al., 2015).

In reverse logistics, products and components are to be made from as much recycled content as possible (wherever legally and technically feasible). This enables a reduced dependence on virgin (fossil) feedstocks and creates a demand-pull for the recycled plastics, sending a clear signal stimulating investments in collecting, sorting and recycling industry (*New plastics economy* …, February 2020, p. 17). In practice, this can be achieved through implementing waste management from the smallest social unit, i.e. a household, up to an enterprise and then to a territorial unit.

The reverse logistics processes cover the following stages (de Brito, Dekker, 2003, p. 3-27; Wadhwa, et al., 2009, p. 462; Zielińska, et al., 2016, pp. 207-214):

- repairs and reuse – re-introducing the unchanged product to the system, while its quality cannot be lower than that of a new product;
- renovation (rejuvenation) – bringing the appropriate quality to returns by dismantling, control and exchange of faulty elements, and also by technological modernization being the replacement of old modules and components with the technologically better and more advanced ones;
- regeneration – bringing the appropriate quality required from new goods to the used ones through their total disassembly, a detailed repair process and exchange of out-dated parts;
- cannibalisation – recovering a relatively small number of parts and modules from a used product based on the repair process, renovation or regeneration;
- recycling – reprocessing the materials as part of the production process returns in order to obtain materials to be used in accordance with their original purpose or with another one.

All these processes create one joint reverse logistics system, of which waste management constitutes an important element (Fig. 1). In a reverse logistics system, the course of action is directed from a consumer to a producer.

Reuse models are the preferred 'inner loop' wherever relevant, and beneficial, since it retains the most value in the system. New (information) technologies, innovative business models, and evolving use patterns are unlocking and facilitating new reuse opportunities (*New plastics economy* …, February 2020, p. 8).

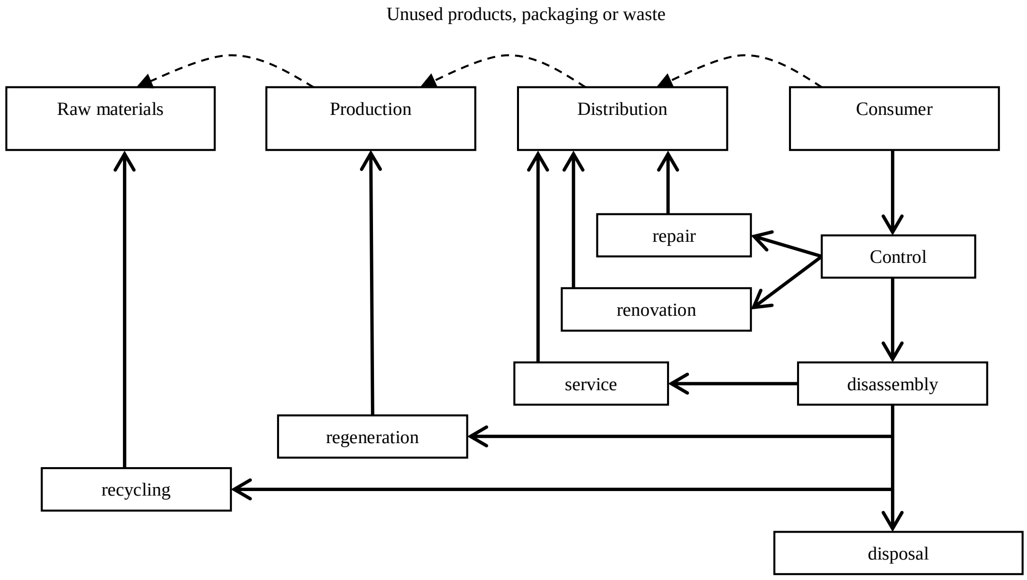

Figure 1. Reverse flow diagram
Source: Srivastava S.K. (2008)

The implementation of reverse logistics is visible already at the stage of product design by companies which apply the Design for Recycling approach, also referred to as Design for Environment, so that after using it is possible to reuse certain elements, typically considered waste, in the production of new products. This approach is followed, e.g., in the clothing industry, which establishes recycling points for clothes and underwear (clothing manufacturers: LPP - Polish, Calzedonia - Italian), the first brand second-hand shops (H&M) or stores offering collections of clothes unsold in previous seasons (COS - online store). Price comparisons of bio-based carbon to fossil-based carbon, as well as cost comparisons of processing bio-based materials with the corresponding fossil-based materials cannot be easily specified, but depend on the raw materials and the molecular economy of the processes into the final products (Popp et al., 2021, p. 77).

Over 50% of customers admitted reducing the amount of disposable plastic they use. 42% of U.S. and UK consumers say products that use sustainable materials are important when it comes to their day-to-day purchases. 73% of U.S. consumers who care about sustainable packaging say it is important to them because they are concerned about the future of the environment (*Sustainable Packaging Unwrapped*, March 2019, p. 8, 13, 16). Globally, replacing just 20% of single-use plastic packaging with reusable alternatives offers an opportunity worth at least USD 10 billion (*The New Plastics Economy: catalysing action*, 2017). An estimated 50 million tons of electronic equipment is discarded every year globally, a figure increasing 17% a year due to the lack of reverse logistics and remanufacturing initiatives (*Creating a reverse logistics ecosystem*, 1.11.2020).

The purpose of the article is to present the potential for implementing reverse logistics in view of the growing threats resulting from waste. A multidimensional comparative analysis is used in the study, based on the indicators describing waste management as an important element of reverse logistics for the European Union Member States (EUROSTAT data). As a result, the EU countries are divided into those placed at the forefront and the ones which cannot handle the level of reverse logistics implementation through waste management. Based on the conducted analysis, attention was drawn to the unfavourable position of Poland in the implementation of waste management, which is manifested in the level of reverse logistics implementation.

1. LITERATURE REVIEW

Scientists started defining the term reverse logistics aa early as the 1970s (Guiltinan et Nwokoye, 1975, Ginter et Starling 1978), they paid attention to returns, however, without referring to them as reverse flow logistics. It was Lambert and Stock (1981) who defined reverse logistics as the direction of flow opposite to the traditional flow of materials in the logistics chain (Lambert, et Stock, 1981). They focused on the costs of bringing the consumer's products back to the business and addressed the reverse logistics problem in terms of impact on the distribution system (Layti, et al., 2019, p. 1296). In the 1980s, Murphy (1986) defined reverse logistics as the flow of goods from the consumer to the producer in the distribution channel (Murphy, 1986, pp. 12-21). According to Pohlen and Farris (1992), reverse logistics can be defined as "the movement of consumer products towards the producer through a distribution chain" (Pohlen, et Farris II, 1992, pp. 35-47). In the 1990s, Stock (1992) formulated a definition which highlighted the role of recycling in the logistics of waste disposal and reuse (Stock, 1992, p. 7). In turn, Eymery (1997) presented a precise definition: "Reverse logistics responds to the need to withdraw the products after use and to treat them by destroying them, transforming them or recycling, in order to reduce costs by valuing recovered products and, increasingly, to meet the requirements of respect for the environment" (Eymery, 1997). According to D.S. Rogers and R.S. Tibben-Lembke (1998) reverse logistics is a process involving both planning and control of the flow of materials, work in progress, finished goods and the related information from the place of their consumption to the place of their origin, in order to recover added value or the proper method of their disposal (Rogers, et Tibben-Lembke, 1998, p. 262). M. Fleischmann et al. believe that reverse logistics is a process that covers all logistics activities, starting from the used and unnecessary products to the ones that can be reused (Fleischmann, et al., 1997, p. 5; Ślusarczyk and Kot 2018). Finally, K. Hawks claims that it is "the process of moving goods from their typical final destination for the purpose of capturing value, or proper disposal. Remanufacturing and refurbishing activities may also be included in the definition of reverse logistics" (Hawks, 2006).

In Polish literature, J. Szołtysek identifies reverse logistics with the "reverse logistics is the entirety of processes managing the flow of waste (including defected goods) and information (connected with those flows), from the places of their origin to the places of their destination in order to regain value (through repair, recycling or processing) or an appropriate treatment and long-term storage in a way that such flows were effective economically and minimized the negative influence of waste on the environment" (Szołtysek, 2009, p. 80). A. Sadowski is of a similar opinion, as according to him reverse logistics represents the area of logistics responsible for analysing regularities occurring in the flow of products, the life cycle of which has ended (Sadowski, 2006).

The source literature suggests diverse directions of reverse logistics studies in their various aspects. Reverse logistics is analysed, e.g., from the objective and subjective, processual, decision-making, organizational and implementation oriented perspectives. All of these angles are demonstrated both theoretically and practically, and the respective studies are carried out in selected countries, sectors of industry or individual enterprises (Starostka-Patyk, 2019).

Based on the conducted source literature analysis, it is noticeable that the majority of Polish scientists approach reverse logistics as a tool for more effective waste and packaging management. The situation is different from the perspective of foreign scientists who perceive reverse logistics as a system regulating the flow of unwanted or damaged goods from a consumer to a manufacturer, i.e. managing both returns and complaints. What does it result from? It is only for several years that Poland has been implementing a functional system of waste management and obtaining the respective added value, e.g., through the process of recycling.

Therefore, further research can illustrate the broader aspect of waste management definition as well as a more detailed approach to waste management. In accordance with the Act on Waste (Act of December 14, 2012, Art. 3, section 1, point 3), "waste management is the generation of waste and waste management", whereas (Act of December 14, 2012, Art. 3, section 1, point 2) "waste management is the collection, transport, processing of waste, including the supervision over such activities, as well as the subsequent handling of waste disposal sites and the activities performed as a waste seller or waste management intermediary".

2. EU AND POLISH LAW REGULATING REVERSE LOGISTICS AND WASTE MANAGEMENT

The European Union legislation regulates the guidelines for reverse logistics and waste management in the following documents:

- "Waste package" consisting of four directives: Directive 2018/851 amending Directive 2008/98/EC on waste (Directive (EU) 2018/851), Directive 2018/852 amending Directive 94/62/EC on packaging and packaging waste (Directive (EU) 2018/852), Directive 2018/850 amending Directive 1999/31/EC on the landfill of waste (Directive (EU) 2018/850), Directive 2018/849 amending Directives 2000/53/EC on end-of-life vehicles, 2006/66/EC on batteries and accumulators and waste batteries and accumulators, and 2012/19/EU on waste electrical and electronic equipment (Directive (EU) 2018/849);
- Directive 2019/904 of the impact of certain plastic products on the environment (Directive (EU) 2019/904);
- Communication, Strategy for Plastics in a Circular Economy (Communication, 16.1.2018).

Directive 2018/851, amending Directive 2008/98/EC on waste, increased the preparation levels for reuse and recycling of municipal waste (Directive 2018/851, p. 21):

a) till 2025 to a minimum of 55% by weight;
b) till 2030 - 60%;
c) till 2035 - 65%;
d) till 2035 the amount of municipal waste landfilled has to be reduced to 10% of the total amount of municipal waste generated.

The EU "Waste Package" is valid since 5 July 2020.

In turn, Polish legislation provides the regulations on reverse logistics and waste management in the following documents:

- The Act of September 13, 1996 on Maintaining Cleanliness and Order in Municipalities (Act, September 13, 1996),
- The Act of December 14, 2012 on Waste (Act of December 14, 2012),
- The Act of June 13, 2013 on Packaging Management and Packaging Waste (Act, June 13, 2013),
- *The 2030 National Environmental Policy – development strategy in the field of environment and water management* (Council of Ministers, 2019)

In order to meet the guidelines set by the European Union, Polish Parliament adopted, on November 19, 2020, the draft Act amending the Act on Maintaining Cleanliness and Order in Municipalities (Act of September 13, 1996, amendment). The adopted draft provides the levels of preparation for reuse and recycling of municipal waste which the municipalities will be obliged to achieve in the years 2021-2035. The new recycling levels for the coming years are as follows:

a) 2021 - 20%,

b) 2022 - 25%,
c) 2023 - 35%,
d) 2024 - 45% and
e) 2025 - 55%.

In view of the above, Polish central government and local governments should take decisive measures aimed at reducing the total amount of generated waste. The following preventive actions are crucial: withdrawing difficult and non-recyclable products and packaging from the market, supporting reusable solutions, i.e. bottles, diapers, second-hand stores, promoting tap water drinking, preventing food waste and others (*New levels of recycling* ..., November 27, 2020). Waste management processes are continuously supported by legal amendments, as a result, public administration units (municipalities) and enterprises were obliged to develop efficient waste management.

3. METHODOLOGICAL APPROACH

The following empirical research findings were obtained based on applying a multidimensional comparative analysis (MCA) covering the European Union Member States in relation to waste management indicators, as an important element of reverse logistics for the European Union Member States on the basis of Eurostat data. The research problem is focused on the assessment of the level of waste management implementation (part of reverse logistics) in the analysed countries. The research findings aim at ordering the countries from the highest to the lowest level of waste management implementation, primarily in relation to the position of Poland.

The variety of data presented in comparative analyses in relation to waste management as an element of reverse logistics requires the use of diverse measurement units demonstrating various values. It results in the absence of possibility to compare facts and figures not only in different areas but also in the same domain, characterised by the changing intensity of specific phenomena. Taking this approach it is justified to examine the tools and methods allowing for the application of an objective procedure to assess, in general terms, the situation regarding waste management. For this reason, the method of multidimensional comparative analysis, taking the form of linear ordering, can be used in the discussed case (Zeliaś, 1989; Pluta, 1986; Pociecha, et al., 1988). Linear ordering, which uses a synthetic measure of development (SMD) provides for ranking the objects (countries) "from the best to the worst one" (Walesiak, 2006; Walesiak, et Gatnar, 2009).

The addressed research problem, i.e. the implementation level of waste management in the European Union Member States represents a complex research area. The objects of the classification (countries) are referred to by means of numerous indicators. It results in difficulties encountered when describing the similarities of objects under study as well as classifying them. The similarity level of such objects, in terms of one characteristic, may turn out different than their similarity from the perspective of another characteristic. Therefore it is crucial to classify objects based on formal procedures. It provides for an objective analysis addressing the conditions of the complexity typical for the waste management phenomenon (Zielińska, 2019, p. 341).

The first stage of multidimensional comparative analysis is focused on the unification of variables' nature (indicators referring to waste management). This unification is not applied when all variables take the form of stimulants, i.e. have a positive impact on the analysed collective problem (the condition of waste management). If destimulants or nominants are included in the set of indicators, they have to be converted into stimulants[1].

The conversion of destimulants into stimulants through applying the quotient form (Walesiak, 1993, pp. 38-40) was used in the paper:

$$S_{ij}=b[D_{ij}]^{-1} \tag{1}$$

where: D_{ij} – value of *j*-th destimulant observed in i-th object (country),

b - constant adopted arbitrarily, in calculations $b=\min D_{ij}$.

The next stage of multidimensional comparative analysis consists in removing values of the studied variables (indicators referring to waste management) and unifying orders of magnitude to make them comparable (normalization) (Walesiak, 1988, pp. 63-71). The following normalization formula was used in the discussed case (Jajuga, Walesiak, 2000, p. 109):

$$\mathbf{z_{ij}} = \frac{\mathbf{x_{ij}} - \bar{\mathbf{x}}_\mathbf{j}}{\mathbf{S_j}} \tag{2}$$

where: z_{ij} – normalized value of *j*-th of a given waste management indicator in *i*-th object (country),

- arithmetic mean of *j*-th of waste management indicator, j x

S_j – standard deviation of *j*-th waste management indicator,

x_{ij} – value of *j*-th waste management indicator observed in *i*-th object (country).

The application of the normalization formula to all indicators of waste management was followed by developing a normalized data matrix (Z), applied in further calculations (see Zielińska & Sej-Kolasa, 2004).

Having determined the normalized data matrix, the linear ordering methods were applied for the set of objects using hierarchical classification. These methods aim at ranking (ordering) the objects or their sets in accordance with the adopted criterion. It is possible to apply them only if a given overriding criterion is adopted. Next the objects can be ranked from the "best" to the "worst". The synthetic measure of development (SMD), being the tool in linear ordering methods, is the function which aggregates partial information within the individual indicators and is assigned to each single object included in the particular set. In general terms, the aggregation formulas referring to indicator values can be divided into model and non-model ones (for more see: Gatnar, et Walesiak, 2004, 351-355; Grabiński, 1984, p. 38).

A non-model formula was applied for the calculations, where p_i takes the mean normalized value of waste management indicators for individual countries. The "best" country is considered the one with max p_i value, whereas the "worst" – min p_i:

$$\mathbf{p_i} = \frac{\mathbf{1}}{\mathbf{m}} \sum_{\mathbf{j=1}}^{\mathbf{m}} \mathbf{z_{ij}} \tag{3}$$

where: p_i – synthetic measure of development for *i* – th object (country),

m – number of data describing waste management indicators,

z_{ij} – normalized value of *j*-th of a given waste management indicator in *i*-th object (country).

In the study not all waste management indicators were assigned ranks, because there is no information in the source literature or the conducted research that would describe the function of the analysed indicators in the assessment of the reverse logistics implementation.

[1] The set of variables referring to waste management can cover: stimulants, destimulants and nominants. Stimulants stand for the variables the higher numerical values of which indicate the expected changes in terms of a particular phenomenon. Destimulants represent the variables the higher values of which demonstrate unwanted changes within the phenomenon under study. The features of nominants show a certain level of saturation with any deviations indicating negative changes in the examined phenomenon (Pluta, 1986).

4. CONDUCTING RESEARCH AND THE RESULTS

A multidimensional comparative analysis was conducted applying the possible to determine waste management indicators being a part of reverse logistics for each European Union country. The indicators were retrieved from Eurostat database for 2016, 2018 and 2019. 11 waste management indicators were chosen for the analysis to describe the European Union Member States, as presented in *Table 1*:

1. Municipal waste generated by waste management (kilograms per capita).
2. Waste electrical and electronic equipment (WEEE) by waste management operations (kilograms per capita).
3. Recycling rates for packaging waste glass packaging (%).
4. Recycling rates for packaging waste - plastic packaging (%).
5. Recycling rates for packaging waste - paper and cardboard packaging (%).
6. Recycling rates for packaging waste - wooden packaging (%).
7. Recycling rate of e-waste (%).
8. Disposal municipal waste - energy recovery (kilograms per capita).
9. Disposal municipal waste - landfill and other (kilograms per capita).
10. End-of-life vehicles (recovery and reuse) (%).
11. Trade in recyclable raw materials by waste imports (thousand Euro).

Table 1

Waste management indicators in the European Union countries for 2016, 2018 and 2019

Countries	Municipal waste generated by waste management (kilograms per capita, 2018)	Waste electrical and electronic equipment (WEEE) by waste management operations (kilograms per capita, 2018)	Recycling rates for packaging waste glass packaging (%, 2016)	Recycling rates for packaging waste - plastic packaging (%, 2016)	Recycling rates for packaging waste - paper and cardboard packaging (%, 2016)	Recycling rates for packaging waste - wooden packaging (%, 2016)	Recycling rate of e-waste (%, 2016)	Disposal municipal waste - energy recovery (kilograms per capita. 2018)	Disposal municipal waste - landfill and other (kilograms per capita, 2018)	End-of-life vehicles (reuse, recycling and recovery, totals) (%, 2018)	Trade in recyclable raw materials by waste imports (Thousand euro, 2019)
Belgium	411	9,77	100	44,5	92,9	83,7	29,3	177	4	97,3	6 273 931
Bulgaria	407	6,68	64	64,8	79,6	31,9	68,8	30	249	95,8	330 250
Czechia	351	9,06	75,1	58,9	90,6	51,2	46,5	58	172	99,3	546 237
Denmark	814	11,7	92,1	38,5	88,5	76,7	38,5	397	9	98,2	133 370
Germany	615	9,13	84,4	48	87,6	25,8	38,7	192	5	95,7	9 932 823
Estonia	405	5,57	61	26,5	76,9	16,4	69,8	167	87	91,2	77 811
Ireland	576	9,6	84,2	30,5	78,5	74,3	49,5	183	130	95,2	74 055
Greece	504	5,08	36	41,4	99,5	20,4	32,9	5	403	99,5	511 716
Spain	475	5,63	72,2	47,9	74,6	67,5	41	62	242	92,6	3 035 158
France	527	10,18	77,9	26,5	98,4	30,8	36,6	185	110	94,2	1 186 974
Croatia	432	8,21	57	37,3	83,7	2,9	81,3	0	286	97,7	48 878
Italy	499	4,54	70,8	42,4	79,7	60	34,4	95	107	82,6	4 763 233
Cyprus	637	5,27	39,4	62,3	99,7	10	23,1	2	482	96,8	386
Latvia	407	4,77	65,5	36,6	86,2	38	40,6	8	240	96	75 885
Lithuania	464	4,34	45,8	74,2	89,1	33	35,1	58	114	95,4	237 367
Luxembourg	610	10,17	98,4	33,4	83,6	23,6	45,6	266	38	95,9	809 692
Hungary	381	6,39	34,2	32	74,5	24,1	51,1	51	189	95,8	211 946
Malta	640	5,26	29,5	23,5	59,7	0	6,2	0	550	54,4	499
Netherlands	511	8,86	86,2	50,4	87,1	72,7	40,4	218	7	98,4	2 430 995
Austria	579	12,9	84,1	33,4	83,5	19,9	50,1	224	13	97,8	1 535 313
Poland	329	5,98	63	34,6	82,2	32,4	36,1	79	137	95,3	1 087 760
Portugal	508	6,17	49	34,9	66,9	89,9	43,5	91	247	94,9	431 453
Romania	272	2,19	64,1	46,5	92,5	27,6	19,4	12	200	92,1	245 586
Slovenia	486	5,87	98,5	60,4	76,2	32,2	33,9	50	47	91,3	493 406
Slovakia	414	5,01	68,7	52,4	74,2	47,2	36,7	34	229	96,8	219 099
Finland	551	9,95	91,8	26,5	116,1	14,5	48,2	314	4	97,3	80 732
Sweden	434	12,25	93	48,4	81,8	50,4	55,4	232	3	95,3	702 348
United Kingdom	463	13,04	67,6	46,2	79	30,8	42,2	181	69	92,8	2 748 987

Source: *own compilation on the basis of www.ec.europa.eu/eurostat*

The presented set of indicators for the EU Member States does not provide much data to describe reverse logistics, but only the indicators describing waste management processes. It is caused by the absence of data for all countries. The majority of indicators cover 2018 (only one indicator refers to 2019). No current data are available for the indicators 3-7, therefore their levels were taken from 2016 as they were important for the analysed research problem. Table 2 presents the most important parameters for waste management indicators in the European Union Member States.

Table 2

The most important information for waste management indicators in the European Union countries for 2016, 2018 and 2019

Indicators	Arithmetic mean	Standard deviation	Nature of variables: S-stimulant D-destimulant	Levels max for S and min for D	Country with the the best level according to S or D variable
Municipal waste generated by waste management (kilograms per capita)	489,4	113,3	D	272,0	Romania
Waste electrical and electronic equipment (WEEE) by waste management operations (kilograms per capita)	7,6	2,9	D	2,2	Romania
Recycling rates for packaging waste glass packaging	69,8	20,6	S	100,0	Belgium
Recycling rates for packaging waste - plastic packaging	43,0	12,9	S	74,2	Lithuania
Recycling rates for packaging waste - paper and cardboard packaging	84,4	11,2	S	116,1	Finland
Recycling rates for packaging waste - wooden packaging	38,9	24,8	S	89,9	Portugal
Recycling rate of e-waste	42,0	15,1	S	81,3	Croatia
Disposal municipal waste - energy recovery (kilograms per capita)	120,4	107,3	S	397,0	Denmark
Disposal municipal waste - landfill and other (kilograms per capita)	156,2	146,8	D	3,0	Sweden
End-of-life vehicles (recovery and reuse) (%)	93,8	8,4	S	99,5	Greece
Trade in recyclable raw materials by waste imports (Thousand euro)	1365210,4	2266133,2	S	9932823,0	Germany

Source: *own compilation on the basis of www.ec.europa.eu/eurostat*

The uniform preference postulate was used with reference to the analysed indicators (formula 1 was applied), where 1, 2 and 9 (indicator numbers) were classified as destimulants, following a subjective assessment, while nominants were not found in the group of the examined indicators.

The results showed in Table 2 highlight that the best levels of waste management indicators, in line with variable S or D, were recorded twice in Romania. This result was influenced by the indicators 1 and 2.

At the next stage the normalization of indicators was performed (formula 2 was used), i.e. the values of indicators were deleted and the orders of magnitude were unified for comparability purposes.

The final stage consisted in a linear ordering taking the form of a synthetic measure of development (SMD) (Table 3).

Table 3

Synthetic development measure (SDM) for the level of waste management in the European Union countries

Country position	Country name	SMD	Country position	Country name	SMD
1	Belgium	0,764	15	Luxembourg	-0,043
2	Sweden	0,540	16	Slovakia	-0,057
3	Germany	0,479	17	Ireland	-0,060
4	Netherlands	0,439	18	Poland	-0,068
5	Finland	0,405	19	United Kingdom	-0,094
6	Romania	0,318	20	Latvia	-0,112
7	Denmark	0,260	21	Estonia	-0,127
8	Czechia	0,256	22	France	-0,132
9	Bulgaria	0,128	23	Croatia	-0,170
10	Lithuania	0,055	24	Portugal	-0,218
11	Spain	0,040	25	Greece	-0,260
12	Italy	-0,004	26	Cyprus	-0,328
13	Austria	-0,040	27	Hungary	-0,359
14	Slovenia	-0,042	28	Malta	-1,571

Source: *own compilation*

The highest ranked European Union Member States in terms of high level of waste management implementation, and partly also reverse logistics, are as follows: Belgium, Sweden, Germany and The Netherlands. Romania's high ranking position (No. 6) deserves attention. It may raise doubts, therefore the methodology of collecting statistical data in Romania should be carefully examined. In turn, Malta, Hungary, Cyprus and Greece are the worst implementers of waste management. Poland was ranked 18th, which is not a satisfactory result as almost 2/3 of the EU countries present a higher level of waste management implementation.

Such a low position of Poland results, e.g., from the unfavourable results of two analysed indicators:

1) municipal waste disposal - energy recovery,
2) municipal waste disposal - landfills and other.

Additionally, not even one analysed indicator showed that Poland recorded the best or high result among all countries covered by the study.

In Poland, the system of municipal waste disposal through incineration with energy recovery or landfilling is poorly developed. Currently, only 9 modern municipal waste incineration plants are in operation, another one in Olsztyn is under construction. Their total capacity accounts for approx. 9.3% of the total amount of municipal waste produced in Poland. It is definitely not enough to tie up the municipal waste management system in Poland. The optimal solution is the construction of approx. 50 installations incinerating up to 30 thousand tonnes of Mg combustible fraction per year, or 15, but larger ones (Wielgosiński, 2019; Szymański, 23.06.2020; Zamorowska, 30.06.2020).

Concerns are raised by the conclusions related to the level of combustible fraction from municipal waste, according to which it is not a resource in recovery processes. Feasibility studies performed 5 years ago showed that one ton of waste will result in PLN 80 profit, while at the moment it is necessary to pay additional PLN 300, i.e. the resource has turned into a cost (Marlière, 2020, p. 32).

On the other hand, the trade in recyclable raw materials by waste imports indicator is connected with the process of waste cross-border shipment. Attention should be paid to the relatively high level of this indicator for Poland. In recent years, Polish recovery installations have been interested in processing foreign waste suitable for recycling instead of using raw materials from the selective collection in Poland. What is the reason of such situation? - lower costs of obtaining foreign raw materials suitable for recycling.

The demand for primary (fossil) resources should be reduced by reusing the recycled materials and, at a later stage, by replacing any remaining primary raw materials with renewable ones whose source of origin is responsibly managed and remains environmentally beneficial (*New Plastics Economy Global Commitment …* , October 2019, p. 41).

CONCLUSIONS

The research findings allow formulating several conclusions for Poland:

- reverse logistics represents a broader approach, not only limited to waste and packaging management, but also proper after-sales service. Businesses should invest in proper tools to handle consumer returns and complaints. As a result, it will ensure high level of customer service and a quick response of enterprises resulting in the elimination of defects in products or components;
- waste management as an element of reverse logistics should be competitive and self-financing. The process of municipal waste segregation and delivery to the recovery installations (recycling, energy recovery from combustion) should be effective both for the municipalities and the recyclers;
- ensuring readiness and ability for effective collection, segregation, processing and municipal waste reusing. It will contribute towards efficiency improvement of the system for collecting recyclable municipal waste fractions. The system should be legally and financially supported by the state and also by the external EU funds for the recovery programs;
- there are not enough modern waste recycling installations. More recycling centres should be established, specializing in the specific waste streams;
- thermal treatment of waste cannot replace recycling, but landfilling alone.
- Therefore, segregation system should be improved at its source, in particular the treatment of mixed municipal waste and its preparation for energy recovery (meeting the appropriate combustible fraction levels) or for storage.

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