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REVERSE LOGISTICS AS A MEANS OF REDUCING THE ECOLOGICAL FOOTPRINT

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Abstract. Rapid technological development and related global challenges encourage the industrial sector to seek innovative solutions that would allow it to adapt to increasingly stringent environmental requirements and, at the same time, ensure the sustainability of its operations. Research shows that the industrial sector is experiencing the most significant impact due to growing requirements to reduce negative environmental impacts; therefore, the need to implement environmentally friendly processes is increasing. One of the most promising directions in this area is the integration of reverse logistics into the supply chains of industrial enterprises. Reverse logistics creates the prerequisites for reducing the ecological footprint, rational use of natural esources, reducing waste disposed of in landfills, and optimising energy costs. This article aims to analyse the possibilities of applying reverse logistics and its contribution to reducing the ecological footprint of different industrial sectors. The study is based on a systematic analysis of scientific literature and secondary data. The results of the study can be significant in shaping sustainable industrial policies and helping companies make strategic decisions related to the use of secondary raw materials, waste reduction and management of return product flows. The results of a Life Cycle Assessment (LCA) analysis comparing forward and reverse logistics processes showed that the application of reverse logistics has the potential to improve environmental performance. By modeling different situations, it was determined that reverse logistics is more efficient from an environmental point of view than traditional direct logistics.

Keywords: reverse logistics, ecological footprint, situation simulation, industry, life cycle assessment.

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1. Introduction

Rapid technological progress and global environmental challenges are driving industrial companies to seek innovative solutions to help them adapt to increasingly stringent environmental requirements. International commitments, such as the European Union's Green Deal and the Paris Climate Agreement, set ambitious goals for reducing greenhouse gas emissions, conserving natural resources, and developing a circular economy (European Commission, 2020). In the context of these initiatives, the industrial sector, as one of the most significant sources of environmental pollution, must radically restructure its business processes to reduce its ecological footprint. Statistical data show that the industrial sector is responsible for over a fifth of the European Union's carbon dioxide emissions, generating a significant share of waste in landfills or incinerators (Agency, 2022).

To address these problems, more and more attention is being paid to circular economy solutions, and reverse logistics is becoming one of its key components. Reverse logistics is defined as a set of processes involving the return of products, materials or components from the consumer back to the supply chain to reusing, recycling, upgrading or properly disposing of them (Kirchherr et al., 2023). Such an approach not only creates the prerequisites for reducing environmental pollution and conserving natural resources but also contributes to the competitiveness of companies and the promotion of innovation in the field of sustainability (Govindan et al., 2015).

Reverse logistics is one of the key elements of circular business processes, and its importance is widely emphasized in the literature. Its main objective is to reduce waste by increasing the value of products that have reached the end of their life cycle, thereby redirecting the flow of goods in the opposite direction. Reverse logistics also represents the starting point for product recycling and highlights the cyclical nature of production processes. The effective management of reverse logistics depends on several factors. One is a company culture oriented toward process sustainability, which encourages greater efforts for the efficient and careful handling of reverse logistics. This, in turn, improves the quality of returned goods and reduces costs related to waste management. Another important factor is technological progress, which makes it possible to optimize different waste flows (Dore & Gallo, 2023). The methodological framework of this study followed a structured and logical sequence. Initially, a comprehensive literature analysis was conducted to define the concept of reverse logistics, examine its environmental implications, and explore its integration within the circular economy and waste management contexts. Based on insights from the literature, the Life Cycle Assessment (LCA) method was selected to evaluate and compare the environmental impacts of reverse and forward logistics systems. The modelling process involved defining key parameters, including transportation mode, product type, transportation distance, and waste disposal methods. Finally, the outcomes of the assessment were analyzed to identify the environmental advantages and implications of reverse logistics practices.

This article aims to assess the role of reverse logistics in reducing the ecological footprint and analyse the possibilities of its application in the activities of industrial companies. To achieve this aim, an analysis of scientific literature will be presented covering the theoretical aspects of reverse logistics and its significance in the circular economy context. An analysis of the contribution of reverse logistics to reducing the ecological footprint will be performed. Also, in order to achieve the research objective – to assess the impact of reverse logistics on environment – a life cycle assessment (LCA) methodology was applied. The analysis was performed using SimaPro software, which is a widely used tool for modeling and assessing the environmental impact of various systems at various stages of the life cycle. The data required for the modeling process were obtained from SimaPro integrated databases, ensuring data reliability. The results of the modeling confirm the effectiveness of reverse logistics processes, revealing their positive impact on environmental indicators and the overall level of system sustainability.

2. Analysis of the theoretical aspects of reverse logistics

The rapidly increasing public attention to sustainable development and the circular economy, together with stricter environmental requirements, oblige companies to accept responsibility for the entire life cycle of their products. The goal of reverse logistics is to maximise residual value recovery from obsolete products by properly designing, exporting, controlling and maintaining them in efficient and economically significant flows, starting from customers and moving to primary suppliers and manufacturers. Products whose life cycle ends must be appropriately disposed of (Sun et al., 2022). Butt et al. (2024) define reverse logistics as the process of planning, implementing and regulating the transfer of raw materials, manufactured goods, inventories obtained during production and related information from the point of consumption to the original place of origin, to recover the original value (Butt & Govindan, 2024). Reverse logistics also helps to reduce, reuse and recycle waste, thus promoting the creation of an environmentally friendly and socially responsible company image, contributing to greater demand for products and services (Kurniawan et al., 2023). However, the development of this activity is limited by specific challenges, such as complex process management, high costs and insufficient infrastructure development, which complicate the transition from a linear economic model to a more efficient circular economy (Salas-Navarro et al., 2024). Despite these obstacles, a systemic approach that includes internal actions of organisations, favourable state policies, and the implementation of new technologies creates the prerequisites for effective reverse logistics integration. This integration not only optimises resource use and reduces waste but also increases the resilience and flexibility of supply chains, thereby contributing to the implementation of more sustainable and responsible production practices (Agrawal & Singh, 2019).

He et al. (2024) argue that the circular economy can be treated as a tool to eliminate high levels of resource consumption and waste generation. As the circular economy grows, the waste recycling industry must move to a circular model. Unlike the linear economy, which causes environmental pressures, such as CO_2 emissions, the circular economy promotes waste prevention, reduction and recycling to reduce the impact of solid waste on the interface between the environment, society and the economy. This can be one of the measures to solve problems related to resource scarcity, climate change and environmental pollution (Shahidzadeh & Shokouhyar, 2022). Ding et al. (2023) note that both the circular economy and reverse logistics are oriented towards economic and social aspects. The application of reverse logistics principles does not mean the need to abandon or fundamentally change the existing direct logistics system. On the contrary, to achieve maximum efficiency and sustainability, the compatibility of these two systems – direct and reverse logistics – is necessary (Lee & Lam, 2012). Their integration allows for a holistic approach to supply chain management, where both the delivery of products to the consumer and their return or reuse are coordinated and strategic.

Products are often returned for two reasons: they do not work correctly or are no longer needed (Ramos et al., 2014). These reasons for returns can be divided according to the supply chain stages: manufacturing, wholesale, retail and end-user. Based on this, three main types of returns are distinguished (Abbasi et al., 2025). Manufacturing returns include excess raw materials, quality control non-conformities and unprocessed or leftover products (Dabees et al., 2023). Distribution returns relate to product recalls, commercial returns (e.g., incorrectly delivered, damaged or unsold products), inventory adjustments and functional returns such as the return of vehicles, packaging or other logistical elements. Consumer returns include money-back guarantees, warranty repairs, spare parts or services returns, and products that have reached the end of their useful life or end of life (Hashemi, 2021). Such return flows not only contribute to more efficient use of resources but also have a significant impact on the environment by reducing waste and promoting reuse.

Many countries have set national greenhouse gas (GHG) reduction targets and strategies in response to growing environmental restrictions in recent years (Mohammadkhani & Mousavi, 2022). European industrial sectors provide significant economic and social benefits: goods and products are produced, jobs are created, and taxes are paid. However, the largest European industrial installations are responsible for the largest share of emissions of key air pollutants and greenhouse gases into the ambient air and other, but no less significant, environmental impacts, including water and soil pollution, waste generation and energy use (Alnoor et al., 2019). Industry is one of the most critical components of the European economy, but it is also a source of pollution. Increasing environmental requirements are also driving companies to integrate reverse logistics into their supply chains as a means of enhancing profitability while reducing environmental impact. This shift is linked to a growing culture of organizational responsibility across the supply chain. Such accountability, shaped by both legal obligations and social expectations, has generated strong incentives for companies to adopt reverse logistics, with economic, social, and environmental sustainability as its core pillars.

From an economic perspective, reverse logistics can yield significant benefits. The cost of returned products is typically lower than that of raw materials, which helps reduce the high expenses associated with producing new goods. Companies adopt reverse logistics not only for direct financial gains, but also as a strategic response to strengthen competitiveness and prepare for stricter regulations in the future. At the same time, reverse logistics supports brand positioning by fostering a sustainable corporate image. Demonstrating responsibility for environmental impact enhances a companys reputation in the eyes of consumers, contributing to a positive green image and, ultimately, higher sales (Ni et al., 2023).

Reverse logistics is essential to improve resource utilization by circulating products and materials and reusing, repairing, recycling or remanufacturing them instead of generating waste and filling landfills. By implementing reverse logistics in conjunction with advanced logistics, it is possible to close the production-consumption cycle, thereby reducing waste and conserving resources. The benefits of implementing reverse logistics go beyond economic incentives, as it also supports sustainability and helps reduce our environmental impact (Malmgren & Mötsch Larsson, 2020).

Figure 1 illustrates the steps that a product goes through in a reverse logistics flow. Collection is the first stage, which involves the collection, transportation, and storage of returned products. Inspection is a subsequent activity, during which returned products are inspected and the quality of the product is measured by testing them. In the separation activity, products are selected based on different characteristics determined by the previous inspection. Separation is used to make the most profitable and

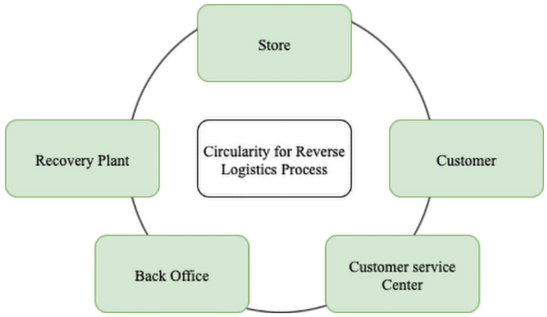

Figure 1. Circularity for reverse logistics process

appropriate disposal decision and includes sorting and storage. Recycling refers to the recovery of a product and includes reuse, repackaging, repair, refurbishment, remanufacturing, and recycling, depending on the inspection and separation. Finally, redistribution involves the reintegrating of reused products into the market through sales, rental, transportation, storage, and marketing (Fu et al., 2021).

Although the concept of sustainability is new, sustainable production emerged from sustainable development, which was introduced in the 1980s to address the environmental impacts of economic growth, globalisation and other factors (Zaloznova et al., 2018). Thus, it is a process of change in which resources and investments are used for technological development and institutional changes that ultimately meet the needs of the people.

3. Analysis of the impact of reverse logistics on the ecological footprint

The ecological footprint describes the overall impact of human activities on the environment, measured in terms of natural resources consumed, greenhouse gas emissions and the amount of waste generated. The industrial sector is one of the most significant sources of the ecological footprint – according to the European Environment Agency (EEA, 2022), industrial activity in the European Union generates about 20–25% of all carbon dioxide (CO_2) emissions, as well as a significant amount of industrial waste, a large part of which still ends up in landfills or incinerators (EEA, 2022). In this regard, international and national strategic documents increasingly emphasise the need to implement the principles of the circular economy, which would allow for the creation of sustainable resource use and waste management models. Reverse logistics, as an integral part of the circular economy, plays a vital role in reducing the ecological footprint in the industrial sector, as it includes processes by which products, their components or materials are returned to the supply chain for reuse, recycling, renewal or proper disposal. This reduces the demand for natural resources and significantly contributes to reducing emissions and improving waste management. As Govindan et al. (2015) point out, effectively operating reverse logistics can reduce greenhouse gas emissions by up to 25%, depending on the industry and the type of returned products or materials. These processes also reduce the amount of waste disposed of in landfills, optimise energy consumption and reduce environmental pollution associated with the extraction of raw materials and the production of new products.

One of the main contributions of reverse logistics to reducing the ecological footprint is resource conservation. Returned goods and their components can be refurbished or recycled, reducing the need for primary raw materials. For example, in the electronics industry, returned device components – batteries, screens, metal housings – are often refurbished or recycled, and the resulting materials are used to produce new products. This practice reduces the need for metals, plastics and other materials, and the CO_2 emissions and energy costs associated with their extraction (Mtetwa, 2024).

Waste management is a fundamental component of reverse logistics, and its effectiveness largely depends on the capacity of organizations to manage waste. Waste management can be approached from both a process perspective and an object perspective. From the process perspective, the key elements are as follows (Starostka-Patyk & Grabara, 2010):

1. Waste prevention – through the rationalization of production and consumption;
2. Waste generation – including product design that accounts for the remaining amount of recyclable waste after use;
3. Separate collection – primarily by sorting waste at the point of generation;
4. Utilization – recovering materials and energy contained in waste, or recycling it in whole or in part;
5. Recycling – reusing materials to obtain a resource for the original or an alternative purpose;
6. Waste disposal – applying biological, physical, or chemical treatment to render waste harmless to human life, health, or the environment.

Importantly, the application of reverse logistics principles does not require abandoning or fundamentally altering the existing direct logistics system. On the contrary, achieving maximum efficiency and sustainability depends on the compatibility and integration of both direct and reverse logistics systems (Lee & Lam, 2012). Their integration allows for a holistic approach to supply chain management, where both the delivery of products to the consumer and their return or reuse take place in a coordinated and strategic manner (Salas-Navarro et al., 2024). Traditionally, forward logistics is the process of delivering finished goods to customers. The Logistics Management Council states that logistics is that part of the supply chain process that plans, implements, and controls the efficient flow and storage of goods, services, and related information. This activity is also included in reverse logistics, but is performed in the opposite direction from the consumer to the manufacturer or supplier (Ali et al., 2018).

Products are most commonly returned for two main reasons: they either fail to function properly or are no longer needed (Ramos et al., 2014). These reasons for returns can be categorized by supply chain stages: manufacturing, wholesale, retail and end-user. Based on this, three main types of returns are distinguished. Manufacturing returns include excess raw materials, quality control non-conformities and unprocessed or leftover products (Dabees et al., 2023). Distribution returns include product recalls, commercial returns (e.g., misdelivered, damaged, or unsold products), inventory adjustments, and functional returns such as the return of transportation vehicles, packaging, or other logistical elements. Consumer or user returns include money-back guarantees, warranty repairs, returns for parts or services, and products that have reached the end of their useful life or end of life (Hashemi, 2021). Such return flows not only contribute to more efficient resource use, but also have a significant impact on the environment by reducing waste and promoting reuse. In response to growing environmental pressures, in recent years more and more countries have set national greenhouse gas (GHG) reduction targets and strategies (Mohammadkhani & Mousavi, 2022). Europe's industrial sectors deliver many important economic and social benefits: goods and products are produced, jobs are created and more taxes are paid. However, Europe's largest industrial installations are responsible for the largest share of emissions of key air pollutants and greenhouse gases into ambient air, as well as other, but no less significant, environmental impacts, including water and soil pollution, waste generation and energy use (Alnoor et al., 2019). Industry represents one of the most significant pillars of the European economy, yet it also remains a major source of pollution.

In the textile sector, reverse logistics solutions, such as the recycling of fabrics or textile fibres, reduce the need for raw materials, such as new cotton, and reduce the water consumption and chemical use associated with textile production (Leal Filho et al., 2024). Studies show that using recycled cotton can reduce water consumption by up to 90% compared to producing new cotton. In addition, reverse logistics solutions in the textile industry contribute to reducing the amount of textile waste going to landfills, which significantly impacts soil and water pollution (Fakfare et al., 2024).

Waste reduction is another crucial advantage of reverse logistics in reducing the ecological footprint. Waste disposed of in landfills accounts for a large part of environmental pollution, as its decomposition often releases methane and other greenhouse gases. Reverse logistics processes allow returning products and materials to be directed into the recycling, reuse or renewal cycle (Fidan et al., 2021). According to the European Commission (2020), effectively operating reverse logistics can reduce waste by 30–50% depending on the sector. For example, returnable packaging collection systems can reduce single-use packaging waste by up to 35%. Another important aspect is the reduction of greenhouse gas emissions. Recycling returned products requires less energy than producing new products from virgin raw materials. For example, recycling aluminium uses only about 5% of the energy needed to produce aluminium from ore. Similar relative distributions apply to most other materials, such as steel, plastic or glass. Guide and Van Wassenhove (2009) note that closed-loop supply chains that integrate reverse logistics can reduce the total CO_2 emissions of the supply chain by 10 to 25%, depending on the industry and the scale of the solutions. This result is determined not only by the lower energy demand for raw material processing, but also by shorter transport chains, optimised logistics flows and more efficient warehousing.

The benefits of reverse logistics are not limited to environmental indicators – they also create social and economic benefits. The development of return, recycling and renewal processes promotes the creation of new jobs in recycling, sorting, logistics and innovation. In addition, it increases consumer awareness and involvement in sustainability initiatives and encourages the development and implementation of new technological solutions. Kazancoglu et al. (2021) emphasise that reverse logistics is strengthening environmental protection, social responsibility, and corporate reputation.

In this era of significant ecological change and uncertainty, highlighted by the wide-ranging impacts on energy consumption, resource depletion, water waste, global warming and sustainable material consumption and production, industrial ecology gains significant appeal in the context of the broader Sustainable Development Goals. Sustainable development tools and practices can be used to address global sustainability challenges related to sustainable consumption and production. According to the Sustainable Development Goals, the benefits of SDG 12 lie in implementing industrial ecology initiatives in strategic management, supply chain, marketing, industrial economics and consumer behaviour by 2030 (Awan, 2022).

Environmental requirements require complete neutrality – CO_2 emissions are zero. However, reducing CO_2 emissions alone cannot contribute to carbon reduction. Although climate change adaptation is a new business opportunity in the waste sector, discussions on climate change action are still focused on traditional waste management (Sonar et al., 2024). Figure 2 shows trends in waste management volumes and economic value in the manufacturing sector from 2013 to 2022.

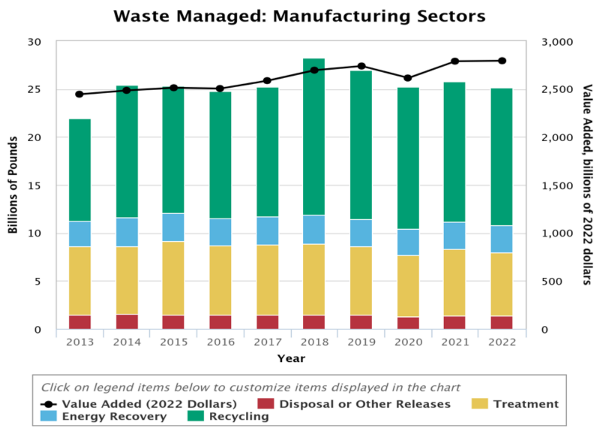

Figure 2. Managed waste by manufacturing sectors (source: U.S. Environmental Protection Agency, 2025)

The data shows the total volume of waste treated (in billions of US dollars), broken down into different waste management methods. In addition, the black line shows the economic value in billions of dollars, which has increased over the period under analysis, even with fluctuations in the overall trend in waste volumes. It is noted that the presented waste volumes managed by the manufacturing sector have increased slightly from 2013 to 2018. Since 2018, a decrease in waste volumes has been observed. The generation and treatment of chemical waste has decreased, while recycling and incineration for energy production have increased. It is essential to consider how the economy affects waste generation in facilities. This figure includes the trend in value added in the manufacturing sectors.

Since 2013, the value added in the manufacturing sectors and the waste managed by these sectors have increased by 14 percentage points. The amount of waste handled and the added value increased, indicating that manufacturing facilities dealt with approximately the same amount of waste per unit of product in 2022 compared to 2013. Although the data in the diagram is not directly related to reverse logistics used in industry, it can be assumed that the industrial sector applies the principle of reverse logistics in practice. The manufacturing sector, guided by these principles, has undoubtedly improved waste management quantitatively (higher recycling rate) and qualitatively (lower disposal rate, increased added value). This indicates a positive transformation of the industry towards more sustainable operating models.

4. Methodology

A comprehensive assessment of the environmental impacts associated with circular economy strategies and logistics management processes is essential to prevent adverse outcomes. Life cycle assessment constitutes the most widely adopted methodology for evaluating the potential environmental impacts of products and processes, encompassing all stages from raw material extraction to end-of-life management. When applied to logistics management systems, this approach facilitates the identification of solutions that minimise environmental burdens. This method requires identifying and quantifying the materials and energy used, emissions released, and waste generated at each stage of the life cycle. Such assessment supports resource optimisation and reduces environmental burdens. Consequently, organizations pursue two key objectives—preventing and reducing environmental impacts. Achieving these goals requires tools capable of identifying and quantifying the impacts associated with any product, process, or activity. Among the available methodologies, life cycle assessment stands out as one of the most comprehensive approaches for evaluating environmental performance (Kaynak et al., 2025).

In the life cycle assessment conducted in this study, six principal stages were included. The first stage, raw material acquisition, covers the extraction and pre-processing of materials and associated energy requirements, along with the environmental burdens linked to emissions, land degradation, and resource toxicity. For this analysis, raw materials were selected from the SimaPro database, with cardboard identified as the primary input. The second stage involves the production and manufacturing processes, where environmental impacts arise mainly from energy consumption and process waste; in this case, the system includes the production of 24 tonnes of cardboard boxes. The third stage encompasses packaging, distribution, and transportation, during which design choices and logistics efficiency influence overall impacts; for this study, a transportation distance of 200 km was considered. Under forward logistics, the product moves directly from use to disposal, while in reverse logistics it is returned to the manufacturer for recycling. The fourth stage, use, reuse, and maintenance, includes the resources required during the product's functional lifetime; cardboard products generally have low direct energy use but may have reuse potential depending on handling. The fifth stage, recycling, begins when the product has fulfilled its primary function and may re-enter either a closed-loop or open-loop material cycle; in the reverse logistics pathway the cardboard is returned for recycling. The final stage, waste management, applies to materials that cannot be reused or recycled and are therefore directed to disposal processes such as landfilling, incineration, or energy recovery.

5. Analysis of examples of the simulated situation

In light of the growing global concern about the depletion of natural resources and climate change, a study was conducted that compared life cycle analyses (LCA) to assess and compare the environmental impacts arising from two different stages of the cardboard box supply chain: (1) when the boxes are produced from virgin (unprocessed) raw materials and are incinerated after use, and (2) where waste collection, paper recycling processes and product manufacturing from recycled raw materials are included.

In both cases, a situation was modelled under equivalent conditions: a 24-ton load is transported 100 kilometres with a EURO6-compliant freight truck. The assessment was performed using SimaPro software, one of the recognised and widely used LCA tools that allows detailed modelling of environmental aspects and comparison of different supply chain scenarios.

The environmental assessment is based on the CML-IA baseline method (EU25, version 3.10), which covers many of the most critical impact categories at a medium level, including: depletion of non-renewable resources, greenhouse gas emissions, human health effects (toxicity), as well as impacts on freshwater and marine ecosystems and other significant environmental indicators. Figures 3 and 4 present normalized datasets of evaluation forward emissions and normalized datasets of evaluation reverse logistics emissions, respectively.

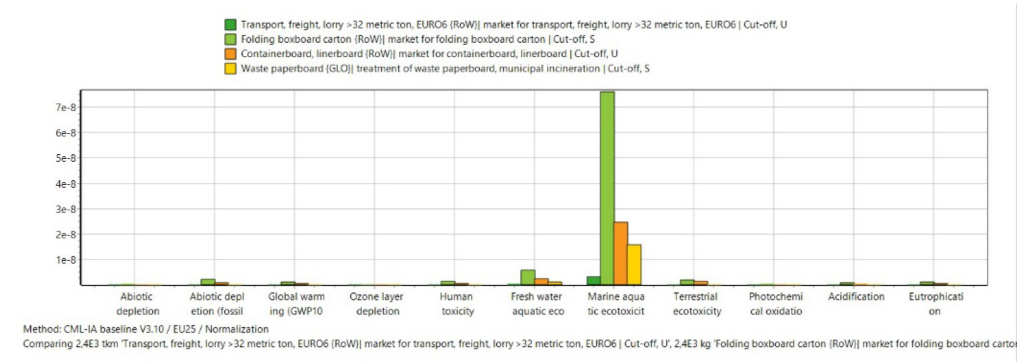

Figure 3. Normalized datasets of evaluation forward emissions

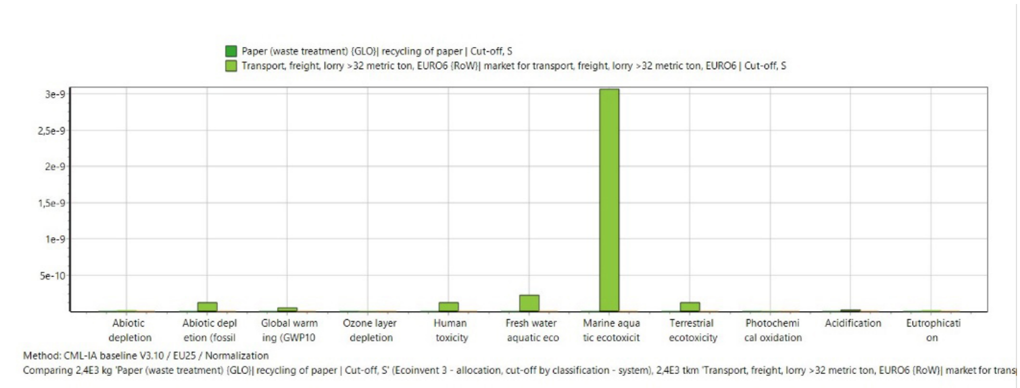

Figure 4. Normalized datasets of evaluation reverse logistics emissions

The results of characterised and normalised data show that the direct logistics scenario has a significantly higher environmental impact in almost all assessment categories. In particular, higher consumption of non-renewable resources, greenhouse gas emissions and human health effects (toxicity) stand out. This result is obtained precisely because primary raw materials are used (their extraction) to produce cardboard packaging, and the used packaging is incinerated. In contrast, the reverse logistics scenario, based on recycling waste paper, has a significantly lower environmental impact. This system eliminates energy and resource intensive stages of primary material production, replacing them with recycling processes.

The most significant difference is in fossil resource consumption and greenhouse gas emissions – in the recycling scenario, emissions are almost insignificant. This is also in line with the general trend in the LCA (life cycle analysis) literature, which emphasises the efficiency of a circular material economy compared to a linear consumption model.

One significant aspect of the insights emerges when comparing the results of characterisation and normalisation. While characterisation shows absolute quantities, the normalised data presented in Figures 3 and 4 shows the impacts of the scenarios in a general context, which allows us to understand which impact category is the most significant within the overall background of implications. The Table 1 provides a detailed analysis of the environmental impact of reverse logistics processes, comparing it to the impact of direct logistics.

The comparison shows that direct and reverse logistics have the most significant impact on water pollution. In the case of direct logistics, this impact is mainly due to emissions related to the primary cardboard production processes. Although this impact is reduced by about 25 times in the reverse logistics system, it remains the most significant relative factor. This means that even recycled raw materials pose a risk to water bodies, likely due to emissions from processing plant effluents into water bodies. This comparison and assessment are essential to show the nuance of the interpretation of life cycle analysis – even if the absolute amount of emissions decreases, this does not necessarily mean that the impact becomes insignificant on a normalised basis.

6. Conclusions

Based on a comprehensive analysis of scientific literature on reverse logistics topic, covering reverse logistic as a tool for footprint reducing, reverse logistic in circular economy context and statistical data on the volume of emitted emissions across three industrial sectors, as well as corporate waste management and reduction practices, it is clear that reverse logistics is an effective way to reduce the environmental impact of the industrial sector. It allows for more efficient waste management by collecting, reusing or recycling it, thus contributing to developing a circular economy. Instead of destroying used products, they become raw materials for a new production cycle. This not only reduces the need for raw materials, but also allows companies to form an image of an environmentally friendly and socially responsible business. Although recycling processes are often not very profitable – they require a lot of time and labour - their significance in resource saving and environmental protection is undeniable.

Recycling is becoming a waste management solution and a strategic tool that increases the efficiency of raw material use and reduces overall costs in the long term. This trend is visible in the continuous investment of companies in recycling technologies and equipment, renewable energy sources, and cleaning and filtering equipment. These investments are often not costs for companies, but the currency of creating added value, which reduces company costs over time.

The study confirms that recycling and using recycled materials in product production significantly reduce emissions. The life cycle assessment results show that reverse logistics significantly reduces impacts in key categories: the depletion of fossil abiotic resources is reduced by more than 80%, and the global warming potential is

Table 1. LCA analysis results on how reverse logistics reduces ecological footprint

Environmental impact category	Reverse logistics impact on environment comparing to forward logistics processes (results provided approximately)
Abiotic depletion	Impact reduced about 40%
Abiotic depletion (fossil)	Impact reduced about 45%
Global warming (GWP100)	Impact reduced about 50%
Ozone layer depletion	Impact reduced about 30%
Human toxicity	Impact reduced about 40%
Fresh water aquatic ecotoxicity	Impact reduced about 50%
Marine aquatic ecotoxicity	Impact reduced about 57%
Terrestrial ecotoxicity	Impact reduced about 60%
Photochemical oxidation	Impact reduced about 50%
Acidification	Impact reduced about 50%
Eutrophication	Impact reduced about 50%

reduced to an almost negligible level compared to direct logistics. However, the study also showed that recycling and reuse of materials do not reduce emissions to zero, but are superior to waste incineration.

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REVERSINĖ LOGISTIKA KAIP EKOLOGINIO PĖDSAKO MAŽINIMO PRIEMONĖ

M. Linkevič

Santrauka

Sparti technologinė plėtra ir su ja susiję pasauliniai iššūkiai skatina pramonės sektorių ieškoti novatoriškų sprendimų, kurie padėtų prisitaikyti prie aukštų aplinkosaugos standartų ir užtikrinti veiklos tvarumą. Tyrimai rodo, kad aplinkosauginiai reikalavimai verčia pramonės sektorių pereiti prie tvaresnių procesų diegimo. Viena perspektyviausių krypčių šioje srityje yra reversinės logistikos integravimas į pramonės įmonių tiekimo grandines. Reversinė logistika sudaro prielaidas mažinti ekologinį pėdsaką, racionaliau naudoti gamtos išteklius, mažinti į sąvartynus patenkančių atliekų kiekį ir optimizuoti energijos sąnaudas. Šio tyrimo tikslas – išanalizuoti reversinės logistikos taikymo galimybes ir jos indėlį mažinant įvairių pramonės sektorių ekologinį pėdsaką. Tyrimas grindžiamas sistemine mokslinės literatūros ir antrinių duomenų analize. Gauti rezultatai gali būti reikšmingi formuojant tvarią pramonės politiką ir padedant įmonėms priimti strateginius sprendimus, susijusius su antrinių žaliavų naudojimu, atliekų mažinimu ir grįžtamųjų produktų srautų valdymu. Gyvavimo ciklo vertinimo (LCA) analizė, kurioje lyginami tiesioginės ir reversinės logistikos procesai, atskleidė, kad reversinės logistikos taikymas gali pagerinti aplinkosauginius rodiklius. Modeliuojant įvairius scenarijus nustatyta, kad reversinė logistika aplinkosauginiu požiūriu yra efektyvesnė nei tradicinė tiesioginė logistika.

Reikšminiai žodžiai: atvirkštinė logistika, ekologinis pėdsakas, situacijų modeliavimas, pramonė, gyvavimo ciklo analizė.