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# Innovative Logistics Solutions for Reducing $CO_2$ Emissions in Industrial Enterprises

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***Abstract:***

***Prupose:*** *The aim of this article is to analyse the role of innovative logistics tools and strategies in reducing carbon dioxide ($CO_2$) emissions in industrial enterprises. The study focuses on identifying practical logistics solutions that support the achievement of environmental goals and the transition towards sustainable development.*
***Approach/Methodology/Design:*** *The article uses a qualitative approach based on an analysis of the literature, industry data and case studies, including a detailed description of the activities of Omega Pilzno. The research is based on three hypotheses concerning the impact of the use of low-emission vehicles, the optimisation of transport routes using TMS systems, and the implementation of energy-efficient warehouse solutions and ERP systems.*
***Findings:*** *The analysis showed that the implementation of the discussed logistics innovations can contribute to a reduction in $CO_2$ emissions of up to 20–30% in specific areas of logistics activities. In addition, the digitisation of logistics processes and the integration of environmental data into ERP systems also generate economic and operational benefits.*
***Practical Implications:*** *The main limitation is the qualitative nature of the research and the limited number of cases analysed. In the future, it is advisable to extend the research with a quantitative approach and comparative analyses in different industrial sectors.*
***Originality/Value:*** *The article contributes scientific and practical value by presenting specific logistics innovations as effective tools for reducing $CO_2$ emissions in industry. It is a source of knowledge for logistics managers, decision-makers and those responsible for sustainable development strategies in companies.The aim of this article is to analyse the financial condition of enterprises in Poland in 2022–2024 in sectoral terms, broken down into the public and private sectors.*

***Keywords:*** *Sustainable logistics, route optimization, low-emission vehicles, ERP systems, energy-efficient warehouses.*
***JEL codes:*** *O32, L91, Q55.*
***Paper Type:*** *Research article.*

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## 1. Introduction

In recent decades, we have seen a rapid increase in environmental awareness among the public and a tightening of climate policies at international and national level. The Paris Agreement, the European Green Deal and the Fit for 55 strategy commit European Union member states to significantly reducing greenhouse gas emissions. In this context, industry – one of the main sources of $CO_2$ emissions – is faced with the need to implement measures to minimise its impact on the environment.

One of the key areas where significant environmental effects can be achieved is logistics (Brzozowska *et al.,* 2021). Industrial logistics, including transport, warehousing, inventory management and information flow, generates a significant share of companies' total carbon footprint (Kabus and Lenort, 2024). At the same time, it offers enormous potential for optimisation and reduction of $CO_2$ emissions. More and more companies are investing in low-emission vehicles, IT technologies that support transport planning, and green warehouse infrastructure (Miciuła *et al.,* 2020). However, the scale of these activities varies, and their effectiveness requires systematic analysis.

The aim of this article is to examine how modern logistics strategies and digital technologies contribute to the reduction of $CO_2$ emissions in industrial enterprises. The issue addressed is part of the current trend in research on sustainable development and the green transformation of the industrial sector.

To achieve the research objective, a case study method and qualitative analysis of secondary data were used. Real industrial companies that have implemented specific sustainable logistics solutions were selected, including Omega Pilzno.

Environmental reports, operational data and information contained in industry and scientific publications were analysed. Data source triangulation was also used, combining data from academic studies, company publications and external reports. This approach allows for an assessment of the actual effectiveness of the analysed solutions and their impact on $CO_2$ emissions.

The results of the study aim to fill a research gap in the empirical verification of the effectiveness of logistics tools in the context of the environmental strategies of industrial companies.

## 2. Methodology

### 2.1 Theoretical Background

Sustainable logistics is an approach that combines operational efficiency goals with minimising negative environmental impact (Krawczyk *et al.,* 2020). The literature on the subject is devoting more and more space to analysing the impact of logistics on

greenhouse gas emissions, particularly in the industrial sector, where transport and storage are among the main sources of $CO_2$ emissions.

According to Rodrigue (2020), logistics accounts for approximately 14% of global $CO_2$ emissions, a significant portion of which is attributable to road transport. The author emphasises that it is not only important to change the means of transport, but also to manage them effectively – by reducing empty runs and implementing the concept of 'green routing'.

Morana and Gonzalez-Feliu (2015) point out that industrial companies implementing green logistics strategies not only have lower $CO_2$ emissions, but also achieve cost savings through increased energy efficiency and process digitalisation. McKinnon *et al.* (2010) propose the development of intermodal transport and a shift in transport from roads to rail and inland waterways as a way to systematically reduce emissions from industrial logistics.

From Polish sources, the ILiM report (2022) showed that as many as 67% of the companies surveyed declare investment plans in a green fleet and automation of warehouse processes, treating them not only as a response to regulations, but also as a source of competitive advantage.

A McKinsey & Company report (2023) on Central and Eastern Europe points out that the integration of transport management systems with environmental data platforms can lead to a 15-25% reduction in emissions, depending on the industry and scale of operations.

Mindbox research (2024) indicates that companies using ERP systems to track $CO_2$ emissions and energy efficiency gain access to more accurate ESG analyses that support strategic environmental decision-making.

AIUT (2023), on the other hand, describes the implementation of automated energy systems in high-bay warehouses as an example of the practical implementation of the Industry 4.0 concept supporting sustainable logistics.

Finally, the Omega Pilzno (2021) case study shows the real impact of investments in LNG-powered tractors, solar-powered refrigeration units and advanced telematics, which resulted in a reduction of $CO_2$ emissions by more than 22% in one year.
The above sources indicate that sustainable logistics not only supports environmental goals, but is also becoming part of modern strategic management in industry.

The above studies confirm the importance of the topic and the multidimensional nature of approaches to sustainable logistics. However, despite growing interest in this topic, most analyses focus either on general technological trends or on individual solutions (e.g., green fleets or process digitalisation).

According to what has been identified in the literature review, there is a lack of research directly related to a comprehensive approach to innovative logistics solutions as an integrated tool for reducing $CO_2$ emissions in industrial enterprises – covering transport, storage and system management at the same time. This study aims to fill this gap by offering an approach that synthesises various technologies and strategies in the context of practical implementation.

## 2.2 Methods

The study adopted an exploratory and diagnostic approach, using a qualitative method – a case study. The case study was considered the main research technique in the presented analysis. This method allows for the analysis of specific implementations in real business conditions and the assessment of the impact of these activities on $CO_2$ emissions. Qualitative analysis of secondary data (desk research) was also used, including industry reports, press materials, implementation studies, operational data, and scientific and technological publications.

The following research hypotheses were adopted to achieve the set objective:

- *H01: The implementation of low-carbon means of transport (e.g. LNG, electric, hybrid) in industrial enterprises contributes to the reduction of $CO_2$ emissions in logistics.*
- *H02: The use of transport management systems (TMS) and the optimisation of transport routes reduces fuel consumption and greenhouse gas emissions.*
- *H03: The modernisation of logistics infrastructure, including warehouse automation, the use of renewable energy sources and ERP systems, has a positive impact on reducing $CO_2$ emissions.*

The diagnosis covered companies from the industrial sector that have implemented modern, environmentally friendly logistics solutions. These included: Omega Pilzno – a transport and logistics company that uses a fleet of LNG-powered vehicles, solar-powered refrigerated trucks and route optimisation systems; AIUT – a company specialising in the implementation of Industry 4.0 solutions in the field of warehouse automation and energy management; as well as manufacturing companies analysed in reports by McKinsey & Company and Mindbox, focusing on the implementation of ERP systems and energy management.
The selection of cases was based on three criteria: representativeness in terms of green technology implementation, availability of operational and environmental data, and the possibility of comparing the situation before and after the implementation of a given solution.

A number of analytical techniques were used in the study. A comparative analysis made it possible to compare $CO_2$ emission levels before and after the implementation of specific solutions. Data triangulation, which involves verifying information from various sources (e.g., company reports, industry reports, scientific publications),

increased the reliability of the findings. The categorisation of solutions made it possible to assign specific activities to one of three categories: transport, storage or information management.

The research process consisted of five stages: identification of companies implementing green logistics solutions, collection and verification of source data, analysis of the implemented solutions and their impact on $CO_2$ emissions, interpretation of the results in relation to the hypotheses, and formulation of conclusions regarding the replicability and scalability of the analysed practices.

## 3. Research Results

The analysis conducted as part of this study allowed for the identification and assessment of the effectiveness of selected logistics activities implemented in industrial enterprises in terms of $CO_2$ emission reduction. Below are the summary results of the analysis of four key areas of logistics intervention, supported by empirical examples (Table 1).

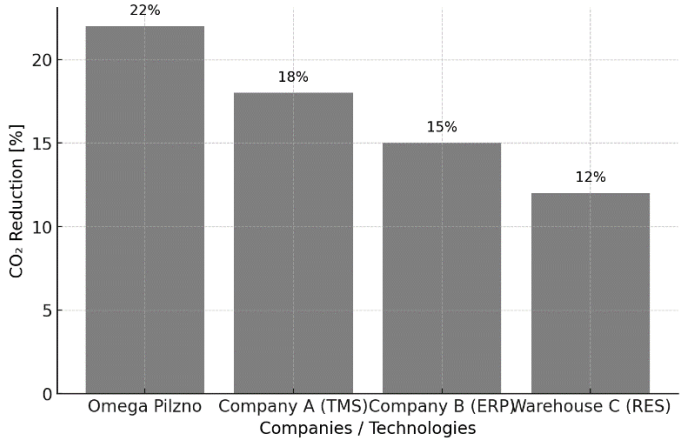
***Table 1.*** *Pro-environmental activities in logistics and transport*

| AREA OF IMPLEMENTATION | COMPANY / FACILITY | IMPLEMENTED SOLUTIONS | RESULTS |
|---|---|---|---|
| Modernization of Transport Fleet | Omega Pilzno | Solar-powered refrigeration units; LNG-powered trucks | 30% fuel reduction; 22% $CO_2$ reduction; Improved cooling efficiency |
| Route Optimization and Transport Management (TMS) | Company A | Dynamic route planning; Integration with GPS and telematics | 40% reduction in empty runs; 18% $CO_2$ reduction |
| ERP Implementation and Digital Logistics Management | Company B | ERP with environmental modules; Automation of purchasing and inventory | $CO_2$ emission monitoring; Energy optimization; 15% $CO_2$ reduction |
| Sustainable Warehousing and Infrastructure (RES) | Warehouse C | PV panels (60% of energy demand); HVAC A++ with heat recovery; Smart LED lighting with sensors | Energy savings; Improved infrastructure efficiency |

***Source:*** *Own work.*

As a result of these measures, the annual reduction in $CO_2$ emissions was estimated at 12%. Figure 1 below compares the level of $CO_2$ emission reductions achieved in the four companies or technological solutions analysed. The greatest effectiveness was observed in the use of alternative fuels and refrigeration technologies in transport (Omega Pilzno). Digital tools supporting transport and energy.

***Figure 1.*** *Reduction of $CO_2$ emissions in the analysed cases*




***Source:*** *Own work.*

The greatest environmental impact was achieved through the modernisation of the transport fleet – the implementation of LNG-powered vehicles and PV refrigeration technology at Omega Pilzno resulted in a 22% reduction in $CO_2$ emissions. TMS systems, which support route optimisation and reduce empty runs, provided almost comparable efficiency (18%), confirming their high utility in operational logistics.

ERP systems and infrastructure measures (renewable energy sources, LED, HVAC) also had significant environmental effects, but their impact was slightly smaller, suggesting that they are of a supporting nature, complementing strictly transport-related activities.

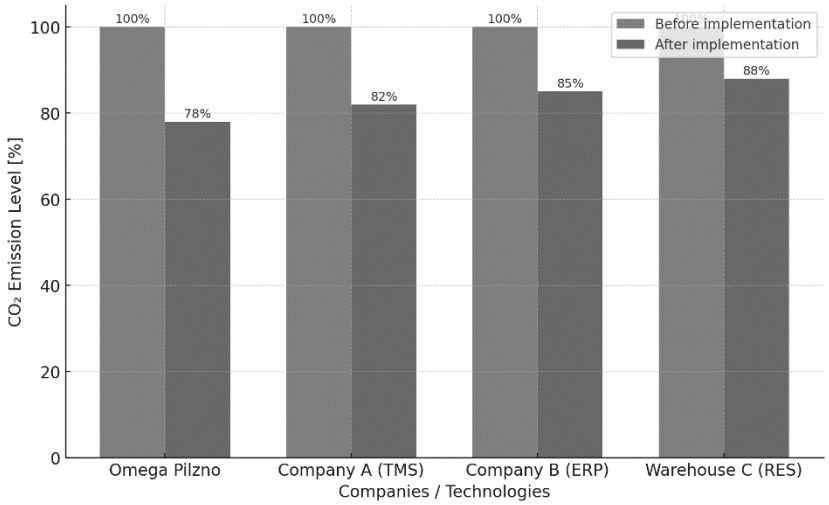
Figure 2 illustrates the level of $CO_2$ emissions (calculated as a percentage of the initial level) before and after the implementation of logistics solutions in the four cases analysed. As can be seen:

- Omega Pilzno reduced emissions to 78% of the original level (22% reduction),
- Company A, thanks to the TMS system, reduced emissions to 82%,
- Company B, using ERP, reduced emissions to 85%,
- Warehouse C, using renewable energy sources, reduced emissions to 88%.

All of the implementations analysed resulted in a clear improvement in environmental performance, confirming the effectiveness of environmentally friendly logistics activities.

The solutions analysed contributed to a real and measurable reduction in $CO_2$ emissions, with none requiring a drastic change in the business model – reductions of 12% to 22% were achieved while maintaining operational efficiency.

***Figure 2.*** *Net profit of privatesector enterprises in Poland by province in 2022-2024*




***Source:*** *Own work.*

The data confirms that logistics is one of the most easily scalable areas of decarbonisation, and the implementation of specific technologies yields quick results – which may encourage other companies to invest in green solutions.

Post-implementation emissions for all companies fell significantly, but still remain above 75% of original emissions, suggesting that full climate neutrality requires a combination of multiple technologies and long-term actions.

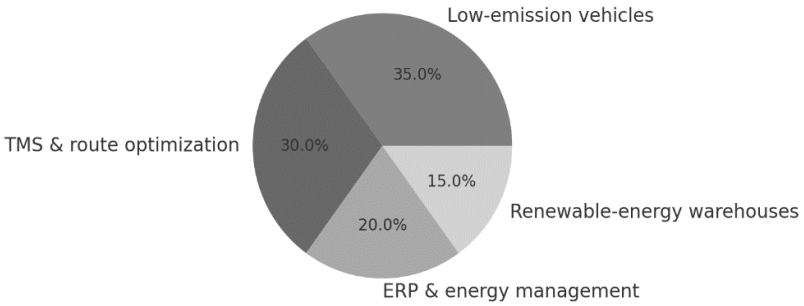
The largest share of various types of logistics activities (Figure 3) in the total $CO_2$ reduction achieved by the analysed companies is attributable to:

- Low-emission vehicles (35%) – thanks to the use of LNG, electric vehicles and solar cooling,
- TMS systems and route optimisation (30%) – reduction of empty runs and fuel consumption,
- ERP systems and energy management (20%) – digital emission control and process optimisation

Warehouses with renewable energy sources and efficient installations (15%) – lower energy consumption and emissions in the supply chain.

This points to the need for a comprehensive approach to environmental logistics – the synergy of multiple tools ensures maximum environmental efficiency. More than two-thirds of the total reduction in $CO_2$ emissions was achieved through transport-related measures – low-emission vehicles (35%) and route management systems (30%) have the greatest decarbonisation potential.

***Figure 3.*** *Share of logistics activities in total $CO_2$ emissions reduction*




***Source:*** *Own work.*

Digital solutions (ERP) and green warehousing (RES, automation) are essential for balancing emissions in the supply chain, but their share is smaller – which means that they should play a complementary rather than an exclusive role. The proportions indicated confirm the need to integrate technological strategies – companies that combine transport, energy and digital tools achieve the best results in terms of emission reduction.

## 4. Discussion

The results of the analysis confirm that logistics plays an important and increasingly strategic role in the decarbonisation process of industrial enterprises. Both the modernisation of the transport fleet and the digitisation and development of warehouse infrastructure allow for a measurable reduction in $CO_2$ emissions in various links of the supply chain.

Empirical data indicate that the greatest environmental effects are achieved in the area of transport. The use of low-emission vehicles, in particular those powered by LNG, has contributed to a reduction of more than 20% in emissions at Omega Pilzno. This result is consistent with the findings of Rodrigue (2020) and McKinnon (2010), who identify road transport as the main source of $CO_2$ emissions in logistics and the area with the greatest potential for optimisation.

In addition, the implementation of TMS systems not only reduces empty runs, but also automates scheduling, which shortens vehicle operating time and reduces emissions. This confirms the observations of Morana and Gonzalez-Feliu (2025), according to whom the digitisation of transport management affects not only economic efficiency but also environmental efficiency.

Smaller, but still significant, environmental benefits are observed in the area of digital energy management and logistics infrastructure. Companies implementing ERP

systems integrated with $CO_2$ emission monitoring are able to make faster and more informed decisions about energy efficiency. Mindbox (2024) presents similar conclusions, pointing out that ERP with ESG functionality is becoming an indispensable tool in modern enterprises.

Infrastructure solutions – such as PV panels, HVAC systems with heat recovery, and smart lighting – also contribute to reducing emissions, although their impact is more long-term and depends on the scale of the facilities. This is confirmed by the AIUT report (2023), which emphasises the importance of Industry 4.0 in reducing energy consumption in warehouses.

An important conclusion from the analysis of the pie chart (Chart 3) is that no single solution is sufficient on its own – only the integration of transport, digital and infrastructure measures can deliver the full environmental effect. This holistic approach should form the basis of a sustainable logistics strategy in industry.

Furthermore, case studies show that environmentally friendly implementations can go hand in hand with operational efficiency. Companies not only reduce emissions, but also reduce fuel costs, increase delivery reliability and better manage regulatory risk.

The results are consistent with earlier studies of the European market (McKinsey, 2023), which indicate that a 15-25% reduction in $CO_2$ emissions in logistics is achievable with current technology. Furthermore, data from the Polish market (ILiM, 2022) suggest a growing willingness among companies to invest in green transformation, albeit varying in terms of scale and pace of change.

From a practical point of view, the results indicate that companies should:

- Treat logistics as a strategic area for decarbonisation,
- Combine technological investments with digital tools,
- Regularly monitor emissions and incorporate them into ESG strategies

In the future, it would be worthwhile to expand the research to include quantitative analyses (e.g., LCA – life cycle analysis), examining the long-term effects of individual technologies and their impact on other environmental indicators (e.g., primary energy consumption, NOx/PM emissions, external costs).

## 5. Conclusion

Industrial logistics, and transport in particular, is one of the key sectors in the context of decarbonisation efforts. The implementation of low-emission vehicles, such as LNG-powered units, hybrid or electric drives, brings immediate and measurable results, allowing for a reduction in emissions of over 20%. This means that companies investing in a green fleet are able to significantly reduce their carbon footprint in a relatively short period of time.

Transport management systems (TMS) and integrated ERP platforms with environmental modules, which enable real-time tracking, analysis and optimisation of $CO_2$ emissions, are key to this process. The use of these tools not only increases operational efficiency, but also allows for the creation of comprehensive ESG strategies and environmental reporting in accordance with regulatory requirements, such as the CSRD directive or the EU taxonomy.

Although the impact of sustainable logistics infrastructure, including photovoltaic (PV) installations, modern HVAC systems and process automation, on $CO_2$ emissions is smaller than that of the transport sector, it is an indispensable part of the green transition. Investments in energy-efficient warehouses are particularly important for companies with large operating areas and high energy demands.

However, the greatest effectiveness in reducing $CO_2$ emissions is achieved by companies that combine a variety of technological and organisational solutions – from modernising their transport fleet, through digitising processes, to using green energy in their warehouses. This kind of integrated approach enables synergies to be achieved, leading to a 15-30% reduction in emissions per annum, while improving the economic efficiency of operations.

Logistics should be treated as one of the main pillars of corporate sustainability strategies and a key area of management within the ESG concept. The implementation of modern logistics technologies requires not only access to environmental data, but also return on investment (ROI) analyses, which enable rational investment decisions to be made.

An important element of this process is education and training for operational staff, which supports the implementation of green solutions and increases their effectiveness in practice.

The study shows that industrial logistics can also be an effective tool for decarbonisation in the context of medium and large enterprises in Central and Eastern Europe, which is an important addition to the existing knowledge, based mainly on examples from Western Europe and Scandinavia. Due to the qualitative nature of the analyses carried out, the study did not include a quantitative assessment of investment costs or savings resulting from emission reductions – this area requires further detailed analysis in the future.

In subsequent stages, it is recommended to apply the life cycle assessment (LCA) method to logistics, as well as to conduct comparative analyses between different sectors of the economy. It is also reasonable to examine the barriers hindering the implementation of green logistics in the small and medium-sized enterprise (SME) sector and to analyse the impact of the EU regulatory environment on the pace of logistics transformation.

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