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Factors influencing intermodal transport efficiency and sustainability

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Abstract

A dynamic development of intermodal transport is observed worldwide, which is related to the increase in the level of transport efficiency and sustainability. That increase presents a decision challenge for the participants of intermodal transport systems. Therefore, there is a need to analyze the factors influencing the efficiency and sustainability of intermodal transport. This article analyzes these factors from the viewpoint of transport chain participants. Ten were identified. The case study of the Polish market was analyzed using a marketing research tool. A questionnaire was developed, and the survey was carried out among the representatives of intermodal terminals located at seaports, rail-road terminals and forwarders. On the basis of collected information, it was possible to set the ranking of the particular factors. It was stated that efficient handling of cargo and transport means in transshipment terminals forms the most important factor from the practitioners' viewpoint.

Keywords

Efficiency, sustainability, intermodal transport, transshipment terminals, factors

1. Introduction

Today, a dynamic development of intermodal transport is observed worldwide. Intermodal transport deals with transport of goods in intermodal loading units (containers, swap-bodies, semitrailers, etc.) using the infrastructure of various transport modes (mainly road, rail (Gasparik, 2020), maritime, aviation (Cokorilo, 2020)) and transport means to carry these units (Čižiūnienė et al., 2020; Jarašūnienė et al., 2019). Handling operations are carried out at transshipment terminals located at seaports (e.g. container and ferry terminals) and inland (e.g. rail-road intermodal terminals), where numerous activities related to the operation of these units are carried out (Filina-Dawidowicz et al., 2020). The transport process is organized by a forwarder (or multimodal transport operator) who plans and organizes needed activities and offers a price to the customer for cargo carriage from sender to recipient (Filina-Dawidowicz and Stankiewicz, 2021).

Globalization and international trade development cause market changes. Moreover, the cargo is moved to greater distances from producers through distributors to consumers. This situation creates new challenges that must be faced by transport activity. On the one hand, the needs of the society should be met. Customers want to receive the cargo according to their requirements. On the other hand, transport activity should be performed leading to minimalization of time and costs of transport processes, as well as emission reduction. These processes have to be accomplished effectively, considering Sustainable Development Goals (The United Nations, 2022).

It should be noted that there are many factors affecting intermodal transport efficiency and sustainability to a variable extent. Along with the development of intermodal transport, new technologies and organizational solutions are developed and implemented to increase the level of quality, efficiency and sustainability of its operation. Therefore, there is a need to investigate the impact of different factors on the efficiency and sustainability of intermodal transport. Thus, this article aims

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to analyze the factors influencing intermodal transport efficiency and sustainability, based on the opinions of intermodal transport chain participants.

2. Criteria

Intermodality is used around the world as a means of promoting the efficiency of travel and intermodal transport (Pazzini et al., 2022). With the development of the transport network, qualitative modality is becoming important, which is based on a sustainable door-to-door intermodal network (Sina Mohri and Thompson, 2022).

For a full assessment, it is necessary to use measured assessment criteria that correspond to the real conditions of use of intermodal transport. For this purpose, the criteria mentioned in the literature are used, which are approved according to the real conditions examined in the works of other authors. One of the most important criteria mentioned in the literature is *transport infrastructure*. It enables the development of intermodal transport opportunities not only internationally but also regionally, reducing social, economic, and political exclusion of the region (Lu et al., 2022). It also allows the level of sustainability to be quantified not only at the regional, but also at the local level (Song et al., 2021). Of course, realistic planning is possible thanks to the developed infrastructure, which ensures the cost-effectiveness effect in intermodal transport (Yannis and Chaziris, 2022). The sustainable and balanced development of intermodal transport is important. Therefore, all elements of the intermodal transport supply chain must be monitored and constant communication between the participants is also required (Wessel, 2019).

Additionally, a very important indicator in the literature is the *condition and structure of vehicles*. Environmental aspects are directly dependent on the condition of the means of transport. This is particularly important in the case of intermodal transport, where interactions between different modes of transport predominate, and where it is necessary to provide for both urban and rural areas (Basso et al., 2021). The transport process itself also requires the appropriate type of vehicle to be used in order to make the most rational use of the above-mentioned infrastructure elements (Facca et al., 2021). *Loading units used in intermodal transport* are inseparable from the type of vehicle and, depending on the volume of freight transported, have a direct impact on the efficiency of intermodal transport (Basallo-Triana et al., 2021).

Interoperability of intermodal transport elements allows for an efficient solution of organizational issues in the freight supply chain, and their timely optimization according to emerging issues (Chen et al., 2022). Therefore, the next factor, *efficient handling of cargo and transport means in intermodal terminals and seaports*, becomes very important for the efficient use of intermodal transport in freight transport. This can be done through a variety of Hub-and-spoke (HS) networks (Kreutzberger and Konings, 2016), by directly monitoring and managing the presence of containers at terminals (Yan et al., 2020), or by implementing a direct management algorithm based on the history of previous cargo transportation (Bergqvist and Monios, 2021). This gives rise to the factor of *educated and qualified staff*. Supply chain management is highly dependent on it (Jiang and Zhang, 2019), and it also influences the prospects for the creation and development of further logistics clusters, which directly affects the efficient use of intermodal transport and improves the quality of freight transport (Rivera et al., 2016).

Another criterion discussed in the literature is the *use of IT or telematics*. These tools allow companies to perform important monitoring and management processes in the cargo transportation process, and allow them to evaluate important nuances as transportation accuracy, adherence to schedules, or prompt solution of transportation problems (Arnold et al., 2012; Dalla Chiara and Pellicelli, 2016; Schmitz et al., 2016). Such solutions enable the use of criteria for the use of *innovative technical and technological solutions*. They not only structure the transport process, but also activate possible optimization options to increase sustainability and efficiency when using intermodal transport (Altuntaş Vural et al., 2020; Agamez-Arias and Mayono-Fuentes, 2017). This also necessitates the implementation of *organizational measures*, which are associated with both technological innovation and human resources. It is the organizational measures that ensure the stable compatibility of intermodal transport, its development prospects and its adaptation to specific freight transport (Akdoğan and Durak, 2016; Aldakhil et al., 2018; Pehlivan et al., 2018).

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Intermodality distinguishes several levels of sustainability that affect the efficiency of the transport process: social, economic and environmental and resource sustainability (Ambra et al., 2021). Therefore, the criterion of *support through national / international regulations, transport policy* becomes important. In order to achieve this qualitatively, and intergovernmental regulatory mechanisms, which have a direct impact on the effectiveness of intermodality itself, are important (Tamannaei et al., 2021). Optimizing models are used to assess this type of regulation, which not only offer intermodality options but also estimate the subsidies applied by individual countries (Hu et al., 2022). This is a rather complex process that requires reliable input data, a large database, and a constant update of the regulatory framework. Therefore, the criterion of *continuous improvement of performed processes* arises. This results in an increase in both material and human costs in the efficiency process (Kramarz et al., 2021). Therefore, current trends are developed or simplified by low-cost models based on factor priority weights (Kumar and Anbanandam, 2020) or by intelligent self-taught methods based on artificial intelligence (Barrachina et al., 2019).

2 Methodology

To investigate the opinions of intermodal transport market representatives, a questionnaire survey was developed. The questionnaire was divided into two sections. The first one consisted of questions that allowed to determine the respondent's profile, including:

1. Gender;
2. Age range;
3. Type of represented company (e.g. intermodal terminal located at seaport, rail-road terminal, forwarder);
4. Work experience.

The second section contained thematic questions, including:

1. What share of orders handled by represented company is related to the service of intermodal transport?
2. What modes of transport are used in the intermodal transport chains serviced by the company?
3. What is the impact of selected factors on intermodal transport efficiency and sustainability?

The survey was conducted during September and October 2021. The questionnaire was prepared in electronic form in Polish and sent to 53 intermodal transport companies located in Poland. The selected companies included container and ferry terminals operating at seaports, rail-road intermodal terminals, as well as freight forwarding companies. The questionnaire was completed by 21 professionals involved in the organization and/or implementation of intermodal transport process. The obtained results were statistically analyzed, and appropriate conclusions were drawn. Based on collected information it was possible to set the ranking of the particular factors.

3. Results

On the basis of conducted literature review the factors influencing intermodal transport efficiency and sustainability were identified. Ten factors were selected for further detailed analysis (Table 1):

Table 1 Factors selected for the analysis

Code	Factor
F1	Density and quality of transport infrastructure
F2	Condition and structure of the transport means (rolling stock)
F3	Condition and structure of intermodal loading units (containers, trailers, etc.)
F4	Efficient handling of cargo and transport means in intermodal terminals and seaports
F5	Educated and qualified staff
F6	Usage of modern IT and telematics solutions
F7	Usage of innovative technical and technological solutions
F8	Usage of innovative organizational solutions
F9	Support through national / international regulations, transport policy
F10	Continuous improvement of performed processes

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The analysis of the replies to the general questions formulated in the first section of the questionnaire revealed that among the 21 respondents there were 18 men (constituting 86% of the respondents) and 3 women (14% of the respondents). The vast majority of the respondents were practitioners aged 25–40, followed by companies' representatives aged 41–55 years old and 1 person under 25. No person over 55 completed the survey.

The position of the respondents was distributed as follows:

- 14 managers (67% of respondents) represented intermodal terminals, of which:
  - 7 people represented intermodal terminals located at seaports (container and ferry terminals),
  - 7 people worked in operation of rail-road intermodal terminals.
- 7 freight forwarders.

It should be emphasized that the vast majority of respondents represented intermodal terminals that are the key nodes of intermodal transport chains, allowing the integration of various modes of transport.

Managers with 5–15 years of work experience constituted the largest group (61% of the respondents) of the tested sample, followed by people with work experience of 16–25 (34%) and less than 5 years (5%). No person with more than 25 years of experience completed the survey.

The questions in the second part of the questionnaire concerned the company operation, as well as factors influencing the efficiency and sustainability of intermodal transport.

Enterprises employing practitioners in the sample were characterized by a diversified share of orders related to intermodal transport (Figure 1):

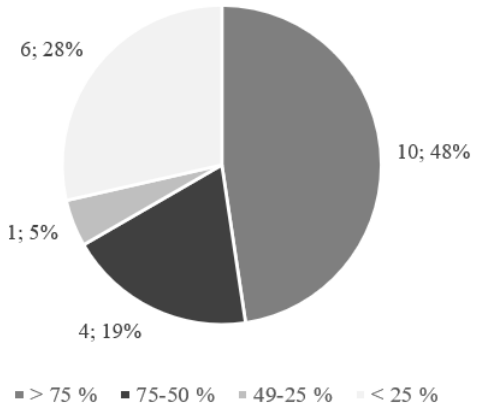

Figure 1 "What share of orders handled by represented company is related to the service of intermodal transport?"

The largest group of responses was obtained from representatives of companies with a share of these orders assumed at a level more than 75% (48% of respondents selected this option). The second largest group were companies with a share of the above-mentioned orders below 25% (28% of respondents). 4 people indicated the companies with a 50–75% share of orders related to intermodal transport, and 1 person chose the range of 49–25%.

Based on the response analysis, it can be noticed that the companies participate in the implementation of intermodal transport chains that involve road, rail and maritime transport modes (Fig. 2). Only two practitioners mentioned that companies are able to service transport chains that include, in addition to the above, air transport and inland navigation (intermodal terminal and freight forwarding company):

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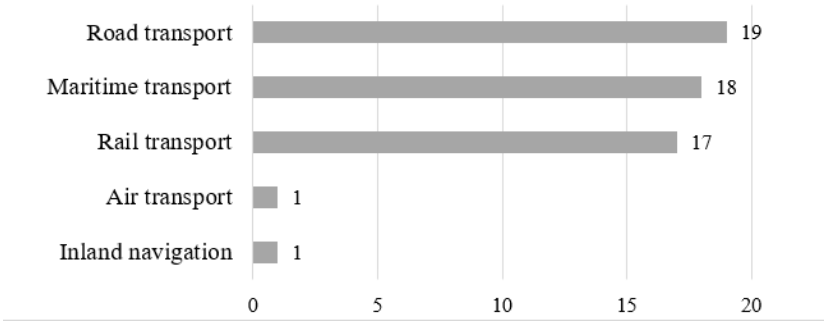

Figure 2 “What modes of transport are used in the intermodal transport chains serviced by your company?"

The respondents were asked to indicate the factors that influence the intermodal transport efficiency and sustainability by ranging them in a Likert-scale (Joshi et al., 2015) from 1 to 5, where 1 – the least important factor, 5 – very important factor. While analysing the opinions of all respondents it was possible to create the ranking of assessed factors (Fig. 3). It can be noted that the factors having the greatest impact on the efficiency of intermodal transport are: efficient handling of cargo and transport means in intermodal terminals and seaports (F4), as well as the density and quality of transport infrastructure of individual modes of transport (F1), and continuous improvement of performed process (F10). Moreover, respondents are convinced that the performed services and processes must be constantly improved, which may be related, inter alia, to the need to expand the existing transport network and improve the quality of processes implemented in the nodes of intermodal transport chains.

According to the respondents, the factors with the least impact are the condition and structure of intermodal loading units (F3) and the support provided by national regulations and international (F9).

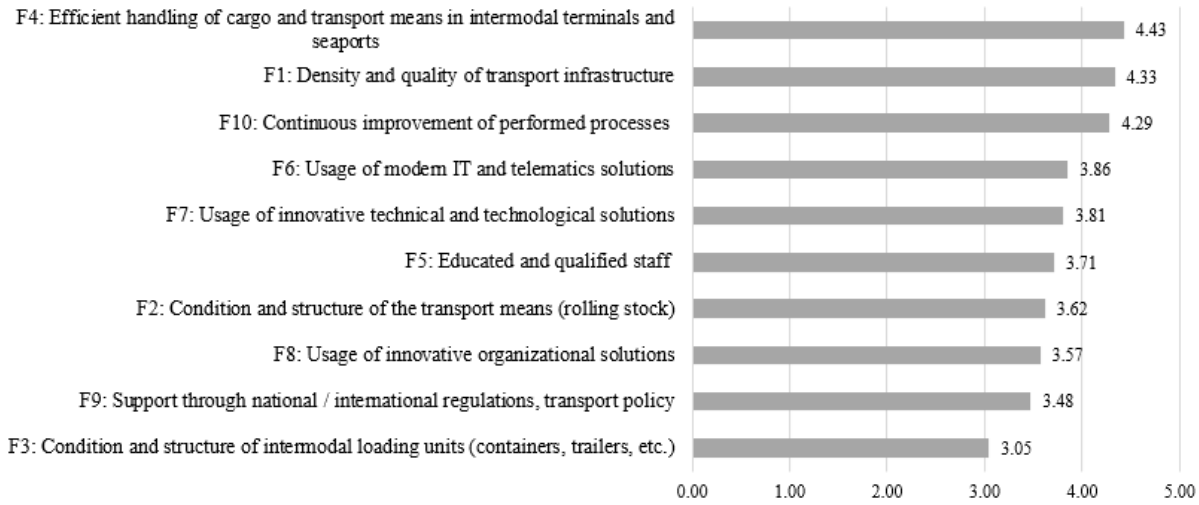

Figure 3. Ranking of factors by the respondents

Each of the above-mentioned factors affects the efficiency and sustainability of intermodal transport, but the most important ones of them focus on technical and technological aspects and organizational issues. Among them there is also the usage of innovative IT and telematics solutions, which improve the efficiency of transport process, as well as handling and storage activities in intermodal transport chains. Therefore, it is necessary to strive for the effective development of these areas with the available resources.

4. Expert assessment

Expert assessment, taking into account all groups of respondents, was carried out to find out about the impact of selected factors on intermodal transport efficiency and sustainability.

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Experts were asked to assess what the impact of selected factors is on intermodal transport efficiency and sustainability in Poland? Experts from three areas of activity were involved in the process: representatives of intermodal terminals located in seaports, representatives of rail-road intermodal terminals, and representatives of freight forwarding companies. Data from 21 expert questionnaires were randomly compiled and calculations performed according Kendall (1970) and Sivilevičius (2011). The results are presented in Table 2.
The concordance coefficient is calculated according to Formula (1) when there are no linked ranks.

$$W = \frac{12S}{n^2\left(m^3 - m\right)} = \frac{26114.5}{21^2(10^3 - 10)} = 0.7178 \quad (1)$$

where,

W is the concordance coefficient,

S is the deviations of the values (ranks) of the indicators from the squares of the overall mean of the ranks of the experts,

m is number of experts,

n is number of indicators.

Table 2. Ranking table of received ratings (source: compiled by the authors)

	Factor Encryption Symbol (m = 10) *									
	a	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**
$\sum_{i=1}^{n} R_{ij}$	**182**	**89**	**38**	**198**	**114**	**121**	**115**	**70**	**57**	**167**
$\bar{R}_j = \frac{\sum_{i=1}^{n} R_{ij}}{n}$	**8.67**	**4.24**	**1.81**	**9.43**	**5.43**	**5.76**	**5.48**	**3.33**	**2.71**	**7.95**
$\sum_{i=1}^{n} R_{ij} - \frac{1}{2}n(m+1)$	**66.5**	**-26.5**	**-77.5**	**82.5**	**-1.5**	**5.5**	**-0.5**	**-45.5**	**-58.5**	**51.5**
$\left[\sum_{i=1}^{n} R_{ij} - \frac{1}{2}n(m+1)\right]^2$	**4422.25**	**702.25**	**6006.25**	**6806.25**	**2.25**	**30.25**	**0.25**	**2070.25**	**3422.25**	**2652.25**

* Criteria coding: Density and quality of transport infrastructure (a); Condition and structure of the transport means (rolling stock) (b); Condition and structure of intermodal loading units (containers, trailers, etc.) (c); Efficient handling of cargo and transport means in intermodal terminals and seaports (d); Educated and qualified staff (e); Usage of modern IT and telematics solutions (f); Usage of innovative technical and technological solutions (g); Usage of innovative organizational solutions (h); Support through national / international regulations, transport policy (i); Continuous improvement of performed processes (j).

The number of factors influencing the efficiency and sustainability of intermodal transport is $m > 7$. The weight of the concordance coefficient is then calculated according to the formula and a random variable is obtained.

$$\chi^2 = n\left(m-1\right)W = \frac{12S}{nm\left(m+1\right)} = \frac{26114.5}{21\times10(10+1)} = 135.6597 \quad (2)$$

where,

χ^2 is the criteria.

The calculated value of χ^2 (135.6597) was higher than the critical value χ^2_{kr} (equal to 16.919), which is why the opinion of the respondents is considered harmonized, and the average ranks show the general opinion of the experts. The lowest value of the concordance W_{min} coefficient was calculated according to the formula. The opinions of all 21 respondents on the 10 factors influencing the efficiency and sustainability of intermodal transport, are still considered to be harmonized at the minimal value.

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(3) $$W_{\min} = \frac{\chi^2_{v,\alpha}}{n(m-1)} = \frac{16.919}{21(10-1)} = 0.0895 < 0.7178$$

Calculations have shown that 21 respondents agree on 10 factors that affect the efficiency and sustainability of intermodal transport and that the views of experts are consistent.

The significance indicators of the factors influencing Q_j are calculated. The obtained data are presented in Table 3:

Table 3. Ranking table (source: compiled by the authors)

Indicator marker	**Factor encryption symbol**										**Sum**
	a	b	c	d	e	f	g	h	i	j	
$\bar{q}_j$	0.1581	0.0773	0.0330	0.1720	0.0990	0.1051	0.0999	0.0608	0.0495	0.1451	1
d_j	0.8419	0.9227	0.9670	0.8280	0.9010	0.8949	0.9001	0.9392	0.9505	0.8549	9
Qj	0.0935	0.1025	0.1074	0.0920	0.1001	0.0994	0.1000	0.1044	0.1056	0.0950	1
Q'_j	0.0426	0.1234	0.1677	0.0287	0.1017	0.0956	0.1008	0.1399	0.1512	0.0556	1
Factor arrangement	9	4	1	10	5	7	6	3	2	8	

Table 3 lists all the factors and their order from most important to least important. Based on expert assessments and calculations, the factors influencing the efficiency and sustainability of intermodal transport are listed below:

1. F3: Condition and structure of intermodal loading units (containers, trailers, etc.);
2. F9: Support through national / international regulations, transport policy;
3. F8: Usage of innovative organizational solutions;
4. F2: Condition and structure of the transport means (rolling stock);
5. F5: Educated and qualified staff;
6. F7: Usage of innovative technical and technological solutions;
7. F6: Usage of modern IT and telematics solutions;
8. F10: Continuous improvement of performed processes;
9. F1: Density and quality of transport infrastructure;
10. F4: Efficient handling of cargo and transport means in intermodal terminals and seaports.

4. Conclusions

Our original research, based on the survey results, it can be concluded that according to the surveyed practitioners, the use of road, sea and rail transport dominates in intermodal transport chains serviced by companies they represent. The factors influencing the efficiency and sustainability of the intermodal transport were analyzed. The case study of the Polish market was analyzed using a marketing research tool, a self-developed questionnaire. On the basis of collected information, it was possible to set the ranking of the particular factors. It was stated that efficient handling of cargo and transport means in transshipment terminals forms the most important factor from the practitioners' viewpoint.

The direction of future research will cover the analysis of intermodal terminals representatives' viewpoint on the implementation of innovations that could influence transport efficiency.

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