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ASSESSING THE POTENTIAL OF POLISH REGIONS TO DEVELOP INTERMODAL TRANSPORT

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Purpose: One of the most important factors for the development of intermodal transport is the potential of the country and its regions in this respect. The purpose of the article is to assess the potential of the Polish regions for the development of intermodal transport.
Design/methodology/approach: In order to achieve the stated purpose of the article, a literature review on the determinants of intermodal transport development was carried out. It allowed to extract a set of key factors influencing the potential of regions for intermodal transport development. On this basis, a synthetic index for the assessment of the region's potential for the development of intermodal transport (IRPIT - Index of the Region's Potential for Intermodal Transport) was developed, based on a taxonomic measure of development in the form of the so-called Hellwig pattern.
Findings: In the conducted research, the IRPIT indicator was determined for 16 regions (provinces) of Poland. Recommendations were indicated for provinces with lower levels of the indicator.
Originality/value: The article presents a methodology for assessing the potential of Polish regions for the development of intermodal transport. The advantage of the developed indicator is the ability to evaluate regions and their linear order in terms of the analysed potential.

Keywords: intermodal transport, regional potential assessment, taxonomy.

Category of the paper: Research paper.

1. Introduction

The development of intermodal transport is driven by the contemporary transport policy outlined in the White Paper on Transport (European Commission, 2011), which aims to relieve road transport and reduce external transport costs. This policy envisions the creation of an integrated and sustainable freight transport system in which multimodal and intermodal transport will play a significant role. Currently, road transport dominates freight transportation

in Europe. In Poland, in 2022, 86.8% of all transported goods were carried by road, accounting for 81.7% of the transport work (GUS, 2023, p. 8). For comparison, in 2015, these figures were 83.5% and 75.7%, respectively (GUS, 2016, p. 89). Therefore, there is an unfavorable trend associated with the substantial share of road transport in cargo transportation, and it is also on the rise. In such a situation, it is necessary to consider actions that would reduce the reliance on road transport while simultaneously increasing intermodal transport.

One of the key factors for the development of intermodal transport is the potential of a country and its regions in this respect. The potential is understood as a set of resources available in a given area (e.g. economic, demographic, social, technological, geographical, etc.), manifested in the quantity, quality and efficiency of their use (Nazarczuk, 2013, pp. 73-74). Therefore, the aim of the article was to assess the potential of Polish regions for the development of intermodal transport. The following research questions were formulated in relation to the task undertaken:

1. Which measure should be used to assess the potential of regions for the development of intermodal transport?
2. Which regions in Poland have the highest potential for the development of intermodal transport?

In order to achieve the aim of the article and to answer the research questions posed, the first part of the article carried out a literature review. This made it possible to identify a number of key factors that influence the potential of regions to develop intermodal transport. It also allowed a taxonomic measure of development to be proposed to assess this potential. The next section of the article proposes a methodology for assessing the potential of regions to develop intermodal transport. This assessment uses a synthetic index to evaluate a region's potential for the development of intermodal transport (IRPIT - Index of the Region's Potential for Intermodal Transport), which is based on the aforementioned taxonomic measure of development. It allows a linear ordering of the regions studied in relation to the so-called development pattern. In our study, we determined the IRPIT index for 16 regions (voivodeships) of Poland. The results, together with their discussion, are presented in the next part of the article. The whole article is concluded with conclusions, which highlight the contribution of the article to the science and practice of management, as well as the limitations and directions of our further research.

2. Theoretical background

The potential of a region to develop freight, intermodal transport is a category that is difficult to measure. This is mainly due to the very concept of "potential of a region", as well as its multidimensionality and the selection of appropriate tools that allow

a comprehensive assessment. The development potential of a region can most often be seen as a set of resources available in a given area, manifested in the quantity, quality and efficiency of their use. They are also the unique and distinctive features of a region that allow it to develop (Nazarczuk, 2013, pp. 73-74). Wyszkowska and Godlewska (2019, p. 104) identify development potential with the conditions of an area, with the resources it possesses, its skills and the possibilities to use them. Nadolny (2018, p. 219) interprets development potential as the ability of a regional economic system to self-develop, become richer and develop, with its own resources, competitive, improved or and innovative products, services and knowledge. As the literature shows, the development potential of a region consists of a number of components that can be divided into several groups. Among them, the following are mentioned: demographic and social potential, natural and cultural potential, economic potential, space potential, institutional potential (Bański et al., 2014, p. 100). Milczarek (2005, p. 9), on the other hand, points primarily to economic, demographic-social, technological and geographical resources. Nazarczuk (2013, pp. 78-79) distinguishes five groups of factors: economic potential, human potential, infrastructure potential, scientific and research potential, and quality of life potential. At the same time, he emphasises that external resources cannot replace the factors accumulated in the region. If a region does not have a developed potential, even significant external assistance will not be able to dynamise the pace of development in the region.

On the basis of the literature reviewed, the potential of a region for the development of intermodal transport is understood as: the set of resources present in a given area together with the capacity to use them to support the implementation of intermodal transport. Intermodal transport is the concept of transporting goods in a single unalterable unit load, using different modes of transport along the entire route, with the assumption that most of the route is carried by sea, rail or inland waterway, while road transport is minimised (Li et al., 2023, p. 2; Caris et al., 2013, p. 105). It leads to sustainability by, among other things, reducing negative environmental impacts or congestion and increasing the efficiency of supply chains (Krstić et al., 2022, p. 1). The development of intermodal transport depends on a number of exogenous and endogenous factors. For example, Zieliński (2010, p. 284) includes the following among the key factors influencing the development of transport in a region: geographical location, wealth of natural resources, level of economic development, location of entities participating in a given transport system, supply potential (production and distribution), absorption potential (demand of entities), transport distances, capacity of the transport network - routes and nodes. Research on the identification of key factors influencing the potential of regions to develop intermodal transport was conducted by Dohn, Przybylska, Żebrucki (2019, pp. 15-30). For this purpose, they identified a list of 17 factors that were subjected to expert research. The experts participating in the study were asked to rate the importance of the proposed factors on a scale from 0 to 100 points (the higher the number of points, the higher the importance of the factor). Taking into account the scores obtained, the authors selected the key factors,

i.e. all those factors with an average score of at least 60 points. The results of the evaluation of the factors are presented in Table 1 (key factors are highlighted in grey).

Table 1.
Factors influencing the region's potential for intermodal transport development

No.	Factor	Weight
1.	number of intermodal logistics centres	78
2.	number of storage areas available	82
3.	number of intermodal transhipment terminals	89
4.	number of production and trade companies	69
5.	number of employees in transport and storage (according to PKD 2007 section H)	68
6.	number of logistics operators, including operators with the potential for intermodal transport	74
7.	number of enterprises in Section H according to PKD 2007	83
8.	length and quality of roads: railways, waterways, motorways	85
9.	number and condition of container vans	55
10.	number and condition of trailers, semi-trailers	42
11.	number of transport and logistics colleges and the associated number of graduates	26
12.	number and condition of available rolling stock	31
13.	number and condition of container platform wagons	36
14.	modern ro-ro transhipment systems	48
15.	infrastructure and capacity of transhipment terminals	58
16.	number of innovations by transport and logistics companies	35
17.	number of transport-related R&D institutions	34

Source: Dohn, Przybylska, Żebrucki (2019, p. 17).

The key factors identified in the table are confirmed by the literature review. Kovač et al. (2023, p. 2) emphasise the need for continuous development of the entire logistics network, which includes both nodes and connections between them. Important nodes are all types of facilities involved in the flow of goods, mainly warehouses, logistics centres, ports and intermodal terminals. Connections between them are provided by linear road, rail, sea or inland waterway infrastructure. Zieliński (2010, p. 284) also emphasises the importance of linear and point infrastructure for the development of intermodal transport, paying special attention to the location of logistics centres in the region. Antonovich (2022, pp. 112-113) not only stresses the importance of the existence of line and point infrastructure, but also draws attention to its condition, which is crucial for the development of intermodal transport. Ližbetin (2019, p. 1) also stresses the importance of a high-quality infrastructure and technical base for the development of intermodal transport. A multi-branch and integrated intermodal transport network must be based on a modern and well-designed infrastructure. Furthermore, an important element of freight transport is the forecasting of future transport needs, which influences the development of transport networks (Pyza, Jachimowski, 2019, p. 1). These needs related to freight transport are mainly represented by manufacturing and trading companies. Kędzior-Laskowska and Kownacka-Waśkiewicz (2022, p. 84) also draw attention to the volume of demand for freight transport, including intermodal transport, in a given area. On the other hand, Šakalys, Batarlienė (2017, p. 282) attribute an important role in the formation of the transport system to both the mentioned transport flows and the operators serving these flows. From the point of view of the development of intermodal transport,

a lot of attention is paid to intermodal terminals in the literature. They are indicated as key elements of intermodal transport, providing connections between different transport modes (Ližbetin, 2019, p. 1; Ližbetin, Caha, 2016, p. 1198; Kovač et al.,2023, p. 2). Due to the use of different transport modes in intermodal transport, they can be of different nature - land, sea, inland waterways (Pyza, Jachimowski, 2019, p. 2). They should be designed and operated to enable efficient loading and unloading, minimising the time and cost of moving goods. In addition, they can help reduce congestion and improve traffic flow throughout the transport network. This is influenced by the choice of transhipment technologies used at the terminal, together with the transhipment facilities used (Krstić et al., 2022, p. 14). Transshipment facilities are identified as key elements that determine the competitiveness of an intermodal transport network (Bassalo-Triana et al., 2023, p. 2). The number, location and capacity of intermodal terminals is also an important issue (Ližbetin, 2019, p. 1; Kędzior-Laskowska, Kownacka-Waśkiewicz, 2022, p. 87; Bassalo-Triana et al., 2021, pp. 1-2). In addition to intermodal terminals, the potential of the study areas is also influenced by linear infrastructure. In their study of the potential for the development of intermodal transport in various countries, Kędzior-Laskowska and Kownacka-Waśkiewicz (2022, pp. 84-87) highlight linear infrastructure in the context of rail transport by referring to the length of rail tracks, the length of rail lines or the density of rail lines. In addition, the capacity of linear infrastructure, the average commercial speed of transport and the coordination of linear infrastructure managers are important parameters (Šakalys, Batarlienė, 2017, p. 282; Antonovich, 2018, 112-113). Dohn et al. (2019, p. 54) also highlight the importance of linear infrastructure for the development of intermodal transport. In addition to railways, they also stress the importance of inland waterways and their parameters for classification into different navigability classes. Special attention is paid to the need to develop waterways of an international character. The research by Przybylska et al. (2017, pp. 195-206) also emphasises the role of line and point infrastructure in the development of intermodal transport (e.g. the number and equipment of terminals, the uniformity of terminal distribution, the existence of logistics centres, the quality of line infrastructure in different modes of transport). However, in addition to infrastructure, the authors also draw attention to other factors, such as the number of operators involved in intermodal transport or the availability of qualified staff.

The presented diverse group of factors influencing the potential of regions in the development of intermodal transport indicates the significant multidimensionality of this issue from the perspective of measurement and assessment. At the same time, focusing separately on individual factors does not allow for a comprehensive assessment. Therefore, it is proposed to use a synthetic indicator that enables a complete picture of the potential of individual regions for the development of intermodal transport and allows for comparison between them. Such a synthetic indicator can be the so-called taxonomic development measure, belonging to the group of taxonomic methods (Dohn et al., 2019, p. 101). Taxonomic methods, including the taxonomic development measure, are often used to analyze the level of development of regions

considering various research areas (e.g., innovation, economic development, and many others). Taxonomy can be seen as a scientific discipline creating principles of ordering (Tarka, 2010, p. 194). In other words, taxonomy is the science of classification, understood as a division into classes consisting of objects with common properties (Gatnar, 1998). Taxonomic analysis involves assessing the level of differentiation of different objects described by a set of statistical features (Tarka, 2010, p. 194). In taxonomy, linear and non-linear ordering methods are used. Linear ordering in a geometric approach involves projecting points representing objects placed in a multidimensional space of variables onto a line. It is used when determining the hierarchy of objects, i.e., arranging objects from the highest to the lowest in the hierarchy. Mainly used in this area are methods like Czekanowski's method, taxonomic development measure by Hellwig, and patternless development measure. On the other hand, non-linear ordering in a geometric approach involves projecting objects placed in a multidimensional space of variables onto a plane. In this method, similarities between objects can be determined without indicating their hierarchy, e.g., the dendrite method known as Wrocław taxonomy, cluster analysis using the Ward method (Łogwiniuk, 2011, p. 13).

Taking into account the analysis of the literature on both the factors influencing the potential of regions to develop intermodal transport and the possibility of using taxonomy to assess this potential, in our research we used linear ordering with a taxonomic measure of development.

3. Methodology

A taxonomic measure of development in the form of the so-called Hellwig pattern was used to assess the potential of individual regions of Poland in terms of intermodal transport development. This measure allows for the construction of a synthetic indicator based on a number of partial measures testifying to certain aspects of the development of the analysed objects (Łogwiniuk, 2011, p. 13). Its advantage is the high transparency of the result, which is associated with the presentation of the results by means of a single synthetic numerical value (Koszel, Bartkowiak, 2018, p. 90). The aim of using a taxonomic measure of development in research is to develop a so-called synthetic index for assessing the potential of a region for the development of intermodal transport (IRPIT - Index of the Region's Potential for Intermodal). This index will make it possible to present the potential of the regions taking into account the different levels of the variables studied. It will also make it possible to perform a linear ranking, i.e. to rank the regions described by many heterogeneous diagnostic variables in terms of this potential, taking into account the distance from the so-called reference region. In this way, the analyses carried out will make it possible to identify the regions with the highest potential for the development of intermodal transport and those with the lowest potential. At the same time, it will be possible to identify regions with similar development potential.

The methodology of the research carried out is presented in Figure 1.

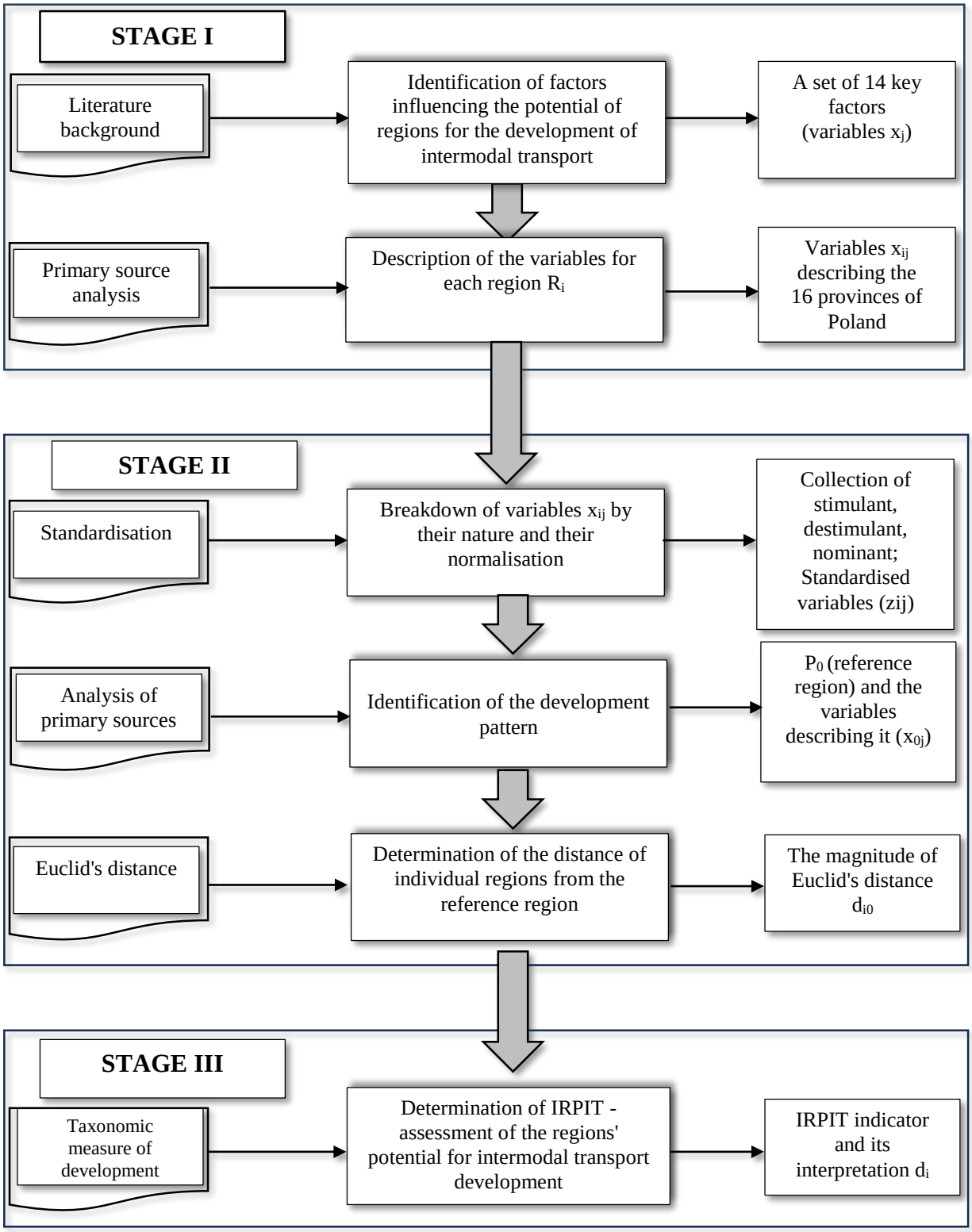

Figure 1. Methodology for assessing the potential of regions for the development of intermodal transport.

Source: own elaboration.

The used methodology consists of three stages divided into six steps. The first stage consists of two steps. The first step focused on conducting a literature review that identified a set of key factors influencing a region's potential for intermodal transport development. These factors are at the same time characteristics of the analysed regions (xj, where j = 1, …, m – the number of factors). In the second step, the studied regions Ri were identified (where i = 1, …, n – number of regions). Due to the subject of the article, the studied regions were individual voivodships of Poland. This approach is a result of the chosen administrative division of the country. Thus, 16 regions (voivodships) were distinguished for the study: Dolnośląskie, Kujawsko-Pomorskie, Lubuskie, Lubelskie, Łódzkie, Mazowieckie, Małopolskie, Opolskie, Podkarpackie, Podlaskie, Pomorskie, Śląskie, Świętokrzyskie, Warmińsko-Mazurskie, Wielkopolskie, Zachodniopomorskie. All identified Ri regions were then described taking into account the key factors identified in step one that influence the potential for intermodal transport development. Thus, each region was described by a set of characteristic variables (features) xij (where: i = 1, …, n – number of regions; j = 1, …, m – number of factors). In order to obtain data on the characteristics of each region, a primary source analysis was carried out using a number of reports and statistical studies, mainly data from the Railway Transport Office (UTK, 2023), reports on the warehouse market (Colliers, 2023), data from the Central Statistical Office (CSO, 2023) and data from the Ministry of Maritime Affairs and Inland Navigation (MI, 2023).

The second stage of the research carried out consisted of three steps (steps 3-5). In the third step, according to the idea of taxonomic methods, the collected variables xij were divided into three groups, taking into account their nature. These are (Mazur, Witkowska, 2006, p. 252):

- Stimulants - characteristics for which higher values of the variables indicate a higher level of development of the phenomenon in question.
- Destimulants - characteristics for which higher values have a negative effect on the phenomenon under study.
- Nominants - characteristics for which the best value is a fixed quantity or numerical range.

The collected variables describing the potential of the regions were then normalised. This is a result of the variables describing the regions being captured in different units, depending on the type of characteristic being described. Normalisation makes it possible to transform the values of the variables into a comparable form. This is the so-called additivity condition (Feltynowski, Nowakowska, 2009, p. 15). Normalisation was carried out by standardisation according to the formula:

$$z_{ij} = \frac{x_{ij} - \overline{x}_j}{S_j} \quad (1)$$

where:

z_{ij} - the standardised values of the j-th characteristic in the i-th object,

x_{ij} - initial values of the jth characteristic in the i-th object,

$\overline{x}_j$ - arithmetic mean of the j-th characteristic,

S_j - standard deviation of the j-th characteristic.

In the fourth step, we determined the so-called development pattern P_0 which is described by the best values of the individual variables analysed ($P_0 = \{x_{01}, x_{02}, x_{03}, \ldots, x_{0m}\}$, where x_{0j}, for j = 1, …, m – the values of the variables for the reference object). It can therefore be concluded that a development benchmark is such an ideal region (not necessarily an existing one) that can be proposed as a model in terms of its potential for intermodal transport development. The benchmark values (desired values of variables characterising the benchmark object) have been established on the basis of an analysis of primary sources (reports and statistical studies). It should be remembered that the best values for stimulating variables are the maximum values, while the best values for discouraging variables are the minimum values. In the fifth step, we determined the distances (d_{i0}) between a given reference object P_0, and each of the study regions R_i. When using distance measures, it should be borne in mind that an increase in their values means an increase in the degree of differentiation of the regions under study. The function that is a measure of the distance (d) between two regions X and Y has the form (Gatnar, 1998, p. 27):

d: Ω ´ Ω ® $R^{+,}$ (where Ω is a finite set of objects subject to taxonomic analysis)

and meets the conditions:

- d (X,Y) = 0, if X=Y
- d (X,Y) ³ 0
- d (X,Y) = d (Y,X)
- d (X,Z) £ d (X,Y) + d (Y,Z)

For characteristics represented by quantitative variables, examples of distance measures are (Gatnar, 1995, pp. 6-7): Euclidean distance, squared Euclidean distance, Chebyshev distance (Chebychev), urban distance (Block), Minkowski distance (Minkowski) which is a generalisation of Euclidean distance, urban distance and Chebyshev distance, user-defined (Customised). In practice, the Euclidean distance is most often used to determine the distance between the studied objects and the development pattern P_0, expressed by the formula:

$$d_{i0} = \sqrt{\left[\sum_{j=1}^{m}\left(x_{ij} - x_{0j}\right)^2\right]} \quad (2)$$

In our research, we also used the aforementioned Euclidean distance to determine the distance of individual regions (R_i) from the developmental pattern (P_0).

The third stage of the research included step six, which was the determination of a **synthetic indicator to assess the region's potential for intermodal transport development** (**IRPIT**). This indicator is based on a taxonomic measure of development. The calculation was carried out according to the following formula:

$$IRPIT = d_i = 1 - \frac{d_{i0}}{d_0} \quad (3)$$

where:

d_i – taxonomic measure of development for i-th object,

d_{i0} – Euclidean distance of object i-th from the reference object P_0 (pattern 2),

d_0 – Is expressed by the relation:

$$d_0 = \overline{d_0} + 2 \cdot s_0 \tag{4}$$

where:

$\overline{d_0}$ – the arithmetic mean of the values of d_{i0}, expressed by the formula:

$$\overline{d_0} = \frac{1}{n} \sum_{i=1}^{n} d_{i0} \tag{5}$$

s_0 – standard deviation of the distance from the reference, expressed by the formula:

$$s_0 = \left[\frac{1}{n} \cdot \sum_{i=1}^{n} \left(d_{i0} - \overline{d_0} \right)^2 \right]^{\frac{1}{2}} \tag{6}$$

By calculating the IRPIT indicator for each region according to the steps outlined above, we obtain information on the extent to which the region under study deviates from the benchmark and whether it has the potential to develop intermodal transport. It should be emphasised that as the IRPIT indicator approaches unity, the level of a region's potential for intermodal transport development increases. Based on the guidelines of Dohn, Przybylska, Żebrucki (2019, p. 19), the following interpretation of the IRPIT indicator was adopted in the study:

- from 0-20% – the region has no potential for intermodal transport development;
- from 21-40% – the region has very low potential for intermodal transport development;
- from 41-60% – the region has a medium potential for the intermodal transport development, and considerable investment is needed to strengthen the identified factors;
- from 61-80% – the region has strong potential for the intermodal transport development;
- from 81-100% – the region has very strong potential for the intermodal transport development.

4. Results

The literature review identified eight factors that can be considered as key factors in assessing the potential of regions for the development of intermodal transport. These are: the number of intermodal logistics centres in the region, the number of available storage areas in the region, the number of intermodal transhipment terminals in the region, the number of manufacturing and trading companies operating in the region, the number of people employed in transport and storage, the number of logistics companies, including those with the potential to provide intermodal transport, the number of transport and logistics companies in the region, the length and quality of rail, water and road routes. Taking into account the above-mentioned factors, the conditions in Poland and the analysis of primary sources, we collected a set of data describing all 16 regions of Poland studied (Table 2).

Table 2.
Set of factors taken into account in assessing the potential of regions to develop intermodal transport

No.	Factors by Dohn, Przybylska, Żebrucki (2019)	Factors taken into account in the study
1	number of intermodal logistics centres in the region	• number of intermodal logistics centres in the region
2	the number of warehousing facilities available in the region	• existing storage stock/regional area, • stock under construction/regional area
3	the number of inter-branch transhipment terminals present in the region	• density of intermodal terminals present in the region (number of terminals/area of region)
4	the number of manufacturing and trading companies operating in the region	• number of manufacturing and trading companies operating in the region
5	number of persons employed in the transport and storage sector	• average employment in the transport and storage sector in the region/number of inhabitants in the region
6	number of logistics operators, including those with the potential for intermodal transport	• according to the classification system of enterprises adopted in Poland (PKD 2007), the category of logistics operators is not distinguished in the statistics. Hence, in a direct way this group was not mentioned separately in the research. On the other hand, this does not indicate that these enterprises were not included in the research in any way. In accordance with the adopted classification, these enterprises are included in the group of entities of the so-called "Transport and warehouse management" section (item 7 of the table)
7	number of transport and logistics companies in the region	• number of enterprises within the section: land and pipeline transport, • number of enterprises within the section: water transport, • number of enterprises within the section: air transport, • number of enterprises within the section: warehousing and support activities for transport
8	the length and quality of rail, waterways and motorways	• density of motorways (number of motorways/area of region), • density of motorways and motorways (number of motorways and expressways/area of region), • density of railways (number of railways/area of region), • density of waterways (number of waterways/area of region)

Source: own elaboration.

As shown in Table 2, based on the factors influencing the potential of regions for the development of intermodal transport identified in the literature review, we identified 14 variables for further research. They were used to describe all analysed regions in Poland. When analysing the variables collected for the study, it was found that:

- In Poland, there are four main intermodal logistics centers (one each in the Silesian and Pomeranian voivodeships, and two in the Pomeranian voivodeship).
- The highest density of intermodal terminals is found in the Silesian voivodeship (4.05 terminals/10,000 km^2). Three voivodeships do not have a single intermodal terminal. In two voivodeships, the density exceeds the level of three terminals/ 10,000 km^2, while the remaining 10 voivodeships have a density ranging from 0.56 to 2.18 terminals/10,000 km^2.

- The Mazowieckie voivodeship has the highest amount of existing warehouse space [m^2] as well as warehouse space under construction. Meanwhile, the Silesian voivodeship has the highest density for both of these mentioned parameters. The lowest density of warehouse space is significantly observed in the Podlaskie voivodeship.
- The highest number of manufacturing and trading companies, as well as companies operating in the transportation and warehouse management sector, is located in the Mazowieckie voivodeship. The second position in this regard is held by the Silesian voivodeship.
- The highest average employment in the transportation and warehouse management sector per 1000 residents is found in the Mazowieckie voivodeship.
- The highest density of overall roadways, as well as specifically motorways and expressways, is present in the Silesian voivodeship (1.78 km/km^2 and 0.03 km/km^2, respectively).
- The highest density of railway lines is found in Silesia (0.15 km/km^2). At the same time, this density is significantly higher than that of all other regions, with the second highest voivodship having a density of 0.089 km/km^2.
- Lubuskie has the highest density of inland waterways (0.028 km/km^2).

According to the adopted research methodology, all collected variables were classified as stimulants and then subjected to normalization. As part of the fourth step of the study, a so-called reference object (region) P_0 was determined. Unfortunately, both the literature and economic practice do not indicate or describe a reference region in terms of intermodal transport development. Therefore, an ideal, non-existent region characterized by the best parameters in the analysis of the region's potential was chosen as the reference region. Table 3 presents the values of variables describing the created reference region.

Table 3.
Values of factors describing the reference region P_0

No.	Name of factor	Value of the factor for the reference region P_0	
		Numerical value of the factor (x_{0j}) (voivodeship)	Normalized value of the factor (z_{0j})
1.	Number of intermodal logistics centers	2 (wielkopolskie)	3,031088913
2.	Density of intermodal terminals [10 000 m^2/km^2].	4,054163626 (śląskie)	2,200927241
3.	Number of entities - sections C and G in the PKD 2007 classification	255902 (mazowieckie)	2,764549353
4.	Average employment in transport and storage (according to PKD 2007 section H) per 1000 residents	55,35761478 (mazowieckie)	3,399416561
5	Division 49 of section H - land and pipeline transport	43345 (mazowieckie)	2,800273099
6	Division 50 of section H - water transport	437 (małopolskie)	2,854967966
7	Division 51 of section H - air transport	934 (mazowieckie)	3,628237334
8	Division 52 of section H - warehousing and transportation support activities	6599 (mazowieckie)	3,162961334
9	Density of motor roads (length of roads/area of region [km/km^2])	1,781148139 (śląskie)	2,13202115

Cont. table 3.

10	Density of highways and expressways (length of roads/area of the region [km/km^2])	0,029506203 (śląskie)	2,233883777
11	Density of railroads (length of roads/area of the region [km/km^2])	0,151787886 (śląskie)	3,207874011
12	Density of inland waterways (length of roads/area of region [km/km^2])	0,027881041 (lubuskie)	2,557517978
13	Density of available storage resources (m^2/area of region [km/km^2])	393,2538717 (śląskie)	2,882527173
14	Density of storage resources under construction (m^2 /area of region [km/km^2])	46,39584854 (śląskie)	2,658586562

Source: own elaboration.

As can be seen from Table 3, the model region (P_0) is a combination of the values of the factors of the Mazowieckie and Silesian provinces in the first place, as well as the Wielkopolskie province (in terms of the number of logistics centres), the Małopolskie province (in terms of the number of water transport companies) and the Lubuskie province (in terms of the density of inland waterways).

According to the subsequent research steps, the Euclidean distances of the individual provinces from the designated benchmark region P_0 shown in Table 2, were determined. On the basis of these distances, the IRPIT index (Index of the Region's Potential for Intermodal Transport) was calculated according to the formulas described in the methodology (Fig. 2).

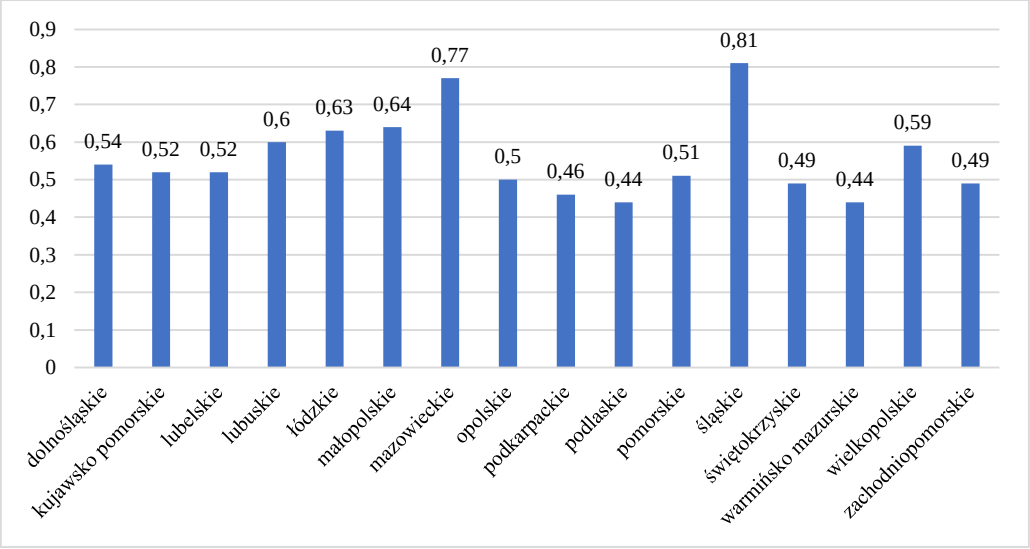

Figure 2. IRPIT indicator.

Source: own study.

As shown in Figure 2, the highest IRPIT index and thus the highest potential for the development of intermodal transport is in the Silesian province (0.81). The second highest is in Mazowieckie (0.77). The other regions have an index between 0.44 and 0.64.

Figure 3 presents a histogram showing the distribution of the IRPIT indicator obtained for each region. This distribution is not symmetrical, but takes the form of a right-skewed distribution. The first thing that stands out is the absence of regions for which the indicator would be below 0.44. At the same time, it can be seen that as the value of the IRPIT indicator

increases within the accepted ranges, the number of regions representing them decreases. In the last interval, where the value of the indicator is the highest, there are only two regions: the Silesian and Mazowieckie voivodships.

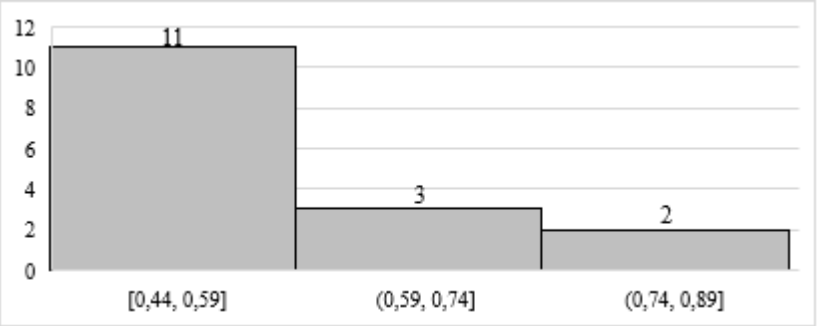

Figure 3. Histogram for the IRPIT indicator.

Source: own study.

Figure 4 below shows the detailed distribution of the IRPIT index for the regions studied, using the interpretation proposed in the research methodology.

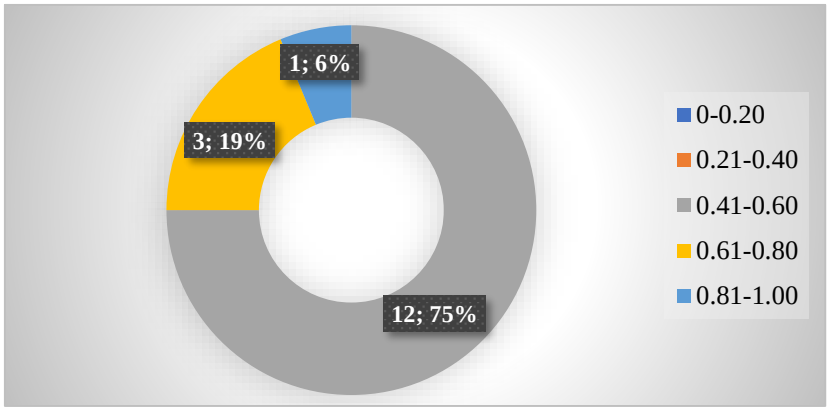

Figure 4. Distribution of the IRPIT indicator according to the adopted interpretation (number of regions and percentage value).

Source: own study.

On the basis of this indicator and Figure 4, it is possible to identify the potential of each region for the development of intermodal transport:

- In the case of one voivodship (6% of the surveyed collective), the indicator is in the range of 81-100% (Silesian Voivodship). It should be noted that this region has a very strong (and highest) potential for the development of intermodal transport;
- In the case of 3 provinces (19% of the surveyed collective) the index is in the range of 61-80%, which means that these provinces have a significant potential for the development of intermodal transport. Among these provinces, Mazowieckie stands out with an IRPIT index of 0.77 (77%), which is in the upper limit of the assumed range. The other two are Łódzkie and Małopolskie, which are at the lower end of the range;

In the case of 12 provinces (75%), the indicator is in the range of 40-60%, which means that these provinces have an average potential for the development of intermodal transport. At the same time, three provinces in this group have an indicator within the range of 44-46%, i.e. at the lower end of the range (Podlaskie, Warmian-Masurian and Subcarpathian provinces). It is also worth noting the Wielkopolska and Lubuskie provinces, whose indicators are practically at the limit of the range (59% and 60% respectively).

5. Conclusions

The article presents a methodology for assessing the potential of Polish regions for the development of intermodal transport. For this purpose, a synthetic IRPIT indicator based on the taxonomic measure of development was developed. The advantage of the indicator is the ability to evaluate regions and their linear order in terms of the analysed potential. It should be noted that the adopted methodology for determining the indicator and its interpretation is universal. However, its application was presented for 16 regions in Poland. The study of Polish regions showed that one province (Silesia) obtained the highest level of the IRPIT index (0.81), which indicates its highest development potential in the field of intermodal transport. A high level of the IRPIT index was also achieved by three other provinces, of which Mazowieckie stands out. It obtained an index of 0.77, which is slightly lower than that of Silesia. Therefore, it can be assumed that these two provinces currently have the potential to take a leading role in the development of intermodal transport in Poland. On the positive side, no voivodship was placed in the ranges indicating a total lack or very low potential for intermodal transport development (index at 0-0.4). On the other hand, the existence of 12 voivodships (75%) with a potential defined as medium indicates the need to take a number of measures to increase this potential. Such measures would be fully in line with the current transport policy.

The study carried out is not without its limitations. The main one is that the assessment of the regions' potential did not take into account factors of a qualitative nature, which cannot be quantified, but which are also important for the development of intermodal transport. This was the result of the construction of the IRPIT index, which is based on a taxonomic measure of development that only takes into account quantified characteristics. The second limitation is the acquisition of accurate, reliable and up-to-date data describing the factors included in the study. These data are often difficult to obtain because they are scattered and often not collected or published.

Taking into account the relevance of the topic addressed and the assumptions and limitations of the analyses presented, two main directions for future research have been identified. The first is to try to include in the index factors of a qualitative nature that influence the potential of regions for the development of intermodal transport. The second is to carry out research using the developed indicator in regions of other European countries.

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