

Selected Logistics Development Level Indicators – a Review and Comparative Analysis in European Union Countries

Joanna Górnica  <https://orcid.org/0000-0003-0345-6428>

Ph.D., University of Lodz, Faculty of Economics and Sociology, Department of Logistics and Innovations, Lodz, Poland, e-mail: joanna.gorniak@uni.lodz.pl

Abstract

The logistics industry today is well developed. The efficient movement of goods, people, and information is a crucial link in each supply chain and the entire logistics system. For systems to function effectively, they must be properly assessed, compared, and analyzed. Therefore, there are many different indicators, both simple and complex. The purpose of this article is to review these indicators and conduct a comparative analysis for a selected indicator, the LPI (Logistics Performance Index), which measures logistics performance. The subjects of the study are European Union countries. Multivariate comparative analysis was used for the study.

Keywords: logistics system, logistic indicators, Logistics Performance Index, multivariate comparative analysis

JEL: L91, M20, O18

Introduction

Globalization and growing competition have a huge impact on the growing importance of logistics in the economic structure. Influential logistics services promote product mobility, ensure product safety and velocity, and help achieve cost reduction when trading between nations. Logistics processes in the economy are vital for transport, storage, and other logistics operations. They may also be a part of competitiveness. Efficient logistics generate lower costs and make it possible to achieve higher additional effects.

Logistics is an activity that manages the flow of goods, money, and information between the points of delivery and demand, which include activities such as transport, storage, packaging, and material handling. Logistics systems provide appropriate solutions to problems related to transport and storage, and in general, they increase the competitiveness of the company's and country's economy (Navickas, Sujeta, and Vojtovich 2011).

Within an enterprise, the efficiency of logistics activities may be verified using various indicators. Countries may use the Logistics Performance Index (LPI) to evaluate performance. On this basis, the strengths and weaknesses of an individual or area may be assessed to determine the direction of further development and improve the situation.

This article focuses on the possibilities of describing and assessing the development of logistics systems using various types of quantitative indicators. The subject of the article is a review of indicators and an assessment of the development of the logistics system. The logistics system has been characterized by six diagnostic features that are components of the LPI. The article aims to review logistic indicators and classify and group European Union (EU) countries in terms of the development of their logistics system. To achieve this, multidimensional comparative analysis, cluster analysis (a model-less method), and a taxonomic measure of development (a model method) were used.

Logistic systems – characteristics, classification, and types

Thinking in terms of systems is extremely important in logistics. The system concept itself is intended to show that the whole is more than the sum of its parts. On the other hand, knowledge of the whole comes before knowledge of the component parts (which create the whole). The guiding principle of systems theory is a holistic approach to reality. In this context, three basic research trends may be distinguished (Nowakowski 2011, pp. 37–38):

- philosophical and methodical,
- axiomatic and formal,
- analytical and systemic.

The systems approach may be characterized by features (Nowakowski 2011, p. 38):

- from part to its entirety, taking into account the role of the parts as a whole,
- from the structure of the system to the processes taking place within it,
- from objective (absolute) to epistemic science, which means being dependent on the reference system,
- from the concept of science as a “building” to the concept of a “network” as a scientific metaphor,
- from certain to approximate knowledge, which is the next step in the approximation of reality,

- from a linear model of cognition and implementation (basic sciences – applied sciences – development works – new technologies (process and products)) to a network model of interaction of each level with everyone,
- from absolute truth to contextual statements.

The system may be defined as:

- a set of elements that are mutually related (Pfohl 1998, p. 27),
- an internally coordinated system of components that has a defined operating structure (for example, a production system composed of different machines),
- a set of methods of operation, performing complex activities (for example, a system for designing vehicle elements),
- a set of organization rules, norms, and standards in force in specified fields (for example, the company's financial system),
- a holistic and ordered set of tasks related to each other by specific and logical relations (in this context, any methodologically correct theory that concerns a sufficiently extensive fragment of reality is a system) (Nowakowski 2011, pp. 38–39).

Thinking in terms of the system is a comprehensive way of considering issues. There is an awareness that in order to explain the whole, it is not enough to explain the elements, but also the dependencies between them (Odlanicka-Poczobutt 2008, p. 71).

Logistic problems should be solved comprehensively; therefore, it is essential to take into account a series of actions (Odlanicka-Poczobutt 2008, p. 71):

- searching for the causes of disruption, e.g. unplanned of stock, extending product flow time cannot be limited to only part of the system (subsystem), it must be extended to other parts of it,
- decisions related to one element of the system must take into account its impact on the efficiency of the system as a whole, e.g., the impact of transport on the efficiency of the system,
- solving logistics problems requires the immediate integration of temporal and spatial elements of the system.

Identifying interdependencies and synergy are the two basic elements that make it possible to consider a logistics system. They can be defined as a set of logistics elements with appropriate properties and relationships between them. To characterize a logistics system, data should be collected (Dworecki 1999, p. 144; Barcik and Jakubiec 2011, p. 76; Nowakowski 2011; p. 47):

- purpose: orientated at the operation of all subsystems,
- output: resulting from the adopted goal, the form of the system performance (products or services),
- inputs: determining the power supply of the system (materials, energy, information, people),
- transformation process (processing input to output): determined by a sequence of basic processing operations,

- close and distant environment: created by receivers, suppliers, and formal and legal regulations, etc.,
- facilities and infrastructure: which includes machines, buildings, means of transport and transport infrastructure, and IT infrastructure,
- human resources: the workforce and the structure of employees, their qualifications, material status.

There are many ways to define a logistics system. For example, for Blaik (2001, pp. 71–72), a logistics system is a multi-structure and multi-faceted problem that considers many possible components and relationships. With such a high degree of complexity, shaping a logistics system, while taking into account many points of view, is not only very difficult, but in practice, usually impossible. Nowicka-Skowron pointed out that a logistics system is a consequence of implementing a systemic concept of logistics. This is a new quality thanks to the links between the elements that create the system (Nowicka-Skowron 2000, pp. 18–19). Meanwhile, according to Golembaska (2005, p. 47), a logistic system can be defined from two points of view:

- the links between elements of the system: a logistics system is a collection of subsystems such as supply, production, transport and storage, and sales, with links between subsystems and between their properties, with a constant tendency to increase the degree of organization of the system,
- the dynamics of the logistics system and the flows within it: the logistics system is deliberately organized and connected within a specific economic system; it is a physical flow of goods, with the flow of physical means and information.

Topolska and Topolski pointed to two significant consequences of the system approach in logistics. Firstly, it enables optimization involving whole-system solutions instead of sub-optimization of partial solutions. Secondly, it secures logistic decisions by taking into account synergy effects (Topolska and Topolski 2006, p. 70).

As shown in Table 1, logistics systems may be identified in various ways, depending on the degree of aggregation and the scope of the system. Classification may be distinguished by three criteria: institutional (by type and number of participants; it includes micrologistics, metalogistics, macrologistics, and international logistics systems), phase (according to the process of space-time transformation; it divides logistics into supply, production, distribution, and return; for more detail, see Grupa 2012, pp. 462–463), and functional (according to type and number of logistic activities that occur in the company, i.e., logistics processes and activities, such as transport, storage, inventory level, and structure shaping, shaping the level and structure of stocks, and packaging management (Frankowska and Jedliński 2012, p. 100; Kauf et al. 2016, pp. 32–33).

More detailed classification is presented by Szpon, Cyran-Dembińska, and Wiktorowska-Jasik (2005, p. 26), where some criteria were taken into account, including institutional, functional, structural and decision-making, object-structural, and efficiency.

Table 1. Logistics processes and activities

Process	Activities
Transport	Selecting the type of transport and the level of transport services Planning the transport network Scheduling vehicle traffic Selecting specific transport equipment Handling a complaint Controlling transport rate
Shaping the level and structure of stocks	Formulating the policy of stocks of raw materials, materials, and final products Studying short-term sales forecasts Identifying the inventory structure at storage points Identifying the quantity, size, and location of storage points
Logistics customer service	Arranging the scope of customer needs and requirements in terms of the customer service system Predicting customer reactions to the specified customer service system Setting up the final quality of the customer service level
Storage	Identifying the demand for storage space Designing inventory layout Receiving, completing, and releasing materials to and from the warehouse
Packaging management	Choosing packaging to facilitate: <ul style="list-style-type: none"> - loading, unloading, and reloading operations - storage processes - protection against damages

Source: Kauf et al. 2016, p. 27.

In the logistics system, apart from the physical flow system, there is an information system in which data is collected, properly processed, stored, and made available to managers, who, based on the information received, make specific logistics decisions (Świerczek 2006, p. 118). The systemic approach in logistics allows for many benefits, including describing and comparing differences in the logistics systems, taking into account interdependencies, explaining the links between logistics systems, or providing the basis for making decisions (Kauf et al. 2016, p. 34). Therefore, it is essential to perform analyses using various indicators, both simple and complex, which make it possible to evaluate the logistics system as a whole (an example of a measure is LPI – the logistics performance index, which is discussed in more detail in the following part).

Selected indicators for evaluating logistics systems – examples

The many ways to consider logistics systems may influence the various ways of analyzing and comparing them and the variety of indicators that are used for this assessment. The criteria that may be assessed include costs, efficiency, quality of services, the duration of the logistics cycle, and the system's resistance to risk (Lapkouskaya 2019, p. 164). Sometimes a more extensive scope is indicated and may point to (Piechura 2016): the

complexity and dynamics of the environmental conditions, the scope and degree of homogeneity of the enterprise's operation program, the structure of the production system and technology, the structure of the distribution and inventory system, the scope and size of logistics costs, the required level of supply service, the number of logistic decisions, the number of separate logistic decision-making areas, the size of the company, the type of industry, the business culture, the quantity and quality of information, the intensity of streams of material and product streams, the degree of mutual interaction between partial logistic areas, the nature and role of logistic tasks in the function structure and tasks of the company, and the level of knowledge and awareness of the essence and assumptions of the concept of logistics among employees.

There are many measures that assess logistics systems in terms of reliability, efficiency, and flexibility. To assess reliability, one may use indicators such as the coefficient of the lack of the logistic system's ability to perform supporting tasks, indicators of logistics support flexibility, and indicators relating to the reliability of the system in terms of its ability to support tasks without interruption (Kramarz and Zaczyk 2015, pp. 33–34). A more detailed list is presented in Table 2.

Table 2. Reliability indicators of a logistics system

Definition – indicator (unit of measure)	Calculation formula
Ensuring availability of the relevant products – the volume of demand which may be realized from stocks (%)	$\frac{\text{order possible from stock}}{\text{all orders}}$
Completeness of order fulfillment – share of complete deliveries (%)	$\frac{\text{number of complete deliveries}}{\text{all orders}}$
Delivering the product without damage – the share of deliveries without damage (%) and the share of defective deliveries (%)	$\frac{\text{number of deliveries without damage}}{\text{all orders}}$ $\frac{\text{number of incorret deliveries}}{\text{all orders}}$
Order fulfillment in terms of destination – the share of deliveries delivered to the right place (%)	$\frac{\text{number of deliveries delivered to the right place}}{\text{all orders}}$
Timely realization of the order – share of deliveries made on time in the total number of deliveries during the period (%) and the average delivery time of products (days)	$\frac{\text{number of deliveries made on time}}{\text{all orders}}$ $\frac{\text{delivery time}}{\text{all orders}}$
Accuracy of the order– share of returned deliveries (%) and the share of deliveries with complaints (%)	$\frac{\text{number of product deliveries returned}}{\text{number of product deliveries which complained}}$ $\frac{\text{all orders}}{\text{all orders}}$
Compliance of payment documents – share of documents issued that comply with the requirements in the total number of documents (%)	$\frac{\text{number of documents issued correctly}}{\text{total number of issued documents}}$

Source: own study based on Kramarz, Zaczyk 2015, p. 34 [as quoted in:] Stajniak 2012; Gajewska 2016, pp. 1323–1324; Strojny 2017, p. 4.

To ensure a high level of services provided, IT systems may be implemented in logistics departments, facilitating decision-making based on current information. The generally used types of measures that support managing a company are KPIs (Key Performance Indicators). The basis for building an effective structure that gives access to KPIs should be sought both in the data available to the company and in the mechanisms of recording them in IT systems. KPIs are performance or efficiency indicators used as measures for assessing the process of achieving the company's goals. Properly formulated KPIs and the proper setting of goals enable efficient commercial communication with clients. The following elements are involved in the process of creating a KPI: deciding what to measure, collecting data, analyzing data, reporting results, and taking action (Gajewska 2016, p. 1324).

Importantly, building a KPI is based on the simple measures listed in Table 2. For example, when referring an indicator to a logistics system and conducting an analysis for a warehouse (objective: control), the following elements should be taken into account (Innovative Business Solutions and Cloud 2020):

- occupancy rate – shows pallet places occupied in the warehouse, rack, zone, etc.,
- stock flow rate – points out how long the stock is in the warehouse,
- inventory flow rate – shows the inbound and outbound flows to/from the warehouse in a certain period,
- indicator of orders completed/shipped on time – related to timeliness, efficiency, and quality of deliveries,
- storage employee performance indicator – goal: to determine the optimal number of employees needed to operate the warehouse; to assess this, many use the indicator of the number of orders completed per employee,
- financial indicator – shows sales every step.

Another indicator that measures the condition of the logistics system and the economy is the PMI (Purchasing Managers' Index). It is based on the analysis of monthly questionnaires. The PMI is based on the equal weights (20%) of five components: new orders, production, employment, deliveries, and inventory. The activities (indicator) may be defined as (Forex Biznes 2015):

- new orders – from customers,
- production – the rate and direction of changes in the level of production,
- employment – increase or decrease,
- deliveries – fast or slow,
- investments – increase or decrease,
- customer inventory – inventory-level indicator kept by consumer organizations,
- prices – whether someone pays more or less for services and goods,
- backlogs in orders – decrease or increase,
- new export orders – the level of export orders,
- import – measures changes in imported materials.

An indicator value above 50 points means an increase in industrial activity, and below – a decrease. For example, in 2020 in Poland, the indicator reached its lowest

value in April (31.9 percentage points), and the highest in July (52.8 p.p.) (MacroNext 2020). The increase in July was mainly due to higher production and a recovery in the number of new orders, when the growing number of new orders contributed to the volume of production.

The LPI index in the European Union countries

This chapter presents the essence and issues of the LPI and a comparative analysis of the LPI among EU countries. Multivariate comparative analysis was used. Research on the LPI was conducted by Tundys (2011), Guner and Coskun (2012), Pitel et al. (2019), and Ulutaş and Karaköy (2019).

LPI – characteristics

The LPI is a multidimensional assessment of logistics efficiency – assessed on a scale from 1 to 5. The index is analyzed based on the results of questionnaires sent to economic units that specialize in logistics around the world (Figure 1). The research has been conducted, on average, every two years since 2007, and the results make it possible to rank the surveyed countries in terms of their logistics efficiency.

The indicator may also determine the logistics potential of the region/country and the factors that contribute to the lack of logistics obstacles. A high LPI value may directly cause economic growth, and one of the factors may be the ability to attract foreign investments. There may be doubts about the reliability of the LPI and whether it reflects the essence of logistics activities in individual countries. The difficulty is in examining all enterprises and receiving answers to all the questions. That is why the questionnaire is addressed to over 1,000 specialists from shipping, transport, and logistics companies, which are the main carriers and forwarders in the world, and their activities are carried out in many countries and online. The advantages of the LPI include its accuracy, completeness, and the large number of respondents to whom the questions are addressed (Tundys 2011, pp. 737–738).

The international LPI is a summary performance indicator of the logistics sector that connects the data of six basic performance components: customs, infrastructure, international shipments, logistics quality and competence, tracking and tracing, and timeliness (Table 3). Some respondents do not provide information on all six components, so an interpolation method is used to fill in the missing values. Missing values are replaced by the adjusted average of the answers to each question by the mean deviation of the respondent.

The LPI is constructed from six indicators by principal component analysis (PCA), and a standard statistical technique is used to reduce the data set. In the LPI, the input data for the PCA are the results of the countries in questions 10–15, averaged for all respondents who provided data on the foreign market. The results are normalized,

minus the average of the sample, and divided by the standard deviation before conducting the PCA. The PCA score is a single indicator – the LPI, i.e., the weighted average of these scores. The weights are selected to maximize the percentage of variability of the six original LPI indicators, which is included in the overall index (for more detail, see Arvis et al., 2014; Arvis et al., 2018).

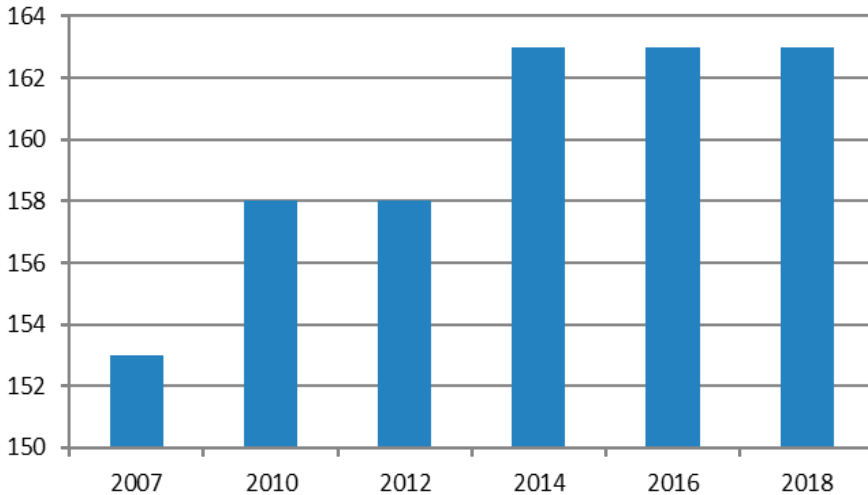


Figure 1. Number of countries analyzed by the LPI per year

Source: own study based on International LPI from 2007 to 2018; World Bank.

Table 3. The six primary components for the test LPI

No.	Components	Scale
1	The efficiency of customs and border clearance, rated from „very low” (1) to „very high” (5) in survey question 10.	0.40
2	The quality of trade and transport infrastructure, rated from „very low” (1) to „very high” (5) in survey question 11.	0.42
3	The ease of arranging competitively priced shipments, rated from „very difficult” (1) to „very easy” (5) in survey question 12.	0.40
4	The competence and quality of logistics services, rated from „very low” (1) to „very high” (5) in survey question 13.	0.42
5	The ability to track and trace consignments, rated from „very low” (1) to „very high” (5) in survey question 14.	0.41
6	The frequency with which shipments reach consignees within scheduled or expected delivery times, rated from „hardly ever” (1) to „nearly always” (5) in survey question 15.	0.40

Source: own study based on Arvis et al., 2014, p. 51.

Comparative analysis of the European Union countries in 2018

As the LPI comprises six additional and more detailed indicators, it was decided to use multivariate comparative analysis to assess the logistics system. The variables are stimulants and are characterized by appropriate variability (the coefficient of variation is above 10%). The data used to assess the development of the logistics industry in the EU come from the resources of the World Bank and relate to 2018.

The Statistica program was used to verify the cluster analysis, i.e., to group the EU countries in terms of the studied variables. The economic distance was determined using the Euclidean metric, and the objects were combined based on Ward's method. Figure 2 shows the results of the dendrite analysis. When analyzing the dendrite (Figure 2), it should be noted that there are many small clusters at the lowest level of the binding distance. This means that countries show diversity at this level. At the binding distance above 2, three clusters of countries can be distinguished:

1. Germany, Sweden, Austria, the Netherlands, Belgium, Denmark, the United Kingdom, Finland, France, Italy, and Spain,
2. The Czech Republic, Portugal, Luxembourg, Poland, and Ireland,
3. Hungary, Slovenia, Estonia, Greece, Romania, Cyprus, Croatia, Lithuania, Bulgaria, Slovakia, Malta, and Latvia.

At a binding distance level above 4 – the first two groups came together. However, all countries showed similarities to each other at a binding distance of around 16.5.

The taxonomic measure of development was based on the development pattern method. Using this measure made it possible to organize the EU countries in 2018 by the development of the logistics system, operationalized by means of diagnostic variables (components) in terms of the LPI indicator. Table 4 presents the research results. The values of the development measure fluctuate between 0.05474 and 0.957037. The country which leads the ranking is Germany, while Malta and Latvia are at the bottom. Attention should be paid to the range (which is 0.902297) between the maximum and minimum value of the measure, indicating a large diversity of the examined objects.

The EU countries are highly diverse in terms of the LPI. It was also noted that countries can be grouped into those with a higher economic level (measured by GDP) or a lower level. Thus, it was decided to make a detailed review of the component features for three selected countries: Germany – the best, Poland – in the middle, and Latvia – the worst (see: Figs. 3–5). These countries are at different levels of logistics system development. Therefore, it is important that the weak points relate to other elements.

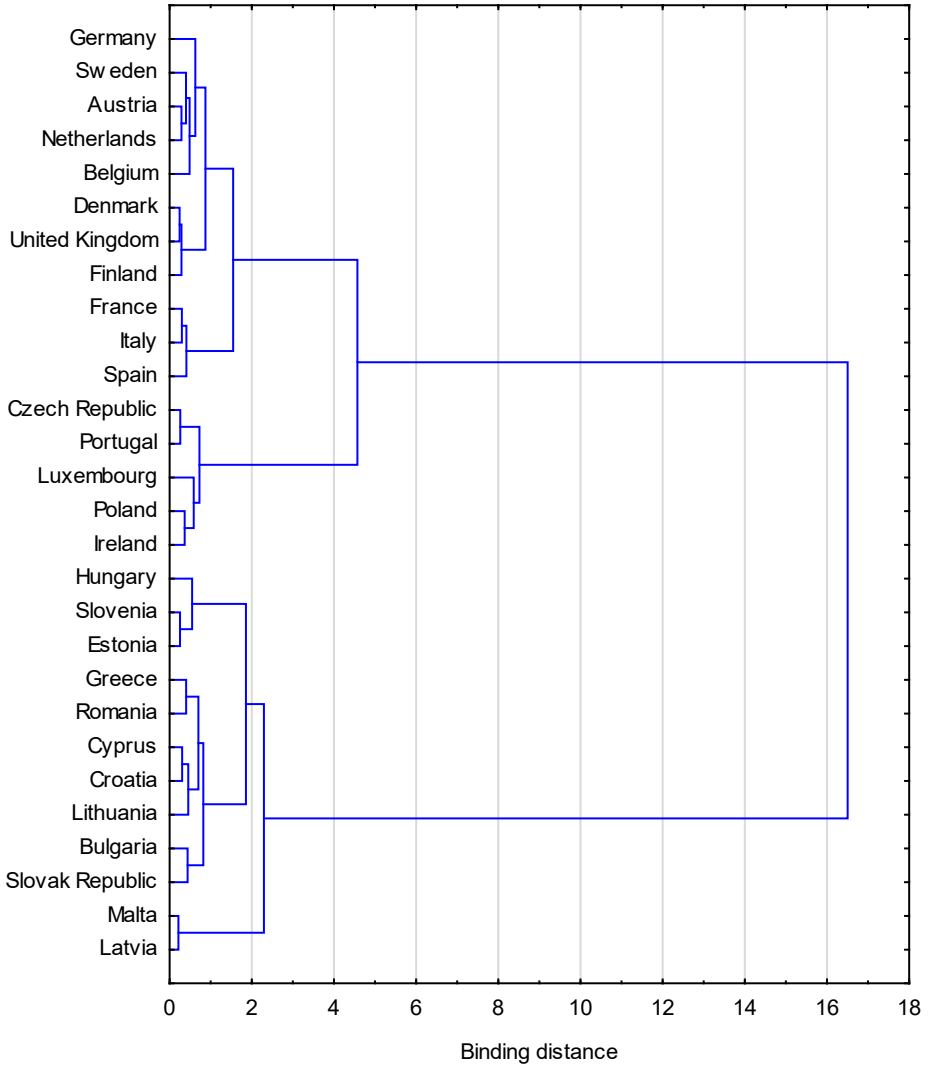


Figure 2. Dendrogram based on LPI variables in 2018
 Source: own study based on data World Bank in Statistica.

Table 4. Classification of European Union countries according to the variables that describe the LPI in 2018

No.	Country	Measure	No.	Country	Measure
1	Germany	0.957037	15	Ireland	0.502444
2	Netherlands	0.848895	16	Poland	0.494660
3	Austria	0.847175	17	Hungary	0.440488
4	Sweden	0.841149	18	Slovenia	0.369924
5	Belgium	0.822111	19	Estonia	0.359954
6	United Kingdom	0.821833	20	Greece	0.295355
7	Denmark	0.804894	21	Cyprus	0.257857
8	Finland	0.793326	22	Croatia	0.239620
9	France	0.733708	23	Romania	0.230214
10	Spain	0.712661	24	Slovakia	0.190606
11	Italy	0.659762	25	Bulgaria	0.177388
12	Luxembourg	0.592456	26	Lithuania	0.172959
13	Czech Republic	0.589833	27	Malta	0.059594
14	Portugal	0.540143	28	Latvia	0.054740

Source: own study based on data World Bank.

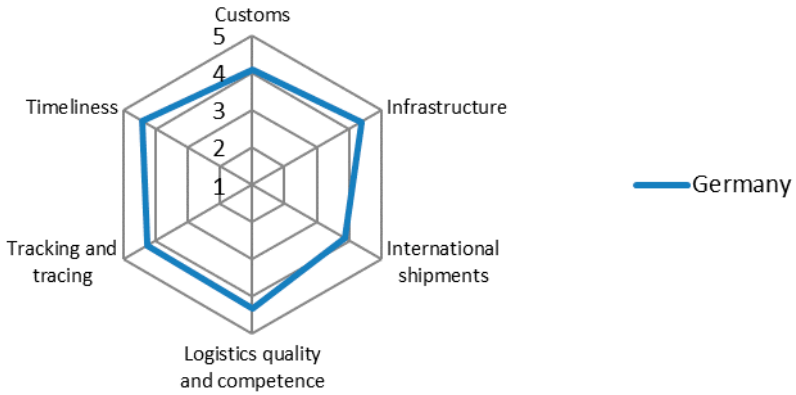


Figure 3. Values of the components of the LPI for Germany in 2018

Source: own study based on World Bank data.

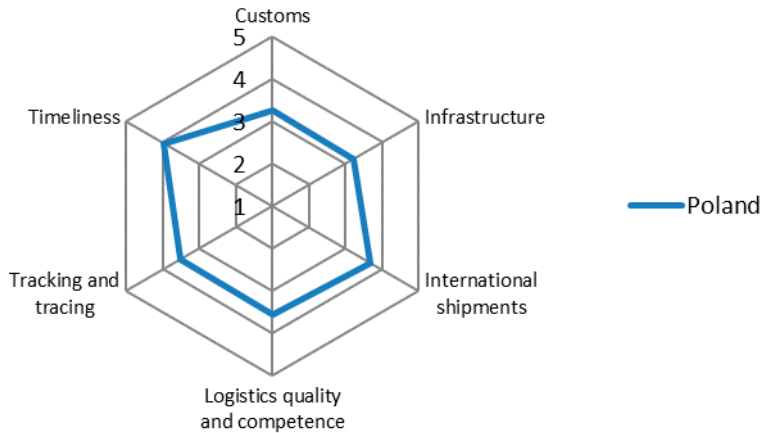


Figure 4. Values of the components of the LPI for Poland in 2018
Source: own study based on World Bank data.

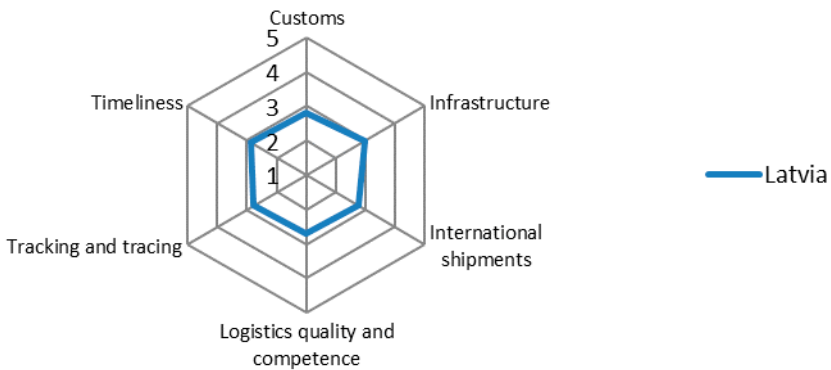


Figure 5. Values of the components of the LPI for Latvia in 2018
Source: own study based on World Bank data.

In the case of Germany, which is at the forefront of the classification in terms of logistics efficiency, the weaker elements are customs and international shipments. In Poland, the weakest links in the logistics system are customs and infrastructure. Meanwhile, in Latvia, timeliness and infrastructure were rated slightly higher than the other components, although all elements were verified at a fairly low level, on average, around 2. On this basis, it may be concluded which elements should be improved in the overall logistics efficiency structure.

The World Bank study largely reflects logistics efficiency, considering the breakdown of countries according to their income. On the one hand, this is the correct ap-

proach; however, income alone does not make it possible to show the diversity of services or the level of technical and organizational advancement in the TSL (transport, shipping and logistics) sector. The LPI report assumes that it is income that influences a country's logistic potential and performance. However, the research results indicate that countries with a similar income but with different geographic conditions, for example, are characterized by a different LPI value. Knowing the barriers of the TSL market, its specificity, dependencies, economic factors, and structures of the supply chains, one should be careful in drawing hasty conclusions in the future for individual regions.

Conclusions

The development of logistics systems is a vital element of an efficient supply chain and the processes that take place within it. In-depth quantitative and qualitative analyses provide information on the functioning of the above-mentioned points. Efficient flows in the logistics system are important from the economic point of view. This article presented several different types of quantitative measures that characterize logistics systems. Using indicators, it is possible to describe, evaluate, and compare systems that operate on a microeconomic (i.e., enterprises) and macroeconomic (general – for example, countries) scale. The methods of assessing logistics systems presented in the article constitute only some of those available in the literature on this subject.

The study presented interesting results. First of all, a number of indicators that describe the processes in the logistics system are shown. In addition, the facilities (EU countries) were compared in terms of the development of logistics systems. They show diversity in terms of the development of the logistics system in 2018. Consequently, it may be pointed out that countries can compete with each other in this respect, as a highly developed logistics system brings economic and social benefits.

The use of multivariate comparative analysis methods for research enables interesting conclusions. Cluster analysis made it possible to group countries in terms of diagnostic features that characterize the logistics system. Meanwhile, the taxonomic measure of development made it possible to classify the countries in terms of the development of the logistics system, from the best developed to the worst.

The conclusions of the research are:

- it is possible to distinguish EU countries that are definitely leaders in terms of the development of the logistics system (from the point of view of efficiency measured by the LPI) in the analyzed period: Germany, the Netherlands, and Austria; meanwhile, countries with the lowest rank include Lithuania, Malta, and Latvia,
- countries with a higher level of gross domestic product per capita are higher in the ranking of the taxonomic measure of development and form groups in the cluster analysis; the same regularity applies to countries with a lower level of gross domestic product per capita,

- a poorly developed logistics system is characteristic of countries located in the eastern and south-eastern part of Europe, while a higher level is generally found in countries located in the western and north-western part of Europe,
- based on a detailed analysis of the components of the LPI, it is possible to identify the strengths and weaknesses of each of the surveyed countries, which may allow detailed conclusions to be drawn in the context of improving the logistics situation.

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Wybarane wskaźniki poziomu rozwoju logistycznego – przegląd i analiza porównawcza w krajach UE

Branża logistyczna współcześnie rozwija się bardzo dynamicznie. Sprawne przepływy towarów, osób i informacji są bardzo istotnym ogniwem każdego łańcucha dostaw i całego systemu logistycznego. Aby systemy mogły funkcjonować efektywnie, należy je odpowiednio oceniać, porównywać, jak i analizować. W tym celu istnieje wiele różnorodnych wskaźników, zarówno prostych i złożonych. Celem niniejszego artykułu jest dokonanie przeglądu tychże wskaźników, a także przeprowadzenie analizy porównawczej dla wybranego wskaźnika mierzącego poziom rozwoju systemu logistycznego (LPI – Logistics Performance Index). Podmiotem badania są kraje Unii Europejskiej. Do analiz wykorzystano metody wielowymiarowej analizy porównawczej.

Słowa kluczowe: system logistyczny, wskaźniki logistyczne, Logistics Performance Index, wielowymiarowa analiza porównawcza

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