International Logistics Performance Feature Extraction Insights and Portugal's Global Positioning

Aldina Correia[1,2,[0000−0002−4693−4867]] and David Mendes[1,3]

[1] CIICESI, Escola Superior de Tecnologia e Gestão,
Instituto Politécnico do Porto, Portugal **
[2] aic@estg.ipp.pt
[3] 8210763@estg.ipp.pt

Abstract. The importance of countries' logistical performance in engineering innovation is well known, ranging from rationalization of supply chains, optimizing inventory management, in addition to promoting/hindering global collaboration. It is therefore essential for the faster and more efficient development of new technologies and products. The integration of efficient logistics, with innovative technologies, allows the timely delivery of materials and components, thus increasing the speed and effectiveness of engineering innovation processes.
investigates the existence of a robust correlation structure among Logistics Performance Index (LPI) Indicators. LPI is an index that attempts to measure performance in terms of conditions in the area of logistics in different countries around the world. Including information on the quality of infrastructure related to trade and transport, the ease of customs procedures, the efficiency of customs clearance and other factors that affect the flow of goods across borders, the LPI is calculated using several Indicators. Our results suggest the LPI's conceptualization as a latent variable, defined by its Indicators, with exceptional internal consistency. This coherence reinforces the LPI's reliability for evaluating logistics performance globally. The recognition of LPI as a good indicator of countries' logistical performance allows it to be used in engineering as a source of practical knowledge for innovation. Indicating paths for the best strategic decisions on the topics measured and, consequently, improving the cost-effectiveness and competitiveness operations.

Keywords: Logistics Performance, LPI, Logistics decision-making in Engineering, features aggregation, Exploratory Factor Analysis.

1 Introduction

Knowing the efficiency and effectiveness of logistics and supply chain management in countries around the world can be a differentiating factor when a company wants to make the decision to internationalize [11]. As logistics has many

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dimensions, the World Bank developed the Logistics Performance Index (LPI) [18], which is an index that provides information on the quality of infrastructure related to trade and transport, the ease of customs procedures, the efficiency of the customs clearance and other factors that affect the flow of goods across borders.

The LPI is based on a survey of global freight forwarders and logistics professionals who provide feedback on various aspects of the logistics environment in a given country (Appendix A – Figure A).

The index is calculated based on six key dimensions [1, 2]:

1. Customs Clearance Process: The efficiency of customs and border clearance processes.
2. Infrastructure Quality: The quality of trade and transport-related infrastructure, including ports, railroads, and roads.
3. Ease of Arranging Shipments: The ease of arranging competitively priced shipments.
4. Competence and Quality of Logistics Services: The competence and quality of logistics services, such as transport operators and customs brokers.
5. Tracking and Tracing: The ability to track and trace consignments.
6. Timeliness of Shipments: The frequency with which shipments reach the consignee within the scheduled or expected delivery time.

The LPI is scored on a scale from 1 to 5, with higher scores indicating better performance in logistics and supply chain management [18]. It is a valuable tool for governments, businesses, and researchers to assess and compare the logistics performance of different countries, identify areas for improvement, and make informed policy decisions [18, 11, 15].

According the last report [3], the 2023 edition encompasses an expanded dataset comprising (i) the Logistics Performance Index (LPI) based on a survey conducted with logistics professionals, and (ii) novel key performance indicators (KPIs) gauging the real-time pace of global trade. These new KPIs are extracted from extensive global tracking datasets (Big Data) that encompass shipping containers, air cargo, and parcels.

The new Key Performance Indicators (KPIs) are not yet incorporated into the primary Logistics Performance Index (LPI) indicators, which continue to rely solely on survey data. These complementary indicators provide a comprehensive understanding, with KPIs measuring specific links' time or performance, while the survey-based LPI assesses country-wide logistics performance across multiple aspects.

There are various ideas or recommendations that can be put forward to enhance the Logistics Performance Index. These proposals could encompass a range of strategies or changes aimed at improving the assessment and measurement of logistics performance in a given context [5, 14]. Given the importance of the LPI, to design appropriate policies to optimize the logistical conditions offered by countries, and in the possibility of not being able to collect data, as happened during the pandemic, there have been several attempts to automate the calculation of an index of logistics performance [16, 4].

The International LPI 2023 allows for comparisons across 139 countries [3] (Appendix B – Table 1). Over the past decade, LPI general score has shown an increase, indicating an overall improvement in logistics performance, [3]. Between 2018 and 2023, a smaller secondary peak emerged around a score of 3.5, signifying that more countries now exhibit relatively strong performance. However, it's essential to note that the lowest scores have tended to rise, particularly in the 2023 LPI, partly due to a reduced sample size of 139 countries compared to 160 in 2018. The 2018 sample included 20 countries with a score of 2.6 or below (with an average score of 2.4) that were not present in the 2023 sample, making direct comparisons in the lower range challenging between the two years.

LPI typically includes a considerable number of countries (Appendix B – Table 1), covering a broad spectrum of economies around the world. The specific number of countries included in the index may vary from one edition to another, as the World Bank updates the list based on the availability of data and participation from different nations. In the 2018, 2016 and 2014 editions of the LPI, there were 160 countries included in the assessment. However, the countries covered in each edition can be different, for example, 2014 edition has not Portugal Data.

The highest-ranking economies in the 2023 LPI, with the top 12 scorers, all of which are classified as high-income economies. Singapore, leading with a score of 4.3, retains its top position, a status it also held in 2007 and 2012. Among these top 12 scorers, 8 are located in Europe. The lowest 10 scorers predominantly consist of countries with low and lower-middle incomes, spanning various continents. These nations face challenges such as economic fragility due to armed conflicts, natural disasters, or political unrest. Additionally, some are landlocked countries grappling with geographical constraints or economic scale issues in establishing connections to global supply chains [3].

The primary objective of this paper is to verify if LPI is a reliable measure of countries' logistical performance. For that in this paper are identified the essential characteristics that contribute to the logistics performance of countries, discern patterns, and explore the main relationships among its Indicators.

The recognition of LPI as a good indicator of countries' logistical performance allows it to be used in engineering as a source of practical knowledge for innovation. Indicating paths for the best strategic decisions on the topics measured and, consequently, improving the cost-effectiveness and competitiveness operations [13]. In engineering, as in other areas, knowing a country's capacity in relation to a given subject is a valuable source of practical knowledge for innovation. Therefore, verifying that the LPI is a reliable indicator of countries' logistical performance allows its use in strategic decision-making.

Furthermore, the paper aims to describe Portugal's performance over the period from 2007 to 2023, particularly focusing on its overall LPI score.

2 Data and Results

To identify essential LPI indicators it is necessary to implement an analytical process involving the identification and isolation of essential variables contributing to logistic performance. This may include selecting key indicators, evaluating relevant datasets, and applying statistical techniques or algorithms to extract meaningful insights. Additionally, it is crucial to consider the specific context and study objectives to ensure that the extracted features are relevant and informative for the analysis of the Logistics Performance Index. This procedure can be done using feature selection or extraction techniques. In this work Exploratory Factor Analysis in JASP [9] software. This analysis is grounded in the scores of the 2023 LPI indicators.

This analysis is based on the scores of the 2023 LPI [18] indicators, encompassing data from 139 countries, distributed by Continent as illustrated in Appendix B – Table 4. A predominance of European nations is evident in the dataset, followed by representation from Asia, Africa, and the Americas, with Oceania having a less pronounced representation.

In 2023, the global LPI exhibited a range from 1.9 (Libya) to 4.3 (Singapore), with an average score of 3 and a standard deviation of 0.6 (Appendix B – Table 5). This indicates a diverse spectrum of performance levels among the countries assessed, reflecting the considerable variability in their logistics capabilities. The spread from the lowest to the highest scores underscores the nuanced nature of logistics performance on a global scale during that year.

Descriptive Statistics in 2023 Global LPI and Indicators are presented in Appendix B – Table 5, which reveals the crucial dimensions to logistics performance. Timeliness stands out as the top-performing indicator, boasting an average score of 3.2. This suggests that, on average, surveyed countries excel in ensuring timely and efficient logistics operations, a critical aspect for supply chain effectiveness. Following closely is Tracking and Tracing, with an average score of 3.1. This indicates a strong emphasis on the ability to monitor and trace shipments throughout the logistics process. The high score in this category implies a robust system for visibility and control in the movement of goods, enhancing overall efficiency. Logistics Competence and Quality maintain a solid position with an average score of 3.0, reflecting a generally high level of expertise and quality in logistics operations. This dimension underscores the importance of skilled personnel and quality processes in ensuring a smooth logistics experience. International Shipments and Infrastructure, with an average score of 2.9, signifies a reasonably strong performance in handling international shipments and maintaining well-developed infrastructure. This is critical for facilitating global trade and fostering economic connectivity. Lastly, Customs, with an average score of 2.8, suggests that improvements can be made in customs-related processes. Enhancing customs efficiency is vital for reducing delays and ensuring a seamless flow of goods across borders.

In summary, the detailed breakdown of LPI indicators offers a comprehensive understanding of the specific areas where countries excel and areas that

may require attention. This nuanced evaluation aids in identifying priorities for improvement and emphasizes the multifaceted nature of logistics performance.

It is also noteworthy that across all indicators, the minimum scores range from quite low, starting at 1.5 for Customs, to maximum scores of 4.6 for Infrastructure. This highlights significant disparities among countries. However, it's important to note that all standard deviations are below one, implying that there is not a substantial dispersion around the mean. It can be asserted that most countries exhibit similar performance despite the notable variations in individual indicator scores.

The trajectory of Portugal's logistics performance reveals a consistent maintenance of its overall Logistics Performance Index (LPI) score since 2007. Despite this stability in the score, Portugal has experienced shifts in its global ranking over the years. In 2007, Portugal occupied a position within the top 18% of countries evaluated by the LPI. By 2018, there was an improvement, with Portugal now positioned among the top 14% globally. Interestingly, in 2023, Portugal found itself in the 38th position, reflecting a dynamic period of change. During that year, Portugal's LPI was surpassed by 27% of the 139 countries assessed. This fluctuation in ranking over the years highlights the evolving nature of Portugal's logistics performance relative to other nations in the study. Understanding these changes can provide valuable insights into the factors influencing Portugal's logistics landscape and its competitiveness on the global stage [7].

Table 1. Number of Economies in LPI and Portugal´s position

Year	2023	2018	2016	2014	2012	2010	2007
Economies	139	160	160	160	155	155	150
Portugal LPI	3,4	3,6	3,41	NA	3,5	3,3	3,4
Portugal Rank	38	23	36	NA	28	34	28
> PT (%)	27%	14%	22%	NA	17%	21%	18%

3 Relationships among 2023 LPI Indicators

LPI indicators influence countries' logistics performance, therefore is fundamental uncover patterns, and investigate the core relationships among these factors. In this section Exploratory Factor Analysis (EFA) is performed, for this propose.

Assumptions for this technique are: (i) sample dimension – 5 to 10 observations by variable; (ii) normality of the variables; (iii) linearity of the variables; (iv) homocedasticity.

(i) Sample dimension - The sample comprises 139 countries, and there is no missing values. Therefore, the sample size is adequate for the analysis of the six indicators.

(ii) Normality Assessment - For evaluating normality, we can employ the Mardia's Test of Multivariate Normality [4]. This test examines the symmetry and kurtosis of the dataset. The null hypothesis assumes multivariate normality. Since the p-values are greater than 0.05, we do not reject the null hypothesis of the test at a significance level of 5%. Therefore, there is statistical evidence to suggest that the six variables in our dataset follow a multivariate normal distribution (Appendix B – Table 6).

(iii) Linearity – Pearson's Correlations between Indicators (Appendix B – Table 7) all show statistical significance at a 5% significance level, furthermore, they are all high, surpassing the threshold of 0.8. This high level of correlation among the indicators suggests a strong interdependence between them. Consequently, the extraction of factors from these features is not only justified but becomes imperative due to the presence of multicollinearity among the LPI indicators. Multicollinearity indicates a substantial correlation between all dimensions of the LPI, emphasizing the need for factor extraction to address potential redundancy and enhance the robustness of the analysis.

(iv) The assumption of homoscedasticity is justifiable based on the descriptive statistics in the Appendix B – Table 5). In this table, it is evident that the standard deviation values for the indicators are consistently and similar below 1. This uniformity in standard deviations suggests a relatively consistent distribution of the data around their respective means for each indicator. The observed similarity in standard deviation values reinforces the assumption of homoscedasticity, providing confidence in the reliability of statistical inferences drawn from the data.

After fulfilling the necessary conditions, EFA can be implemented to assess the relationships within the observed variables.

Table 2. Kaiser-Meyer-Olkin Measure of Sample Adequacy and Factor Loadings

Indicator (Score)	MSA	Factor Loadings	Uniqueness
Customs Score	0.912	0.950	0.097
Infrastructure Score	0.897	0.960	0.078
International Shipments Score	0.973	0.888	0.212
Logistics Competence and Quality Score	0.932	0.973	0.053
Timeliness Score	0.944	0.922	0.150
Tracking and Tracing Score	0.923	0.964	0.071
Overall MSA	0.929		

The MSA (Measure of Sample Adequacy) for each variable indicates the suitability of the variable for EFA. It compares the magnitudes of the coefficients of observed correlations with the magnitudes of the coefficients of partial correlations that would be observed if the variable not considered. Measures below

[4] The statistic for skewness is assumed to be χ^2 distributed and the statistic for kurtosis standard normal.

0.5 suggest that it is not appropriate to include that variable in the EFA. The variable with the lowest MSA should be removed one at a time until none are below 0.5.

In this case, all individual MSAs are greater than this threshold, indicating that they are adequate for the analysis. Additionally, the overall MSA or Kaiser-Meyer-Olkin Measure of Sample Adequacy is 0.929, suggesting excellent suitability for applying EFA [10]. KMO values closer to 1.0 are consider ideal while values less than 0.5 are unacceptable.

The Bartlett's test of sphericity is employed to test the null hypothesis that the correlation matrix is an identity matrix [5]. An identity correlation matrix implies that the variables in study are unrelated and is not conducive to factor analysis. For the features to be extracted the χ^2 of the Bartlett's Test is $1776.413(df = 15)$, with $p - value < 0.001$, less than 0.05, indicating the rejection of the null hypothesis, for a 5% significance level, and conditions for the application of EFA.

EFA application requires a judicious balance between simplicity and comprehensiveness. Striking a compromise between these extremes involves constructing a model with just enough factors to account for significant covariation among measured variables. This compromise entails making decisions about the number of factors to retain in the model for further analysis [5].

The eigenvalues derived from Principal Component Analysis (PCA) have conventionally served as a means to estimate the number of factors to be further explored in a common factor analysis ([6]).

The chi-square goodness-of-fit test has a $\chi^2 = 62.216$ with $df = 9$ and a $p - value < 0.001$. This chi-square tests the null hypothesis that the observed data correlation matrix is a random sample realization from population having correlation matrix equal to the one returned by the extracted factors. That is, the residuals are random noise, sliding to 0 as the sample size grows to infinity.

In determining the number of factors to retain by focusing on eigenvalues exceeding 1, a single factor was extracted, encompassing all LPI indicators explaining 89% of the variance of these indicators. Within this factor, Logistics Competence and Quality is the indicator with highest loading (0.973), fallowed by Tracking and Tracing, Infrastructure, Customs, Timeliness and International Shipments (0.888). This signifies that all the indicators contribute to the same latent variable, indicating a high level of correlation among them.

The reliability of factors in the context of factor analysis refers to the consistency or stability of the measurement of underlying constructs represented by those factors. There are several ways to assess the reliability of factors, being the commonly used measure the Cronbach's Alpha, a frequentist scale Reliability Statistics. It assesses how well the items within a factor consistently measure the same underlying construct. A higher Cronbach's alpha value (typically above 0.70) indicates greater reliability.

The estimate Cronbach's α of the factor obtained in this EFA is 0.978, indicating excelent reliability ([12]). Additionally, even if an item is dropped, the frequentist individual item of reliability (see Table 3) remain very high. This sug-

Table 3. Frequentist Individual Item Reliability Statistics

Item	If item dropped Cronbach' α
Customs Score	0.972
Infrastructure Score	0.973
International Shipments Score	0.979
Logistics Competence and Quality Score	0.970
Timeliness Score	0.976
Tracking and Tracing Score	0.972

gests that each individual item significantly contributes to the overall reliability of the factor, confirming the exceptional internal consistency of the measures employed. This internal consistency is crucial to ensure the reliability and validity of the analysis results. Consequently, this provides evidence of the excellent internal consistency of the latent variable.

4 Conclusion and Future Work

In this study, a comprehensive examination revealed a strong correlation among all the indicators encompassed within the Logistics Performance Index (LPI). This observation suggests that the LPI can be conceptualized as a latent variable, representing an underlying construct with remarkable internal consistency, as elucidated by its constituent indicators. The high level of correlation among these indicators implies a coherent and unified measurement of the latent variable, reinforcing the reliability and coherence of the LPI as a robust tool for assessing logistics performance. This insight contributes to a nuanced understanding of the interrelationships among the various dimensions captured by the LPI, providing a solid foundation for further analysis and interpretation of logistics performance on both a national and global scale. Verifiing LPI as a reliable indicator of countries' logistical performance enables its utilization in engineering as a valuable source of practical insights for innovation. It guides optimal strategic decision-making, providing a comprehensive view of a nation's logistical capabilities, including infrastructure, process efficiency, and transportation services. By using LPI as a source of practical knowledge, governments, companies and engineers can identify specific opportunities and challenges related to logistics in various geographic contexts. For example, a country ranking high on the LPI may indicate an environment conducive to the development of new transportation technologies or efficient supply chains. Conversely, a low LPI score may flag areas where engineering interventions are needed to improve transportation infrastructure or optimize logistics processes.

Concerning with Portugal's performance over the period from 2007 to 2023, particularly, focusing on its overall LPI score, has remained consistent since 2007, although its global ranking has undergone fluctuations. In 2007, Portugal ranked within the top 18%, improving to the top 14% by 2018. However, in 2023,

Portugal dropped to the 38th position, reflecting a dynamic shift. During that year, 27% of the 139 assessed countries surpassed Portugal's LPI.

As mentioned in the LPI reports, for example [1, 2], but namely in the 2023 report [3], several dimensions of the logistic performance can be out of this index, they try to include other KPI in the index, or to complete information with other type of indicators. It can be a good suggestion for future work. Also to develop a logistic performance index for logistic companies and extend these concepts to the industrial level would be very useful for these companies.

As highlighted in the LPI reports, such as those in 2016 and 2018 [1, ?], and particularly in the 2023 report [3], various dimensions of logistic performance may fall outside the scope of this index. Efforts have been made to incorporate additional Key Performance Indicators into the index or supplement information with other types of indicators. This observation provides valuable insights for potential future research. Furthermore, the suggestion to develop a logistic performance index tailored specifically for logistics companies and extend these concepts to the industrial level could be highly beneficial for such entities.

A Appendix: Figures

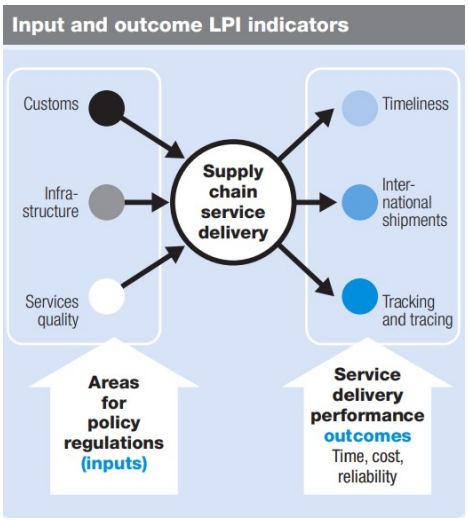

Fig. 1. LPI 2023 Questionnaire – Input and outcomes LPI Indicators [3]

B Appendix: Tables

Table 4. Frequencies for Continent in 2023 LPI

Continent	Frequency	Percentage
Europe	39	28
Africa	32	23
Asia	36	26
Oceania	4	3
America	26	19
Europe/Asia	2	1
Total	139	100

Table 5. Descriptive Statistics in 2023 Global LPI and Indicators

Acronym	Indicator (Score)	Mean	Std. Dev.	Minimum	Maximum
C	Customs	2.8	0.63	1.5	4.2
I	Infrastructure	2.9	0.7	1.7	4.6
IS	International Shipments	2.9	0.5	1.7	4.1
LCQ	Logistics Competence and Quality	3.0	0.6	1.8	4.4
T	Timeliness	3.2	0.6	2.1	4.3
TT	Tracking and Tracing	3.1	0.7	1.6	4.4
LPI	Logistics Performance Index	3.0	0.6	1.9	4.3

Table 6. Mardia's Test of Multivariate Normality

	Value	Statistic	df	p
Skewness	3.987	92.376	84	0.249
Small Sample Skewness	3.987	94.878	84	0.196
Kurtosis	64.022	0.536		0.592

Table 7. Pearson's Correlations between Indicators

Variable	Pearson's r	C	I	IS	LCQ	T	TT
C		–					
		–					
I		0.949	–				
	p-value	< 0.001	–				
IS		0.832	0.845	–			
	p-value	< 0.001	< 0.001	–			
LCQ		0.929	0.940	0.856	–		
	p-value	< 0.001	< 0.001	< 0.001	–		
T		0.863	0.863	0.831	0.898	–	
	p-value	< 0.001	< 0.001	< 0.001	< 0.001	–	
TT		0.898	0.911	0.870	0.934	0.911	–
	p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	–

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