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Key Logistics Performance Indicators in Low-Income Countries: The Case of the Import–Export Chain in Ethiopia

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Abstract: Performance evaluation in logistics is crucial in identifying improvement opportunities. This study assessed performance indicators (PIs) for import–export logistics chains, including transport, dry ports, transhipment and warehouses, focusing on Ethiopia. PIs were identified by means of a literature review. An expert survey based on the analytical hierarchy process (AHP) was used to obtain weightings for the indicators to allow an evaluation of the overall performance of the country's import–export chains. Key challenges faced in the sector were also identified. Indicators such as turnaround time and damage frequency were given high weightings by experts for dry port PIs, security was given the highest weighting for transport PIs, and order lead time was given the highest weighting for warehouse PIs. Technological advancements, human resource capacity building and government policies were found to be the main areas that could improve the performance of logistics operations and address the challenges faced by the sector. These findings could provide a new and comprehensive picture of the key performance indicators of Ethiopian import–export logistics chains.

Keywords: performance indicators; logistics; low-income countries; dry ports; landlocked countries

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1. Introduction

Logistics connects suppliers and customers internationally, making it critical for global trade [1]. It is, therefore, a crucial component in economic development that enables the delivery of the right product, at the right place, at the right time, in the right condition, at the right cost and in the right quantity to the right customer. A high standard of logistics performance increases profitability, advances the national economy and improves competitiveness [2], while also easing business transactions, making countries attractive places in which to conduct international trade. Thus, organisations can improve their logistics performance by identifying bottlenecks in their operations, optimising processes, building better infrastructures, improving policies and training workforces.

The overall quality of a logistics chain depends on the performance of logistics components. A typical import–export corridor involves the components of port activities, transport, warehousing and customs checks [3,4]. Dry ports are also integral parts of the import–export chain, particularly in landlocked countries, and are defined as ports that are located inland where the temporary storage of cargo, inspection and customs clearance take place [5]. The purpose of dry ports is to improve accessibility between seaports and inland trade zones, while also relieving constraints at seaports [6]. Transport provides a link between seaports, dry ports and warehouses, adding both time and space utilities to the goods being transported. Inefficiencies in transportation in the import–export sector cause major losses in terms of efficiency and profitability. Inefficiencies in transportation usually take place due to incompetent drivers, aged trucks, issues related to loading and unloading, availability of trucks, traffic accidents and security threats. Warehousing is

another important activity in the import–export chain. Warehouses are used to store raw, partially assembled or finished products, accumulate and consolidate products, and receive, pick and ship products to customers [1]. The way goods are handled, tracked and stored in warehouses has a huge impact on the import–export chain. Companies that have effective warehouse and inventory management make major cost savings due to lower levels of damage and loss.

The occurrence of logistics inefficiencies and bottlenecks affects the performance of the import–export chain. One method for addressing logistics bottlenecks in the import–export chain is through the application of enabling technologies. Bottlenecks due to inefficiency, lack of integration and poor responsiveness have been addressed by previous studies following the increased use of enabling technologies [7–10]. Visibility of port operations can be improved through the use of tracking technologies [11], while automation technologies are used to improve throughput and port accessibility [7–9]. In transport, information and communication technology (ICT) solutions have been used to make transport choices and goods movements less costly and more efficient [12]. Using virtual clustering in transport, which is a temporary virtual cooperation network, logistic companies can choose cost-effective transport services, while at the same time reducing their environmental impact by increasing the load factor [13]. Furthermore, technologies have also been implemented in warehouses to reduce loading and unloading time, costs and damage rate [14,15].

The measurement of logistics performance is a critical step in logistics management. Logistics performance has been evaluated by many researchers at both a national and international level [3,16,17]. The World Bank has also been measuring and ranking the logistics performance of nations since 2007. This ranking is based on the logistics performance index (LPI), which comprises customs, infrastructures, ease of arranging shipments, quality of logistics services, timeliness, and tracking and tracing. A report by Arvis et al. [18] revealed that, based on the World Bank's LPI, the top logistics performers were from high-income countries, whereas low-income countries were the least effective performers.

Numerous studies have measured logistics performance, but few have assigned weightings to indicators using the multi-criteria method. One of the most common multi-criteria methods used in the literature is the analytical hierarchy process (AHP). Bolat et al. [19] used AHP to identify factors affecting port congestion, while Chiu et al. [20] used this method to analyse factors that contribute to green ports, applying the weightings they obtained to evaluate the green performance of three ports in Taiwan. The application of AHP has also been extended to measure the performance of transportation. For instance, Hanaoka and Kunadhamraks [21] evaluated the performance of intermodal transportation using a fuzzy AHP method. This method also has a wide range of applications in warehouse management. Lam et al. [22] applied it to rank the risk factors in warehouse order fulfilment and develop a logistics operation strategy. Srisawat et al. [23] used fuzzy AHP to prioritise performance indicators (PIs) related to logistics efficiency.

According to UN-OHRLLS [5], compared with coastal countries, it costs landlocked countries double the amount and takes them almost twice as long to import or export goods. Thus, the high costs and long lead times incurred by landlocked countries reduce their competitive advantage in the international market. In addition to being a landlocked country, Ethiopia is a low-income country with limited infrastructures, causing the country's logistics performance to become poor. Its aggregated ranking in terms of the World Bank's LPI is 131 out of 160 countries [18]. In contrast, countries such as Botswana, Rwanda and Uganda are also landlocked countries in the region but have better logistics performances, with aggregate LPI rankings of 58, 65 and 72, respectively [18]. One of the reasons for Ethiopia's poor logistics performance is its lack of access to seaports, while another is the lack of technological advancement in logistics components [24–26]. Inefficiencies during customs operations, poor road infrastructures, deficient storage and material handling techniques, and inadequate freight vehicles have led to a deterioration in the country's logistics system [25].

When looking at the import–export chain in Ethiopia, previous research has focused on different aspects of the chain. For instance, Nitsche [27] mapped current challenges faced by the Ethiopian import–export chain and recommended strategies to address them; Gebrewahid and Wald [28] evaluated the export barriers confronting the Ethiopian leather industry; and Amentae and Gebresenbet [3] assessed intermodal freight transport services in Ethiopia. However, none of the above studies identified PIs for the Ethiopian import–export chain considering different weightings for these PIs. Studies argue that criteria should be provided with weightings because not all criteria are equally important to the overall performance of the chain [29,30].

In low-income countries with a poor logistics performance similar to that of Ethiopia, major costs arise from port handling, transport and warehousing [31]. Therefore, it is important to understand the performance of these sectors and identify the bottlenecks within them. The aim of this study was, therefore, to develop PIs for dry ports, transportation and warehouse operation, and to weight their importance in terms of the overall performance of the Ethiopian import–export chain. The most important challenges faced by the sector were also assessed.

2. Materials and Methods

2.1. Overview

To identify the key PIs for dry ports, transportation and warehousing, first of all, a review was undertaken of earlier studies in these areas. The literature was categorised into low-income countries and high-income countries based on the study area on which they focused. The literature on the two categories was then compared to identify sets of PIs that are relevant for low-income countries. These sets were then presented to experts working in government offices influencing logistics activities in Ethiopia to check their relevance and the need for additional indicators. The offices contacted included the Ethiopian Shipping and Logistics Services Enterprise (ESLSE), the Ethiopian Maritime Authority (EMA) and the Ministry of Transport (MoT). The experts contacted from these organisations were team leaders and operation managers with a minimum experience of 7 years. The final set of indicators were then presented to customers and service providers in order for them to weight each indicator. Using the analytical hierarchy process (AHP), the weighting for each indicator was determined. The overall methodology followed in the study is depicted in Figure 1.

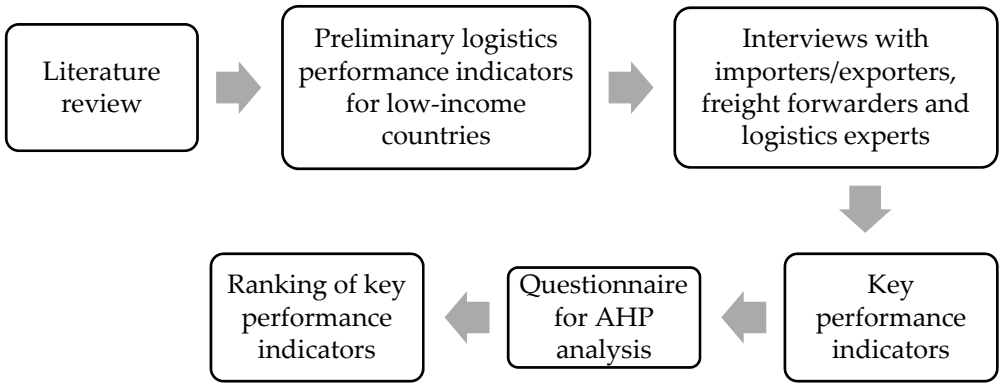

Figure 1. Methodology followed in this study.

2.2. Literature Review

An extensive review of previous studies was conducted by evaluating journals and reports from around the world focusing on import–export chains, which allowed the major activities affecting their efficiency to be identified, along with criteria for measuring the performance for each of these activities. Thus, indicators were obtained for dry port operations, transportation and warehouse management.

2.3. Expert Survey

A survey was carried out in two stages in the study. The first stage was interviews with logistics experts working in government offices. The purpose of this interview was to assure the relevance and adequacy of the indicators gathered from the literature for the case of Ethiopia (Appendix A). After the completion of this step, lists of performance indicators that were to be weighted in the following stage were obtained. In the second stage of the survey, paper-based questionnaires were distributed to customers and service providers (Table 1). The questionnaire is presented in Appendix B. The purpose of this was to weight the PIs according to their importance. The experts required for the survey were divided into two categories, service providers and customers, because it was assumed that the importance of each criterion might be different for stakeholders in the respective groups.

Table 1. Stakeholders approached in the survey.

Customers	Number of Respondents	Service Providers	Number of Respondents
Importers/exporters	35	Ethiopian shipping and logistics service enterprise (ESLSE)	6
Freight forwarders	18	Ethiopian Maritime Authority (EMA)	2
		Ministry of Transportation (MoT)	1

The experts in the survey were selected using a purposive sampling technique. This is a type of non-probability sampling technique where respondents are deliberately selected for the information they can provide that cannot be obtained from other sources [32]. When using the AHP method for conducting pairwise comparisons and obtaining weights, a large sample size is not required as long as the consistency ratio (CR) is within the acceptable limits [33]. Hence, using the purposive sampling technique, interviews were conducted with 53 customers and 9 service providers. The customers interviewed included importers, exporters and freight forwarders that had significant experience in the field of logistics. The service providers interviewed included staff working in the Ethiopian Shipping and Logistics Service Enterprise (ESLSE), the Ethiopian Maritime Authority (EMA) and the Ministry of Transportation (MoT) (Table 1). The experts that were interviewed represented the views of their organisations and not their personal views.

Importers and exporters were asked to undertake pairwise comparisons for port operations, transport and warehouse management. The reason for this is that these experts are involved in all three stages of the operation (i.e., dry port operation, transportation and warehousing). In contrast, freight forwarders were only asked to conduct pairwise comparisons for port operations and transport, as these two aspects fall within the scope of their responsibilities. Staff at ESLSE, EMA and MOT were only asked to conduct pairwise comparisons for the dry port PIs, as they are responsible for providing dry port services.

The questionnaire used in the study comprised three sections. The first section asked respondents to provide general information. The second section provided lists of PIs for the respondents to provide their opinion on their importance level using the scale provided by Saaty [34], which is based on a Likert scale with values ranging from 1 to 9. According to Saaty [34], the values 1, 3, 5, 7 and 9 on the Likert scale represent equally important, slightly important, moderately important, very important and extremely important, respectively, while 2, 4, 6 and 8 are intermediate values between two adjacent scales. This section was required to conduct pairwise comparisons using the AHP method. Finally, the last section required respondents to list the challenges they faced in the sector.

2.4. Analysis

The AHP method is a type of multi-criteria decision-making (MCDM) framework that is used for making pairwise decisions when faced with several competing choices [35]. According to Brunelli [36], the main objective of AHP is to assign weights to a set of alternatives using pairwise comparisons. The method is useful for the analysis of both qualitative

and quantitative attributes [37]. The method assumes that the decision makers are rational and that they can assign weights to each criteria using positive real numbers [35].

The other common MCDM methods include Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [21], the Best Worst Method (BWM) [30] and Decision-Making Trial and Evaluation Laboratory (DEMATEL) [35]. Table 2 summarises the strengths and limitations of these MCDM methods. However, the AHP method is preferred over the other methods as it is one of the highly accepted MCDM methods [21] with a wide range of applications. Additionally, the AHP method integrates the judgments of multiple stakeholders and quantifies their judgments [33].

Table 2. Some of the common MCDM methods along with their strengths and weaknesses.

MCDM Method	Strengths	Limitations
AHP	Ability to evaluate both qualitative and quantitative data [38]	Pairwise comparisons increase as the number of variables increase [39] Issues with inconsistency [40]
TOPSIS	Does not require pairwise comparisons [40] No issues with inconsistency [40]	Needs to be combined with other methods to have quantitative results in qualitative problems [41]
BWM	Lesser pairwise comparisons [39] Weights are always consistent [39]	Complex calculation process
DEMATEL	Can weight dependent alternatives [42] Understands cause and effect relationship [42]	Individual weightings of experts are not used to obtain the final weighting for an alternative [42]

AHP has been used for the identification of potential risk factors in warehouse management [22], the selection of appropriate locations for intermodal freight logistics centres [42], the selection of the location of a manufacturing plant [37] and the identification of the most important criteria for implementing digitalised logistics in low-income countries [43].

The main steps in the AHP method, according to Chang and Lin [37], are: (1) identification of criteria for comparison, (2) pairwise comparisons based on the scale outlined by Saaty [34], (3) calculation of the weightings for each criterion and (4) calculation of the consistency ratio (CR). The CR is obtained from the maximum eigenvalue by first calculating the consistency index (CI) using Equations (1) and (2):

$$CI = (\lambda\_max - n)/(n - 1) \quad (1)$$

$$CR = CI/RI \quad (2)$$

where n is the number of criteria and RI is the random consistency index. The value for RI depends on the number of criteria and is obtained from Saaty [34]. The weightings obtained in step (3) are acceptable if the CR calculated in step (4) is less than 10%. If the CR is greater than 10%, the weights should be revised and the participants should be consulted to check whether they agree with the newly assigned weightings.

2.5. Study Area

Ethiopia's main access to the sea is through the port of Djibouti, and over 90% of trade in Ethiopia is conducted through the Ethio-Djibouti corridor [44]. Ethiopia also has eight dry ports located in different parts of the country (Figure 2). The focus of this research was on the Modjo dry port located approximately 73 km from the capital city, Addis Ababa. The Modjo dry port is also the country's largest dry port, with an operational capacity of 17,539 Twenty-foot Equivalent Unit (TEU) at a time, and it handles 78% of the country's imports [45].

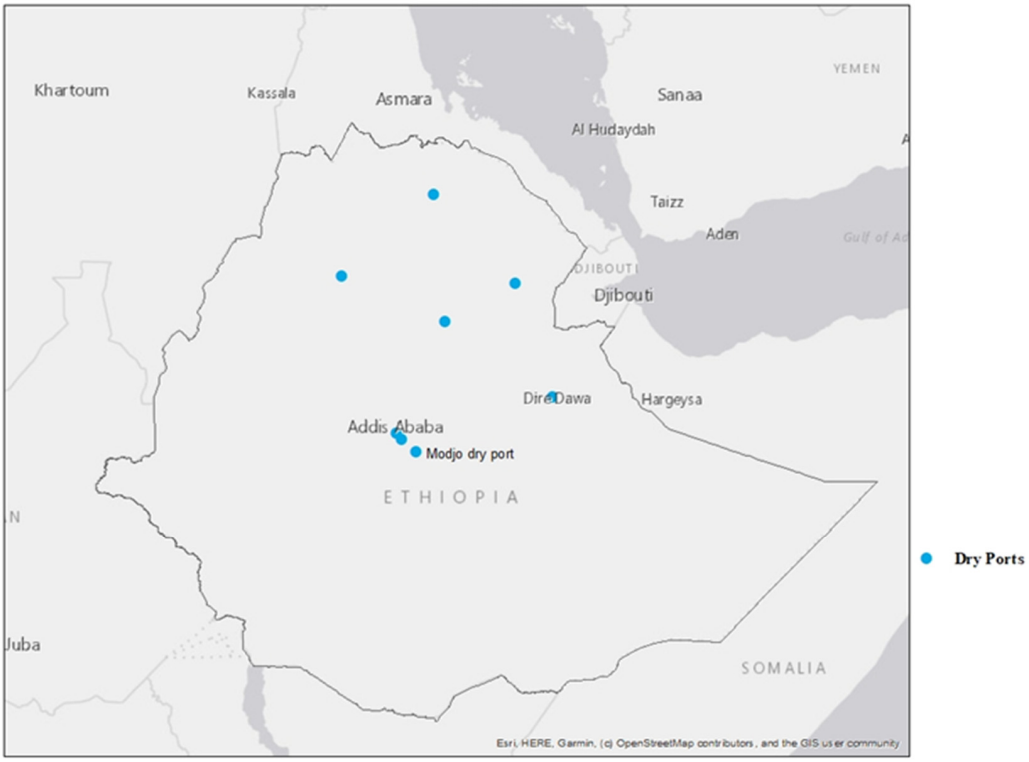

Figure 2. Location of the eight dry ports in Ethiopia.

3. Results

3.1. Preliminary Sets of Logistics Performance Indicators

The identification of logistics PIs enables areas in the supply chain that need improvement to be established. Several authors have measured the performance of various aspects of it. Table 3 summarises the contributions of selected authors on logistics performance.

Table 3. Selected literature focusing on logistics performance.

Author	Contributions
Çelebi [46]	Studied the impact logistics performance has on promoting international trade by comparing countries by their income levels. The authors found that countries from all income groups should collaborate to improve their logistics performance.
Gunasekaran et al. [47]	Developed a framework to measure supply chain performance at strategic, tactical and operational levels. The supply chain performance framework developed by the authors enables the identification of areas in the supply chain that require improvement.
Jin and Wang [48]	Categorised the performance measurement levels in logistics as infrastructure, operational and user-level performance measures.
Kabak et al. [49]	Developed a new approach for investigating the relationship between logistics performance and export. The authors found a direct relationship between logistics performance and export level. Their findings indicate that countries should improve their logistics performance to improve their export levels.
Liebetruth [50]	Studied the various approaches for measuring logistics performance. The authors then studied the possibility for integrating sustainability aspects for measuring the performance of supply chains.
Lin [51]	Studied the factors affecting the adoption of new technologies in Taiwan to improve logistics performance. Their findings indicate that adopting new technologies improves the performance of supply chains.
Rashidi and Cullinane [52]	Used a new approach known as sustainable operational logistics performance to measure the logistics performance of selected countries. The authors compared the logistics rankings with the World Bank's LPI. The approach used by the authors can be used with the World Bank's LPI to identify inefficiencies in logistics performance.
Özceylan et al. [53]	Measured the logistics performance of provinces in Turkey using geographic and economic indicators. The authors then developed a logistics performance map of countries. The findings of the authors facilitate making logistics decisions based on a Geographic Information System (GIS).

Although the aforementioned literature in Table 3 has shed light on various aspects of logistics performance, studies that develop logistics PIs and assigned weightings for the context of low-income countries are still lacking. On the other hand, several authors have taken an interest in measuring the performance of specific logistics activities. The sections below discuss the literature that focuses on logistics PIs for dry port operation, transportation and warehouse management.

3.1.1. Performance Indicators for Dry Ports

There is a considerable amount of literature on the performance of dry ports. Some studies have suggested key PIs that should be used to evaluate dry ports. Others have applied the indicators to evaluate certain ports, compare different ports and model how interventions in port operations affect port performance. Ha et al. [54] classified port PIs considering the goals and objectives of stakeholders in port operations. Accordingly, the indicators were classified into core activities, supporting activities, financial strength, user satisfaction, terminal supply chain integration and sustainability goals. The authors considered human capital, including the knowledge, skill and work ethics of human resources, as port PIs, which were not included in most of the literature. Operational, finance, quality, environmental and safety aspects were recommended as port PIs by Martin et al. [55]. Carboni and Deflorio [56] studied the effect of technologies on environmental and operational PIs, including time-related indicators, loss and damage frequency, utilisation rate and delays. Overall throughput, time aspects and financial aspects were considered in many studies. The indicators shown in Table 4 were found in most of the articles.

Table 4. PIs for dry ports obtained from the literature.

Dimension	PI	Source
Global PIs for dry ports		
Financial	Throughput	[54,55,57,58]
	Equipment costs	[55]
	Profitability	[55]
	Turnover revenues/expenditures	[55,57]
	Labour costs	[55]
	Maintenance costs	[55]
Efficiency	Storage area utilisation	[55,59]
	Equipment productivity and utilisation	[26,54–56,60]
	Labour productivity and utilisation	[26,54,55,60]
Time	Turnaround time	[54]
	Cut-off time [1]	[56]
	Entrance waiting time	[56]
	Exit waiting time	[56]
	Average waiting time under crane	[54]
	Document exchange time	[56]
Service quality	Handling costs	[26,54,56,60]
	Loss frequency	[26,56,60]
	Damage frequency	[26,56,60]
	Supply chain visibility	[26,56,60]
	Information availability	[26,56,60]
Environmental	Carbon footprint	[54,56]
	Water consumption	[54]
	Energy consumption	[54,56]
	Noise emission	[56]
Multi-modality aspects	Multimodality rate [2]	[26,58,60]
	Expandability	[26,58,60]
	Distance from city centre, commercial areas and industrial zones	[26,58,60]
	Intermodal connectivity	[26,58,60]

Table 4. *Cont.*

Dimension	PI	Source
Dry port PIs in low-income countries		
Financial	Throughput	[61]
Efficiency	Distribution of plants and equipment [3] Average number of vessels Capacity utilisation	[61]
Time	Turnaround time Berth occupancy	[61]

[1] time interval between the last container delivered and vehicle departure. [2] percentage of multimodal shipments over total. [3] shows how much of the port area is utilised.

Similar to the global indicators, the financial and time aspects of dry port PIs have attracted a great deal of attention in low-income countries (Table 4).

3.1.2. Performance Indicators for Transport

Transportation provides vast and multi-dimensional services. Several studies have measured the performance of transport. For instance, Hanaoka and Kunadhamraks [21] measured the logistics performance of intermodal transport using the fuzzy AHP method. Lai et al. [62] developed a performance measurement system for measuring the performance of transport logistics that reflected the performance of shippers, transport logistics service providers and consignees. Stoilova et al. [63] used infrastructural, economic and technological criteria to assess the performance of railway transport. Šakalys et al. [64] identified the main indicators influencing synchro-modality and used multi-criteria to obtain the weightings of each indicator. Studies conducted in the area have focused on infrastructural service quality and its impact on the environmental aspects of transport performance [65]. Table 5 summarises the categories of these indicators.

Table 5. PIs for transport obtained from the literature.

Dimensions	PIs	Sources
Global PIs for transport		
Service quality	Travel time (dwell time, processing time, transit time)	[65,66]
	Travel time reliability	[65]
	Delay/out-of-date deliveries	[66–68]
	Safety	[65,66]
	Vehicle operating costs	[65]
	Accessibility	[65,66,68,69]
	Truck capacity	[65,66,68,69]
	Loss and damage frequency	[66–68]
	Accident	[66,68]
Financial	Transport costs	[66]
	Distance travelled per day	[66]
	Turnover per km	[66]
	Delivery frequency	[66]
	Profit per delivery	[66]
	Vehicle loading capacity utilised per journey/vehicle	[66]
	Infrastructure condition	[65]
Environmental	Congestion	[65]
	CO_2 emissions	[65]
Transport PIs in low income countries		
	Safety	[70]
	Infrastructure	[70,71]
	Vehicle condition	[71]

Transport PIs in low-income countries were also identified from the literature focusing on low-income countries. The studies on low-income countries focused mainly on safety, infrastructure and vehicle condition, as shown in Table 5.

3.1.3. Performance Indicators for Warehouses

Warehousing is the other value-adding activity in supply chain management that facilitates activities involved in the availability of inventory, customisation of products and consolidation [1]. A number of researchers have measured the performance of warehouses. For instance, Chen et al. [72] conducted case studies to identify the critical functions and operations involved in warehouse management and then used their findings to develop key performance indicators (KPIs) focusing on quality, accuracy, costs, security and timeliness of warehouse operations. Karim et al. [73] developed warehouse KPIs by focusing on the productivity dimension, while Kusrini et al. [74] identified warehouse KPIs by conducting a case study in a construction materials warehouse. The global PIs obtained from the literature for warehousing are presented in Table 6.

Table 6. PIs for warehousing obtained from the literature.

Dimension	PI	Source
Global PIs for warehousing		
Time	Timely shipping	[72,75]
	Lead time	[1,47]
	Loading/unloading time	[73,75,76]
	Warehouse location	[1,77]
Quality	Order accuracy	[72,75,76]
	Damage rate	[72,75,78]
	Delivery accuracy	[72]
Financial	Operational costs	[72,76]
	Storage space costs	[1]
	Shipping costs	[1]
	Labour costs	[1]
	Material handling equipment costs	[1,78]
Productivity	Inventory turnover	[73,79]
	Storage space utilisation	[72,73,78,79]
	Backorder rate	[75]
	Labour productivity	[73,79]
	Throughput	[73,76,79,80]
Warehouse PIs in low-income countries		
	Order lead time	[81]
	Inventory turnover ratio	[81]

Few studies have focused on identifying and evaluating warehouse PIs for low-income countries. The PIs obtained from the literature for warehousing are presented in Table 6.

The initial evaluation of the indicators by experts developed a suitable list of indicators at a regional level that are representative of local conditions [23]. Thus, taking into consideration the global indicators in the first part of Tables 4–6 and indicators focusing on low-income countries in the second part of Tables 4–6, a preliminary list of PIs depicted in Table 7 were presented to experts from government offices.

Responses from the experts showed that the given indicators were relevant for the evaluation of performance in dry ports, transportation and warehousing for the case of Ethiopia. Feedback, for example, on combining indicators representing similar aspects, was also provided and, based on this, transhipment time and cut-off time were combined to give the turnaround time as a dry port PI. Indicators that comprised economic aspects were put into financial PIs, as shown in Figure 3. Based on the perspectives of transport users, indicators such as number of trips per month were removed from the list. Finally, the PIs depicted in Figure 3 were analysed further.

Table 7. Preliminary list of PIs for the three sectors.

Dry Port PIs	Transport PIs	Warehouse PIs
Distance from commercial areas	Availability	Loading/unloading time
Transhipment time	Travel time	Inventory turnover rate
Transhipment costs	Travel costs	Damage rate
Cut-off time	Integration with other means of transport	Inventory carrying costs
Turnaround time	Frequency of accident	Order accuracy
Damage frequency	Security	Backorder rate
Loss frequency	Number of trips per month	Order lead time
Process utilisation rate	Truck capacity	On-time delivery rate
Environmental impacts		Total warehouse costs
Throughput		Accessibility from road
		Quantity error rate
		Stock accuracy
		Excess inventory rate

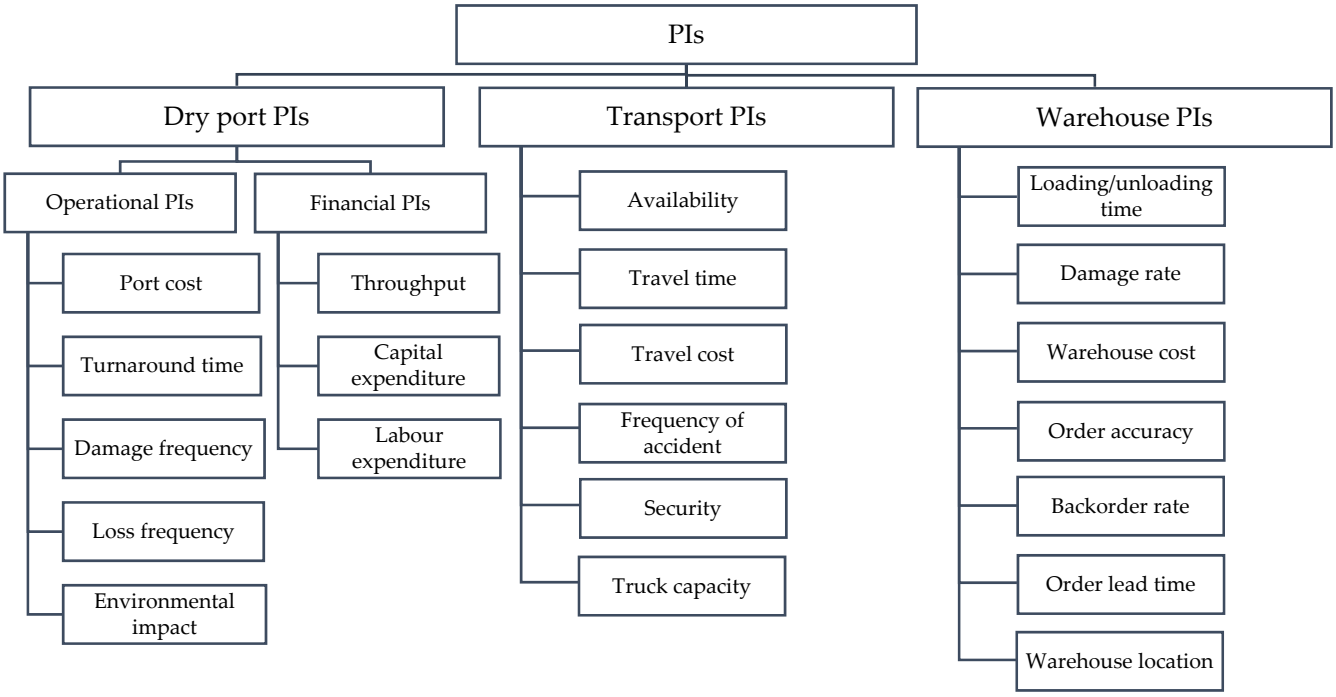

Figure 3. Final list of PIs presented to experts for pairwise comparisons.

3.2. Assessment of Weightings for Each PI

Following the identification of suitable indicators, the experts in the two categories of service providers and customers were asked to perform a pairwise comparison, based on a Likert scale, with values ranging from 1 to 9. The weightings of the PIs shown in Figure 3 were then assessed using the AHP method.

3.2.1. Dry Port PIs

The criteria for the PIs of dry ports were divided into two categories: operational port PIs and financial port PIs. Customers were asked to perform pairwise comparisons for the operational port PIs, while service providers were requested to perform pairwise comparisons for both the operational and financial port PIs.

Operational Dry Port PIs

To obtain the operational dry port PIs, customers (importers/exporters and freight forwarders) and service providers were asked to conduct pairwise comparisons. The results of

the pairwise comparison showed that customers gave the highest weighting to turnaround time, with a value of 30.4%. In contrast, service providers gave the highest weighting to damage frequency, with a value of 29.6%. Both customers and service providers gave the lowest weighting to environmental impact, with values of 14.4% and 10.4%, respectively (Figure 4). The CR obtained was 10% for the customers and 7% for service providers. Since the CRs were within the acceptable limits, the calculated weightings were accepted.

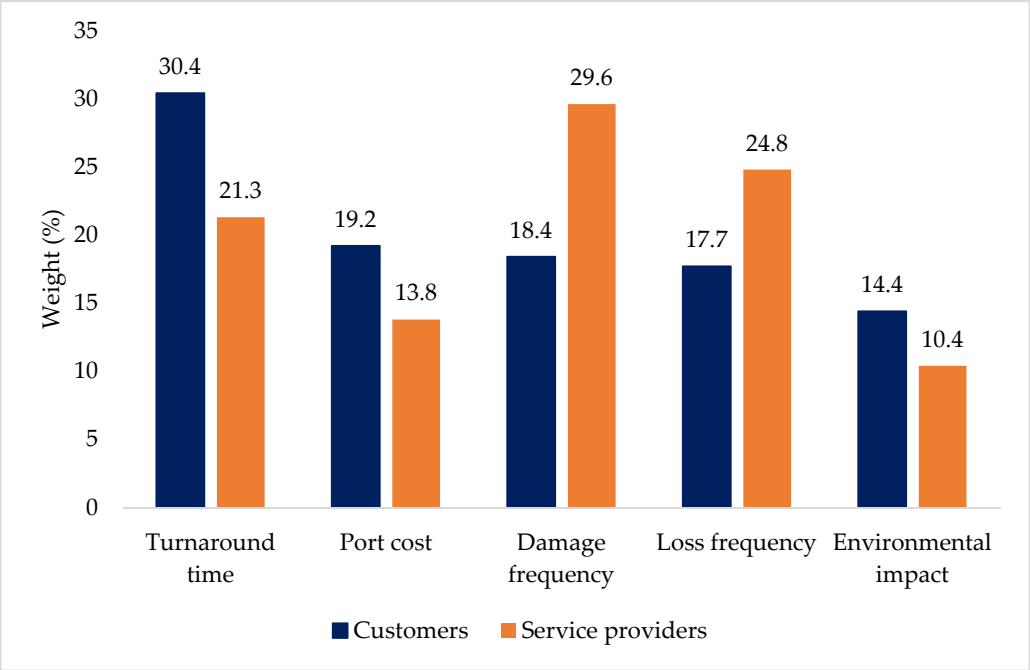

Figure 4. Weightings given by experts for operational dry port performance.

Financial Dry Port PIs

To obtain the weightings for dry port financial PIs, service providers were asked to conduct pairwise comparisons. They gave the highest weighting to capital expenditure per tonne of cargo (53.6%) and the lowest weighting to labour expenditure per tonne of cargo (15.9%) (Figure 5). The CR for financial dry port PIs was 0.2%, making the weightings obtained accepted, as they were within the acceptable range.

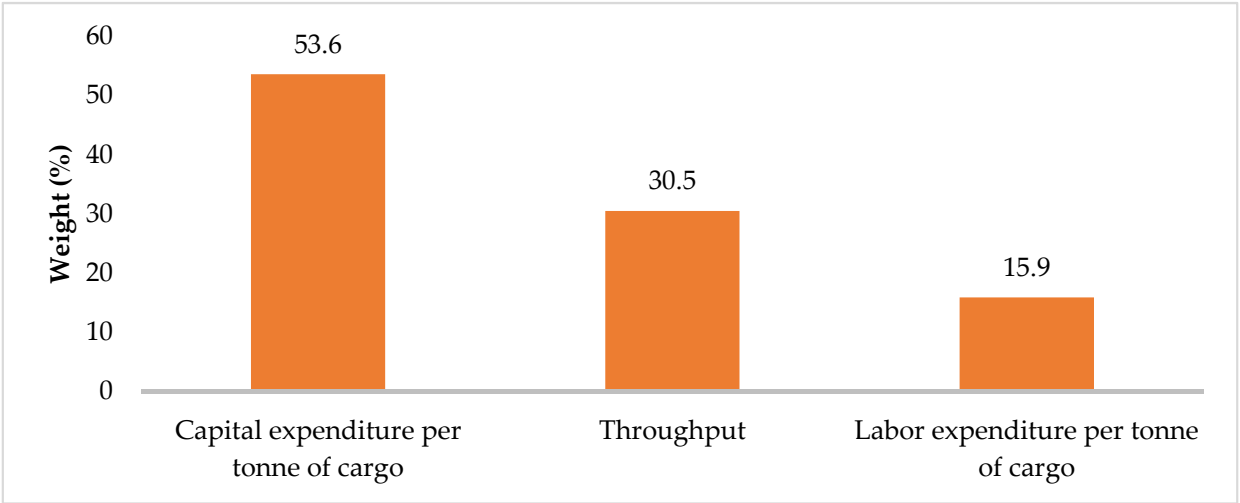

Figure 5. Weightings given by service providers for financial dry port performance.

3.2.2. Transport PIs

Customers of transport services in the import–export chain, including freight forwarders, importers and exporters, gave their opinion about the importance of each criterion. Accordingly, the experts gave the highest weighting to security (24.4%), followed by availability (20.5%). Frequency of accident was found to be the least important criterion, with a weighting of 11.6% (Figure 6). The CR obtained for transport PIs was 9.7%, resulting in the weightings being accepted.

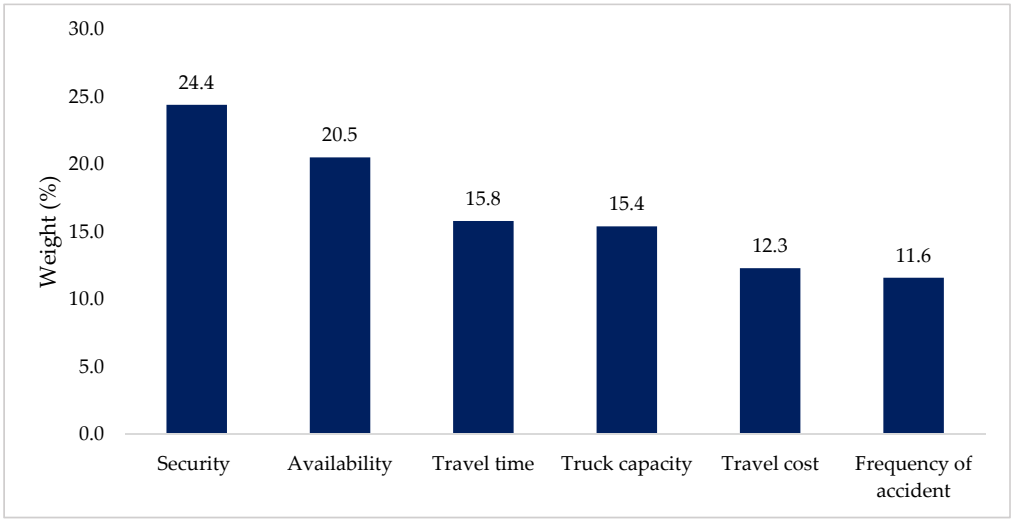

Figure 6. Weightings given by experts for transport performance.

3.2.3. Warehouse PIs

Importers and exporters conducted pairwise comparisons to obtain the weightings of warehouse PIs. The results of the AHP analysis showed that importers and exporters weighted order lead time as the most important criterion, at 24.3%, followed by order accuracy, with a weighting of 20.7%. The analysis also showed that the respondents gave the lowest weighting to damage rate, with a weighting of 8% (Figure 7). The CR obtained for warehouse PIs was 1.3%, resulting in the weights being accepted.

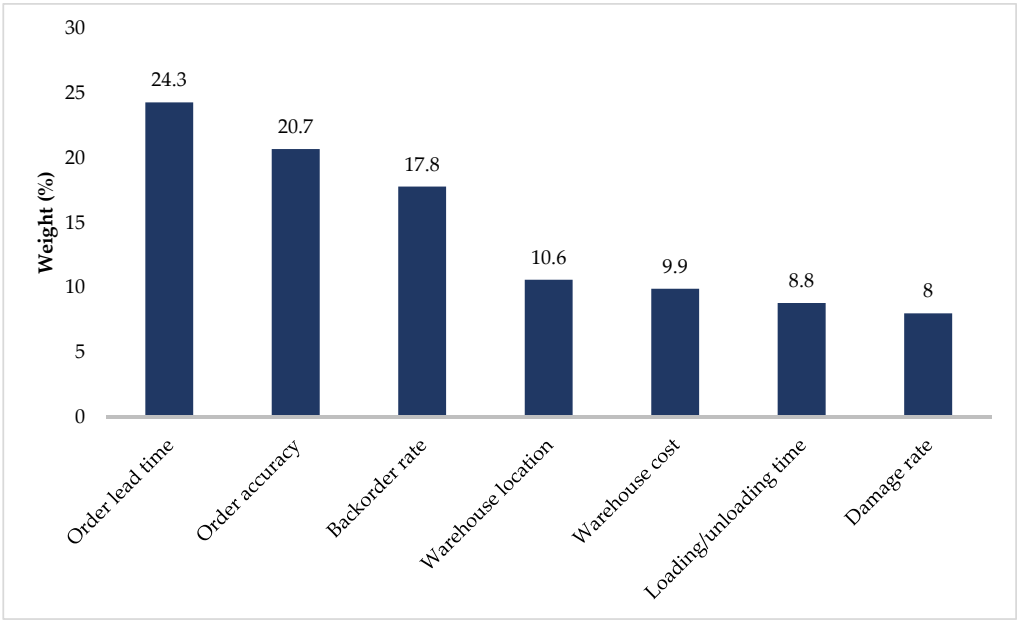

Figure 7. Weightings given by experts for warehouse performance.

3.3. Challenges in the Import–Export Sector

The import–export sector faces a number of challenges related to dry ports, transportation and warehouse management. In response to the question about the challenges faced in the elements of the import–export chain, the respondents' answers are summarised in Table 8.

Table 8. Main challenges faced in the import–export chain.

Activity	Main Challenges
Dry port	Inadequate technology implementation, long waiting times, lack of skilled staff, unfair/inconsistent tax, misplaced containers, corruption, high port fees, bureaucracy
Transport	Aged trucks, low truck availability, poor security, poor road infrastructure, lack of standardised tariffs, poor driver behaviour
Warehouse management	Inadequate technology implementation, lack of skilled staff, high rental costs, warehouse location, poor storage conditions

4. Discussion

4.1. PIs for Low-Income Countries

Results from the literature review showed that, in contrast to high-income countries, the literature focusing on low-income countries used dry port PIs that mainly consider financial aspects. This is likely because dry port services need to be sustained before there can be any focus on providing a quality service and, therefore, operations focus on financial performance. Dry port PIs related to service quality, human resources and their environmental impact are given less attention in low-income countries. This could possibly be because the system is still developing and the priority is on basic indicators.

The literature on transport performance showed that there is a great similarity in the indicators used for both high-income and low-income countries. The limited infrastructure in low-income countries has led to less emphasis being placed on interconnectivity and the traceability aspect of PIs. Indicators related to sustainability are lacking in the literature on low-income countries. This is something that needs attention given the large impact of the transport system on the environment.

For the warehouse PIs, the literature from high-income countries mainly focused on improving quality by reducing damage to the inventory. Furthermore, the literature also focused on improving the productivity of warehouses by increasing throughput and improving the utilisation of storage spaces. However, adequate literature covering the performance of warehouses in low-income countries is lacking. The available literature from low-income countries focused on order lead time and inventory turnover ratio.

4.2. Importance Level of the PIs

For dry port operations, customers from the expert survey gave the highest weighting to turnaround time, with a value of 30.4% (Figure 4). This shows that customers prefer to have their customs and clearance processes handled as soon as possible to avoid incurring high port fees due to the prolonged stay of their shipment in the dry port. A longer turnaround time also poses a risk for customers' importing/exporting time for sensitive or seasonal products. Turnaround time is a critical factor affecting logistics performance in landlocked countries, as outlined by Arvis et al. [82]. The timeliness of logistics service, which is in the World Bank's LPI, can be reflected by reduced turnaround times in ports.

Service providers gave the highest weighting to damage frequency, with a value of 29.6% for dry port operations (Figure 4). The amount of goods damaged or lost during port operations reflects the quality of service provided by the agencies. This is also a measure of the reliability of the service provided. Reliable services ensure predictability and certainty in the supply chain [18] and thus help improve customer satisfaction. This, in turn, likely results in more customers using the port services, thereby increasing the throughput in

the port. Hence, port operations in low-income countries should focus on improving the quality of their service to achieve greater reliability [46].

From the financial dry port PIs, service providers gave the highest weighting to capital expenditure per tonne of cargo, with a value of 53.6% (Figure 5). This shows that service providers want to reduce the expenditure that results from investing in port equipment. However, investing in technological advancements and increasing the number of cranes can improve the throughput in the port and increase the efficiency and profitability of the dry port. In contrast, labour expenditure per tonne of cargo was given the lowest weighting, implying that labour is readily available and not costly in port operations, especially in low-income countries.

For both customers and service providers, the environmental impact was given the lowest weighting, with values of 14.4% and 10.4%, respectively (Figure 4). Although there have been some initiatives in Ethiopia to reduce the impacts of climate change [83], the results of the survey showed that this issue has not gained much traction in dry port operations. This might be because the impact that dry port operations can have on the environment has not been well addressed and awareness of their consequences has not been raised. Instead, both customers and service providers are looking for options that boost their profit, mostly at the expense of the environment. Nath and Behera [84] state that low-income countries have fewer initiatives to combat climate impacts, and this is not a priority for governments in these countries. However, strong initiatives and policies should be in place to reduce the impact of climate change in low-income countries to create a sustainable environment. Additionally, seminars and training courses can be provided to learn how other more environmentally friendly ports are operated [20].

From the transport PIs, customers gave the highest weighting to security, with a weighting of 24.4% (Figure 6). The respondents also stated that one of the biggest challenges they face in the transport of containers from dry ports to warehouses is issues related to security. Security threats can arise in the import–export corridor due to political instability, theft and robbery. The issue with security is also a recurring problem in other low-income countries. For instance, it has hindered efficient port operations in Ghana [85]. Security threats due to political instability might cause loaded trucks to be stuck either in the dry port or along the corridor. This leads to delays in delivering products to end users, resulting in supply shortages. Furthermore, if the goods that are to be transported are time sensitive, such as food or medicine, then the products might be spoiled or expire due to poor storage conditions in trucks.

For warehouse management, importers/exporters gave the highest weighting to lead time, with a value of 24.3% (Figure 7). Lead times are generally longer for landlocked countries such as Ethiopia, where imported products have to cross borders and pass through long and bureaucratic customs clearance processes. This could explain the highest weighting given to lead time by importers/exporters. Furthermore, longer lead times also cause stock-outs due to unmet demands. Organisations in countries such as Ghana, Kenya, Uganda and Nigeria also have problems controlling and holding inventory [86]. In addition to improved customs services, lead times in low-income countries can be improved by having effective inventory management systems. Thus, schemes that can enable them to manage their inventories effectively and efficiently are recommended.

4.3. Challenges in the Import–Export Sector

The experts reported that they faced challenges such as long waiting times, high port fees and bureaucracy (Table 8). A survey of ESLSE customers conducted by Amentae and Gebresenbet [3] on the efficiency of services given by the service provider also showed that customers experienced cumbersome customs clearance processes and long waiting times. According to UN-OHRLLS [5], extensive documentation during customs and border clearance is an issue in other landlocked, less developed countries such as Botswana. Challenges faced by respondents, such as long waiting times, high port charges and bureaucracy in dry port operations, are captured by the identified PIs (Figure 4). Measurement and

evaluation of these PIs enables progressive improvement to be monitored in areas that present challenges. Interventions related to improvement of these indicators should be given priority, since, based on the survey results, customers gave these a high weighting. One type of intervention that can help in addressing the challenges and improve PIs is the adoption of technologies.

The experts also reported that there is a lack of skilled and professional staff (Table 8). According to the case study of Ansah et al. [85], issues related to shortages of skilled staff have been observed in Ghana's dry port operations. The lack of skilled staff hinders the smooth operation of dry ports, transportation and warehouses, leading to customers receiving a poor service, and delays and inefficiencies in how they are run. To address this issue, training courses and capacity-building programmes should be provided for employees so that they can become more competent at their jobs. There are different alternatives to carry out training and capacity building. One way is by formulating collaboration with higher education institutions. Applying for funding in interested organisations is another way of financing budgets. For big organisations, allocating a specific budget for capacity building is also an alternative. Government policies should also address issues associated with human capital [10]. In addition, the challenges related to skilled staff performance in dry port, transportation and warehouse operations are not included in the identified PIs. Few studies have considered employee performance as an indicator. Therefore, indicators focusing on the performance of human resources, including those working in dry port operations, as truck drivers and in warehouse operations, should be formulated.

The other challenge the experts mentioned was poor technological advancements in port operations (Table 8). They also stated that they experienced delays in receiving services due to poor network or system failures. Poor network availability is a recurring issue in other low-income countries as well, resulting in inefficiencies during port operation [87]. Although advances in information technology can improve information flow and facilitate customs clearance, a low level of technology implementation is an issue in other dry ports, such as in Ghana [85]. UN-OHRLLS [5] also state that landlocked, less developed countries face challenges related to technological advances in their ports. The report states that drawbacks for most landlocked countries in relation to the adoption and implementation of information technologies are related to accessibility, affordability and skills.

Improvement in government policies can help reduce the high documentation requirements for import and export. According to the interview with the experts, the Ethiopian government has commenced the implementation of a single-window service. This service facilities the submission of documents and information required for import/export through a single entry point, thereby reducing delays, facilitating clearances and improving transparency [87]. Trade portals are implemented in dry ports for customs declaration and verification [88], yet the integration with customers and other actors is low because of their lack of use of digital technologies. By providing visibility and control over goods in ports, tracking technologies such as RFID ensure the safety of goods [11]. Automation of equipment in ports results in low environmental impacts, short turnaround times and high equipment utilisation, and increases throughput and port accessibility [7–9]. Smart ports are the next emerging technologies with minimal human involvement in carrying out tasks, thus ensuring accurate and rapid port operations. To guarantee the effectiveness of these technologies, PIs measuring the implementation of technologies should also be in place. This enables an audit of the technologies addressing the challenges faced in the sector.

A commonly observed challenge during the transportation of containers from dry ports to warehouses is the extensive use of aged trucks (Table 8). Freight transportation services in Ethiopia are marked by a prevalence of aged trucks and lack of traceability [28]. According to Kine et al. [89], the use of aged trucks is a common problem in other low-income countries as well. They are not only a cause of traffic accidents along the route, but also a huge contributor to the emission of pollutants to the environment. Furthermore, drivers of these trucks are mostly inexperienced, making them a threat not only to the security of the goods being transported, but also to other road users. Thus, to counteract

the risk posed to the environment and society by aged trucks and incompetent drivers, fleet modernisation is important. Fleet modernsation could occur by implementing technologies on the existing trucks or replacing the aged trucks with new ones. The cost of replacing aged trucks is not cost intensive, as the cost of buying new trucks is compensated by avoiding the huge cost encountered in maintaining and running old trucks. In addition, government intervention could be crucial, as government policies could allow the use of aged trucks to be limited and regulate the minimum number of years' experience required by drivers before they are able to drive heavy trucks.

The experts also stated that they faced challenges in finding trucks that can transport their containers from the dry port to warehouses, particularly during peak seasons (Table 8). This explains the high weighting given by the experts to availability when conducting the pairwise comparisons (Figure 6). Using ICT solutions, transport choice and goods movement become less costly and more efficient [12]. Using virtual clustering in transportation, logistic companies choose less costly transport services and at the same time reduce their environmental impact by increasing the load factor [13]. Behrends et al. [90] discuss how installing telematics in railways can improve their share of use by increasing responsiveness, reliability and wagon efficiency. Hence, implementation of truck telematics and other ICT solutions can alleviate the challenges faced by experts in relation to truck availability. The cost for the implementation of telematics for trucks and other ICT solutions depends on the degree of implementation of the technologies. The government could subsidise some of the encountered costs to promote technology implementation. The cost also depends on a number of factors, including type of truck, specific solutions required, type and amount of data that needs to be collected and installations of tools.

In terms of warehouse management, the experts stated that there were few or no technologies in place for handling and/or managing inventory (Table 8). Warehouse operations lack integration with selling points and visibility, and are highly reliable on manpower [29,30]. This causes damage to goods during loading/unloading and loss of inventory due to theft, as there are few or no means for tracking inventories. Digital technologies make management of warehouses and inventories efficient. The use of digital technologies significantly reduces loading time, costs and damage rates in warehouses [14,15].

To improve the performance of dry ports, warehousing and transportation, technology adoption plays a vital role. However, the adoption of new technologies, particularly in low-income countries, is dependent on the economic advantages of the technologies, the presence of necessary infrastructure and the affordability of the technologies [43]. Thus, detailed studies regarding the technologies and ways on how to implement them is important.

5. Conclusions

This study developed PIs for dry ports, transportation and warehouse operations, and the importance of these indicators were weighted. The results of the study show that customers in the expert survey considered time-related PIs such as turnaround time important for dry port operations and order lead time important for warehouse activities. For transportation, customers considered security and availability as the most important PIs. Service providers considered damage frequency as the most important PI. The survey results also show that both customers and service providers gave a low weighting for environmental impact.

The PIs identified in this study could be adopted by other low-income countries to improve the performance of their dry port operation, transportation and warehouse management by taking local conditions into account. Moreover, the approach and methodology used to obtain the PIs in this paper could be used by other low-income countries to assess areas of logistics activities that require improvement.

The study showed that the logistics-related challenges faced in the import–export chain included high costs, low utilisation level of digital technologies, scarcity of skilled and professional workforce, aged trucks and the lack of integrated systems. To address these

challenges, implementation of digitalisation and automation technologies, together with appropriate policy, could be recommended. These technologies could improve the performance of dry ports, transportation and warehouse management by increasing throughput, improving accessibility, boosting efficiency, lowering costs and reducing damage and losses. In addition to technological interventions, capacity-building programmes are recommended to develop skilled workers to make services efficient. The public institutions could play an important role in improving logistics services by making systems more transparent, better coordinated and less bureaucratic.

Although this study developed and weighted the performance indicators of dry ports, transportation and warehousing, seaports are also seen as a critical part of the import–export chain. Thus, further research studies could be recommended for the seaports. Furthermore, measuring the impact of the performance of dry ports, transportation and warehouse operations on supply chains and the required improvement of performance from the perspective of low-income countries could be recommended.

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Appendix A. The First Round Questionnaire Deployed in the Study

Appendix A.1. Introduction

The purpose of this survey is to identify key logistic performance indicators in the import–export chain of Ethiopia. For this, logistics performance indicators for the main import–export components, including dry ports, transport and warehouses, are collected from the literature and presented. Please provide your responses for the following questions.

Appendix A.2. General Information

a. What is the name of the company?

_____

b. What is your position in the company?

_____

c. What is your education level?

_____

d. How many years of experience do you have?

_____

Appendix A.3. Dry Port

The table below shows the performance indicators of dry ports that are found from the literature. The indicators suitable for low-income countries are selected and presented here. Please rate the relevance of the performance indicators to measure dry port performance in Ethiopia.

Table A1. Dry port PIs.

Performance Indicators	Not Important	Important
Distance from commercial areas		
Transhipment time		
Transhipment costs		
Cut-off time		
Turnaround time		
Damage frequency		
Loss frequency		
Process utilisation rate		
Environmental impacts		
Throughput		

a. Are there any dry port performance indicators other than the ones mentioned above?

_____

b. If your response to part a is yes, please provide the indicators in the space provided below.

_____

c. Do you perform performance evaluation in your company?

_____

d. What performance indicators do you implement in your company (can be from the list above or any different indicators?)

_____

Appendix A.4. Transport

The following table shows the performance indicators of transport that are gathered from the literature. The indicators suitable to low-income countries are selected and presented here. Please rate the relevance of the performance indicators to measure transport performance in Ethiopia.

Table A2. Transport PIs.

Performance Indicators	Not Important	Important
Availability		
Travel time		
Travel costs		
Integration with other means of transport		
Frequency of accident		
Security		
Number of trips per month		
Truck capacity		

a. Are there any transport performance indicators other than the ones mentioned above?

_____

b. If your response to part a is yes, please provide the indicators in the space provided below.

_____

c. Do you perform performance evaluation in your company?

_____

d. If yes, what performance indicators do you implement in your company (can be from the list above or any different indicators?)

_____

Appendix A.5. Warehouse

The following table shows the performance indicators of warehouses that are gathered from the literature. The indicators suitable to low-income countries are selected and presented here. Please rate the relevance of the performance indicators to measure warehouse performance in Ethiopia.

Table A3. Warehouse PIs.

Performance Indicators	Not Important	Important
Loading/unloading time		
Inventory turnover rate		
Damage rate		
Inventory carrying costs		
Order accuracy		
Backorder rate		
Order lead time		
On-time delivery rate		
Total warehouse costs		
Accessibility from road		
Quantity error rate		
Stock accuracy		
Excess inventory rate		

a. Are there any warehouse performance indicators other than the ones mentioned above?

_____

b. If your response to part a is yes, please provide the indicators in the space provided below.

_____

_____

c. Do you perform performance evaluation in your company?

_____

d. What performance indicators do you implement in your company (can be from the list above or any different indicators?)

_____

_____

Appendix B. The Second Round Questionnaire Deployed in the Study

Appendix B.1. Introduction

The research aims to develop logistics and supply chain management performance indicators for low-income countries, focusing on the export and import chain.

Accordingly, a multi-criteria decision framework is used in this questionnaire to identify the key performance indicators where a set of factors is given to you, and you rate the relative importance of each factor compared to its corresponding alternative. The relative importance is measured on a scale of 1 to 9. The meaning of each number value can be found in Table A4 below.

Table A4. Legend for performance indicator rating numbers.

Importance Scale	Definition of Importance Scale
1	Equally important preferred
2	Equally to moderately important preferred
3	Moderately important preferred
4	Moderately to strongly important preferred
5	Strongly important preferred
6	Strongly to very strongly important preferred
7	Very strongly important preferred
8	Very strongly to extremely important preferred
9	Extremely important preferred

Appendix B.2. Respondent's Information

a. What is the name of the company?

_____

b. What is your position in the company?

_____

c. What is your education level?

_____

d. How many years of experience do you have?

_____

e. Do you own a truck? If yes, how many

_____

f. Do you own a warehouse? If yes, how many?

_____

Appendix B.3. Performance Indicators of Dry Ports

The following performance indicators are related to the dry port performance. Please rate the relative importance of each performance indicators in the row to the performance indicators along the column on a scale of 1 to 9. Please find the meaning of each number value in Table A4.

1. Operational Performance Indicators

Table A5. Pairwise comparisons for operational dry port PIs.

Factors	Turnaround Time	Port Cost	Damage Frequency	Loss Frequency	Environmental Impact
Turnaround time					
Port cost					
Damage frequency					
Loss frequency					
Environmental impact					

2. Financial Performance Indicators

Table A6. Pairwise comparisons for financial dry port PIs.

Factors	Capital Expenditure Per Tonne of Cargo	Throughput	Labour Expenditure Per Tonne of Cargo
Capital expenditure per tonne of cargo			
Throughput			
Labour expenditure per tonne of cargo			

a. What are the main challenges you face in port operations?

_____

b. Are there any forms of digitisation or automation implemented in your company?

_____

If yes, please list them?

_____

Appendix B.4. Performance Indicators for Transport Services

The following performance indicators are related to transport performance. Please rate the relative importance of each performance indicator in the row to the performance indicators along the column on a scale of 1 to 9. Please find the meaning of each number value in Table A4.

Table A7. Pairwise comparisons for transport PIs.

Factors	Security	Availability	Travel Time	Truck Capacity	Travel Cost	Frequency of Accident
Security						
Availability						
Travel time						
Truck capacity						
Travel cost						
Frequency of accidents						

a. What are the main challenges you face in transport operations?

_____

b. Are there any forms of digitisation or automation implemented in your company?

_____

If yes, please list them?

_____

Appendix B.5. Performance Indicators for Warehousing

The following performance indicators are related to warehouse performance. Please rate the relative importance of each performance indicator in the row to the performance indicators along the column on a scale of 1 to 9. Please find the meaning of each number value in Table A4.

Table A8. Pairwise comparisons for warehousing PIs.

Factors	Order Lead Time	Order Accuracy	Backorder Rate	Warehouse Location	Total Warehouse Cost	Loading/Unloading Time	Damage Rate
Order lead time							
Order accuracy							
Backorder rate							
Warehouse location							
Total warehouse cost							
Loading/unloading time							
Damage rate							

a. What are the main challenges you face in warehouse operations?

_____

b. Are there any forms of digitisation or automation implemented in your company?

_____

If yes, please list them?

_____

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