LEX LOCALIS-JOURNAL OF LOCAL SELF-GOVERNMENT
ISSN:1581-5374 E-ISSN:1855-363X
VOL. 23, NO. 11(2025)

# LOGISTICS DEVELOPMENT AND ECONOMIC GROWTH NEXUS: EVIDENCE FROM A WEST AFRICAN LANDLOCKED COUNTRY (MALI)

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**Abstract**
Landlocked economies encounter unique logistical challenges that influence their growth and competitiveness. This research investigates the interrelation between logistics development and economic growth in Mali, a landlocked nation in West Africa, by evaluating the contributions of transport infrastructure, information technology, logistics expertise, governance and bilateral partnerships in enhancing national logistics performance and regional economic results. Primary data were collected through an online questionnaire administered to 250 stakeholders across transport, trade and policy sectors using purposive and snowball sampling. Constructs were validated through exploratory and confirmatory factor analysis, with some weaker items removed during CFA to ensure model reliability. Structural equation modeling with SPSS and AMOS confirmed strong reliability (Cronbach's alpha 0.82–0.93) and validity (CR > 0.70; AVE > 0.50). Results reveal that transport modes and infrastructure, IT integration, and logistics skills exert significant positive effects on both logistics performance and regional economic growth, while governance and bilateral partnerships further enhance import/export flows and regional exchanges. However, the analysis also highlights persistent challenges unique to Mali, including inadequate infrastructure, shortages of skilled labor, high transit costs, customs inefficiencies, political instability, and the impact of economic sanctions. Overall, the findings underscore that targeted investment in multimodal infrastructure, ICT integration, and professional capacity-building supported by effective governance and partnerships is vital to strengthening logistics efficiency and fostering sustainable growth in Mali. The study contributes to the literature on logistics in landlocked economies and provides actionable insights for policymakers, practitioners, and development partners.

**Keywords:** Logistics Development; Economic Growth; Structural Equation Modeling; Landlocked Countries; Transport Infrastructure; Information Technology; Mali; Regional Competitiveness

## 1. Introduction

Landlocked nations face notable structural hurdles that inflate transport and logistics costs, primarily due to geographical isolation, insufficient infrastructure, and crippling transit delays. By definition, such a country confronts a dual economic challenge: lacking direct access to open seas, it must first optimize the cost of access through transit neighbors before it can fully pursue national development (Chakroborty, 2022a). Like many in sub-Saharan Africa, a country such as Mali perfectly exemplifies this dilemma, perpetually balancing the need to secure reliable coastal access with the simultaneous necessity of building a resilient economy[1]. In light of the intense competition in global trade and its repercussions on a nation, coupled with the disparities between developed and developing landlocked countries, as well as the high demands from customers; there is a pressing need for significant technological innovation and the formulation of strategic solutions that can foster logistics advancement and regional economic growth, thereby generating jobs and business opportunities (Kuteyi & Winkler, 2022). However, when discussing strategic solutions, this paper highlights the necessity of establishing a robust and stable logistics industry

[1] SAHEL HUMAN DEVELOPMENT REPORT 2023 | United Nations Development Programme

capable of providing optimized solutions for regional economic growth through elements such as IT integration, governance, bilateral and multilateral cooperation, transport and logistics infrastructure, and skilled labor. Mali, with its area of 1,241,238 square kilometers, is not only predominantly (two-thirds of the territory) desert-covered but also geographically disadvantaged (Izteleuova et al., 2024). Like other West African nations, Mali grapples with numerous challenges, including inadequate transport infrastructure, cumbersome transit and trade procedures, a shortage of qualified logistics professionals, security concerns, and political issues, among others. Although the government of Mali has constructed warehouses in all its transit countries (Senegal, Côte d'Ivoire, Guinea Conakry, Togo, Benin, Ghana, Mauritania) to reduce transit delays, further efforts must be directed towards addressing storage costs, types of storage, and customs procedures (Okorefe C. et al., 2024). Unlike countries like China, Japan or Germany, Mali lacks behind when it comes to develop comprehensive transportation infrastructures (Gorgulu et al., 2023). With its few rail links and high number of airports, roadways remain the main transport mode if not the only available and cost-effective choice to carry goods/passengers in and outside of the country.
The Bamako-Dakar Railway link, which has been disrupted since 2015 and was restored in 2022, plays a significant role in facilitating the exchange of passengers and cargo. Several factors contribute to this disruption, including the willingness and awareness of the authorities in Senegal and Mali regarding the impact of transport infrastructure on economic growth, insufficient investment in the transport sector, a shortage of skilled operators, inadequate infrastructure, and the maintenance of rail blocks and tracks (Byiers & Karkare, 2022). To exemplify the issues related to poor infrastructure, it is noteworthy that just months after its restoration, a cargo train derailed due to outdated tracks. Understanding the logistics and transport industry and its potential impact on regional economic growth is essential for both decision-makers and the general public. One of the challenges faced by landlocked developing countries is the need to define logistics development for governments, job seekers, and business owners (Okunsanya & Azmat, 2025). In contrast to developed nations, the logistics sector in the three landlocked countries Mali, Burkina Faso, and Niger is still in its early stages, with logistics operations often managed by individuals who lack formal training in logistics or transport (Shibuya et al., 2023). Many of these individuals possess only a bachelor's or master's degree, and it is rare to find a professional logistician with a Ph.D. in logistics within these countries. This scarcity is attributed to the limited research conducted in the field concerning landlocked developing nations, as well as the absence of research institutes offering logistics programs and the underappreciation of its socio-economic value for job and business opportunities (Hutomo & Hamami, 2020). Meanwhile, the few scholars and experts in logistics and transport who recognize the importance of logistics development at both the microeconomic and macroeconomic levels tend to promote their findings through webinars and conferences, highlighting related opportunities for more skilled labor.
Logistics plays a crucial role in enhancing the economic growth and development of a nation, particularly for landlocked countries. There exists a relationship characterized by complementarity and interactivity, rather than mutual exclusivity, between logistics and economic development (Katı et al., 2022). The evolution of the logistics sector is driven by the demand for economic growth, and conversely, economic development necessitates a sophisticated logistics industry, which is a product of substantial investment in infrastructure (Li et al., 2025). By examining the impact of logistics development on the economic growth of countries such as Japan, the United States, and China, we can forecast the potential for landlocked nations like Mali, provided there is a concerted effort to construct, monitor, and integrate adequate logistics infrastructures, including

railways, roadways, dry ports, and distribution centers, which can enhance both internal and external commercial exchanges for global and regional markets (Programme & Countries, 2024). Moreover, to emphasize the significance of logistics in fostering economic growth in developing nations, one might reflect on the recent political upheavals (military coups) across the continent, particularly in Mali, Guinea Conakry, Niger, and Burkina Faso, which have led to severe economic setbacks due to various sanctions imposed by the ECOWAS community (Akinola & Makombe, 2025). To mitigate the economic losses faced by these nations and to diversify their import/export channels, the Kingdom of Morocco has reached a mutual agreement with the three West African landlocked countries (Mali, Niger, Burkina Faso) to facilitate access to global markets through its maritime gateways. Nevertheless, it has been stressed that the establishment of efficient transport and logistics infrastructures capable of promoting business exchanges (cargo transport) between these countries and Morocco is of utmost urgency (Sénquiz-DÍaz, 2021). Likewise, the presence of NGOs and the high import rate, just like the 14 landlocked countries in Africa, give no choice for authorities to develop logistics sector, transportation infrastructures and IT integration. Although the roles vary in mutual enhancement, the support from the international community and the necessity to bridge the divide between industrialized nations and landlocked developing countries through economically viable logistics alternatives (such as policy implementation, infrastructure construction and maintenance, labor training, and transit/trade facilitation) are crucial. Consequently, to examine and comprehend how logistics and associated factors can influence economic growth while impacting the development of a landlocked nation, this study will concentrate on the case of Mali, a country in West Africa. In light of the previously mentioned observations and the assumptions related to the research topic, we recognize the importance of addressing the following inquiries: (1) How do economic growth and logistics development interact with one another? (2) What are the primary factors influencing the logistics industry's development in landlocked countries? (3) What challenges and sector-specific solutions pertain to logistics development and economic growth?

## 2. Literature review

Landlocked economies often find themselves on the economic periphery, primarily because almost 90% of global trade volume moves via the sea, hindering their access to international markets. While regional ocean access still holds significant value (Chakroborty, 2022b), it’s the exorbitantly high transport costs and deep reliance on the unstable infrastructure of transit nations that truly prevent landlocked regions from leveraging global trade opportunities. Stemming from this geographical and infrastructural predicament, this research is singularly focused on dissecting the cost and development hurdles that profoundly shape the economy and logistics sector of West African landlocked nations (Takele & Tveter, 2025). It thoroughly investigates every potential factor associated with logistics development and the regional economy while taking into account the challenges and trends faced by landlocked countries. The paper discusses logistical issues such as a shortage of skilled labor, political instability, inadequate IT systems, and transport logistics infrastructure; it proposes policy-oriented alternatives and specific regulations robust enough to enhance and maintain the positive relationship between economic growth and logistics development. However, before engaging in any discussion, it is essential to understand the definitions of logistics, a landlocked country, and their connection to economic growth. Obtaining an appropriate definition of logistics can be quite challenging, as it varies based on the domain and purpose for which it is utilized. Logistics serves as a pivotal factor or opportunity cost, as the

success or failure of a strategy hinges on the quality of service and the costs it incurs. However, from Greek (logisteuo meaning to administer), logistics as subjectively defined by the military institution is the combination of two crucial factors (time and space) in managing flows needed to win a battle (Samal, 2019). From the army rules, logistics is the set of activities aiming to provide food[2], weapons, and vehicles to the right place at the right time with the right quantity and quality while, on the other hand, to assure the health of staff, it is about the maintenance of materials. Cade in 1971, considering logistics liabilities, the army defines logistics today as activities that aim at supplying means of transport, food, and related supplies during peace and war on the right time at the right place while ensuring the availability of facilities and healthcare for staff (Cade, 1971).

### 2.1 Transport infrastructure

According to the international organization, countries are considered equal in terms of economic growth, regardless of whether they are landlocked or not (Ngartori & Paughss, 2024). In 2016, Commonwealth indicated that landlocked developing nations rank among the poorest globally. A landlocked nation is defined as one that lacks a coastline on open seas, unlike its coastal counterparts, or freshwater bodies that are crucial for engaging in global trade (Commonwealth Secretariat, 2016). While the distance to the coast is significant, the actual length of the coastline is not. Consequently, regions such as southern Sudan, the Democratic Republic of the Congo, the Seven Sisters, and the Northern States of India (situated between Bangladesh, China, and Burma) are considered nearly or internally landlocked due to the considerable distance between major urban centers and the ocean (Transport, 2011). These countries have found it more advantageous to import and export via neighboring transit land routes to reduce transportation costs. This leads us to two conclusions: firstly, Mali, which is one of the 15 landlocked countries in Sub-Saharan Africa, can be regarded as nearly or internally landlocked due to its distance from the nearest coastlines. Secondly, if a country's primary market becomes its transit links, the costs associated with isolation are diminished, as it is a well-known fact that landlocked nations incur substantial expenses due to their remoteness from coastlines (Kobina & Domfeh, 2017).

### 2.2 Information technology integration

According to a study on third-party logistics, the primary challenge within the logistics industry is the integration of technological innovations while adhering to an optimized budget. This paper identifies ICT as one of the eight key challenges confronting the logistics sector. The significance of ICT innovation and integration is underscored by its potential to save time and costs, thereby enhancing profitability and delivering high-quality services. However, it is important to recognize that such innovations are sensitive to costs, particularly in regions that lack adequate transport, internet, and communication facilities (Olalere, 2019). While IT serves as a supportive function to logistics, its impact is substantial. A prime example of IT integration in logistics operations is the online customs clearance and GPS-based container tracking. In landlocked nations, the development of IT systems is often inadequate, which hampers the seamless exchange of information, diminishes financial oversight (leading to corruption), and delays document processing.

### 2.3 Challenges

Considering above mentioned challenges and gaps, this paper is going to suggest several alternatives, and potential solutions for landlocked countries. By collecting and analyzing data, this paper is adding more into the scientific work/value related to logistics development in

[2](Sun Tsu, 1990) considered logistics as supplies, while for Alexander the Great and Paul Virilio, it is the freedom of movement. The three authors agreed that logistics power is necessary if not vital in the success of an army.

landlocked African countries. Moreover, it gives updated data that is socioeconomically valuable for funding and foreign direct investment. On top of that, through up-to-date data provided by this paper, further research on landlocked countries can continue. Rather than increasing the awareness of socioeconomic value, the paper offers optimized alternatives when it comes to building, maintaining, and enhancing transport links. Building transport and IT infrastructures, leveraging on IT integration, keeping up long and good bilateral partnerships need strong and stable policies which are broadly and carefully available in this paper.

## 3. Hypothesis development

Rigorous hypothesis development is fundamental for advancing logistics theory and ensuring credible empirical testing (Qureshi et al., 2024). This study conceptualizes how logistics can shape regional development and economic growth in landlocked countries, with a focus on Mali. Using Structural Equation Modeling (SEM) in SPSS/AMOS 26, the research tests the reliability and validity of measurement constructs and evaluates both direct and indirect relationships among key factors. The proposed hypotheses, derived from theory and prior evidence, address critical determinants of national logistics performance (NLP) and regional economic growth (REG).

### 3.1 Logistics Skills

Logistics skills encompass the necessary competencies for overseeing intricate logistics operations, which include communication and IT expertise, as well as transport, warehousing, and customs management. The industry is currently experiencing a worldwide deficit of qualified professionals, with 30% of 39,000 employers across 33 nations indicating challenges in hiring skilled logisticians (McKinnon et al., 2017).

⇒ H1a: Logistics skills are positively related to National Logistics Performance.
⇒ H1b: Logistics skills are positively related to Regional Economic Growth.

### 3.2 Information Technology Infrastructure and Integration

Digital transformation is a game-changer for logistics, enhancing flexibility, efficiency, and service quality. While prior research often focuses on firm-level digitalization, national-level integration remains underexplored. Indicators such as the EU's Digital Economy and Society Index (DESI) and the World Bank's Logistics Performance Index (LPI) show that IT infrastructure improves logistics performance (Kern, 2021). In Mali, entrepreneurs increasingly use social platforms (e.g., TikTok, WhatsApp, Facebook) to expand business exchanges.

H2a: IT infrastructure and integration are positively related to National Logistics Performance.
⇒ H2b: IT infrastructure and integration are positively related to Regional Economic Growth.

### 3.3 Logistics Infrastructure

Infrastructure including roads, railways, ports, airports, and communication networks forms the backbone of logistics systems. Its availability and quality directly influence trade efficiency, business exchanges, and socio-economic development (Liu, 2024). For landlocked countries, poor or absent infrastructure exacerbates geographic isolation, as seen in Mali's limited access to regional ports despite geographic proximity. Disruptions such as the Dakar–Bamako railway breakdown highlight the vulnerability of regional trade to weak infrastructure. Hence:

⇒ H3a: Logistics infrastructure is positively related to National Logistics Performance.
⇒ H3b: Logistics infrastructure is positively related to Regional Economic Growth.

### 3.4 Government Policy for Logistics Promotion

Effective governance and policies are essential for reducing logistics costs, enabling fair market practices, and improving competitiveness. International agreements, such as Article V of the General Agreement on Tariffs and Trade, provide transit rights for landlocked states, but effective implementation depends on political will. Case studies from South Korea and Vietnam show how targeted policies, subsidies, and trade agreements can strengthen logistics networks and boost growth (Oluwatosin Esther Ajewumi et al., 2024). For Mali, supportive governance is critical to overcoming structural disadvantages. Therefore:

⇒ H4a: Government policy for logistics promotion positively influences National Logistics Performance.

⇒ H4b: Government policy for logistics promotion positively influences Regional Economic Growth.

### 3.5 Import/Export and Global Trade Partnerships

Trade balance and external partnerships shape the competitiveness of landlocked economies. While export-led growth drives development in countries like China, Mali's dependence on imports due to weak manufacturing and infrastructure limits its growth potential.

⇒ H5a: Import/Export and Global Trade Partnerships positively affect National Logistics Performance.

⇒ H5b: Import/Export and Global Trade Partnerships positively affect Regional Economic Growth.

### 3.6 Transport Modes and Infrastructure

Transport networks are critical for market access and economic activity. In developing economies, reliance on underfunded road transport creates inefficiencies, whereas investment in multimodal infrastructure reduces costs, improves mobility, and supports growth. For Mali, such investment is vital to overcome geographic constraints.

⇒ H6a: Transport modes and infrastructure positively affect National Logistics Performance.

⇒ H6b: Transport modes and infrastructure positively affect Regional Economic Growth.

## 4. Research Methodology

This research is framed by the unique geographical and economic realities of Mali, a landlocked country in West Africa. As one of the fifteen landlocked nations on the continent, Mali faces considerable logistical challenges that hinder its socio-economic development. Few studies have systematically examined how logistics can serve as a driver of growth in such contexts, making this investigation both timely and relevant. The study seeks to provide a clear understanding of logistics development in Mali by comparing it with practices in more advanced economies, while also highlighting sustainable alternatives that can address pressing development needs. Particular attention is given to logistics skills, transport infrastructure, and the integration of information technologies, which are considered critical capabilities for improving logistics performance.

A distinctive aspect of this research lies in its emphasis on decision-making in a landlocked environment. Mali's dependence on surrounding ports, the need for effective inter-regional linkages, and the role of distribution centers are considered alongside external constraints such as political instability, security concerns, and the country's fragile economic environment. To ensure rigorous theory testing and robust empirical validation, the study adopts an advanced analytical approach. Structural Equation Modeling (SEM) using SPSS and AMOS 26 is employed to assess construct reliability, test validity, and evaluate hypothesized relationships, thereby providing a

comprehensive framework for examining the nexus between logistics development and economic growth.

**4.1 Data Collection**

To provide context for this research and due to the inability to conduct face-to-face interviews, a survey methodology utilizing both primary and secondary sources through a mixed methods approach (qualitative and quantitative) has been implemented. A purposive sampling method (specific types of participants required) and snowball sampling (locating participants through referrals) have been employed to engage with participants. The sample primarily consisted of scholars, practitioners, professors, and beneficiaries (users, traders, shippers, customers) within the logistics and transport sectors. Given that logistics is a time-sensitive industry, sending three to four follow-up messages during specific periods (such as national holidays or Muslim feasts) proved beneficial and enhanced the response rate. The risk of nonresponse bias has been considerably mitigated by the methodology applied. In light of the research topic and the area of focus, a descriptive and exploratory approach has been adopted to address the questions of (how, when, what, and where) and to explore alternative options while concurrently evaluating historical trends and existing knowledge. Additionally, data has been collected from government censuses and international organizations (such as the World Bank and the African Development Bank) regarding socio-economic factors and developments in logistics and transport. Furthermore, an online questionnaire (initially in French and subsequently in English) along with follow-up messages via WhatsApp and email facilitated the collection of 250 valuable responses, from which optimized and effective analyses could be conducted. Moreover, through careful and thorough proofreading, insights and best practices have been gleaned from case studies and well-documented notes derived from books and peer-reviewed articles.

In fact, a 5-point Likert scale from ‘strongly disagrees, unimportant, very bad" to "strongly agree, important or very good" was used to help participants share their opinions. Questions were based on the feasibility, capability, necessity/utility and whether concerned suggestions were approved or not by participants. In other words, the questionnaire has been the subject of decision-making regarding validity and reliability aspects. Likewise, a pilot study has been run with the involvement of a logistics expert, an economic scholar, a researcher, and a non-logistician. The present pilot study concluded with an elimination/cancellation of certain items and the rearrangement of others considering the participants' time and understanding, including not only logistics practitioners and scholars but also different stakeholders.

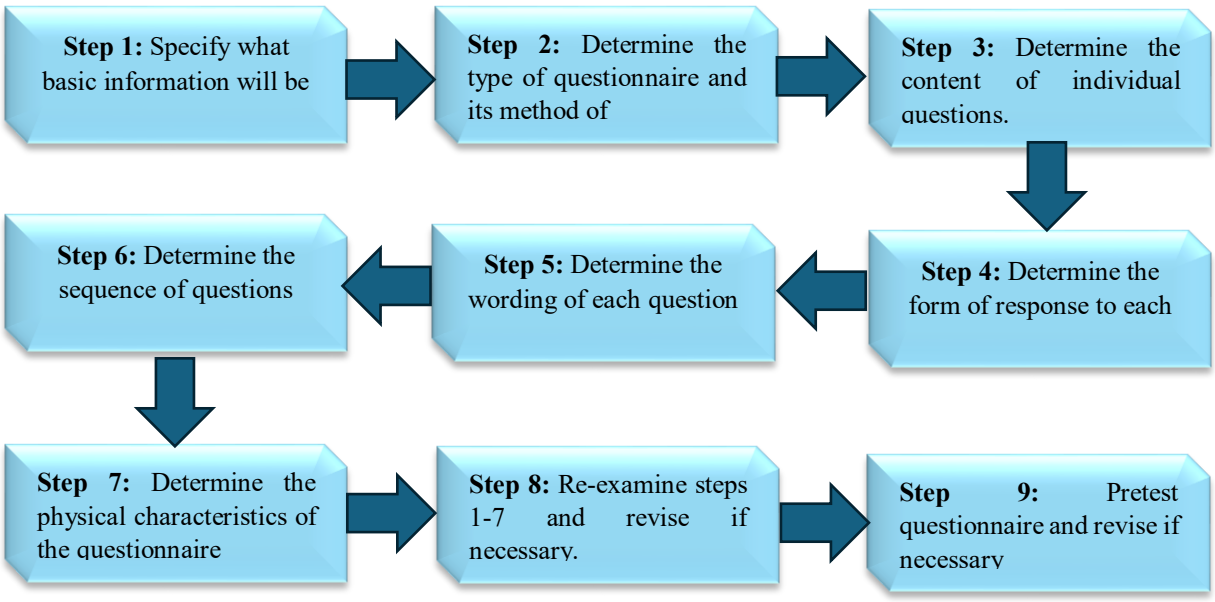


***Figure 1. Procedure for developing a questionnaire (Churchill & Iacobucci, 2010).***

### 4.2 Data Analysis

Using the statistical application software (SPSS), the descriptive statistics have been run to underline information regarding respondents. As shown in Table1, the percentage of males is higher than the female with respectively 77.7% against 22.3%. Regarding logistics experience, the number of nearly experienced (0-6months) or non-experienced equals (36+107) participants, followed by 49 respondents between 1-5 years of experience and 8.9% confirming more than 5 years of experience.

Of the 250 respondents, the fewest number (29) or 11.6% corresponds to logisticians by career, while the highest number concerns those assumed to be logisticians from the background, preceded by 112 non-logisticians, i.e. 44.6% of participants. Regarding the logistics education level, the highest degree obtained is PhD, representing only 0.9% (2 respondents) with 15.2% for master's degree holders, 35.7% for bachelor's and 0.9% for DUT holders. However, it is important to note that 29 participants are trained against 89, i.e. 35.7% of participants who have never had training in logistics (shippers in this case).

***Table 1: Demographic data***

| Demographic characteristics | Options | Frequency | Valid Percent (%) | Number of Respondents |
|---|---|---|---|---|
| **Gender** | **Male** | 194 | 77.7 | |
| | **Female** | 56 | 22.3 | |
| | **No Experien** | 107 | 42.9 | |

| | | | | |
|---|---|---|---|---|
| **Log Exp** | **ce** | | | |
| | **0-6 months** | 36 | 14.3 | |
| | **6-12 months** | 36 | 14.3 | |
| | **1-5 years** | 49 | 19.6 | |
| | **+ 5years** | 22 | 8.9 | **250** |
| **Log_Work_Title** | **Logisticianby career** | 29 | 11.6 | |
| | **Logistician from background** | 109 | 43.8 | |
| | **Non-logistician** | 112 | 44.6 | |
| **Log_Education** | **No training** | 89 | 35.7 | |
| | **Just training** | 29 | 11.6 | |
| | **DUT*** | 2 | .9 | |
| | **Bachelor's** | 90 | 35.7 | |
| | **Master's** | 38 | 15.2 | |
| | **PhD's** | 2 | .9 | |
| **Total Valid** | | 250 | 100.0 | **250** |
| **Total Missing** | | **0** | **0** | **0** |

**4.3 Results and Discussion**

As viewed by (Anderson & Gerbing, 1988), model building is the way to evaluate two different models. Mostly known in psychology and social sciences, SEM is used to test and develop theory through its confirmatory methods. The computation of these methods, i.e. measurement model (estimation) prior to the structural model, provides a comprehensive assessment of construct validity. For a model to be acceptable, the AMOS program should validate data in SEM that follows a multivariate normal distribution (Byrne, 2013). SEM compares to path analysis, is very powerful in so far as it gives a broad view of your data, highlights the path analysis model, and the relationship between variables even in complex cases (Gupta, 2024). SEM is a method that provides a detailed assessment of indicators through CFA, EFA, path analysis model and fit indicators. Mention that the author recommended SEM as the best tool for assessing happiness, tiredness and particularly satisfaction, as in the case of this research. SEM can reply to the following four questions: what exactly to measure? How to measure those concerned? How to meet validity and reliability conditions? and finally, how to explain the causal relationship between constructs?

The popular multivariate SEM follows a sequence of seven steps, with the first three ones being conceptualization, where hypotheses are set up based on theory, visualization (path diagram design)

to see the links and specification/generating of a model with the construction of measurement and structural design of the research problem. The fourth step (model identification) is not more than a validation of the specification model, i.e. ensuring that data is adequate for the model via a complete test of collected information. The fifth step is about parameters estimation, while the sixth deals with the compliance of the specified model and the data used. To achieve that compliance, a goodness of fit is generally employed to check if the model-based covariance matrix goes with the observed covariance matrix. The final and seventh phase is the model modification, where the goal is to improve the fit quality. Because SEM can also play a similar role like its peers (multivariate analysis of variance, factor analysis, multiple regression, discriminant analysis...) and can simultaneously gauge several dependent /independent and mediating relationships, it has become the best multivariate technique. Furthermore, SEM analyses the causal relationship and searches for the most suitable model for the data.

**4.4 Measurement Model**

Research stated that the measurement model evaluates construct validity and explains the link between latent and observed constructs, i.e. how much latent variables can account for observed variables (El-Den et al., 2020). Because a measurement model specifies items for constructs and is valid when the items and constructs are reliable and valid; therefore, reliability and validity tests are launched. The measurement model further gives a satisfactory assessment of convergent and discriminant validity. Likewise, the authors mentioned that between the two errors of SEM, one refers to measurement error (Henseler et al., 2015). One recent work added that SEM helps the researcher to explain measurement error within variables (J. F. Hair et al., 2021)..

ML or General Least Square gives full information estimation with a common factor model, while Partial Least Squares (PLS) gives partial information with a principal factor component (Sarstedt et al., 2020). In fact, ML provides the most efficient parameter estimates test of overall model fit and the best estimates that can explain covariance well. Due to the specificity and random error, there is a lack of determination in the factor scores, which might be relevant for the accuracy of prediction application. To cope with this latter issue, PLS (that does not assume any random error variance or measure specific variance) with the application of predictive approach using principal factor component, comes to explain all the obtained and acceptable variance.

**4.4.1 Exploratory and Confirmatory Factor Analysis**

Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) are complementary stages in construct validation. Although the distinction between them is sometimes blurred, (Howard, 2016) describe factor analysis as an ordered progression, beginning with exploration and culminating in confirmation.

EFA is typically the starting point, used when the underlying factor structure is unknown. At this stage, neither the number of latent factors nor the relationships between items are predetermined (Rijkure, 2024). EFA identifies potential structures by extracting factors (commonly using Maximum Likelihood or Generalized Least Squares methods) and rotating them to maximize interpretability (Carrizosa et al., 2020). The outcome is a preliminary set of latent variables based on empirical patterns, without imposing strict constraints on item–factor relationships.

CFA, often referred to as *restricted analysis*, advances this process by testing whether the hypothesized structure derived from theory or prior EFA is consistent with the observed data.

**4.4.1.1 Application in This Study**

In this research, factor analysis was conducted for each of the eight constructs. During the exploratory stage, Principal Component Analysis (PCA) with Varimax rotation was applied, retaining only factors with eigenvalues greater than one. Items with factor loadings above 0.50 were preserved (with 0.45 as the lower acceptable threshold;
The study's measurement model consists of six predictor constructs and two outcome constructs:

- Predictors:

⇒ Import/Export and Global Trade Partners (IEGTP) — 13 items
⇒ Logistics Infrastructure (LI) — 8 items
⇒ Logistics Skills Assessment (LSA) — 6 items
⇒ Government Policy for Logistics Promotion (GPLP) — 6 items
⇒ Transport Modes and Infrastructures (TMI) — 6 items
⇒ Information Technology Integration and Infrastructures (III) — 5 items

- Outcomes:

⇒ Regional Economic Growth (REG) — 8 items
⇒ National Logistics Performance (NLP) — 7 items

According to one recent work by Marar, a reliable construct should be measured by at least three to four items. The constructs in this study exceed this minimum requirement, thereby supporting measurement reliability. Following EFA, CFA was conducted to confirm the factor structure, validate item–factor relationships, and assess overall model fit before proceeding to hypothesis testing (Marar et al., 2023).

***Table 2: Exploratory Factor Analysis Rotated Component Matrix***

| Analytical Items | LSA | ITII | LI | GPLP | IEGTP | TMI | NLP | REG | Variables Status |
|---|---|---|---|---|---|---|---|---|---|
| **LSA4** | .893 | | | | | | | | **Predictors** |
| **LSA3** | .882 | | | | | | | | |
| **LSA5** | .867 | | | | | | | | |
| **LSA2** | .854 | | | | | | | | |
| **LSA6** | .840 | | | | | | | | |
| **LSA1** | .784 | | | | | | | | |
| **ITII3** | | .899 | | | | | | | |
| **ITII4** | | .894 | | | | | | | |
| **ITII2** | | .892 | | | | | | | |
| **ITII1** | | .880 | | | | | | | |
| **ITII5** | | .854 | | | | | | | |
| **LI8** | | | .901 | | | | | | |
| **LI7** | | | .860 | | | | | | |
| **LI3** | | | .850 | | | | | | |
| **LI6** | | | .845 | | | | | | |
| **LI5** | | | .822 | | | | | | |
| **LI2** | | | .780 | | | | | | |
| **LI4** | | | .737 | | | | | | |
| **LI1** | | | .637 | | | | | | |
| **GPLP2** | | | | .904 | | | | | |
| **GPLP3** | | | | .873 | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **GPLP1** | | | | .849 | | | | |
| **GPLP6** | | | | .846 | | | | |
| **GPLP5** | | | | .826 | | | | |
| **GPLP4** | | | | .815 | | | | |
| **IEGTP12** | | | | | .922 | | | |
| **IEGTP11** | | | | | .912 | | | |
| **IEGTP13** | | | | | .890 | | | |
| **IEGTP7** | | | | | .754 | | | |
| **IEGTP3** | | | | | .708 | | | |
| **IEGTP4** | | | | | .704 | | | |
| **IEGTP6** | | | | | .694 | | | |
| **IEGTP8** | | | | | .691 | | | |
| **IEGTP2** | | | | | .686 | | | |
| **IEGTP10** | | | | | .651 | | | |
| **IEGTP5** | | | | | .635 | | | |
| **IEGTP9** | | | | | .625 | | | |
| **IEGTP1** | | | | | .590 | | | |
| **TMI5** | | | | | | .879 | | |
| **TMI3** | | | | | | .857 | | |
| **TMI4** | | | | | | .825 | | |
| **TMI2** | | | | | | .772 | | |
| **TMI1** | | | | | | .666 | | |
| **TMI6** | | | | | | .639 | | |
| **NLP1** | | | | | | | .858 | **Outcomes** |
| **NLP6** | | | | | | | .844 | |
| **NLP4** | | | | | | | .835 | |
| **NLP2** | | | | | | | .836 | |
| **NLP3** | | | | | | | .797 | |
| **NLP5** | | | | | | | .717 | |
| **NLP7** | | | | | | | .559 | |
| **REG5** | | | | | | | | .883 |
| **REG6** | | | | | | | | .850 |
| **REG8** | | | | | | | | .816 |
| **REG3** | | | | | | | | .780 |
| **REG2** | | | | | | | | .744 |
| **REG7** | | | | | | | | .677 |
| **REG4** | | | | | | | | .566 |
| **REG1** | | | | | | | | .529 |

Extraction method: Principal component analysis.

### 4.4.2 Reliability Analysis and Construct Validity

Because we want to check whether different items measure the assigned and exact latent variables, then a reliability and validity test for measurement is run. The contents of Table 3 include the results of descriptive statistics and reliability tests. In order to assess the reliability and the internal consistency of the factors as mentioned above, the traditional reliability measure called Cronbach's

Alpha was used. Based on the assertion of (Agbo, 2010) about a satisfactory level of reliability, all the variables are highly reliable and stay greater than the threshold value of 0.7.

The means and standard deviation have been determined for each factor in table 3 in order to evaluate normality. In fact, means' values ranged from 3.6885 (logistics infrastructures), the lowest influencer factor regarding respondents' view, to 4.2840 (Transport Modes and Infrastructures), referring to the highest influencer factor. Considering standard deviation values for each construct, they are all well ranked, which proves that the distribution of the sample data corresponds to a normal distribution, i.e. confirmation of normality.

***Table 3: Descriptive statistics and Reliability test***

| Variables | No. of items | Mean | Std. Deviation | Cronbach's Alpha |
|---|---|---|---|---|
| Logistics Skills Assessment | 6 | 3.8707 | .87579 | .925 |
| IT Infrastructures and Integration | 5 | 3.8952 | .89679 | .930 |
| Logistics Infrastructures | 8 | 3.6885 | .78453 | .882 |
| Government Policy for Logistics Promotion | 6 | 3.8253 | .75128 | .817 |
| Import/Export and Global Trade Partners | 13 | 4.2440 | .64862 | .902 |
| Transport Modes and Infrastructures | 6 | 4.2840 | .70617 | .863 |
| National Logistics Performance | 7 | 4.0994 | .72408 | .895 |
| Regional Economy Growth | 8 | 3.8030 | .71921 | .853 |

Because CFA gives more flexibility in manipulating items of every factor and can assess a unidimensional aspect of indicators, then it is stronger than EFA, Alpha reliability and correlation (Goyal & Aleem, 2023). After computation of a confirmatory factor analysis considering a factor loading greater than 0.5, the following seven indicators were removed: LI2, LI3, LI4, GPLP5, GPLP6, IEGTP1 and REG1. Next, an AVE for (constructs validity examination) and CR for (all the constructs based on standardized loadings values shown in Table 4) was calculated.

The results of the critical ratio show significant values for items. They provide further evidence of construct convergent validity (Anderson & Gerbing, 1988). Convergent validity is achieved when the item's coefficient in the construct is significant, i.e. when the item's value doubles its standard error value (Anderson & Gerbing, 1988). Looking at AVE within (Farrell & Rudd, 2017) view, its coefficient refers to the average variance value that a latent variable account in observed variables to which it theoretically relates through factor loading correlation.

***Table 4: Composite Reliability and Convergent Validity results***

| Constructs | Indicators | Standardized Loadings | t-value critical ratio | P-value | CR | AVE |
|---|---|---|---|---|---|---|
| **LSA** | LSA1 | 0.727 | - | - | 0.895 | 0.677 |
| | LSA2 | 0.818 | 12.818 | *** | | |
| | LSA3 | 0.858 | 13.473 | *** | | |
| | LSA4 | 0.882 | 13.850 | *** | | |
| | LSA5 | 0.848 | 13.306 | *** | | |
| | LSA6 | 0.796 | 12.452 | *** | | |
| **ITII** | ITII1 | 0.848 | - | - | 0.906 | 0.727 |
| | ITII2 | 0.865 | 17.498 | *** | | |
| | ITII3 | 0.878 | 17.934 | *** | | |
| | ITII4 | 0.865 | 17.484 | *** | | |
| | ITII5 | 0.806 | 15.574 | *** | | |
| **LI** | LI1 | 0.541 | - | - | 0.851 | 0.641 |
| | LI5 | 0.809 | 8.801 | *** | | |
| | LI6 | 0.813 | 8.826 | *** | | |
| | LI7 | 0.881 | 9.164 | *** | | |
| | LI8 | 0.905 | 9.267 | *** | | |
| **GPLP** | GPLP1 | 0.764 | - | - | 0.862 | 0.692 |
| | GPLP2 | 0.886 | 14.547 | *** | | |
| | GPLP3 | 0.855 | 14.050 | *** | | |
| | GPLP4 | 0.818 | 13.362 | *** | | |
| **IEGTP** | IEGTP2 | 0.925 | - | - | 0.951 | 0.697 |
| | IEGTP3 | 0.625 | 7.884 | *** | | |
| | IEGTP4 | 0.731 | 8.739 | *** | | |
| | IEGTP5 | 0.756 | 8.923 | *** | | |
| | IEGTP6 | 0.933 | 7.534 | *** | | |
| | IEGTP7 | 0.873 | 8.515 | *** | | |
| | IEGTP8 | 0.914 | 8.237 | *** | | |
| | IEGTP9 | 0.778 | 9.077 | *** | | |
| | IEGTP10 | 0.71 | 8.584 | *** | | |
| | IEGTP11 | 0.883 | 8.190 | *** | | |
| | IEGTP12 | 0.893 | 8.156 | *** | | |
| | IEGTP13 | 0.924 | 8.332 | *** | | |
| **TMI** | TMI1 | 0.884 | - | - | 0.936 | 0.762 |
| | TMI2 | 0.913 | 7.994 | *** | | |
| | TMI3 | 0.838 | 9.079 | *** | | |
| | TMI4 | 0.786 | 8.788 | *** | | |
| | TMI5 | 0.886 | 9.304 | *** | | |
| | TMI6 | 0.924 | 7.407 | *** | | |
| **NLP** | NLP1 | 0.862 | - | - | 0.852 | 0.612 |
| | NLP2 | 0.808 | 15.638 | *** | | |
| | NLP3 | 0.718 | 13.072 | *** | | |
| | NLP4 | 0.838 | 16.601 | *** | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | NLP5 | 0.609 | 10.455 | *** | | |
| | NLP6 | 0.828 | 16.284 | *** | | |
| **REG** | REG2 | 0.859 | - | - | 0.945 | 0.763 |
| | REG3 | 0.86 | 16.263 | *** | | |
| | REG4 | 0.729 | 12.969 | *** | | |
| | REG5 | 0.923 | 9.781 | *** | | |
| | REG6 | 0.891 | 8.404 | *** | | |
| | REG7 | 0.913 | 9.044 | *** | | |
| | REG8 | 0.924 | 10.123 | *** | | |

In fact, the average variance extracted values that ranged from 0.641 to 0.763 exceed the 0.5 thresholds suggested by (J. Hair et al., 2017); therefore, AVE values confirmed that all the indicators measure the same and corresponding factors. On the other hand, it is important to note that all the composite reliability values also showed higher values than the suggested value of 0.7 for all the constructs (J. Hair et al., 2017).

$$Average\ Variance\ Extracted = \frac{\left[\sum_{i=1}^{n} \lambda^2\right]\cdot}{\left|\sum_{i=1}^{n} \lambda^2\right|\cdot + \left|\sum_{i=1}^{n} o_i\right|}$$

With $\lambda i$ representing standardized factor loading for the indicators on the observed variable; and $\delta i$ referring to measurement error for each indicator.

(Farrell & Rudd, 2017) in its temptation of describing discriminant validity mentioned that to know whether the outcomes of the hypothesized structural path are real, a discriminant validity test is essential. Discriminant validity determines the relationship and is the degree of difference between two pairs of constructs or else the extent to which an unobserved variable (latent variable) differs from others. It also represents that higher value in observed variables compared to other influential parameters such as measurement error or else.

For discriminant validity to be supported, the AVE of both factors should be greater than the shared variance (sum of squared loadings). Shared variance is the percentage of variance that a variable can account for in another. As shown in table 6, the correlation matrix was applied for further inspection of the square root of AVE. As a result of the inspection, it can be easily seen that all the square roots of the AVE presented higher values than all the correlation coefficients that relate to any two pairs of constructs; therefore, discriminant validity is approved.

***Table 5: Correlation Matrix and Discriminant Validity***

| **Variables Constructs** | **NLP** | **REG** | **LSA** | **ITII** | **LI** | **GPLP** | **IEGTP** | **TMI** |
|---|---|---|---|---|---|---|---|---|
| **NLP** | **.782** | | | | | | | |
| **REG** | .576** | **.874** | | | | | | |
| **LSA** | .530** | .515** | **.823** | | | | | |
| **ITII** | .497** | .838** | .588** | **.853** | | | | |
| **LI** | .481** | .654** | .740** | .769** | **.800** | | | |
| **GPLP** | .629** | .786** | .755** | .750** | .716** | **.832** | | |
| **IEGPT** | .687** | .453** | .411** | .360** | .353** | .563** | **.835** | |
| **TMI** | .588** | .491** | .457** | .420** | .405** | .550** | .766** | **.873** |

***. Correlation is significant at the 0.01 level (2-tailed).*

**4.5 Model Assessment**

**4.5.1 Confirmatory Factor Analysis**

For complex situations such as lack of complete data analysis, error effect of latent variables and so on is confirmatory factor analysis (CFA). It is employed to ascertain convergent validity and attenuate measurement tool error. CFA, compared to EFA, Alpha reliability and correlation, is stronger because it can assess the unidimensional aspect of indicators and allows much more flexibility in the management of items of every factor. The first step of SEM (CFA) accounts for three types, including individual, measurement, and structural model. CFA for individual items of every variable, CFA for measurement of endogenous variables and indirect effect towards dependent variables and CFA for three structural model hypothesis model, original theory, and generating model. To note that hypothesis and generating models both include exogenous and endogenous variables.

To compute the CFA model for applying SEM and provide outputs and path analysis, LISREL (Linear Structural Relations), EQS, or AMOS programs are all suitable. LISREL, although good and developed with its added tool (SIMPlis to simplify reading and PRElis to perform pre-analytical and supplementary works within SEM models), is not as sophisticated as AMOS or EQS; that is why AMOS 26 is used for this research. Working for mean and covariance structures assessment, AMOS (Analysis of Moment Structures) includes AMOS graphic for path diagram drawing and AMOS Basic for equation development. As in the case of this research, most researchers prefer AMOS graphics because particular tools are available for path diagram drawing. Furthermore, another amazing thing about AMOS with its SEM thinking and its simple, fast construction of effective path diagram; is the provision of estimates in both forms graph and table for the researcher to read outputs.

**4.5.2 Model Fit Indices**

After establishing the measurement model, its adequacy was assessed using standard goodness-of-fit indices generated in AMOS. According to Anderson et al. (1988), these indices evaluate the extent to which the hypothesized model reproduces the observed covariance or correlation matrix (Anderson & Gerbing, 1988) . A value close to 1 indicates a good fit, while large chi-square values suggest poor fit.

To confirm model adequacy, multiple fit measures were examined. As shown in Table 5, the Goodness-of-Fit Index (GFI), Comparative Fit Index (CFI), Incremental Fit Index (IFI), and Normed Fit Index (NFI) all exceeded the recommended threshold of 0.90 (Byrne, 2001), confirming strong fit. The Root Mean Square Residual (RMR) values were within the acceptable limit of 0.05 for most constructs, except for IEGTP, which was slightly higher. The Root Mean Square Error of Approximation (RMSEA) values were all below 0.10, indicating a satisfactory level of fit.

***Table 6: Results of Confirmatory Factor Analysis (Model Fit Summary).***

| Dimensions | Chi-square | Degree Of Freedom | RMR | GFI | NFI | IFI | CFI | RMSEA |
|---|---|---|---|---|---|---|---|---|
| **LSA** | 21.305 | 9 | 0.020 | 0.972 | 0.980 | 0.989 | 0.989 | 0.074 |
| **ITII** | 21.233 | 5 | 0.022 | 0.966 | 0.978 | 0.983 | 0.983 | 0.014 |
| **LI** | 17.919 | 5 | 0.032 | 0.973 | 0.977 | 0.984 | 0.983 | 0.032 |
| **GPLP** | 3.574 | 2 | 0.013 | 0.993 | 0.994 | 0.997 | 0.997 | 0.056 |
| **IEGTP** | 630.569 | 54 | 0.037 | 0.973 | 0.968 | 0.988 | 0.986 | 0.027 |
| **TMI** | 69.777 | 9 | 0.049 | 0.910 | 0.908 | 0.919 | 0.918 | 0.065 |
| **NLP** | 40.631 | 9 | 0.034 | 0.950 | 0.955 | 0.965 | 0.965 | 0.019 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **REG** | 201.415 | 14 | 0.021 | 0.922 | 0.971 | 0.983 | 0.982 | 0.032 |

### 4.5.3 Structural Modeling with Path Analysis

Path analysis evaluates the direct relationships between constructs and determines whether the proposed hypotheses are supported. In this study, hypothesis testing relies on the critical ratio (CR) and p-value:

⇒ A path is significant if CR ≥ 1.96 (equivalent to $t \geq 1.96$).

⇒ Statistical significance is accepted at $p < 0.05$, with stronger significance at $p < 0.01$.

Using AMOS 26, standardized path coefficients, standard errors, CR values, and p-values were generated (Table 8). The results show that all estimated paths exceeded the critical threshold, confirming statistically significant relationships between predictors and outcome variables.

***Table 7: Results of the hypothesis test.***

| Factors Effect | Estimates/Coef. | SE. | CR/t-value | Sig./P. | Support |
|---|---|---|---|---|---|
| **LSA-->NLP** | .695 | .066 | 10.479 | *** | Yes |
| **ITII-->NLP** | .233 | .039 | 6.003 | *** | Yes |
| **LI-->NLP** | .539 | .056 | 9.616 | *** | Yes |
| **GPLP->NLP** | .178 | .063 | 2.821 | .005 | Yes |
| **IEGTP->NLP** | .119 | .065 | 2.134 | .033 | Yes |
| **TMI-->NLP** | .552 | .059 | 9.550 | *** | Yes |
| **LSA->REG** | .074 | .026 | 2.846 | .004 | Yes |
| **ITII-->REG** | .495 | .052 | 9.505 | *** | Yes |
| **LI-->REG** | .539 | .056 | 9.616 | *** | Yes |
| **GPLP->REG** | .120 | .027 | 4.412 | *** | Yes |
| **IEGTP->REG** | .061 | .027 | 2.270 | .023 | Yes |
| **TMI->REG** | .648 | .022 | 29.781 | *** | Yes |

Among the twelve tested hypotheses, six came out with high supportive estimates (0.495-0.695), and four ranging from 0.120 to 0.233 were well supported, while the remaining two (0.061-0.074) were marginally supported. Figs 1 and 2 map out the two models and the relationship between outcomes and predictors. The $R^2$ (squared multiple correlations) is used to define how a model could explain the impact of the outcome/independent variables on the predictor/dependent variables. In our case, Fig 1 assumed that National logistics performance (outcome variable) was impacted by 87% of the variance of the six predictors, while Fig 2 refers to Regional Economy Growth (outcome variable) influenced by 95% of the variance.

In other words, the Logistics Skills Assessment, Information Technology Integration and Infrastructures, Logistics Infrastructures, Government Policy for Logistics Promotion, Import/Export and Global Trade Partners add to Transport Modes and Infrastructures were respectively explaining 87% and 95% of the variance for both National Logistics Performance and

Regional Economy Growth. Likewise, Figs 1 and 2 also show the outputs related to the covariance between variables.

The objective of the hypothesis test in this research model is not to validate or prove the truth but instead to map out the significance of the alternatives, i.e. to decide whether there is a potential positive relationship between predictors and outcomes. P-value is the probability of obtaining a sample that goes out of the more extreme observed data. It supports or rejects a hypothesis based on a p-value less or greater than the alpha (0.05/0.01) significance level. As such, the t-test and p-test in table 8 show a significant and positive relationship between variables. The next three paragraphs will gradually give details that can upgrade the view of the hypothesis' relationships:

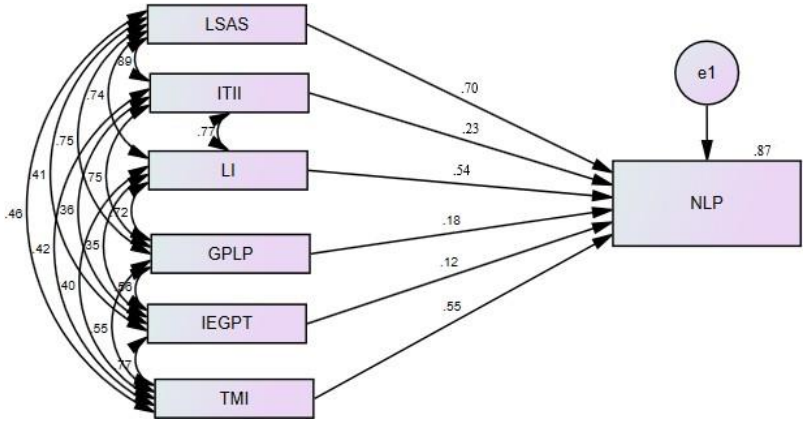


***Figure1. Influence level between NLP and related factors.***

First, six factors have great and positive effects on National Logistics Performance and Regional Economy Growth. Because Logistics Skills Assessment is heading up with ($\beta 1$, $t-value=10.479$, $p<0.01$), followed by Logistics Infrastructures with ($\beta 3$, $t-value=9.616$, $p<0.01$) and Transport Modes and Infrastructures ($\beta 6$, $t-value=9.550$, $p<0.01$) respectively show a positive effect on National Logistics Performance, then H1a, H3a and H6a are supported. Also, because Information Technology Integration and Infrastructures ($\beta 8$, $t-value=9.505$, $p<0.01$) followed Logistics Infrastructures ($\beta 9$, $t-value=9.616$, $p<0.01$) and Transport Modes Infrastructures ranking well with ($\beta 12$, $t-value=29.781$, $p<0.01$) have a similar impact towards Regional Economy Growth, so H2b, H3b and H6b also are supported.

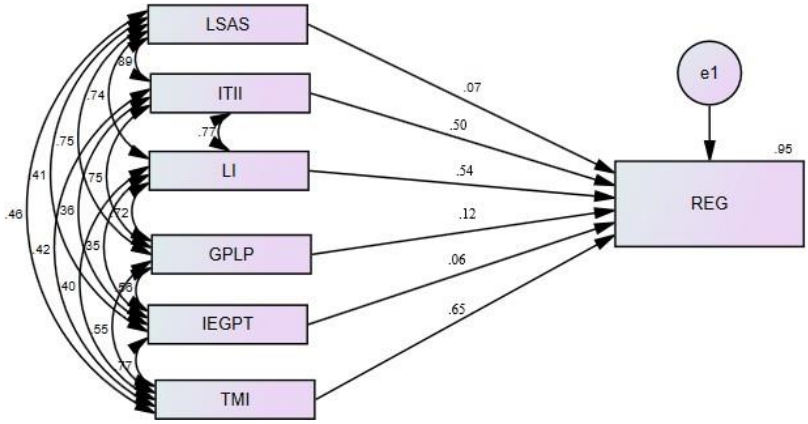

***Figure2. Influence level between REG and related factors.***

Second, there are four variables, i.e. 3 in good relationship with National Logistics Performance and 1 with Regional Economy Growth, which presents an acceptable and strong impact. However, while Information Technology Integration and Infrastructures with ($\beta 2$, $t-value=6.003$, $p<0.01$), Government Policy for Logistics Promotion with ($\beta 4$, $t-value=2.821$, $p<0.01$) and Import/Export and Global Trade Partners with ($\beta 5$, $t-value=2.134$, $p<0.05$) successively reveal green signal towards National Logistics Performance meaning that H2a, H4a and H5a are supported. On the other hand, there is a positive relationship between Government Policy for Logistics Promotion with ($\beta 10$, $t-value=4.412$, $p<0.01$) and Regional Economic Growth resulting in support of H4b. Here are the last two hypotheses that are both lower but present positive effects on Regional Economy Growth. In fact, Logistics Skills Assessment with ($\beta 7$, $t-value=2.846$, $p<0.01$) and Import/Export and Global Trade Partners with ($\beta 11$, $t-value=2.270$, $p<0.05$) moderately influence Regional Economy Growth; therefore, H1b and H5b are both marginally supported.

**Tableau 8.** Recommended threshold values for fit indices

| Recommended Measurement Values for Exogenous and Endogenous Variables | |
|---|---|
| **Measures** | **Threshold Values** |
| **Absolute Fit Level** | |
| RMSEA | < 0.08 |
| RMR | < 0.05 |
| GFI | >= 0.9 |
| P-value | P-value >= 0.05 |
| **Incremental Fit Level** | |
| CFI | >= 0.09 |
| NFI | >= 0.09 |
| IFI | > 0.09 |

## 5. Recommendations

The results of this research highlight several key areas that require attention to enhance logistics performance and promote regional economic development in Mali. Firstly, it is crucial to address the gap in human capital. The nation is experiencing a significant shortage of skilled logisticians and transport professionals. To satisfy both current and future needs, it is imperative to fortify the education system by implementing specialized programs in logistics and transport engineering, establishing dedicated research centers, and incorporating IT skills into educational curricula. Collaborations with international experts and the development of structured career pathways for graduates will ensure that the workforce is adequately prepared to meet the intricate demands of a contemporary logistics sector. Secondly, the advancement of infrastructure is a fundamental driver of growth. The enhancement and upkeep of road and rail networks are essential for facilitating internal connectivity within Mali and linking it to ports in adjacent countries. Investment in

multimodal transport systems including rail, road, air, and river transport should be an integral component of the national strategy. The establishment of dry ports and distribution centers in Kayes, Sikasso, Bamako, and Tombouctou is particularly significant, as these facilities can lower import/export expenses, enhance trade efficiency, and invigorate local economic activity. Additionally, attracting foreign investment through incentives and public-private partnerships will be crucial for financing such extensive projects.

Third, digital transformation must be accelerated to enhance efficiency and transparency. Expanding internet connectivity, especially in rural areas, and ensuring strong cybersecurity measures will enable broader participation in regional trade. The digitalization of customs and logistics operations can reduce corruption, speed up cargo clearance, and improve tracking. Collaborating with technology companies will support the modernization of logistics systems, while equipping workers with IT skills will maximize the benefits of digital integration and help Mali transition towards green and sustainable logistics practices. Fourth, governance and policy frameworks must be reinforced. Establishing a dedicated Ministry of Logistics would provide the coordination and oversight necessary to structure the industry. Long-term logistics policies should focus on attracting foreign direct investment and embedding logistics into national development plans. Strengthening bilateral and regional partnerships with transit countries is essential for securing port access and trade corridors; while investing in port terminals abroad could further reduce dependency. At the international level, Mali should also increase its engagement with organizations such as ECOWAS, the African Union, and the United Nations to influence logistics-related policy agendas.

Finally, the logistics industry requires stronger institutions and standards to build credibility and ensure service quality. National associations such as AsLoG_M@li should take the lead in promoting member services, enforcing standards, and monitoring compliance. Certification schemes and industry awards can incentivize best practices, while standardized procedures across the sector will help harmonize operations. A national logistics plan requiring government agency to use domestic logistics providers, as practiced in countries like China and South Korea, could further strengthen the local industry and enhance competitiveness.

In summary, Mali must simultaneously invest in people, infrastructure, technology, governance, and industry standards to transform its logistics sector. By doing so, the country can overcome its geographic constraints, attract foreign investment, and position logistics as a catalyst for sustainable economic growth and regional integration.

## 6. Conclusion

Logistics is a backbone of the global economy, and for landlocked countries it is especially cost- and time-sensitive. This study examined the role of logistics in Mali's socio-economic development, focusing on six key factors logistics skills, IT integration, infrastructure, government policy, transport modes, and international trade partnerships and their impact on national logistics performance (NLP) and regional economic growth (REG). Using SEM with SPSS and AMOS on survey data from 250 stakeholders, twelve hypotheses were tested. The results show that transport modes and infrastructure exert the strongest influence, improving both NLP (55%) and REG (65%). Logistics infrastructure also plays a major role (54% for both outcomes), highlighting the need for dry ports, distribution centers, and modern transport networks. Logistics skills are highly relevant for NLP (70%) but less impactful for REG (7%), confirming the importance of professional capacity building. Information technology is moderately influential for NLP (23%) but strongly

benefits REG (50%) by reducing corruption, expediting customs, and enabling digital management. Government policy contributes modestly (18% for NLP; 12% for REG), but remains essential for creating a favorable regulatory environment. Finally, import/export access and trade partnerships are critical for diversifying Mali's markets and reducing reliance on costly transit corridors.

Despite these positive findings, Mali's logistics sector continues to face serious challenges: weak infrastructure, high transit costs, corruption at borders, political instability, lack of skilled professionals, and limited IT adoption. Addressing these barriers will be vital for unlocking the sector's full potential.

This study provides valuable insights for policymakers, associations such as AsLoG_M@li, and development partners. Recommended priorities include:

⇒ Investing in multimodal transport and ICT infrastructure.
⇒ Expanding higher education and research in logistics and transport engineering.
⇒ Establishing standards and compliance frameworks to improve service quality.
⇒ Enhancing bilateral and multilateral partnerships to facilitate trade and attract foreign direct investment.

The study also has limitations, including reliance on a relatively small dataset, limited professional representation among respondents, and a lack of comparative analysis with other landlocked economies. Future research should incorporate simulate on tools such as Arena software to test policy alternatives and deepen understanding of logistics dynamics in Mali and across Africa.

Overall, this research highlights the strategic role of logistics in fostering sustainable growth in Mali. With targeted investments, stronger governance, and capacity building, Mali can turn its geographic constraints into competitive opportunities and position logistics as a driver of regional integration and economic transformation.

**Declaration of interest statement**

The authors state that there are no conflicts of interest to declare.

**Acknowledgments**

This work was supported by the National Natural Science Foundation of China [grant number 72202021], the Fundamental Research Funds for the Central Universities, CHD [grant number 300102233606].

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