

# **A System Dynamics Modeling Approach for Investigating the Factors Affecting Logistics at a National Level**

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## **Abstract**

Any country's economy depends on effective logistics to maintain the seamless flow of information and products that support commerce and development. This paper aims to review the related literature to identify the research gaps and potential research directions in this area which helps to formulate a logistics problem at the national level. This research explores the macro and microeconomic factors that affect a country to shape a nation's logistics environment through the use of systems dynamics modeling (SDM). The study combines macro factors like GDP, FDI and infrastructure development with micro factors like inventory management practices, warehouse capacity and transportation costs. This study will allow decision-makers to make valuable decisions in logistic investments and policymaking.

## **Keywords**

GDP, Logistics, Macro-Micro, Modeling and System Dynamics.

## **1. Introduction**

### **1.1 Importance of Logistics for a Country**

Efficient transportation of products is the keystone of every healthy economy (Pyra,2024). A country's logistics system functions as the unseen engine driving commerce, industry, and eventually prosperity from raw materials to completed goods regulations, infrastructure development, and communication networks (Lee et al., 2017). Transport sector companies' financial conditions are affected by shifts in macroeconomic indices including GDP, PMI, and IFO indexes (Wilimowska et al., 2020).

Retailers' investment choices are influenced by (Pyra, 2024; Zhu et al., 2024). Well-oiled logistics are even more important in today's networked world when just-in-time production and global supply chains rule. Transportation delays or storage problems may cause a chain reaction that affects anything from consumer pricing to a country's economic competitiveness.

In many different industries, the significance of logistical operations has been increasing. To increase a country's productivity and competitiveness, logistics helps to improve current production and distribution processes with the same resources via management strategies (Martí et al., 2014). The transport system, which links many operations, is an essential component of the logistics chain. A third of the expenditures associated with logistics are related to transportation, and the transportation system significantly impacts the effectiveness of the logistics system. From manufacture to delivery to the end user and back, shipping is required at every stage of the manufacturing process. Indeed, the most advantage may only be obtained by carefully combining each item (Xuan et al., 2023).

A Macroeconomic factor is a pattern, quality, or state that, rather than being specific to a population, comes from or is related to a broader part of an economy. The Consumer Price Index (CPI), unemployment, GDP, stock market index, corporate tax rate, and interest rates are important economic indicators (Egbunike and Okerekeoti, 2018).

Whereas, Microeconomics investigates and evaluates issues related to supply, demand, pricing, company and individual behavior, and market structures. Microeconomic studies look at three types of market structures: monopolistic, oligopolistic, and perfect competition. Microeconomics also studies the actions of utility-maximizing people and profit-maximizing enterprises in various market settings (Baysal, 2023).

## **1.2 Objectives**

The objective of this research is to provide an extensive review of the investigation and modeling of national logistics systems using the SD. In particular, this study's goal is to identify the key factors (both macro and micro) that affect national logistics systems. In addition, the literature on the modeling of logistics systems is reviewed to investigate the suitability of this technique for these kinds of problems and to identify relevant research gaps.

## **2. Literature Review**

### **2.1 System Dynamics Modeling**

System Dynamics (SD) is often thought of as the conversion of the system's thinking language into a mathematical one. SD is a computer-aided approach to policy analysis and design, according to (Richardson, 1996). It is used to solve dynamic issues that arise in complex systems that are social, managerial, economic, or ecological. It can be applied to any dynamic system that is defined by mutual interaction, interdependence, feedback loops, and circular causation.

SDM is a set of coupled, nonlinear, first-order differential equations that make up the model. When the simulation runs, time is divided into discrete intervals of length (Maghsoudi and Nezafati, 2023) and other sectors including the health sectors (Darabi and Hosseinichimeh, 2020; Yinusa et al., 2022).

Moreover, this model has not only been used in the above sectors but also it has been used widely to solve logistic problems. In a study by (Kazancoglu et al., 2021) investigates how effectively SD models can assess the environmental effects of reverse logistics. The SDM was also applied to evaluate the city logistics policies. In the article (Beiler et al., 2020) the authors discuss how difficult it is to strike a balance between environmental sustainability and economic efficiency therefore the model SD is put out by the authors to assess the impact of policies.

### **2.2 Macro-Economic Factors Affecting Logistics**

The components of macroeconomic factors are GDP, inflation, balance of payment, employment, and international trade. These components have a direct link with the logistics of the nation (Ababou and Ikram Benomar, 2024a).

Logistics are highly impacted by macro-level factors. International logistics systems are shaped by macroeconomic processes and trends in globalization (Gani, 2017). Logistics performance is impacted at a macro level by crucial elements such as industrial regulations, infrastructure development, and communication networks (Lee et al., 2017). Transport sector companies' financial conditions are affected by shifts in macroeconomic indices including GDP, PMI, and IFO indexes (Wilimowska et al., 2020).

Retailers' investment choices are influenced by economic factors that directly impact inventory costs within logistics systems, such as the rate of inflation, interest rates, and demand growth (Khakbaz and Tirkolae, 2022). Furthermore, macroeconomic factors that affect foreign currency gains from visitors, such as GDP and exchange rates, are critical to the growth of the tourism sector (Lee and Chang, 2016) infrastructure development, and communication networks (Lee et al., 2017). Transport sector companies' financial conditions are affected by shifts in macroeconomics. Essentially, macroeconomic factors are deeply entwined with logistical processes, influencing tactics and results in the international business landscape. The below Table 1 summarizes the macroeconomic factors that affect the logistics performance of a nation.

Table 1. Macro-economic factors affecting the logistics of a country

| <b>Factor</b>                            | <b>Definition</b>  | <b>Reference</b>  |
|--|--|---|
| Availability of manpower                 | Relate to the workforce's size and skill set, which affects a country's potential production and rate of economic development.   | (Aboul-Atta and El-Lebody, 2023; Nthiwa and Wanjiru, 2017)  |
| Communication network                    | Includes internet speed, dependability, and accessibility which affect data sharing and real-time coordination across the logistics network  | (Lee et al., 2017; Samadhiya et al., 2023)  |
| Customs, regulations & clearance         | Government-instituted protocols have a significant impact on the cost and effectiveness of cross-border commodities movement, hence affecting global commerce.   | (Jena and Seth, 2016; Plane, 2021; Yang and Chang, 2019)  |
| Energy prices & availability             | Changes in fuel prices have a direct impact on transportation costs, and changes in energy availability can cause logistics rerouting and operational disruptions.   | (Maitra et al., 2021)   |
| Exchange rates                           | It impacts logistics considerably by affecting the price and profitability of international shipping and import/export operations.   | (Jayathilaka et al., 2022; Rajesh et al., 2023; Üre et al., 2023)   |
| Foreign Direct Investments (FDI)         | This impacts logistics by influencing the need for the mobility of commodities.  | (Ababou and Ikram Benomar, 2024b; Ali et al., 2021; Saidi et al., 2020)                                     |
| Geopolitical Alliance & Trade Agreements | This influences via influencing international trade patterns, tariff policies, and infrastructure investment choices.  | (Ababou and Ikram Benomar, 2024b; Khan et al., 2021; Wang and Zhang, 2017; Xuan et al., 2023)               |
| Gross Domestic Product (GDP)             | A major measure of economic activity, GDP (gross domestic product) is the total value of products and services generated in a nation. It has a direct bearing on the amount and demand of items transported via logistical networks. | (Dieu et al., 2021; Lee et al., 2017; Xuan et al., 2023)  |
| Industrial policy priorities             | Represents a government's long-term emphasis on particular industries and has a big influence on logistics by influencing investment flows, infrastructure growth, and ultimately the effectiveness of goods transportation.         | (He et al., 2018; Lee et al., 2017; Shameem et al., 2021)   |
| Inflation                                | The steady rise in price points. It affects labor, storage, and transportation expenses, causing businesses to change their business plans and thus driving up prices for customers.   | (Ababou and Ikram Benomar, 2024b; Mumin Abdul Mubarak and Yakubu Nandom Ibrahim, 2023; Töngür et al., 2020) |
| Information Technology                   | Helps to facilitate real-time tracking, streamlining transportation systems, and raising overall supply chain productivity.  | (Nthiwa and Wanjiru, 2017; Shameem et al., 2021; Thi et al., n.d.; Yang and Chang, 2019)                    |
| Infrastructure                           | Long-term plans to improve capable intermodal transportation network including integration between maritime, land, and air transportation for overall economic growth and societal development                                       | (Aboul-Atta and El-Lebody, 2023; Plane, 2021; Yang and Chang, 2019)   |
| Interest rates                           | It is the cost of borrowing as Because borrowing cash is expensive, firms must make judgments about inventory levels and expenditures in transportation infrastructure.  | (Minh Ngoc et al., n.d.; Üre et al., 2023)  |
| National culture                         | Including expectations on efficiency in the supply chain, work habits, communication styles, attitudes towards time, hierarchy, and formality may all have an impact on logistics.   | (Orji et al., 2020; Radermecker, 2021)  |
| Natural disasters                        | Hurricanes and earthquakes cause major delays and price swings.  | (Gong and Liu, 2020; Li et al., 2020; Verschuur et al., 2020)   |
| Political and economic stability         | The current state of the government of a country and the power of political authorities.   | (Aboul-Atta and El-Lebody, 2023)  |
| Trade barriers                           | These include quotas and tariffs, which can impede the free movement of commodities across borders and raise the complexity and expense of international logistics operations.   | (Brdulak and Brdulak, 2021; He et al., 2021; Zaninović et al., 2021)  |
| Transit time                             | It is the time it takes for items to move from their point of origin to their final destination. It affects supply chain efficiency, production scheduling, inventory management, and other logistics-related aspects.               | (Brdulak and Brdulak, 2021; Zhang et al., 2020)   |
| Transportation modes availability        | These modes affect international commerce and overall economic activity by determining the cost and efficiency of transporting products over long distances.   | (Combs and Pardo, 2021; Paciarotti and Torregiani, 2021)  |

### 2.3 Micro-Economic Factors Affecting Logistics

Operations in logistics are heavily impacted by microeconomic issues. The logistics business is significantly shaped by the actions of individual firms operating within a networked economic system, as noted in (Khakbaz and Tirkolae, 2022). Key elements that influence profitability in the logistics industry include liquidity, market share, debt-to-equity ratios, and firm age.

Furthermore, decision-making processes concerning inventory investments are directly impacted by the cost management in logistics systems, which is affected by economic variables such as inflation and interest rates as explained in (Safeq, 2013). Effective production procedures and the appropriate integration of manufacturing and logistics activities, as highlighted in (Saripalle, 2018), are critical to the seamless operation of businesses in the supply chain. Thus, for logistics performance to be optimized, it is essential to comprehend and manage these microeconomic aspects. Below Table 2 provides a summary of micro-economic factors found in the existing literature that affect logistics at a micro level.

Table 2. Micro-economic factors affecting the logistics of a country

| Factor                                 | Definition   | Reference   |
|--|--|---|
| Access to financing                    | Amount of finance available to sustain the logistics operations.   | (Liu et al., 2023; Tien et al., 2022)                                       |
| Agility of logistics service           | describes a business's capacity to adjust to shifting consumer demands and market dynamics.  | (Abdulla and Musa, 2021; Nurjaman et al., 2021)                             |
| Automation and robotics                | Automation and robots can save labor costs and increase efficiency in transportation and warehousing operations, but they also raise concerns about job loss.  | (Aljawarneh et al., 2021; Yang and Chang, 2019)                             |
| Bargaining power of suppliers & buyers | Within an industry, the relative bargaining power of suppliers and buyers can have an impact on logistics costs.   | (Heydari and Bakhshi, 2022; Mondliwa et al., 2021)                          |
| Competition intensity                  | Intense industry rivalry can put pressure on businesses to streamline their logistics processes in order to provide cheaper or faster delivery.  | (Govindan et al., 2020; Qin et al., 2020)                                   |
| Consumer expectations                  | Growing customer demands for free shipping and quick delivery times may put pressure on logistics firms to run more effectively.   | (Ding et al., 2020; Gajewska et al., 2020; Uvet, 2020)                      |
| Cost Management                        | Through the optimization of transportation, warehousing, inventory levels, and labor utilization, businesses may boost their competitiveness and profitability by drastically cutting total logistics costs.                 | (Atayah et al., 2022; Ulutaş et al., 2020)                                  |
| Customer service level                 | Companies may draw and keep consumers by emphasizing prompt delivery, correct order fulfillment, and responsive communication.   | (Bag et al., 2020; Gajewska et al., 2020; Shameem et al., 2021)             |
| Inspection and quarantine              | Affects logistics by raising the cost of storage and transportation, creating delays at borders, and perhaps sabotaging just-in-time inventory flows.  | (Fu et al., 2022; Yang and Chang, 2019)                                     |
| Inventory management                   | Demand for transportation and storage services is rising as a result of businesses with lean inventory needing regular, dependable delivery.   | (Abdulla and Musa, 2021)  |
| Labor unionization                     | Robust labor unions have the ability to affect labor costs and may have an effect on salary and working conditions negotiations for logistics personnel.   | (Klump and Ruiner, 2020; Moody, 2019)                                       |
| Order Process Management               | Includes activities such as managing inventory and fulfilling orders has a direct influence on logistics effectiveness.  | (Ristovska et al., 2017; Selim et al., 2022)                                |
| Packaging & labeling                   | Affects by affecting product weight, size, and handling needs, logistics expenses can be reduced.  | (Freichel et al., 2019; Mahmoudi and Parviziomran, 2020; Yang et al., 2020) |
| Personnel quality                      | Efficiency is greatly impacted by the knowledge, expertise, and work ethic of the logistics personnel.   | (Abdulla and Musa, 2021)  |
| Risk management                        | Describes the tactics used by businesses to minimize any interruptions and guarantee the efficient flow of commodities.  | (Chu et al., 2020; Gurtu and Johny, 2021; Verschuur et al., 2020)           |
| Supplier relationships                 | Having solid supplier connections that guarantee on-time and dependable deliveries may simplify the logistics process.   | (Jinru et al., 2022; Richnák and Gubová, 2021; Wang et al., 2020)           |
| Sustainability practices               | Companies focusing on sustainable logistics practices, such as using fuel-efficient vehicles or optimizing packaging, might incur higher initial costs but can benefit from long-term cost savings and improved brand image. | (Shameem et al., 2021)  |

|                                  |   |  |
|----------------------------------|---|--|
| Technology adoption              | Businesses may save expenses and increase productivity by implementing technological solutions like route optimization software and warehouse management systems (WMS).   | (Hao et al., 2020; Lagorio et al., 2022; Shamout et al., 2022) |
| The capability of foreign agents | A nation's import/export expenses and overall logistics performance may be greatly impacted by the effectiveness, network of infrastructure, and pricing tactics of international shipping corporations and freight forwarders. | (Yang and Chang, 2019)   |
| Traffic accessibility            | Describes how simple it is to transport commodities inside a nation.  | (He et al., 2018)  |
| Transparency                     | Transparency is the free exchange of data about inventory levels, shipment locations, and probable delays with all parties involved in the supply chain.  | (Shameem et al., 2021)   |

## 2.4 Literature Review Gaps and Analysis

SD is essential to comprehending the complex interactions between logistics and other impacting elements.

After extensive work has been conducted on the literature, it has been found that there is no single paper analyzing both macro and micro factors that affect logistics using the SDM. Studies have been performed using this tool in various areas and sectors but not analyzed at a national country level. Researchers have used this tool to assist decision-making and policymakers in the development of the Logistics Hub in Dubai (Freitag et al., 2022). Therefore, this paper will act as a guide for decision-makers and government bodies to understand the factors both on a macro and micro level and how they are interrelated.

Moreover, this study will also help to have an overview of all the factors affecting logistics at a national level allowing a certain country to better understand their logistics. A table has been extracted from various studies done in the past where it summarizes the research performed in the area of logistics and how SDM was used to analyze these logistics problems. Table 3 represents the last decade of literature existing where systems dynamics was applied to the logistics area.

Table 3. Existing Literature Review on SD Used in Logistics

| Year | Reference  |
|------|--|
| 2024 | (Chai and Tian, 2024) - Growth mechanism on express delivery<br>(Zagloel et al., 2024) - Development of sustainable logistics<br>(Nalbur and Yavas, 2024) - Simulation in green logistics for the electric bus industries                    |
| 2023 | (Abbasi et al., 2023) - Integration of biomass Logistics to reduce GHG Emissions<br>(He and He, 2023)- Logistics Industry and Economic Development Policy<br>(Ji et al., 2023) - Sustainable development of the logistics system             |
| 2022 | (Jayarathna et al., 2023) - Viability of sustainable logistics practices<br>(Giedelmann-L et al., 2022) - Food inventory policy assessment<br>(Mehrerjedi and Karimi, 2022) - Relief Logistics   |
| 2021 | (Kazancoglu et al., 2021) - Performance evaluation of reverse logistics<br>(Omotayo et al., 2021) - Third-Party Logistics towards Business Performance<br>(Liang, 2021) - Urban Logistics System Strategy Based                              |
| 2020 | (Yi et al., 2020) - Behavioral strategies of participants in crowd logistics<br>(Alamerew and Brissaud, 2020) - Modelling reverse supply<br>(Zenezini and De Marco, 2020) - City logistics policy evaluation                                 |
| 2019 | (Sundarakani et al., 2019) - Sustainability of third-party logistics growth<br>(Irfani et al., 2019) - Design of a logistics performance management system<br>(Dong et al., 2019) - Impact of Underground Logistics System                   |
| 2018 | (Kunc et al., 2018) – Literature Review from 1947 to 2017<br>(Adiweno et al., 2018) - Designing Economic and Environmental<br>(Liu, 2018) - City Electric Logistics Vehicle Upgrade  |
| 2017 | (Ghisolfi et al., 2017) - Supply chains of desktops and laptops in Brazil<br>(Sudarto et al., 2017) - Capacity planning for optimal sustainability dimensions  |
| 2016 | (Franco et al., 2016) – Logistics outsourcing policies and decisions<br>(Jhavar and Garg, 2016) - Effects of Investment in IT on Logistics Performance<br>(Hsu et al., 2016) – Performance Evaluation of IoT One-Stop Logistic Services      |
| 2015 | (Abduaziz et al., 2015) - Green Logistics Assessment in the Automotive Industry<br>(Golroudbary and Zahraee, 2015) - Optimizing the recycling and collection of waste material<br>(Costa et al., 2015) - Humanitarian logistics coordination |

### **3. Methods**

The methodology followed to conduct this research was mainly on the basis of extensive literature review. The main factors affecting national logistics performance were determined by this study using a methodical literature review technique. After a comprehensive search on Google Scholar, pertinent scholarly publications and papers were chosen for a more thorough examination. A series of steps were used to improve the information that was collected. At first, the factors affecting national logistics were carefully extracted and categorized from the articles. Making the distinction between macro- and micro-economic viewpoints was a step in this process. Macroeconomic research concentrated on factors like trade regulations and infrastructure growth that affect the larger logistics environment. A thorough grasp of the factors influencing logistics at the systemic and operational levels was achieved by this classification.

### **4. Conclusion**

After the critical review, it is clear that logistics has to be analyzed from a macro and micro level to make it more efficient for a nation. For the last decade, SD has been used in the logistics sector and has been analyzed in different areas to analyze logistics problems and make the logistics network more efficient.

The macro-economic factors identified in this research were GDP, inflation, interest rates, trade barriers and exchange rates on the other hand the identified microeconomic factors were cost management, quality of the personally, inventory management, transparency, etc. Using the SD, the inter-relationship of these factors with each other can be examined and proper policies can be formulated to make better decisions.

Moreover, no single paper has analyzed the logistics issue looking at the macro and micro factors of a nation that is affecting logistics using the tool SDM. Therefore, this integration is extremely important to allow policymakers and decision-makers to make effective decisions.

However, this paper is a basis to evaluate using SDM in the logistics sector of a country by gathering valuable data hence therefore valuable judgments can be gained.

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