OPEN ACCESS

Saudi Journal of Engineering and Technology
Abbreviated Key Title: Saudi J Eng Technol
ISSN 2415-6272 (Print) |ISSN 2415-6264 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Original Research Article

System Dynamics for Local Supply Chain Management: A Literature Review

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DOI: 10.36348/sjet.2024.v09i07.002 | **Received:** 22.05.2024 | **Accepted:** 29.06.2024 | **Published:** 05.07.2024

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Abstract

Nowadays, logistics activities are growing annually by 4.4%, reaching annual valuations of up to 10 billion dollars. This area is key for manufacturing companies and commerce in general, which is why the central question arises in this area of knowledge about how to approach proposals or improvement actions in a sustainable way. On the other hand, technological tools such as simulation are an important element to evaluate sustainability alternatives and operational strategies due to their flexibility and high scope. This article addresses a systematic literature review about the use of system dynamics within the management of current supply chains, covering 144 articles in databases such as Scopus and ScienceDirect, for the period between 2000 and 2022 to generate an overview for new sustainability proposals in México.

Keywords: Simulation; System dynamics; Supply chain; Logistics; Sustainability; Literature review.

1. INTRODUCTION

The world is witnessing an increase in Greenhouse Gases (GHG) to a level never seen before in history, increasing the temperature of the earth and causing a considerable environmental imbalance (Abbasi *et al*., 2023). That is why its control represents a crucial and multifaceted challenge that affects several aspects of modern society, including the social and labor sector, where supply chains are involved because it is one of the largest contributors, occupying the second place as generator with 8,258 megatons of CO2 equivalent of a total of 48,940 for 2018 (Alamerew & Brissaud, 2020),

In recent decades, there has been increasing pressure from various ecological interest groups on the business sector to incorporate social and environmental concerns into their activities. This is due to the impacts that companies themselves generate, while also emphasizing economic performance through the concept of the circular economy (CE) (Alamerew & Brissaud, 2020). In this context, companies are increasingly committed to reducing their carbon footprint through greener logistics practices and responsible supply chains. This commitment has led to the development of indicators to measure this phenomenon and simulation has emerged as an adequate tool for controlling these indicators, providing estimates, and enabling optimal decision-making for new sustainable strategies (Ivanov *et al*., 2017).

Technologies such as simulation contribute to predictively enabling the behavior of logistics and production systems, considering multiple real or foreseeable situations where GHG emissions issues can be addressed (Shi *et al*., 2013). A simulation model serves as a test bed for experimentation and configuration of alternatives, which allows the optimization of logistics or supply chain, achieving the desired objectives.

The present systematic literature review explores the progress of studies concerning the development and application of simulation as a decision-making tool specifically in the field of logistics, highlighting the importance of sustainability. This document consists of five sections. The introduction serves as a preamble, describing basic aspects of the necessity. The second section comprises a background review, while the third section details the methodology and classification framework of the collected

information. The results are presented in the fourth section, concluding with section five, which discusses the conclusions drawn from this exercise.

2. BACKGROUND

Sustainability can be seen as the ability to preserve, promoting practical mindsets and sustainable policies to maintain a healthy natural environment. The rapid growth of the manufacturing industry has highlighted not only many challenges and problems within the logistics system, but also the consequent need for optimization. The rapid growth of the manufacturing industry has not only highlighted numerous challenges and problems within the logistics system but also underscored the urgent need for optimization. The increase in vehicles in urban areas has led to greater congestion, air pollution, and noise, all of which negatively impact traffic safety, quality of life, and urban economic competitiveness. Sustainable development necessitates creating value for the survival of the current business system (including customers, partners, and society) and ensuring its growth for future generations in an equitable and prudent manner (Golroudbary *et al.*, 2019).

It is important to consider the supply chain as a dynamic system, necessitating efficient and proactive risk management to which sustainability must be integrated. This underscores the interest of researchers in utilizing system dynamics as the ideal paradigm for modeling and simulating logistics or supply chains. The goal is to capture the system's behavior more realistically, facilitating a comprehensive study and determination of efficiency. Efficiency is defined as the system's capacity to supply materials, manufacture products, and deliver them to the specific market in the fastest, most accurate, profitable, and sustainable manner (Azizsafaei *et al*., 2022).

In the field of supply chain management, system dynamics has been applied since its inception, as shown in the first publications by Jay Forrester (Aracil, 1995) on the analysis of social behaviors, although it has also been applied used to evaluate environmental scenarios and decision making. The system dynamics modeling approach is used to represent the interaction between multiple decision factors in each subsystem. Each subsystem establishes its own network and the influence of one factor on another is represented in a specific diagram. Representation using a causal loop diagram shows how connections to a system give rise to the behavior of the system and the potential impacts of modifying the connections (Shi *et al*., 2013).

Logistics models are considered the basis of companies, they define the strategy to face a highly competitive market, considering as strategies, flexibility, efficiency, timely delivery and capacity that are already known as resource optimization, with this the authors demonstrate the potential approaches. For the development of tools such as simulation for logistics design and architecture (Klug, 2013), (Potter & Lalwani, 2008a), (Azizsafaei *et al*., 2022).

The parameterization of the model within the process allows for the determination of variables, constants, and parameters, among other factors. It is also important to consider the size of the existing models, including the scenarios considered for simulation in logistics (Helo & Szekely, 2020), this highlights the importance of this literature review in providing a general vision for new future project proposals on system dynamics.

In the same context, one of the targets is to find the dimension of the system and the critical information with the contribution of each article in system dynamics, this will provide recommendations in the analysis of logistics due to the complexity in the interaction of its elements and will evaluate the recovery of value (Das & Dutta, 2013).

3. Methodology and classification framework

In this section a qualitative approach is described, with the main relevance being the analysis of high-impact contributions to model their importance in understanding the system, supported by precise evidence to outline future research (Klug, 2013).

From a methodological point of view, this literature review addresses a systemic, explicit and reproducible approach for the identification, evaluation and interpretation of the existing information as a key tool for decision making (Al-Qatawneh & Hafeez, 2015).

In the present review it will be important to have a methodological structure to follow and which is presented below through sections A) Data collection, B) Classification and evaluation and C) Synthesis and classification framework.

A. Data collection

The data collection used in this study was organized according to specific characteristics providing a structured framework for identifying key elements.

Step 1: Research question

The central question of the research is: *how effective has simulation been in decision-making processes related to sustainability and supply chain?*

Step 2: search for contributions

The methodology is based on selecting articles by a high impact database that is available to the analyst (such as ScienceDirect®, Scopus®, Emerald Publishing®, Taylor & Francis Group®, IEEE®, among others). For this exercise ScienceDirect® source was selected, it is considered an Elsevier® platform and among the main scientific and academic publishers due to its content on multidisciplinary topics. In this way, Scopus® database

also was selected as it is a database of summaries and citations of scientific literature wide, covering a wide variety of disciplines and subject areas, in addition to being updated regularly to include new articles and magazines, guaranteeing the most recent and relevant information (Codina, 2017).

In both databases, the related keywords shown in Table 1, considering supply chain and logistics as keywords that address the line of research to be discussed; simulation and modeling since it is the object of study and finally system dynamics was determined since it is the methodology proposed as ideal for the conditions of the research. In addition, as selection criteria are considering as such as the research-type articles (research articles and literature review), language (English) and period time (2000-2022).

Table 1: Related keywords

Date	2000 to 2022
Keyword	Simulation, Modelling, Dynamic of systems, System dynamics, Supply chain, Logistics
ScienceDirect®	38
Scopus®	164

The articles were fined through the institutional resources of the Advanced Technology Center, CIATEQ, enter the databases using the following standard search:

TITLE-ABS-KEY ((("simulation" OR "modelling" OR "model") AND ("dynamic of systems" OR "system dynamics") AND ("supply chain") AND ("logistics")) AND PUBYEAR > 1999 AND PUBYEAR < 2025 AND PUBYEAR > 1999 AND PUBYEAR < 2023 AND (LIMIT-TO (SRCTYPE , "j") OR LIMIT-TO (SRCTYPE , "p")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp")) AND (LIMIT-TO (LANGUAGE , "English"))

Step 3: Classification and evaluation of selection criteria.

The collection of articles was carefully reviewed to identify those contributions that did not meet either the research focus or the previously defined selection criteria. As a result of the search string entered in both databases, a total of 202 contributions were obtained, of these, 58 were classified as unrelated to the main topic, addressing issues such as obtaining raw materials, production, reverse logistics, and health, leaving only 144 articles within this review.

B. Data analysis

The sample articles were considered with the objective of analyzing and identifying patterns by country or region regarding the topics addressed and the publication journals. These insights can serve as recommendations for researchers interested in the topic. The analysis also included the knowledge area, modeling aspects (such as variables, constants, and level of implementation), and the dimensions of existing models, as well as the resources used (hardware, software). This approach helps determine if there is any guiding line in the technical specifications that align with the research focus, and whether a diagram or model is present or absent.

Under the concepts discussed above and the filters applied to the set of articles, a digital spreadsheet database was utilized as a means of classification and reference for the literature review. A specific taxonomy was designed to process the information and obtain relevant findings, considering the aspects described in Section C.

C. Synthesis and classification framework

Logistics in its different areas covers a significant number of interactions between variables and constants according to the established scenarios, so segmentation or classification is important to carry out the adequate synthesis of the information and obtain important conclusions (Al-Qatawneh & Hafeez, 2015). The classification framework for this article is depicted below:

1) Publication year

For this classification, contributions that have been completed or deemed successful within the specified period must be identified. The objective is to detect the behavior of the research over time about modeling with system dynamics in logistics and supply chain.

2) Countries involved in development

It is crucial to identify the country involved in the development of each article, not only to compare the international interest levels regarding specific topics but also to understand the context in which the research is conducted. This includes considering trade contexts and relating them to economic development, as well as adopting existing best practices related to the topic of interest in logistics.

3) Source

Explore the diversity of publication media allows us to know not only the level of trust that authors have in certain journals, but also outlines the means of publication of related works where there will be the greatest impact.

4) Knowledge area

The knowledge area is an interesting classification to learn about the approaches where simulation is most applied in the supply chain.

5) Simulation model

This classification is used to identify articles with a simulation model or framework, mainly to detect the size of the evaluation, the number of ideal scenarios to work with, variables and actors for a new proposal in Mexico.

6) Evaluation objectives

The purpose of the evaluation is to determine to what extent the goals of each project were achieved, as well as to associate the learning and knowledge generated to contribute to new proposals in the future.

7) Model size

To know the size of the model, the number of variables is considered. and constants that are described and shown in the proposed model.

8) Economic sector

The economic sector where the model is applied is analyzed, this in terms of contributions of each reviewed article, considering the diversity of logistics and its participation in various ecosystems, it seeks to detect the influence of the research regarding the topic in different economic sectors (primary, secondary and tertiary according to (INEGI, 2020).

9) Company name

In this classification section, trends among institutions, organizations, and companies interested in the proposed topic are explored.

10) Business scope

The scope of the organization refers to the main economic activity in which it performs, where you can find public and private ones of different vocations from manufacturing to education and research.

11) Software used

As a contribution to this literature review, it is considered of utmost importance to identify the software tools used by authors as this knowledge will be valuable for future research and practical applications in modeling.

12) Hardware used

During the implementation of a simulation model, it is essential to understand the technology being used, including computers or other electronic devices, as well as their setups and capabilities.

13) Implementation level

The depth of the simulation implementation is determined as a classification framework to evaluate which contributions offer appropriate proposals or knowledge about the simulation tool.

4. Classification Results

This section describes the result of the classification to provide relevant information that denotes the importance of system dynamics simulation.

1) Results by publication year

The results of this classification carried out described a growth behavior starting in 2003 with two declines in 2011 and 2016 to 2017. However, interest in related topics within the scientific community is on the rise, which for some companies and business models seemed invisible years ago.

The Figure 1 present the behavior of publications. A considerable increase in research can be seen in the years 2013, 2020, and 2022, this behavior can be associated with global events such as health alerts (2020) and international conflicts (2022), highlighting mainly for these periods as (Shi *et al*., 2013), (Lehr & Milling M., 2010), (Li & Zheng, 2013), and (Wang *et al*., 2013), for the year 2013, (Alamerew & Brissaud, 2020) and (Melkonyan *et al*., 2020) for 2020, and (Azizsafaei *et al*., 2022) for 2022.

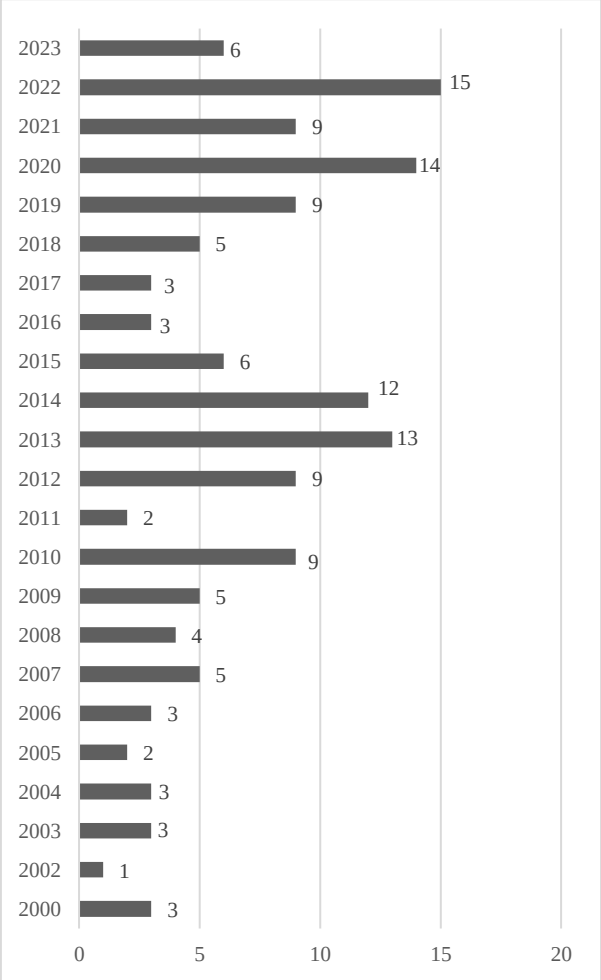

Figure 1: Results by publication year

2) Results by country

The classification results of the articles corresponding to the country or countries involved in the development of the article are presented in Figure 2.

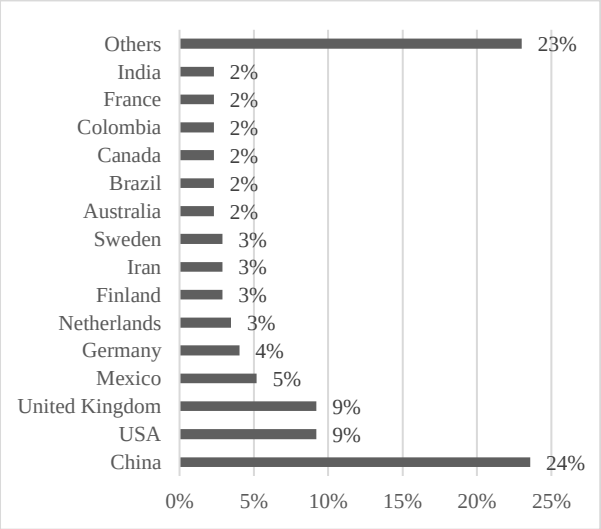

Figure 2: Results by country

It is observed that China represents the first place of interest in system dynamics related with logistics and supply chain with the highest percentage of participation. The second place, the United States of America and the United Kingdom, then Mexico is positioned in third position of contribution. It is important to highlight that within the 24% contribution from China there are exclusive publications that highlight (Li & Zheng, 2013), (Wang *et al*., 2013) and (Peng *et al*., 2014), also scenarios such as (Shi *et al*., 2013) y (Shi *et al*., 2014) whit have a collaboration between China and the United States of America.

The other countries involved have fewer published articles, considering the search characteristics. Countries such as Poland, Vietnam, Italy, Spain, Singapore, Greece, and Korea have less than 2% participation. On the other hand, with less than 1% participation, there are 20 countries categorized as "Others" that have only one publication each.

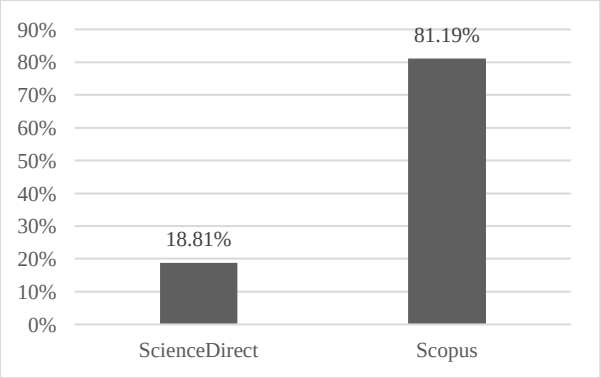

Figure 3: Databases involved

3) Results by source

The greatest participation of journals according to the articles published, stands out directly in ScienceDirect and Scopus as in the percentages shown in the Figure 3.

La Figure 4 presents a list of the main journals where research works are published, where it can be seen that the largest number of contributions are located in the Xplore houses of IEEE and MDPI, likewise, highly prestigious journals can be identified such as Journal of cleaner Production, European Journal of Operation Research and Computers & Industrial Engineering.

Figure 4: Results by source or Journal

In others category there are journals with a single article published, as a reference highlights “International Journal of Production Economics” (Ivanov *et al*., 2017) and (Melkonyan *et al*., 2020), “Journal of Cleaner Production” (Alamerew & Brissaud, 2020), “European Journal of Operational Research” (Shi *et al*., 2013) and (Shi *et al*., 2014), “Research Journal of Applied Sciences, Engineering and Technology” (Wang *et al*., 2013), “International Journal of Production Research” (Klug, 2013) and “Journal of Remanufacturing” (Asif *et al*., 2012).

4) Results by knowledge area

The main area involved in this systematic review is engineering, accounting for 29% of the contributions, followed by science with 22%, as shown in Figure 5.

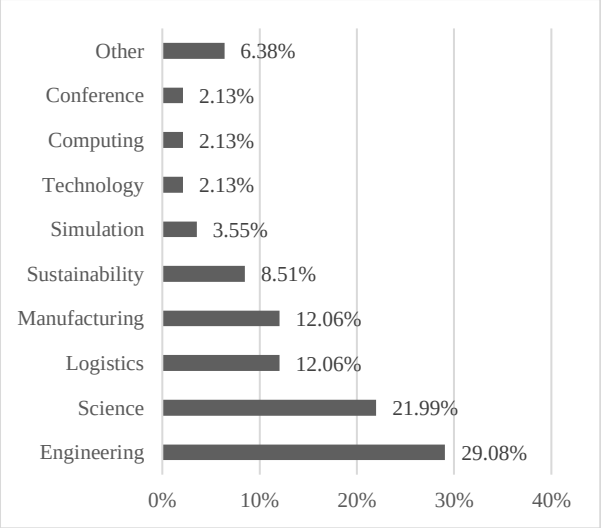

Figure 5: Results by knowledge area.

Also, there is a category "Others" with nine areas of knowledge, each contributing only one published article. It stands out (Raihanian Mashhadi *et al*., 2015) where the high potential for using simulation techniques in different decision making is concluded. considered as a reference point in GHG modeling in addition to the calculation of the carbon footprint.

5) Results by simulation model

It is important to indicate that, from this point forward, only articles that provide a simulation model addressing the research question and the author's objectives will be considered and analyzed.

Of the articles collected, the Figure 6 shows a 117 whit a specific simulation model using system dynamics although there are 27 articles without a model, just they have a proposal of modelling.

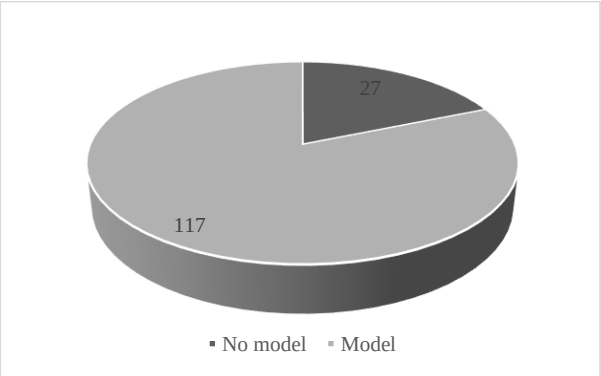

Figure 6: Results by simulation model

This classification depends on the scope of each researcher, however, the contribution of (Asif *et al*., 2012) includes highly complex models developed in parts or multiple simple models that integrate the macro process.

This approach is recommended to understand their operation and results; in this context (Raihanian Mashhadi *et al*., 2015) develops a step-by-step approach to creating the simulation model, starting from conceptualization and leading to the explanation of the system's result; and (Campuzano Bolarin *et al*., 2010) shows in a concrete way a modeling list with variables definition, unit of measurement and comments corresponding to the elements of the modeled system for new proposals.

6) Results by evaluation objectives

The Figure 7 depicted the main objectives focused on the improvement and optimization of logistics and supply chain processes as such as (Ivanov *et al*., 2017), (Lehr & Milling M., 2010), (Potter & Lalwani, 2008b), (Azizsafaei *et al*., 2022), (Klug, 2013), (Li & Zheng, 2013), (Shi *et al*., 2014), (Stewart & Ivanov, 2022) and (Campuzano Bolarin *et al*., 2010). This behavior is expected since these items are integrated into the database search.

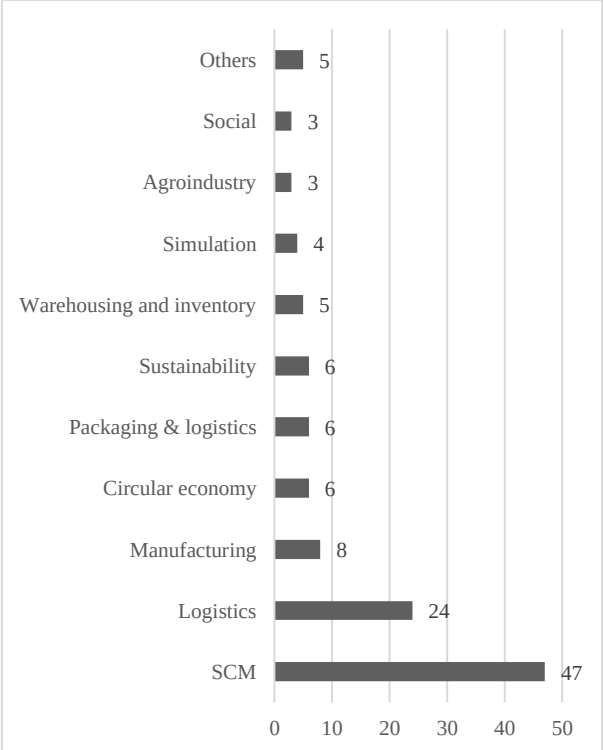

Figure 7: Results by evaluation objectives

The "Other" category includes individual contributions that cover areas such as cost, efficiency, technology, organization, electronic commerce, among others.

7) Results by model size

Of the articles analyzed (117) shown in Figure 8, the size is evaluated to determine their trend in terms of modeled complexity. Most of them show up to 3 level variables, 23 variables, 12 constants, and 3 implemented scenarios.

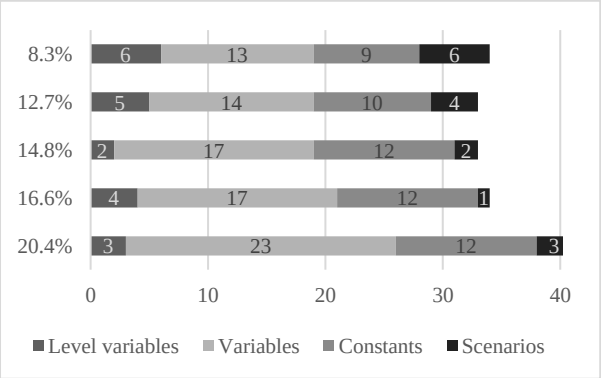

Figure 8: Results by model size

Regarding the models presented, it should be emphasized that the number of variables and constants corresponds to the level of depth in which the system to be detailed.

However, those articles that show the greatest number of scenarios stand out (Potter & Lalwani, 2008b) with 6 scenarios presented, one for each case of possible capacity in the system to understand the behavior with a dynamic condition. On the other hand, (Shi *et al*., 2013), (Golroudbary *et al*., 2019), (Lagarda-Leyva, 2021) and (Campuzano Bolarin *et al*., 2010) present only one scenario, detailing the parameters in a decisive and clear way for the objective of the simulation.

8) Results by economic sector

The Figure 9 depicts that the greatest use of simulation in system dynamics is concentrated in the tertiary sector with a 96% of the articles reviewed for this section. In economically developed countries, the tertiary sector, also known as the service sector, represents a significant part of economic activity, with numerous service jobs playing a key role. In this sector, activities involve providing services rather than directly producing goods, such as logistics or communication services, which are crucial for any economic activity.

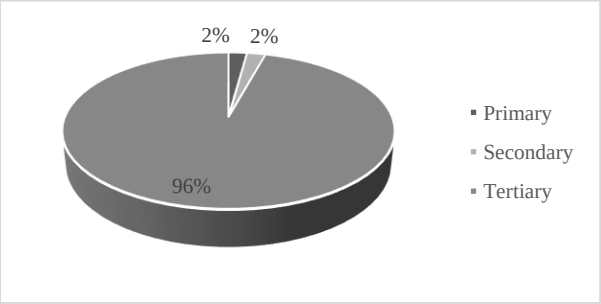

Figure 9: Result by economic sector

On the other hand, the few articles that do not belong to this sector discuss concepts such as agriculture (primary sector) or manufacturing (secondary sector), thus deviating from the focus of interest.

9) Results by company name

As indicated by the articles that mention the name of the company where the study or solution was developed, the Figure 10 shows that 34% of the articles include this information, while 66% do not. This highlights a greater interest in dissemination aspects than in economic advantages.

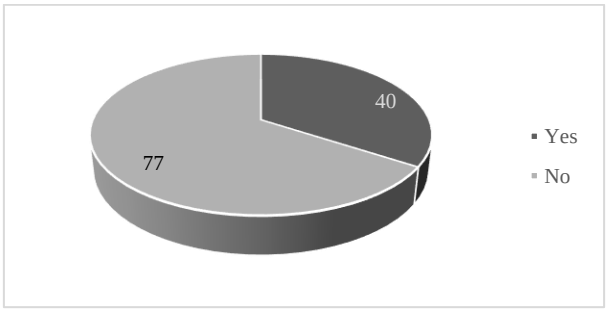

Figure 10: Results by company name

For the most significant contributions that do mention the name of the company or reference it, there are (Alamerew & Brissaud, 2020) "R&D Company", (Golroudbary *et al*., 2019) "ABM", (Potter & Lalwani, 2008b), "UK-based haulage company", (Wang *et al*., 2013) "Maxwell Scientific", (Melkonyan *et al*., 2020) "MCDA", (Asif *et al*., 2012) "OEMs", (Raihanian Mashhadi *et al*., 2015) "ABS", (Lagarda-Leyva, 2021) "VSM" and (Campuzano Bolarin *et al*., 2010) "business organization and management".

10) Results by business scope

The nature of the company, organization or institution in which the research is carried out is important when considering since this concept is defined as the essence of the identity and operation of a company, specialization and its target market.

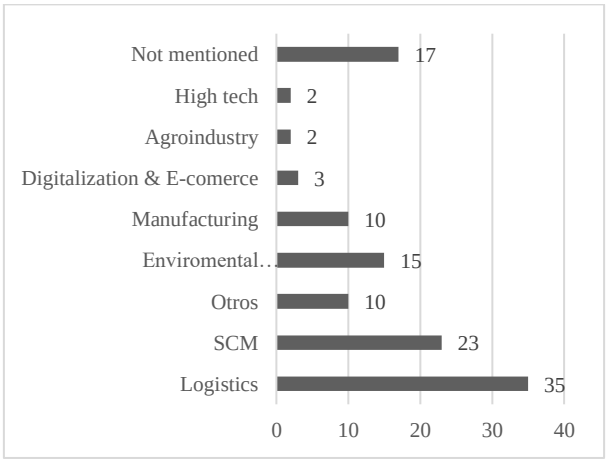

Figure 11: Results by business scope

The behavior observed in Figure 11 turns out to be interesting since although most of the articles do not mention the name of the company, if their business is referred to, in some cases it can be disseminated in the development of the article, as a result of this classification, logistics stands out with a 29% participation, highlighting articles such as (Ivanov *et al*., 2017), (Potter & Lalwani, 2008a), (Azizsafaei *et al*., 2022), (Li & Zheng, 2013), (Shi *et al*., 2014), (Stewart & Ivanov, 2022) and (Campuzano Bolarin *et al*., 2010).

11) Results by software used

The software used for the development of the contributions is evaluated, revealing in the Figure 12 a significant participation in VENSIM software such as (Alamerew & Brissaud, 2020), (Azizsafaei *et al*., 2022), (Größler & Zock, 2010) and (Campuzano Bolarin *et al*., 2010) which presents advantages in conceptualization and documentation of the models with strength in the dynamics paradigm of systems. In second place is Stella that is used by (Asif *et al*., 2012) which has simplicity in the aspect of architecture.

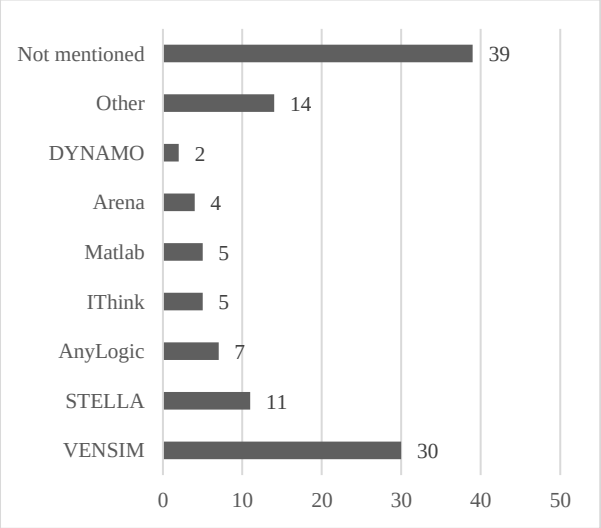

Figure 12: Result by software used

The third place is AnyLogic that is used by (Ivanov *et al*., 2017), (Shi *et al*., 2013), (Golroudbary *et al*., 2019), (Wang et al., 2013) and (Raihanian Mashhadi *et al*., 2015) which handles 3 of the simulation paradigms, in addition to that it has the possibility of simulating highly complex systems in a simple way, not to mention that it has student or academic versions of the software.

12) Results by hardware used

This classification reveals that authors rarely mention the hardware used for system modeling or simulation, likely because most current equipment meets basic requirements. Consequently, the research community does not find it relevant to specify such details, usually only providing the model or operating system used.

13) Results by implementation level

When searching for information based on modeling and simulation, it is expected that most of the articles collected have the same level of implementation, but there are steps shows in the Figure 13 as planning, research, real implementation, modelling without multiple scenarios and complete simulation whir more scenarios evaluated.

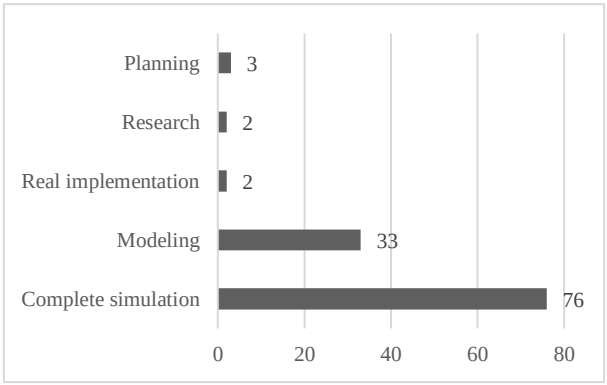

Figure 13: Results by implementation level

5. CONCLUSIONS

Logistics and supply chain research presents a significant evolution in recent years, the above also in relation to modeling focused on system dynamics, which denotes its importance in a globalized world framed by international trade where China have the principal exploration. In this context, it is relevant the participation of Mexico with the fourth position of contributions. Also in a general way, the interest of the scientific and engineering community in improving these kinds of models to achieve optimal efficiency has risen with a mean of 11 contributions per year in the last five years.

Based on the present review, it is also concluded that the trend under the established premises favors medium-level models with three level variables, 23 variables, 12 constants, and three implemented scenarios, with VENSIM, Stella, and AnyLogic being the primary software references used. In addition, most models developed evaluate scenarios without having a real implementation of the solution.

Regarding the organization, it is important to mention that most contributions are developed in the tertiary economic sector, with companies associated with logistics, supply chain, and manufacturing. These companies have a clear objective of finding solutions for their operations and efficiency, leaving opportunities for sustainability or social factors, which are less prioritized.

There are clear opportunities areas to carry out for new proposal soon, especially in health business scope, sustainability strategies or agroindustry that may be publish in one of the prestigious journals as such as Computers & Industrial Engineering and Applied Science of MDPI.

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