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An analysis of JIT from the Perspective of Environmental Sustainability

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RESUMO

Objetivo – O sistema Just In Time (JIT) tem como fundamento fornecer o produto correto, no momento certo e na quantidade necessária, reduzindo os estoques em armazéns e em processo. Em contrapartida, exige aumento na frequência de viagens dos veículos de transporte, o que pode impactar negativamente os indicadores de sustentabilidade ambiental da organização. Visando contribuir com as discussões a respeito deste assunto, este artigo tem como objetivo identificar, sistematizar e analisar a literatura disponível sobre a intersecção dos temas JIT e sustentabilidade ambiental.
Desenho / metodologia / abordagem – Foi realizada uma revisão estruturada da literatura por meio de consultas às bases de dados Scopus e Web of Science. Foram identificados e analisados 53 artigos publicados em journals ou congressos.
Resultados – Os artigos selecionados foram categorizados em cinco dimensões: aspectos ambientais, custos operacionais, desempenho das operações, método da pesquisa e local/região do estudo. Foi identificado que ainda não existe consenso sobre se as operações logísticas fundamentadas no sistema JIT favorecem ou não as práticas sustentáveis.
Originalidade / valor – Para ampliar as análises e discussões sobre os temas JIT e sustentabilidade ambiental e apoiar pesquisas futuras, o artigo fornece uma classificação dos 53 artigos selecionados quanto aos seus propósitos em cinco diferentes dimensões. Frente à necessidade das organizações de se tornarem cada vez mais sustentáveis, foi adicionalmente foi elaborada uma matriz SWOT.
Palavras-chave: Just In Time; Transporte; Meio Ambiente; Sustentabilidade; Logística.

ABSTRACT

Purpose *– The fundamental concept behind Just in Time (JIT) is to provide the right product at the right time and in the required quantity, reducing inventories in warehouses and in manufacturing processes. On the other hand, it requires increased usage of transport vehicles, which may negatively affect the organization's environmental sustainability indicators. In order to contribute to discussions on the subject, this study aims to identify, systematize and analyze the available literature on the intersection of JIT and Environmental Sustainability topics.*
Design/methodology/approach *– A structured literature review was performed through research in the Scopus and Web of Science databases. Fifty-three papers published in journals or at congresses were identified and analyzed.*
Findings *– The selected papers were categorized in five dimensions: environmental aspects, operational costs, operational performance, research method and location/region of the study. A lack of consensus was identified on whether or not logistics operations favor sustainable practices that used the JIT system.*
Originality/value *– To build on the analysis and discussions on the JIT and Environmental Sustainability and support future research on the subject, the study has classified 53 selected papers based on their purposes in five different dimensions. Given that organizations need to become increasingly sustainable, a SWOT (strengths, weaknesses, opportunities, and threats) matrix has been prepared in addition.*
Keywords ***-*** *Just In Time, Transport, Environment; Sustainability; Logistics.*

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1. INTRODUCTION

Despite having long been considered synonymous with lean manufacturing, Just in Time (JIT), which shares the title of pillar of lean manufacturing with jidoka (autonomation), is not the only practice to have been applied to this production and operations management model (LIKER, 2005).

Derived from the Toyota Production System (TPS), lean manufacturing (LM) was developed in the 1940s by Toyota, creator and doyenne of lean business, as a means of aiding the rehabilitation of Japanese assembly plants after the Second World War. Given the economic difficulties faced by the Japanese at the time and as a means of guaranteeing a positive cash flow, Toyota needed to produce small numbers of diverse automobile models, and deliver them quickly to customers following the receipt of orders (OHNO, 1997; WOMACK; JONES, 2004). It is important to note that lean manufacturing is a more contemporary concept that incorporates TPS philosophy and tools (YAMAMOTO; MILSTEAD; LIOYD, 2019). LM works on the premise of a lean, elastic and driven operation, aligned with market demands - different from the Fordist model, widely adopted by North American assembly plants, which preached mass production and a system based on cost reduction (LIKER, 2005).

To reach its objectives of increasing production flow and ensuring high quality, safety and low costs, Toyota created and established various tools and practices, such as kanban, S.M.E.D., genchi genbutsu, andon, manufacturing cell, heijunka, takt time and JIT (DENNIS, 2009, LIKER; MEIER, 2006; SHINGO, 1996).

JIT is a management method which aims to align the inventory required for production with customer service, always linked to consumer demand (ARJONA AROCA, *et al.*, 2020). Milewski (2022) affirms that JIT aims to rationalize inventory so that optimum levels are maintained, since excessive inventory causes a reduction in the economic efficiency of an organization. What controls production utilizing JIT across a supply chain is final consumer demand, given that each item is acquired, produced and delivered following the premises of the exact measure required for the next phase of the chain or for the market (UGARTE; GOLDEN; DOOLEY, 2016).

According to Storhagen and Hellberg (1987), JIT offers businesses benefits such as reduced uncertainties and increased transport quality, in view of the greater attention given to physical flow and flexibility in fulfilling orders, for, since JIT operates with less physical inventory, it is adaptable to changes in consumer habits. Daugherty and Spencer (1990) reinforce the view that the objective of JIT is to obtain improvements in productivity and quality simultaneously, considering that one cannot be sacrificed at the expense of the other.

Companies that implement and apply lean philosophy work with reduced inventory, whether in a central warehouse or in process, making frequent small-volume deliveries (BAE; EVANS; SUMMERS, 2016; LEUVEANO *et al*., 2019; OCCENA; YOKOTA, 1993), deliveries which are made at the exact moment a specific quantity of the right product is needed (PENG *et al*., 2020; RODRIGUEZ *et al*., 2018; WU, 2003).

However, such frequent small-quantity deliveries is equally the aspect that raises most doubts regarding the future environmental impacts of JIT, since, in general, transportation vehicles tend to operate below maximum capacity, taking more journeys to fulfill orders (KONG *et al*., 2018; LUKINSKIY; LUKINSKIY; MERKURYEV, 2018; WANG, 2010). According to Mckinnon (2016), when a company opts for the JIT management method of production and delivery, inventory is optimized, but at the expense of likely increases in cargo vehicle traffic on road networks which, as a consequence, contribute to an increase in emissions of greenhouse gases (GG), the result of a greater consumption of fossil fuels. Navarro (2021) follows this same line, by stating that the need for the constant replenishment imposed by JIT generally leads to an increase in GG emissions.

If, on the one hand, JIT impacts on the costs of transporting merchandise, due to the underutilization of total vehicle capacity, compounded by the difficulty of obtaining return cargo, on the other hand it reduces operational and storage costs, because materials are delivered directly to production areas, reducing operational and storage demands (MILEWSKI, 2022). Establishing a "Milk Run" system of collection and delivery contributes to the lessening of the impacts caused by frequent small-volume deliveries, since transport vehicles and their routes are shared with multiple suppliers (BAE; EVANS; SUMMERS, 2016).

Ugarte, Golden and Dooley (2016) suggest that organizations plan their operations and logistics infrastructure by taking the sustainability of the whole supply chain into consideration. Following this same line, Tseng *et al*. (2019) point out that due to a global increase in environmental and sustainability awareness, in terms of products and services provided by both governments and consumers, companies need to create and operate more sustainable supply chains when considering the JIT system and transport vehicles.

The world need for logistical operations that involve the transport of cargo, the growing adoption of JIT as a strategy to control production and deliveries and the dominant concern for road safety and greenhouse gas (GG) emissions means that studies that analyze the bias of the sustainability of JIT are relevant for society in general. Considering that up to the present time, and in accord with the research criteria here established, we have found no articles that have carried out a systematic review of works dealing with JIT and environmental sustainability, this article aims to update current research, contributing to the debate about the pros and cons of adopting Just In Time - by conducting a literature review and a SWOT (strengths, weaknesses, opportunities, and threats) analysis on the theme. It should be noted that SWOT analyses, initially conceived for managerial use in organizations, have already been adopted in other research papers to support results analysis and guide future studies (MAHMOUDI; HAGHSETAN, 2011; MENA; DOS SANTOS; SAIDEL, 2022; PAES *et al*., 2019).

2. THEORETICAL FOUNDATION

This section presents the theoretical references regarding the two focal themes of this study, which are the system of scheduling and control for JIT production and delivery, and sustainability in the form of transportation operations.

2.1 Just In Time

The JIT system is an approach whose objective is to increase the reliability and punctuality of delivery by involving all partners in a chain. Passing from supply to production to distribution, the demand for a product is always driven by the final consumer (CLAYCOMB; GERMAIN; DRÖGE, 1999). For Kim (2003), in addition to improving quality, the JIT system offers greater flexibility in fulfilling orders, and improves suppliers service levels, obtained through the development of a partnership between buyer and supplier and the establishment of long-term and mutually trustful relationships.

The JIT system was created, and is applied with the intention of minimizing total supply chain costs and improving the effectiveness of delivery quantity decisions, the size of production batches, the number of consignments needed to make deliveries and the quality of logistical operations (LEUVEANO, 2019). Once JIT is implemented, companies benefit from improvements such as increased productivity, machine availability and product quality, in addition to reduce client waiting times and inventory (DAUGHERTY; SPENCER, 1990).

In order to comply with these requirements, the JIT system makes it necessary to frequent deliveries and smaller batches between the suppliers and the manufacturing customer, which can generate negative impacts on the aspects of sustainability and optimized use of transport vehicles (ZHIWEN *et al.*, 2020).

2.2 Environmental sustainability

Sustainability is founded on three pillars, which are (i) economic, (ii) social and (iii) environmental. These pillars are increasingly considered by companies when preparing their strategies, with the aim of creating competitive advantages (KARAKOSTAS; SIFALERAS; GEORGIADIS, 2020). According to Navarro (2021), sustainability may be defined as the 'non-overutilization' of natural resources, instead acting in a way that preserves resources for future generations.

From an environmental point of view, companies need to take GG emissions into account in their transportation operations across the whole supply chain, seeking constant reduction to avoid the risk of being penalized by consumers who may change supplier as a result, or by governments who have taken measures to reduce emissions in their respective countries in the light of the climate agreements in force (TSENG, 2019; WANG, 2018).

In this article, where the focus is on the environmental aspect of sustainability, and considering that the transport sector is one of the biggest emitters of GG, an evaluation of the relationship between JIT and sustainable development is necessary (MARCILIO *et al.*, 2018). Sustainability is evaluated considering the extent to which organizations governed by JIT may impact, positively or negatively, on the environment, security, costs and business efficiency.

3. METHODOLOGICAL PROCEDURES

In this study we used the structured literature review method proposed by Fiorini and Jabbour (2017), the stages of which are given below.

Stage 1: An initial consultation of the databases chosen (Scopus and Web of Science) with the aim of identifying articles that deal with the LM theme, linked to the question of transport. Following this initial search, the main keywords considered by the authors were identified, which were then adopted as the search terms for the current study. The terms used to search the Scopus (S) and Web of Science (WoS) databases are given in Table 1.

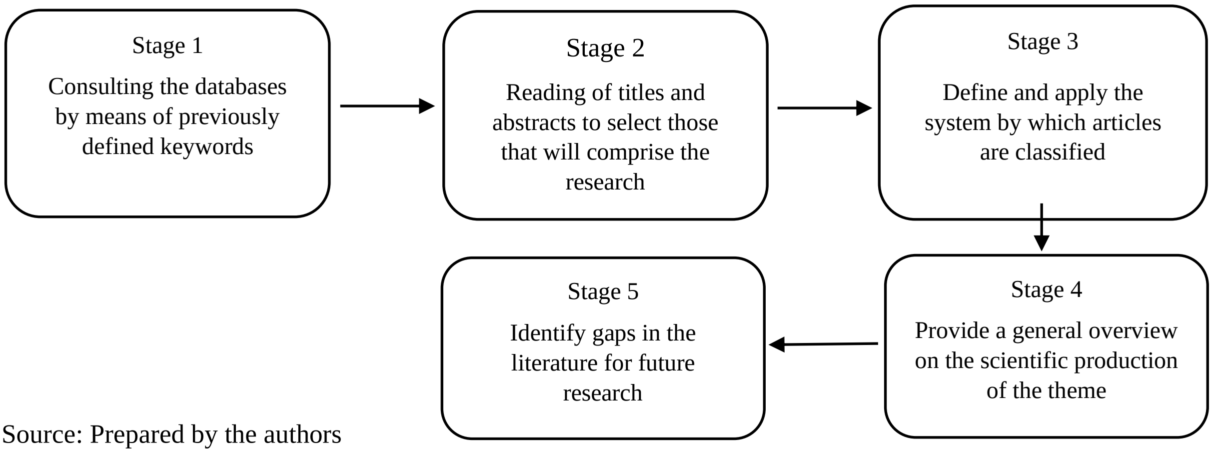
Stage 2: Involved conducting the database searches and applying the inclusion criteria, which were that only articles published in journals or congresses and written in Spanish, English or Portuguese were chosen. Additionally, no time exclusion criteria were applied to the database search string. The titles and abstracts of the articles obtained from the search were initially read. When these initial readings were not sufficient for the purposes of the study, a complete reading of each document was carried out. The results of this selection are given in Table 1.

Stage 3: Considering the objectives of the articles extracted from the databases, the proposals and codification categories to be applied in the classification of the articles considered in the structured revision were defined. The final version of the categories and coding was prepared, following brainstorming meetings with specialists.

Stage 4: The articles selected for the structured review were instrumental in guiding the discussions on the theme, as well as the general overview of scientific production related to JIT environmental sustainability.

Stage 5: During the reading of the articles selected, research gaps were noted and later described in the conclusion section, as suggestions to guide researchers who may wish to carry out studies on the theme in the future.

Figure 1 – Flow diagram for the research stages



Source: Prepared by the authors

Table 1 – Keywords used and database search results

Keywords	Number of articles as a result of the search	Total articles drawn from both databases
Just in Time and Transport and Costs	S = 295 WoS = 172	467
Just in Time and Transport and Benefits	S = 102 WoS = 38	140
Lean Production and Transport and Logistic	S = 474 WoS = 249	723
Lean Manufacturing and Transport and Logistic	S = 580 WoS = 391	971
Just In Time and Logistic	S = 126 WoS = 55	181
Just In Time and Freight	S = 469 WoS = 236	705
Just In Time and Transportation	S = 115 WoS = 40	155
Just In Time and Carriage	S = 9 WoS = 6	15
Total number of articles obtained from both databases		3,357
Number of duplicate articles		82
Total number of articles after excluding duplicates		3,275
Total number of articles after reading titles and abstracts		53
Key: S = Scopus and WoS = Web of Science		

Source: Prepared by the authors.

With the objective of ordering the articles taken from the databases (stage 3), to better understand the lines of research, the proposals of the authors, regions researched and methods used were applied and classified with numbers and letters, according to each aspect. This process was adapted from the model of Fiorini and Jabbour (2017). Table 2 presents the coding categories adopted.

Table 2 – Coding for the classification of the articles considered in the structured review

Groups	Proposal	Coding Categories
1	Environmental aspects	A - Reduction in greenhouse gas emissions B - Reduction in the consumption of fuels C - Reuse and recycling
2	Operational costs	A - Transport costs in terms of the distance between suppliers and clients B - Reduction in inventory volumes C - Reduction in operational costs
3	Operational performance	A - Optimization of assets B - Reduction in production and/or delivery lead time C - Improved operational performance D - Reduction in claims / thefts E - Reduction of traffic accidents
4	Research method	A - Systematic literature review B - Case study C - Simulation D - Quantitative E - Survey F - Qualitative
5	Location / Region of the Study	A - Developed country B - Country in development C - Not determined

Source: Prepared by the authors

4. RESULTS

Table 3 presents the identification and coding for each of the 53 articles selected for the research, based on the classifications described in Table 2.

Table 3 – Classification of the articles selected for the research

Article	Environmental aspects	Operational costs	Operational performance	Research method	Location / Region of the study
Hi; Vollmann (1986)	n.d.	2C	3A	4C	5C
Storhagen; Hellberg (1987)	n.d.	2B	3C	4B	5A
Daugherty; Spencer (1990)	n.d.	2A	3C	4A	5A
Swenseth; Buffa (1990)	n.d.	n.d.	3A / 3C	4D	5C
Fandel; Reese (1991)	n.d.	2C	3C	4B	5A
Occena; Yokota (1993)	n.d.	n.d.	3A	4C	5A
Claycomb; Germain; Dröge (1999)	n.d.	2B	3C	4D / 4E	5C
Roy; Guin (1999)	n.d.	2B / 2C	n.d.	4B / 4D	5B
Kim; HA (2003)	n.d.	2C	3C	4D	5A
Wu (2003)	n.d.	2B	3B / 3C	4B / 4D	5A
Wang; Fung; Chai (2004)	n.d.	2C	3B	4D	5A

Continued

Table 3 – Continued

Article	Environmental aspects	Operational costs	Operational performance	Research method	Location / Region of the study
Kreng; Wang (2005)	n.d.	2C	3B	4B / 4D	5A
Merzouk; Grunder; Bagdouri (2006)	n.d.	2C	3C	4C / 4D	5C
Nie; Xu; Zhan (2006)	n.d.	2C	3A	4C / 4D	5A
Clark (2007)	n.d.	2A	n.d.	4D	5A
Feng; Song (2008)	n.d.	2C	3C	4D	5A
Ghasimi; Ghodsi (2009)	n.d.	2C	3C	4C	5B
Hung; Ro; Liker (2009)	n.d.	2B	3C	4D	5A
Wang (2010)	n.d.	2C	3C	4B / 4D	5A
Wagner; Silveira-Camargos (2011)	n.d.	2C	3C	4D	5A
Ghasimi; Ramli; Saibani (2012)	n.d.	2A	3C	4D	5C
Holl; Pardo; Rama (2013)	n.d.	2A	3C	4E	5A
Breitenbach; Ferreira (2014)	n.d.	n.d.	3B	4B	5B
Bhusiri; Qureshi; Taniguchi (2014)	n.d.	2C	3B	4D	5A
Bae; Evans; Summers (2016)	n.d.	n.d.	3B / 3C	4B / 4C	5A
Mckinnon (2016)	1A	n.d.	n.d.	4A	5A
Ugarte; Golden; Dooley (2016)	1A	n.d.	n.d.	4C	5A
De Carvalho et al. (2017)	n.d.	n.d.	n.d.	4A	5C
Garza-Reyes et al. (2017)	n.d.	n.d.	3A	4B	5B
Lukinskiy et al. (2017)	n.d.	n.d.	3C / 3E	4D	5B
Fallas-Valverde; Quesada; Madrigal (2018)	n.d.	2B	n.d.	4B	5A
Kong et al. (2018)	1A / 1B	2C	n.d.	4C / 4D	5A
Lukinskiy; Lukinskiy; Merkuryev (2018)	n.d.	2B	3C	4C	5B
Marcilio et al. (2018)	1A	n.d.	3A / 3C	4C	5C

Rodriguez et al. (2018)	n.d.	n.d.	3B	4C	5B
Schwerdfeger; Boysen; Briskorn (2018)	n.d.	2A	3C	4C / 4D	5A
Wang; YE (2018)	1A	2C	n.d.	4D	5A
Zhou; Zhang; Ren (2018)	n.d.	n.d.	3B	4C	5A
Chen; Palma; Reyes (2019)	n.d.	2B	3C	4F	5C
Kang; Lee; Do Chung (2019)	1B	n.d.	3B / 3C	4C	5A
Leuveano et al. (2019)	n.d.	2C	n.d.	4B / 4C	5B
Tseng et al. (2019)	1A	2C	n.d.	4B / 4D	5A
Arjona Aroca et al. (2020)	1A	n.d.	3C	4B / 4D	5A
Kaiser; Zimmermann; Metternich (2020)	n.d.	2C	3B	4B / 4C	5A
Karakostas; Sifaleras; Georgiadis (2020)	1A / 1B	n.d.	3A / 3C	4C	5C
Peng et al. (2020)	n.d.	2B	3A	4C	5A
Zhiwen et al. (2020)	n.d.	n.d.	3C	4C	5A
Avetisyan; Hertel (2021)	n.d.	2C	3B / 3C	4A	5C
Karam; Hegner Reinau (2021)	1A / 1B	2C	3A	4B / 4C	5A
Navarro (2021)	n.d.	n.d.	3A / 3C / 3E	4A	5C
Wang et al. (2021)	n.d.	2B / 2C	n.d.	4D	5A
Yang et al. (2021)	n.d.	n.d.	3C	4E	5A
Milewski (2022)	n.d.	2A / 2C	3C	4C	5C

Source: Prepared by the authors (n.d. = not determined).

In terms of the proposals of authors when preparing their respective research, in the coding of environmental aspects (1A, 1B e 1C), the greatest occurrence was 1A, with nine articles debating the reduction of greenhouse gas emissions. This was followed by 1B, in which 4 studies approached the reduction of fuel consumption and transport operations in JIT. In terms of studies relating to reuse and recycling, represented by the 1C coding, no study approached the theme.

For the proposal related to operational costs (coding 2A, 2B and 2C), of greater significance was C, whose search driver, operational cost reduction, was the theme of twenty-two studies, followed by the proposal for inventory volume reduction, coded with the letter B, found in ten studies and, by the six studies that approached transport costs in terms of the distance between suppliers and clients, represented by the letter A.

In terms of the proposal relating to operational performance, with the coding 3A to 3E, the item most considered by the authors of the articles analyzed in this study, with twenty-nine mentions, was 3C, which focuses on achieving operational performance improvements. This was followed by proposal 3B, which had the goal of reducing production and/or delivery lead time, the object of eleven studies within the fifty-three articles. Close on the heels of the second proposal, the third placed coding was 3A, found in ten articles. The proposals represented by coding 3E and 3D were little approached in the articles making up this systematic review, with two and no mentions, respectively.

In reference to the study methods adopted by the authors of the fifty-three articles, quantitative, represented by the coding 4D, was the most employed, with twenty-three works; this was followed by simulation methods, coding 4C, with twenty-one works, and case studies, with fifteen works, as represented by the coding 4B in Table 1. The methods based on systematic literature review (4A) and qualitative (4F) were used by the authors in five and one works, respectively.

Finally, in terms of study locations, coding 5A, representing developed countries, was the most prevalent, the object of thirty-three of the fifty-three works. Developing countries (5B) set the scene for eight studies, while the locations of the other twelve works could not be identified (5C).

According to Occeana and Yokota (1993), for the JIT system to offer the flexibility expected, enabling rapid adaption to demand, operating with low volumes of inventory is required and, consequently, production runs need to be of reduced size, leading to an increase in the number of journeys made by transport and delivery vehicles. For JIT to function appropriately, the system demands that supplier production is strictly coupled to the production of clients; if not, there is a risk of delivery problems occurring when mismatches arise, due to variations in demand (HILL; VOLLMANN, 1986).

For Lukinskiy *et al.* (2017), those responsible for Just In Time delivery programming do not take into consideration possible restrictions imposed by cities or the intensity of traffic. Such restrictions may provoke drivers to commit transport infractions, such as exceeding speed limits, running red lights or prohibited overtaking maneuvers, with the aim of avoiding fines imposed on late deliveries, despite reducing transport safety and putting workers and users at risk. For Mckinnon (2016), in the process of product acquisition in accord with JIT requirements, with the aim of reducing costs through low inventory levels, companies end up sacrificing transport efficiency, causing traffic buildup on highways and related environmental damage.

Increasing the delivery times of suppliers and industries is contrary to the principles of JIT. However, involving final consumers in decisions with respect to increases in delivery times can be an alternative, since such increases, which can bring benefits for sustainability, do not affect the final value of a product (MARCILIO *et al.*, 2018). For manufacturers of low aggregated value products or those who manufacture in small scale, the implementation of JIT generates increased logistical costs when the distances between suppliers and customers are not shortened (MILEWSKI, 2022).

Ugarte, Golden and Dooley (2016) identified, by means of simulations, that the implementation of the JIT system without due coordination and cooperation between other supply chain partners increases greenhouse gases. Recorded emissions were in the order of 1,865 MT CO_2 (Metric Tons equivalent of Carbon Dioxide), while the system operated by the Economic Order Quantity (EOQ) model generates emissions in the region of 580 MT CO_2. On the other hand, the implementation of the JIT system in a gradual and customized way, for example, with the use of smaller capacity vehicles, reached emissions of around 609 MT CO_2, similar to the other models compared in the study, but maintaining the advantage of reduced inventory levels.

In contrast, other authors affirm that the focus of the JIT system is the flow of materials between supplier and buyer, providing cost reduction throughout the supply chain (KIM; HÁ, 2003). This is possible because dimensioning small production runs improves the productivity of a system. For Leuveano *et al*. (2019), the implementation of JIT practices in production and delivery programming brings positive results, improving transport payloads, reducing the quantity of defective products and positively affecting quality. Arjona Aroca *et al.* (2020) point out that the implementation of transport operations in the mold of the JIT philosophy provides improvements to the average efficiency of industries, bringing significant reductions in fuel costs and greenhouse gas emissions, by eliminating waste such as idle time and waiting lines at loading bays.

The simulations carried out in the study by Kong *et al*. (2018) demonstrated that when JIT delivery batches are duly dimensioned between supplier and client, resource waste is avoided. This proves that the JIT system is efficient in eliminating overproduction or excessive waiting times.

Daugherty and Spencer (1990) relate that to circumvent the possible impacts in the use of JIT, Japanese companies seek to be closely to clients, use trucks with lower load capacity, share transport vehicles in the model of mixed load model and implement well-known warehouse as cargo commutation centers, where various suppliers can consolidate the volumes to be transported, increasing the efficiency of the delivery vehicles adopted. This reduces supply chain costs, as well as the number of journeys necessary to fulfill orders.

After the coding and classification of the articles, a SWOT matrix was prepared, serving to identify the Strengths, Weaknesses, Threats and Opportunities faced by organizations: the first two elements being focused on internal aspects of organizations and the other two on external aspects (MOGLIA; HOPKINS; BARDOEL, 2021). For Lee *et al.* (2021), the SWOT matrix provides a contextual analysis, bringing together fundamental internal and external factors, to guide the preparation and adoption of the most relevant strategies for organizations.

In this study, the SWOT matrix was based on the literature drawn from the database searches, with the objective of assisting the analysis of the strengths, weaknesses, threats and opportunities of JIT, and considering the need for organizations to be ever more sustainable. Each of the four elements of the SWOT matrix was prepared from an analysis of the content of the works researched.

5. DISCUSSION AND ANALYSIS BASED ON THE SWOT MATRIX

To bring to light some discoveries from the articles that make up the research, in reference to the benefits and impacts of the implementation and use of the JIT system by companies, an analysis of the strengths, weaknesses, threats and opportunities was made. This analysis is discussed in the section which follows, and presented in the form of a SWOT matrix in Table 4.

Among the strengths of the JIT system for the programming, production and delivery of merchandise between the partners of a supply chain, flexibility in service of demand can be highlighted. Since JIT operates with low inventory levels and production driven by demand, companies are able to quickly adapt to new scenarios (HILL; VOLLMANN, 1986; KANG; LEE; DO CHUNG, 2019; YANG, 2021). Linked to operational aspects with low inventory levels, the eventual loss of parts and/or products due to defects or obsolescence is also recognized as a strength of the system (KIM; HÁ, 2003; WAGNER; SILVEIRA-CAMARGOS, 2011).

Nie, Xu and Zhan (2006) and Wu (2003) highlight that one of the strengths of the JIT system is establishing trusting, long-term relationships between partners in a chain, which bring improved results for all the companies involved as a consequence. Claycomb, Germain and Dröge (1999) identified that when JIT is implemented, costs across the supply chain fall, not only due to the lesser need for warehouse space, repairs or warranty replacement, but also due to a reduction in the time and costs required to carry out audits and stock taking.

Bae, Evans and Summers (2016) emphasize that JIT contributes towards production leveling (*heijunka*), since it avoids overproduction at the same time as establishing a high level of trust among suppliers. In his research work, Mckinnon (2016) identified that JIT has as a premise the reduction of inventory levels across a supply chain, whose objective is zero inventory. As companies are working with low volumes, the need to deliver products without defects is essential, since production processes may be interrupted due to a lack of material; therefore, the need to produce with quality is common sense for companies that operate with JIT, and a strength of the system as a result.

In terms of JIT system weaknesses, Roy and Guin (1999), Wu (2003) and Leuveano *et al.* (2019) point out that a consequence of the need for regular deliveries is the use of transport vehicles with loads below their respective capacities, which has the effect of increasing traffic on roads and highways. Mckinnon (2016) reinforces the point that if a JIT implementation is not appropriately done, and transport planning not well synchronized between companies, an increase in the quantity of vehicles in transit may cause environmental damage in addition to increasing operational transport costs. If, on the one hand, JIT contributes to a reduction in inventory, on the other hand it leads to an increase in noise pollution, road congestion, fuel consumption, greenhouse gas emissions and longer journey times for communities in general.

According to Arjona Aroca *et al*. (2020) and Lukinskiy, Lukinskiy and Merkuryev (2018), although companies that operate under the regulations of the JIT system maintain low inventory levels, delays in deliveries from suppliers or through oscillations in demand can lead to interruptions to production, affecting lead time across a whole supply chain, delaying deliveries to clients and generating costs associated with such interruptions. For Wang (2010), the JIT system is difficult to operationalize when dealing with global suppliers, which generally use shipping to transport items. This delivery method obliges such companies to supply volumes compatible with containers, in addition to the fact that deadlines are subject to the speed of ships and the routes established by ship owners.

In the field of opportunities, Milewski (2022) and Schwerdfeger, Boysen and Briskorn (2018) recommend the use of cross docking, concentrating the deliveries of various suppliers with the aim of bringing together cargo that corresponds in volume and/or weight to the vehicle that will make the delivery to the focal company of a chain. Cross docking may even be used for the preassembly of parts or components, streamlining the final assembly operations of a client. There are also financial advantages. Concentrating deliveries through the adoption of composite cargos can mean logistical cost savings of up to 70%.

Daugherty and Spencer (1990), Ugarte, Golden and Dooley (2016) proposed the use of smaller transport vehicles than those habitually used by logistic companies, as a means of taking greater advantage of load capacity. The simulations carried out in the study of Karakostas, Sifaleras and Georgiadis (2020) demonstrated that when transport companies use a mixed fleet, made up of small- and medium-sized vehicles, the consumption of fuel and greenhouse gas emissions fell by 10%, on average. This can be seen as an opportunity for companies that operate with the JIT system.

Hill and Vollmann (1986) and Roy and Guin (1999) approached the consolidation of freight with the objective of maximizing the use of transport vehicles between companies that are upstream of a focal company. The reductions obtained with this consolidation might vary between 7.91% and 69.40%, depending on the number of suppliers, distance covered and frequency adopted. In this case, a single transport company makes collections at various suppliers located along a route, until arriving at a client, effectively improving the general occupancy of vehicles.

Chen and Palma (2019) point out that the use of Information Technology is an opportunity for maintaining a JIT system updated and compatible with the new strategies of organizations. IT resources provide production and delivery planning in a collaborative way, with inventory managed by suppliers through radio frequency identification (RFID) technology, for example. Navarro (2021) suggests that as an alternative to increasing the sustainability of a JIT system, it can be combined with other tools, such as Six Sigma and green manufacturing.

Despite not having been identified in the articles analyzed in the structured review, the use of electric vehicles has been frequently cited as an alternative means of reducing the environmental impacts of conventional transportation, whether of people or cargo. As motivators for the substitution of vehicles powered by electricity there are: (i) Reduction in GG emissions (ADHIKARI *et al.*, 2020; ALESIANI; MASLEKAR, 2014; BIRESSELIOGLU; KAMBOJ; JAGOTRA, 2018; KAPLAN; YILMAZ, 2018), (ii) A less complex and easily maintained means of propulsion (ADHIKARI *et al.*, 2020; GURUPRASAADH *et al.*, 2021; (iii) Lower operational costs: ADHIKARI *et al.*, 2020;

BIRESSELIOGLU; KAPLAN; YILMAZ, 2018; KAMBOJ; JAGOTRA, 2018; and (iv) Lower noise emission in cities and on highways (KAMBOJ; JAGOTRA, 2018). On the other hand, being a recent technology that is still in a phase of development and expansion, various barriers remain between potential clients and users of electric vehicles, restricting their purchase and use, whether for locomotion or deliveries. The main barriers found in the literature are: (i) Concerns about possible increases in the price of electrical energy as a result of greater demand: ADHIKARI *et al.*, 2020; BIRESSELIOGLU; KAPLAN; YILMAZ, 2018; MAHDAVIAN *et al.*, 2021; (ii) Substituting combustion-engine-powered fleets with electric vehicles would considerably increase the demand for electric energy, which could lead to rationing or precarious supplies: BIRESSELIOGLU; KAPLAN; YILMAZ, 2018; MAHDAVIAN *et al.*, 2021; (iii) There are still limited commercial electric vehicle options in the portfolios of manufacturers/assembly plants: ADHIKARI *et al.*, 2020; BIRESSELIOGLU; KAPLAN; YILMAZ, 2018; DOPPSTADT; KOBERSTEIN, 2020; (iv) Shorter range of electric vehicles, which affects the agility of deliveries and increases journey times: ADHIKARI *et al.*, 2020; ALESIANI; MASLEKAR, 2014; BIRESSELIOGLU; KAPLAN; YILMAZ, 2018; BORGE-DIEZ *et al.*, 2021; DOPPSTADT; KOBERSTEIN, 2020; (v) Difficulty of obtaining raw material for the production of batteries: BIRESSELIOGLU; KAPLAN; YILMAZ, 2018; GURUPRASAADH *et al.*, 2021; (vi) Durability and cost of batteries: ADHIKARI *et al.*, 2020; ALESIANI; MASLEKAR, 2014; BIRESSELIOGLU; KAPLAN; YILMAZ, 2018; MAHDAVIAN *et al.*, 2021; (vii) A shortage of recharging stations: ADHIKARI *et al.*, 2020; BIRESSELIOGLU; KAPLAN; YILMAZ, 2018; DOPPSTADT; KOBERSTEIN, 2020; KAMBOJ; JAGOTRA, 2018; MAHDAVIAN *et al.*, 2021; RASHIDIRAD; DAGDOUGUI, 2021; (viii) A lack of options for the disposal and recycling of batteries: ADHIKARI *et al.*, 2020; GURUPRASAADH *et al.*, 2021; (ix) Higher acquisition price in comparison to combustion-engine vehicles: ADHIKARI *et al.*, 2020; BIRESSELIOGLU; KAPLAN; YILMAZ, 2018; KAMBOJ; JAGOTRA, 2018; MAHDAVIAN *et al.*, 2021; (x) Electric vehicles only contribute to a reduction of GG emissions if the sources of electric energy used to recharge them are “clean”: ADHIKARI *et al.*, 2020; GURUPRASAADH *et al.*, 2021; (xi) Limited technical assistance networks and people adequately prepared to undertake repairs: ADHIKARI *et al.*, 2020; BIRESSELIOGLU; KAPLAN; YILMAZ, 2018; (xii) A reliable and stable network of electrical energy: BIRESSELIOGLU; KAPLAN; YILMAZ, 2018; BOHN; GLENN, 2016;

KAMBOJ; JAGOTRA, 2018; RASHIDIRAD; DAGDOUGUI, 2021; and (xiii) Time needed to recharge batteries: ALESIANI; MASLEKAR, 2014; BIRESSELIOGLU; KAPLAN; YILMAZ, 2018; GURUPRASAADH *et al.*, 2021; KAMBOJ; JAGOTRA, 2018; MAHDAVIAN *et al.*, 2021.

Table 4 –SWOT Matrix on the sustainability of JIT

Quadrants of the SWOT matrix	Sources that contributed to the preparation
Strengths	
Flexibility in meeting demands; Low inventory volumes; Fewer instances of the loss of parts and/or products due to defects or obsolescence; Increase in the quality of products; Reliable deliveries; Improvements in organizational results; Support to leveled production; Long-term relationships and mutual benefits between partners in a supply chain; Reduced time and costs for audits and stock management.	Claycomb; Germain; Dröge (1999); Holl; Pardo; Rama (2013); Kim (2003); Leuveano (2019); Lukinskiy; Lukinskiy; Merkuryev (2018); Milewski (2022); Navarro (2021); Nie; Xu; Zhaz (2006); Occena; Yokota (1993); Roy; Guin (1999); Storhagen; Hellberg (1987); Tseng (2019); Ugarte; Golden; Dooley (2016); Wagner; Silveira-Camargos (2011); Wang et al. (2021); Wu (2003); Zhiwen (2020).
Weaknesses	
The use of transport vehicles below load capacity; Increase in vehicle traffic on roads and highways; In some cases causes an increase in Greenhouse Effect Gas emissions; Interruptions in production in the case of delivery delays; Not honoring orders when demand suffers big swings; Increase in transport costs; Difficulty of operationalizing the system when a supplier is transnational and maritime transport is utilized.	Hill; Vollmann (1986); Karam; Hegner-Reinau (2021); Karakostas; Sifaleras; Georgiadis (2020); Lukinskiy et al. (2017); Lukinskiy; Lukinskiy; Merkuryev (2018); Marcilio et al. (2018); Milewski (2002); Occena; Yokota (1993); Peng (2020); Wang (2010); Wu (2003).
Opportunities	
Use intermediate storage or the cross dock system for the composition of cargo and the optimization of vehicles; Customization of JIT; Coordinated collections between various suppliers; Use of smaller transport vehicles; Implement a local production arrangement, so that the main suppliers are close to the focal factory; Improve delivery planning and reduce stoppage times at loading bays, allowing for a reduction of vehicle speeds, with a consequent reduction in greenhouse effect gas emissions; Combine the use of JIT with other tools, such as Six Sigma and green manufacturing.	Bae; Evans; Summers (2016); Chen; Palma; Reyes (2019); Daugherty; Spencer (1990); De Carvalho (2017); Karam; Hegner-Reinau (2021); Leuveano (2019); Lukinskiy et al. (2017); Lukinskiy; Lukinskiy; Merkuryev (2018); Mckinnon (2016); Milewski (2022); Schwerdfeger; Boysen; Briskorn (2018); Ugarte; Golden; Dooley (2016).
Threats	
Substitution by methods to control production and inventory, such as EOQ; Demand higher levels of coordination and discipline between partners in a chain; Problems of supply, if the communication between supplier and client are not fast and accurate; Climate agreements have established greenhouse effect gas emission reduction targets for business logistics.	Avetisyan; Hertel (2021); Claycomb; Germain; Dröge (1999); Feng; Song (2008); Garza-Reyes et al. (2017); Holl; Pardo; Rama (2013); Karam; Hegner-Reinau (2021); Karakostas; Sifaleras; Georgiadis (2020); Kong et al. (2018); Marcilio et al. (2018); Navarro (2021); Nie; Xu; Zhan (2006); Wu (2003).

Source: Prepared by the authors

In terms of threats, the substitution of JIT for other methods such as the Economic Order Quantity (EOQ), which aims to identify, through calculations, the size of the ideal product run for production and transport, optimizing activities, was discussed by Kreng and Wang (2005), Feng and Song (2008), Wang (2010), Ugarte, Golden and Dooley (2016) and Wang and Ye (2018). Delays in the transport of merchandise lead to interruptions in production operations, annulling the gains offered by JIT and threatening the implementation and use of the system when it is adopted by organizations (LUKINSKIY; LUKINSKIY; MERKURYEV, 2018). The pressure to reduce greenhouse gas emissions and adhering to climate agreements are threats to the frequent, small-quantity transport model proposed by the JIT system (MCKINNON, 2016; UGARTE; GOLDEN; DOOLEY, 2016).

Claycomb and Germain (1999), Daugherty and Spencer (1990), Kim (2003) and Wu (2003) point out that the JIT system demands a high level of coordination and discipline between partners in a supply chain, and such communication needs to be timely, since any failure or delay in communication or data transfer can have impacts, such as a lack of raw materials or parts and, ultimately, interrupt the production process.

5.1 Practical implications

In the light of the information contained in the four quadrants of the SWOT matrix, we have identified that the implementation and utilization of the JIT system to control production and deliveries offers positive financial and operational results for organizations, in addition to heightened satisfaction for clients, due to an increase in product quality. However, to be used in an original way, such as it was when created by Toyota, the JIT system can also bring negative impacts for sustainability, such as a higher consumption of fuel and GG emissions, an increase in traffic on roads and highways, in addition to the greater risk of accidents and possible production interruptions, due to a lack of parts. As an alternative, managers can reap the benefits of the system without impacting or at least attenuating the effects given, by using the alternatives offered in the field of opportunities, such as the implementation of cross docking, sharing vehicle capacities with other suppliers, the use of fewer vehicles or mixed fleets, or operations in conjunction with other tools, such as Six Sigma.

Furthermore, as reinforced by the studies of various authors, such as Holl, Pardo & Rama (2013), Lukinskiy, Lukinskiy and Merkuryev (2018), Mckinnon (2016) and Zhiwen (2020), the JIT system should not be considered as a unique method for organizations desiring to implement lean and obtain better results. The implementation of the diverse tools and practices available under the umbrella of lean manufacturing philosophy, those that, together with JIT, have the potential to eliminate waste and increase the productive flow, quality and satisfaction of clients, are needed.

6. CONCLUSION

This study achieved the objective of identifying and systemizing articles that debate the question of the implementation and use of the JIT system to control production and operations from the perspective of sustainability. To reach this objective, 53 articles published between 1986 and 2022 were analyzed. From these articles, we have highlighted the eventual impacts of JIT operations on transport and the environment, impacts which enabled the development of the SWOT matrix. Based on the studies analyzed, the matrix identified the strengths, weaknesses, threats and opportunities of implementing a JIT system in a way that minimizes its potential negative impacts on environmental sustainability.

6.1 Limitations of the study and proposals for future works

As it relates to research that was based on an analysis of the available literature, the results of the present study need to be analyzed in the light of the inherent limitations of the method chosen. Other search terms, as well as search strings applied to other databases, may lead to results which are distinct from those here observed. The final selection of works sampled in this study was by necessity subjective, because it was based on the readings and interpretations of the researchers. In the same way, the SWOT matrix proposed here reflects the subjective analysis and understanding the authors had of the content of each of the 53 works selected.

As a suggestion for future works, empirical studies that analyze the performance and GG emissions of the transport operations of companies from different sectors operating under the regulations of the JIT system are proposed, with the aim of better defining under which conditions JIT is good or bad for sustainability.

The suggestion of installing and using cross docking as a means of optimizing transport resources, contributing to a reduction in vehicle journeys and GG generation, may be researched, tested and compared, together with the proposal of freight consolidation, which has the objective of concentrating the cargos of various suppliers, destined to the same client, in one vehicle: done in such a way that companies will know under which conditions each of these proposals present the best results.

As a final suggestion for future research, studies could be carried out that seeks to evaluate how beneficial new Information Technology resources might be in JIT operations - as much for the aspect of operational gains as minimizing environmental impacts, thereby making the system more efficient and sustainable.

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