Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 39 (2019) 1577–1586

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

25th International Conference on Production Research Manufacturing Innovation: Cyber Physical Manufacturing
August 9-14, 2019 | Chicago, Illinois (USA)

Sustainable Implementation Success Factors of AGVs in the Brazilian Industry Supply Chain Management

Guilherme T. Aguiar[a], Gilson A. Oliveira[a], Kim Hua Tan[b], Nikolai Kazantsev[c], Dalmarino Setti[a]

[a] *Federal Technological University of Paraná, Via do Conhecimento Km 01, Pato Branco, 85503-390, Brazil*
[b] *Nottingham University Business School, Jubilee Campus, Nottingham, NG8 1BB, Inglaterra*
[c] *Alliance Manchester Business School, Booth Street West, Manchester, M15 6PB, Inglaterra*

Abstract

The management of the supply chain (SC) is crucial for industrial performance. Any shortage of raw materials, intermediate items or finished products for customers leads to bottlenecks in production processes, hampering market competitiveness. Recently, several aspects, such as the spread of automation and the continuous search for cost reduction, as well as increasing labor costs, have led to the use of Automated Guided Vehicles (AGVs) in SCs. AGVs provide efficiency gains, increase worker safety and minimize energy costs. In addition, they strengthen the sustainability tripod based on the economic, social and environmental dimensions. However, most SCs in the Brazilian industry are still inefficient in these dimensions. Currently, forklifts are heavily used in warehousing operations, resulting in idle employees when there is a production shortfall and pollution produced by their engines. Thus, in this context, there is a growing demand for research on the application of AGVs in Brazilian companies. This paper presents the main implementation success factors (ISFs) of AGVs based on a systemic review of the literature and proposes a framework to explore, in future stages, the interrelationships between sustainable implementation success factors (ISFs) of AGVs in the Brazilian context through structural equation modeling (SEM).

Keywords: Automated Guided Vehicles (AGV); Collaborative Robots; Cobots implementation; Supply chain

* Corresponding author. Tel.:+55-018-99101-9271
E-mail address: guilhermea@alunos.utfpr.edu.br

2351-9789 © 2019 The Authors. Published by Elsevier Ltd.
This is an open access article under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0/)
Peer-review under responsibility of the scientific committee of the ICPR25 International Scientific & Advisory and Organizing committee members
10.1016/j.promfg.2020.01.284

1. Introduction

The competitiveness of the international market integrated with sustainability concerns from stakeholders in organizations' operational and economic strategies, environmental awareness and work safety, as well as the paradigm change from mass production to customized production, support the implementation and utilization of flexible and automated systems in supply chains [1], [2]. Supply chain management is crucial to industrial performance. Recently, several aspects, such as the spread of automation, the ongoing pursuit of cost reduction, rising labor costs, and product traceability issues have led to the use of Automated Guided Vehicles (AGVs) in the supply chain. AGVs provide efficiency gains, increase worker safety and minimize energy costs. In addition, they strengthen the sustainability tripod based on the economic, social and environmental dimensions.

AGV systems are implemented to optimize the automatic transport of final products and raw materials between different locations, from the production line to the warehouse, from the warehouse to the shipping center, from the shipping center to the external transport vehicle, and the same for the reverse process. AGVs are also widely employed in sorting for inventory storage and the sorting and packaging of orders that have a mix of small products.

This study identifies the main implementation success factors (ISFs) of AGVs through a systematic review of the literature and proposes a framework to determine the critical factors and find the relationships between the ISFs and SCs for the Brazilian context.

2. Theoretical Framework

For the organization of a bibliographic portfolio to identify the success factors in the implementation of AGVs from a sustainable perspective (ISFs) in SCs, the instrument proposed by [3] called Knowledge Development Process - Constructivist (ProKnow-C) was used, according to Fig. 1. For the development of the Boolean searches in the databases, the research axes and the keywords were selected. All possible combinations of keywords were performed on three databases: (i) ScienceDirect; (ii) Scopus and (iii) Web of Science. The searches in the databases were limited to articles published after 2013, since it was from this year that the AGVs began to be implemented in large scale in the management of SCs.

The searches returned an initial portfolio of 1,945 articles. This initial portfolio was organized through a bibliographic manager and duplicate articles were excluded, resulting in 496 articles. This portfolio was analyzed through the alignment of articles by title, and out of the 496 articles, 118 of them were identified to be aligned with the research. Of these, scientific recognition was verified by searching the number of citations of all 118 articles through Google Scholar. Articles with less than five citations were disqualified from the main portfolio and separated for a secondary portfolio. Subsequently for the verification of scientific recognition, the alignment was done by reading the abstracts of the 45 articles that had more than five citations. Finally, the 16 articles that were fully aligned with the research were read.

During the analysis of the content of the articles that were fully aligned with the research, six articles were inserted in the research portfolio through the Snowball methodology, which uses the references of the aligned articles to complement the research with arguments or factors not addressed by these articles. This analysis was divided into (2.1) Supply chain configurations; (2.2) Description and classification of AGVs; and (2.3) AGVs and sustainable supply chain.

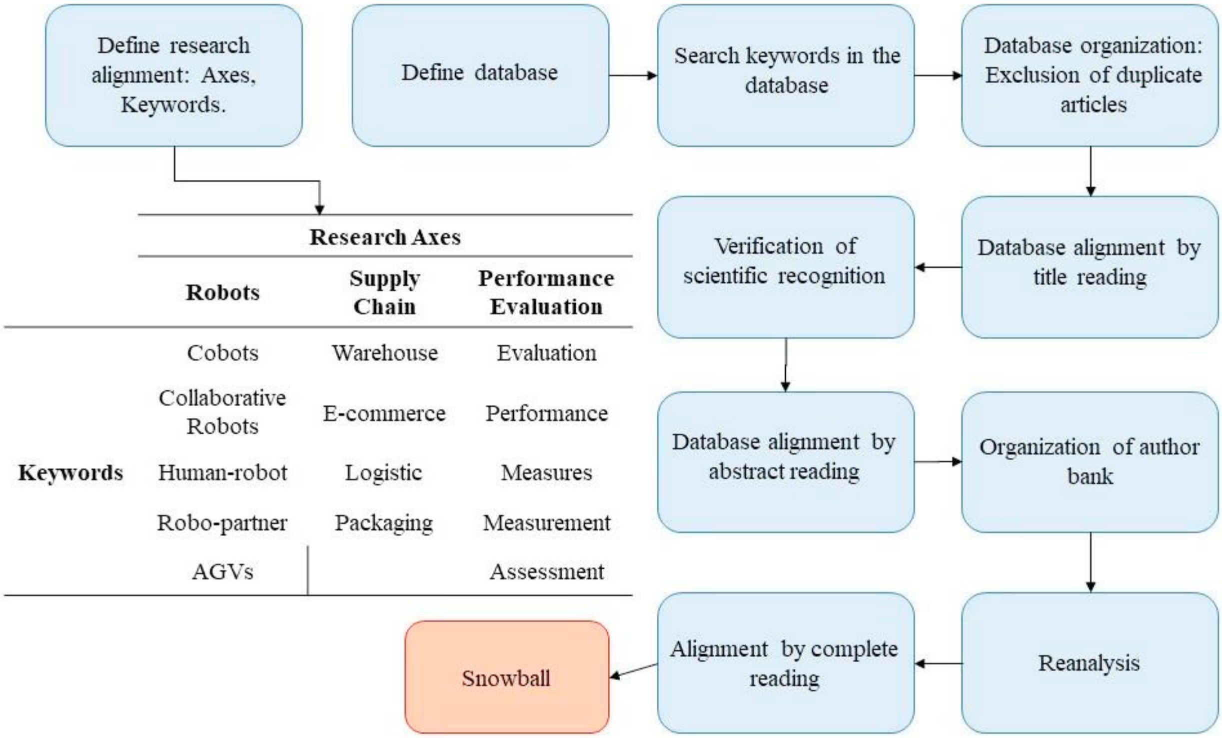

Fig. 1. Proknow-C stages.

2.1 Supply chain configurations

The supply chain aims to efficiently manage the flows of raw materials, products, services, finances and information, from the extraction and transformation of the raw material, to the manufacture of the product and delivery to the customer, with the main objective being to increase the efficiency and competitiveness of companies, as well as adding value to the product and increasing customer satisfaction through tracking [4]. Configurations in the supply chain are conceptualized considering strategic, tactical and operational hierarchical levels such as company size, country of origin, characteristics of the company, market and product, location, customer and supplier maturity level, product life cycle, and operational strategies of the organization [4]. Therefore, any changes in the supply chain are automatically integrated with the decisions of all the companies interconnected in the chain, the main decisions being the selection of the supplier, the design of supply networks, the mode of transportation, the design of distribution networks, the design of raw materials flow, the location of branch offices inside and outside the country of origin, collaboration and information sharing with outsourced companies [5].

For companies to achieve greater efficiency in the supply chain, they need to make adjustments between internal and external structures, listing the functions of the contextual factors that represent the environments, and investigating the impacts of these factors on supply chain performance [6]. [7] studied how companies develop resilience and robustness in the supply chain by considering contextual factors such as the complexity of sales and delivery and geographic dispersion. On the other hand, [8] provides indicators that confirm that the alignment of contextual factors such as supplier selection, customer relationship management, and collaboration and information sharing impacts supply chain efficiency and can be used as a competitive advantage for companies.

Unlike previous research that investigated traditional supply chain management, [9] conducted a study to identify contextual factors relevant to the implementation of a responsive supply chain. The responsive supply chain is dictated by pull production, where there is a proactive sharing of information with customers, enabling the manufacturing company to better assimilate customer dynamics and thereby encourage the company to share information with its suppliers to reduce the uncertainty of the demand. This information is the customer's requirement in terms of range, frequency and innovative capability of product offerings.

According to [9], the main objectives of a responsive supply chain are: (i) to improve agility by providing customers with the right product at the right time and in the right place; (ii) increase flexibility to respond to changing customer demands; (iii) reduce risk by identifying and removing potential sources of bottlenecks in the supply chain. This responsive configuration is suitable for companies that offer a mix of innovative or customized products, redesigned according to the personalization demands of customers.

[10] proposed a structural modeling study to determine driving power and dependency on sustainable supply chain management (SSCM) to improve performance. This research also identified contextual factors and developed interrelations between them. SSCM is the integration of supply chain management with sustainable development, that is, it is the sustainable cooperation of companies involved in the supply chain with the goal of developing in a sustainable manner [10]. Companies need to address the implementation of SSCM due to increased environmental concerns in their routine activities [11]. In addition, SSCM helps managers make decisions to acquire technologies that contribute to a company's profitability in a sustainable manner [10]. Among the various technologies available today, AGVs stand out for promoting a sustainable increase in profitability.

2.2 Description and classification of AGVs

AGVs are autonomous vehicles used to transport, process and sort goods or products in environments where the flow is incessant, a recurrent situation in industrial environments and in seaports. AGVs are unmanned and move using smart guidance and control tools for onboard processing in order to perform decentralized decision making, such as route planning and collision avoidance. Their physical characteristics depend on the function they perform [12]. Although used in large multinational manufacturing operations and being an attractive solution to increase the level of automation in the supply chain, there are still many manual operations performed by forklifts and human labor. The implementation of AGVs in the supply chain is still scarce, since factors such as installation cost, flexibility of operational strategies and safety of perception systems still need to be matured to disseminate AGVs into supply chains [13]. In addition, the installation of the AGVs so that they are fully operational takes several months, requiring highly qualified technicians and involving lengthy and expensive procedures in the workplace [14].

These factors are closely intertwined because greater flexibility of operational strategies and more safety of perception systems result in a higher installation cost. As addressed by [12], the management of routes of multiple running AGVs was considered expensive due to the need for more powerful centralized hardware to process the information and assign the AGVs tasks, usually called Warehouse Management System (WMS) [13]. The physical structure of the AGVs is divided into two architectures like the other process automation technologies: hardware and software. The hardware architecture includes all the parts that make up the AGVs: (i) Mechanical parts, which include structure, motors, transmission, steering and special parts; (ii) Electronic and electrical parts including CPU, microcontroller, sensors and electrical system; (iii) The energy source, which may be electric, liquefied petroleum gas, diesel, biofuel and hybrid methods [1]. The software architecture complements the entire hardware architecture, giving logic to AGV actions, from management, routing, navigation, programming and dispatching. The software management system can be central, hierarchical or decentralized, the latter favoring the flexibility of the vehicles. The navigation systems are divided into two main categories: (i) Trajectory techniques (wire, tape, laser) and; (ii) Free (geo-orientation GPS, internal GPS, inertial, laser with triangulation), and may use single or hybrid techniques [1].

Regarding the environments where the AGVs are implemented, they can be classified in different ways. [15] proposed to classify the environment in relation to AGVs in two categories. The first is only the environment where they are carrying out the missions of these vehicles, without interaction or sharing information with the environment. In the second classification, the AGVs act and interact with the environment in an interactive way. They are often responsible for building, organizing and cleaning the environment. [16] distinctly approached the classification by integrating the objects to be transported by the AGVs according to the structural characteristics of the environments and objects, segregating it in four groups: (i) Industrial: environment and structured objects; (ii) Military, space, underwater, mining: unstructured environment and structured objects; (iii) Medical: structured environment and unstructured objects; (iv) Agricultural: unstructured environment and objects. [16] warn that in unstructured environments and objects, the probability of AGVs to fail due to unexpected events is high. For clarification, structured environments are those that do not have too much change of lighting or rugged terrain, and that do not generate unpredictable and dynamic situations. Structured objects are those that have a known shape, size, texture, position, and orientation. Unstructured environments and objects are those inversely defined previously.

The classification of AVGs with respect to trajectory, load capacity and addressing methods is significant in order to clarify the impacts of the design alternatives on the requirements necessary to implement WMS. [17] classify multi-robot systems that are analogous to AGVs, mentioning important characteristics: (i) Architecture: centralized or decentralized; (ii) Differentiation of agents: homogeneous or heterogeneous; (iii) Communication structure: through the environment, detection or communication; (iv) Models of other agents: intentions, capacities, states or beliefs.

The classification of AGVs and the environment is essential for the use of software simulation tools, which classifies and evaluates the operational performance of AGVs with the sustainability requirements to implement a sustainable supply chain to the exact measure.

2.3 AGVs and sustainable supply chain

Through the dissemination of technological innovations, AGVs perform their functions in a totally sustainable way, because when compared to other equipment used in the supply chain, they promote the reduction of gas emissions and economic expenses, and also promote social benefits such as safety and accessibility for operators in the same environment. According to [18] the AGVs are developed to promote the sustainable performance of SC systems based on the sustainability tripod: (i) economical, with productivity gains and reduction of labor costs; (ii) environmental, with reduction in energy consumption and gas emissions; (iii) social, with greater employee safety. With the implementation of the Internet of Things (IoT) in industrial plants, it has become possible to interconnect, intercommunicate and interact among SCs' stakeholders, allowing greater management of logistics operations and consequently making technology more sustainable. [18] adds that AGVs integrated with IoTs can aid in the efficient management of warehouse stock handling and in support of intra- and inter-logistic services across a range of different sectors.

The selection of suitable AGVs in totally different environments is a complex task due to the SC's entangled operations, under budgetary, functional and sustainability restrictions. Thus, it is necessary to use software simulation tools to provide valuable information prior to implementation and to develop and analyze the operational performance and sustainability implications of AGVs to support the choice of AGVs in a given SC with accuracy [19] [20]. In this sense, [1] proposed a tool called S2C2 that reveals opportunities to facilitate the implementation of AGVs the in SC by identifying the deciding factors of the success of sustainable implementation at the strategic, tactical and operational hierarchical levels.

In the next section, relevant decision-making factors are presented in the steps of designing, planning and managing the implementation of AGVs in SCs in a sustainable way. The structure considers economic, environmental and social aspects at strategic, tactical and operational hierarchical levels in order to ensure that all stages of AGV implementation and operation in SCs are sustainable.

2.4 Sustainable implementation success factors of AGVs

As previously mentioned, sustainable project development and management in SCs with the implementation of AGVs is an arduous task, given the complexity of the decision-making processes. [1] addressed these processes as encompassing strategic, tactical and operational parameters. In this way, the author provides a critical taxonomy of research that addressed the implementation of AGVs in SCs along with a decision-making framework for project development and management of the area in question, considering economic, environmental and social aspects. In the economic dimension, the factors concern all interested in investing and / or developing SCs with AGV systems in a sustainable manner. In the environmental dimension, they concern the stakeholders that aim to develop SCs with concerns about climate change. Finally, the social dimension is related to the capacity of the AGVs to cooperate with human beings by reducing work accidents, given their autonomous nature [1]. The structure proposed by [1] is crucial to assist in the decision making of experts or those interested in implementing AGVs in SCs in order to achieve essential sustainability goals. Table 1 shows the structure with all the sustainable implementation success factors (ISFs) of AGVs in SCs.

Table 1. Sustainable implementation success factors of the of AGVs in SCs.

	SUSTAINABILITY		
	Economic	**Environmental**	**Social**
STRATEGIC	Determination of the required capital and operating costs of AGVs	Determination of strategic environmental goals	Adoption of workforce safety goals
	Application of Economic Feasibility Analysis	Establishment of energy management and control policies	Selection of information and data sharing systems for man-machine communication, cooperation and coordination
	Selection of information and data sharing systems for communication, cooperation and coordination of AGVs	Selection of information and data sharing systems for environmental data exchange	Introduction of standards to regulate the safety of vehicle operators
	Adoption of production and productivity improvements	Determination of vehicle fuel types	Creation of qualified jobs, improvement of workers' ergonomics
	Design of AGVs operation including layout	Identification and adoption of corresponding KPIs	Identification and adoption of corresponding KPIs
	Determination of the type of AGVs and optimum size of the fleet		
	Minimization of labor costs		
	Identification and adoption of the corresponding *Key Performance Indicators* (KPIs)		
TACTICAL	Determination of maintenance operations and relating costs	Selection of the vehicle loading / restocking strategy	Identification of opportunities for the applicability of the sensors to improve workforce safety
	Determination of sensor types and relevant costs	Establishment of emission goals	Adoption of tools to monitor and assess potential risks
		Adoption of environmental assessment tools	
OPERATIONAL	Ensure efficient economic performance	Ensure environmentally efficient performance	Ensure socially efficient performance
	Application of control techniques (navigation, routing) and flexibility of AGVs	Determination of dispatch operations based on environmental criteria	
	Determination of dispatching operation based on economic criteria	Determination of scheduling techniques based on environmental criteria	
	Determination of scheduling techniques based on economic criteria		

3. Methodology

The objective of this study is to list the critical factors and propose a framework that allows exploring the interrelationships between sustainable Implementation Success Factors (ISFs) of AGVs, a step not included in the research. This will allow (in future stages) an exploratory study with structural equations modeling to identify the critical factors for the implementation of AGVs to be considered as an operational strategy for the context of the Brazilian industry. The study has an exploratory character with an initially qualitative approach, giving theoretical support for subsequent measurement of ISFs, which will be developed in the extended version of this paper. The data that will be collected is secondary, as it will be collected through a social network of professionals where experts suitable for the study were identified.

We adopted a mixed research approach applied by [21] according to the three steps proposed in Fig. 2 that takes into account the context studied, which in this case is a developing country. This article covers the first step, and the remaining steps will be developed in the expanded version of this paper.

In Brazil, a small number of AGV implementations in SCs have been noted. The implementation success factors (ISFs) of AGVs in SCs are outlined in section 2.3. The ISFs were presented to 30 experts through a social network of professionals to identify the most crucial factors through the simple ordering method. The experts were identified and certified through the profile in the social network, where the professional experiences related to the study were evaluated: companies in the sector, importance of the position, and projects carried out, not to mention that only specialists with five years or more of experience in the field of research were considered.

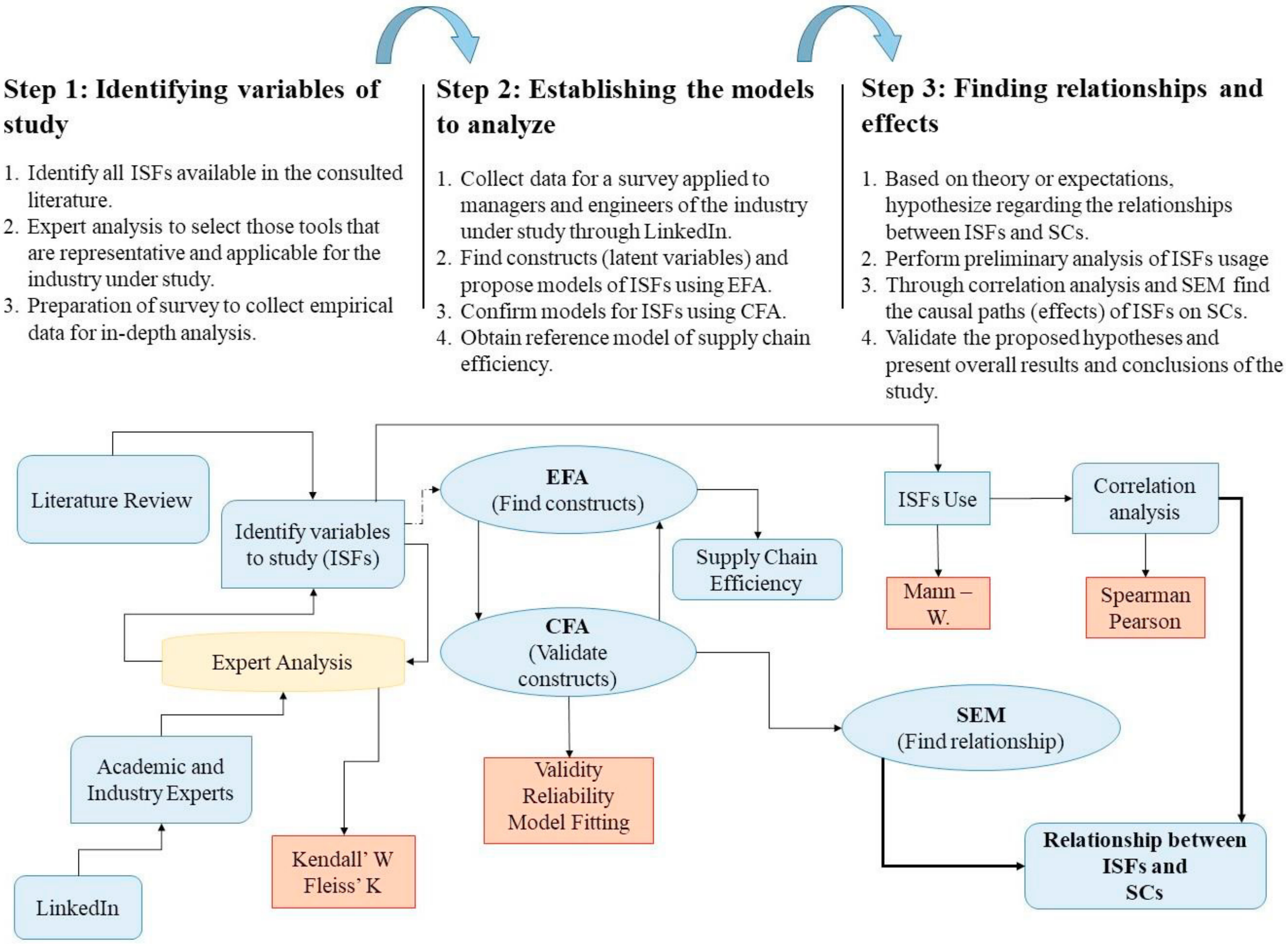

Fig. 2. Stages of the methodology for a mixed approach

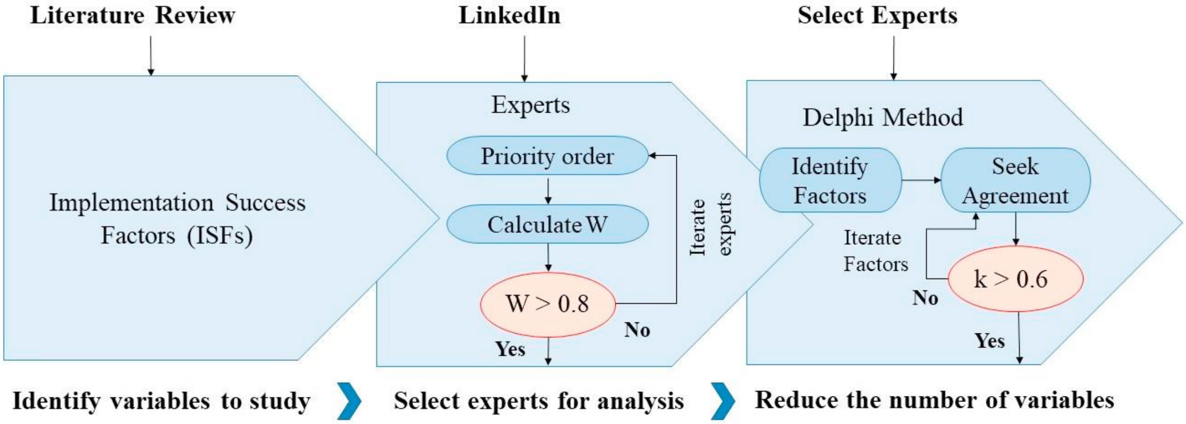

Fig. 3. Reliability test and consensus of the experts.

The use of the professional social network together with the Delphi tool was performed to overcome the difficulty of not having a large enough network to carry out the research and to obtain data for the structural analysis, since identifying specialists in the implementation of AVGs in SCs in Brazil is still a difficult task due to there being few companies with this system implemented in the country. According to [22] the size of the population of the research depends on the consensus among the data of the specialists. Fig. 3 demonstrates the algorithm proposed by [21] to subject the experts to a reliability test and later to seek a consensus among the specialists.

The first process within the step to identify the variables for the study was to subject the specialists to a reliability test in order to measure their criterion unit using (W), and to evaluate which of them had the same level of expertise. To this end, the selected experts were asked to rank by degree of importance the ISFs found in the literature review for the industry under study. The subgroup of experts whose responses obtained the highest value of W was selected as the expert panel for the remainder of the study. The formula used to calculate W is as follows [21], where m is the specialists who evaluate k subjects in order of rank of 1 ak and r is the expert of rating j given to subject i.

$$W = \frac{12\left(\sum_{i=1}^{k}\left(\sum_{j=1}^{m} r_{ij} - \frac{1}{k}\sum_{i=1}^{k}\left(\sum_{j=1}^{m} r_{ij}\right)\right)^2\right)}{m^2\left(k^3 - k\right)} \tag{1}$$

The next process presents the components they did not select as important, along with the number of experts who consider them important. They were asked to reconsider their opinion in light of the response of their anonymous colleagues and present their (dichotomous) response. This step was an iterative process that sought agreement among the experts using the Fleiss kappa coefficient (k). The formula used to calculate k is as follows, where n is the number of subjects, k is the number of evaluation categories, m is the number of specialists for each subject, and $x\ ij$ is the number of specialists who attribute category j to subject i [21].

$$k = \frac{\left(\frac{1}{mn(m-1}\left[\sum_{i=1}^{n}\sum_{j=1}^{k} x_{ij}^2 - mn\right]\right) - \left(\sum_{j=1}^{k}\left(\frac{1}{nm}\sum_{i=1}^{n} x_{ij}\right)^2\right)}{1 - \sum_{j=1}^{k}\left(\frac{1}{nm}\sum_{i=1}^{n} x_{ij}\right)^2} \tag{2}$$

4. Preliminary results

To order the Implementation Success Factors (ISFs) by the specialists, a questionnaire was developed to collect data on an online questionnaire platform, where the platform's questionnaire tool, called the selection box grid, was used. The factors investigated were segmented into nine sorting sections as proposed [1], being classified in the areas: Strategic / Economic, Tactical / Economic, Operational / Economic, Strategic / Environmental, Tactical / Environmental, Operational / Environmental, Strategic / Social, Tactical / Social, Operational / Social.

The selection box grid was organized so that the factors were arranged in a row and the sort numbers in a column. Each row and column were limited to having only one answer so that all factors were sorted without order repetition.

30 apt experts were previously found on the LinkedIn social network to participate in the factor ranking survey. All specialists have been working for more than five years and have experience in projects with industrial segments in logistics, intralogistics and handling and storage systems in Brazilian or multinational companies with branches in Brazil, specialized in the implementation of AGVs in Supply Chains. The specialists have different positions of Director, Project Coordinator, Automation Coordinator, Process Manager, Logistics Manager, Automation Manager, Project Manager, Application Engineer, Project Analyst and Application Analyst.

The research objectives and guidelines along with a link to the questionnaire's virtual address were forwarded via LinkedIn. Some participations were collected, however, these represent a low percentage in relation to the specialists listed. The questionnaire is still available for participation by Brazilian specialists and for data collection. Thus, it is possible to continue the research with the completion of step 1 and the development of steps 2 and 3 as proposed by [21].

5. Conclusion

The present work identified the ISFs of AGVs and the proposed methodology of the current research, containing three steps, which will allow the determination of the critical factors in future studies and the identification of relationships between the ISFs and the supply chain through structural equation modeling (SEM). The identification of ISFs aids in the sustainable implementation of AGVs in supply chains, which involves complex decision processes that permeate the design, planning and management and should be analyzed at the hierarchical levels: strategic, tactical and operational. This enables stakeholders to make the right decisions in the implementation of AGVs and to plan the achievement of crucial goals in relation to sustainability in the long, medium and short term.

The ISFs listed guide decision-making in the sustainable implementation of AGVs in the supply chain in respect to the three hierarchical levels facilitating the process. However, each respective factor needs the knowledge and experience of the implementation team to be defined and specified optimally so that overspecification, over-requirement and overdesign in the implementation do not occur.

Afterwards, with the collection of data provided by the Brazilian specialists, two analyses will be carried out in step 2. First, the Exploratory Factor Analysis (EFA) will be used to help determine the correlation between ISFs and to test the validity of the proposed constructs of the model. After this step, the Confirmatory Factor Analysis (CFA) will be used to confirm the constructs of the previous step. Finally, in step 3, based on the systematic research, the hypothesis of relations between ISFs and the supply chain will be created, the causal paths will be found, the hypotheses will be validated and the results and conclusions of the research in general will be presented.

This framework along with the sustainable ISFs of AGVs listed can be applied in future survey to evaluate the results of the relationship between ISFs and the efficiency of the developing countries supply chain.

References

[1] D. Bechtsis, N. Tsolakis, D. Vlachos, e E. Iakovou, "Sustainable supply chain management in the digitalisation era: The impact of Automated Guided Vehicles", *J. Clean. Prod.*, 142 (2017) 3970–3984.

[2] M. R. Pedersen *et al.*, "Robot skills for manufacturing: From concept to industrial deployment", *Robot. Comput. Integr. Manuf.*, 37 (2016) 282–291.

[3] D. R. M. Reina, S. R. Ensslin, L. Ensslin, e D. Reina, "Seleção e análise do perfil da produção científica sobre o tema Seleção de Projetos", *REGE - Rev. Gestão*, 21 (2014) 3–25.

[4] Y. Sabri, G. J. L. Micheli, e C. Nuur, "Exploring the impact of innovation implementation on supply chain configuration", *J. Eng. Technol. Manag.*, 49 (2018) 60–75.

[5] S. A. Melnyk, R. Narasimhan, e H. A. DeCampos, "Supply chain design: issues, challenges, frameworks and solutions", *Int. J. Prod. Res.*, 52 (2014) 1887–1896.

[6] B. B. Flynn, B. Huo, e X. Zhao, "The impact of supply chain integration on performance: A contingency and configuration approach", *J. Oper. Manag.*, 28 (2010) 58–71.

[7] E. Brandon-Jones, B. Squire, C. W. Autry, e K. J. Petersen, "A Contingent Resource-Based Perspective of Supply Chain Resilience and Robustness", *J. Supply Chain Manag.*, 50 (2014) 55–73.

[8] H. Skipworth, J. Godsell, C. Y. Wong, S. Saghiri, e D. Julien, "Supply chain alignment for improved business performance: An empirical study", *Supply Chain Manag.*, 20 (2015) 511–533.

[9] J. Roh e H. Min, "Implementation of a responsive supply chain strategy in global complexity: The case of manufacturing firms", *Int. J. Prod. Econ.*, 147 (2014) 198–210.

[10] M. K. Lim, M.-L. Tseng, K. H. Tan, e T. D. Bui, "Knowledge management in sustainable supply chain management: Improving performance through an interpretive structural modelling approach", *J. Clean. Prod.*, 162 (2017) 806–816.

[11] P. Ahi e C. Searcy, "A comparative literature analysis of definitions for green and sustainable supply chain management", *J. Clean. Prod.*, 52 (2013) 329–341.

[12] J. Mehami, M. Nawi, e R. Y. Zhong, "Smart automated guided vehicles for manufacturing in the context of Industry 4.0", *Procedia Manuf.*, 26 (2018) 1077–1086.

[13] E. Cardarelli, V. Digani, L. Sabattini, C. Secchi, e C. Fantuzzi, "Cooperative cloud robotics architecture for the coordination of multi-AGV systems in industrial warehouses", *Mechatronics*, 45 (2017) 1–13.

[14] P. Beinschob, M. Meyer, C. Reinke, V. Digani, C. Secchi, e L. Sabattini, "Semi-automated map creation for fast deployment of AGV fleets in modern logistics", *Rob. Auton. Syst.*, 87 (2017) 281–295.

[15] N. Tan, R. E. Mohan, e A. Watanabe, "Toward a framework for robot-inclusive environments", *Autom. Constr.*, 69 (2016) 68–78.

[16] A. Bechar e C. Vigneault, "Agricultural robots for field operations: Concepts and components", *Biosyst. Eng.*, 149 (2016) 94–111.

[17] D. Culler e J. Long, "A Prototype Smart Materials Warehouse Application Implemented Using Custom Mobile Robots and Open Source Vision Technology Developed Using EmguCV", *Procedia Manuf.*, 5 (2016) 1092–1106.

[18] D. Bechtsis, N. Tsolakis, D. Vlachos, e J. S. Srai, "Intelligent Autonomous Vehicles in digital supply chains: A framework for integrating innovations towards sustainable value networks", *J. Clean. Prod.*, 181 (2018) 60–71.

[19] M. J. Black, J. Sadhukhan, K. Day, G. Drage, e R. J. Murphy, "Developing database criteria for the assessment of biomass supply chains for biorefinery development", *Chem. Eng. Res. Des.*, 107 (2016) 253–262.

[20] X. T. Zeng, G. H. Huang, H. L. Chen, Y. P. Li, X. M. Kong, e Y. R. Fan, "A simulation-based water-environment management model for regional sustainability in compound wetland ecosystem under multiple uncertainties", *Ecol. Modell.*, 334 (2016) 60–77.

[21] J. R. Ocampo, J. C. Hernández-Matías, e A. Vizán, "A method for estimating the influence of advanced manufacturing tools on the manufacturing competitiveness of Maquiladoras in the apparel industry in Central America", *Comput. Ind.*, 87 (2017) 31–51.

[22] C. Okoli e S. D. Pawlowski, "The Delphi method as a research tool: An example, design considerations and applications", *Inf. Manag.*, 42 (2004) 15–29.