








RESEARCH PAPER

Validation of challenges in the insertion of ISO/IEC 42001 artificial intelligence system in logistics management

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ABSTRACT

Purpose: The main objective of the study was to conduct exploratory research to systematically analyze and statistically validate the challenges to the adoption of the ISO/IEC 42001 artificial intelligence system in the Brazilian logistics sector, based on the contribution of industry professionals.

Design/methodology/approach: The research strategy adopted was a literature review and a survey of professionals working in the Brazilian logistics sector. The data collected was processed using the Lawshe method to validate the challenges analyzed.

Findings: The results point to the need for specialized training, integration of management systems, organizational resistance and technological limitations as valid challenges, as well as critical issues such as data security and the lack of specific regulations.

Limitations of the investigation: Despite meeting its objective, this exploratory study is limited to Brazil's logistics sector and cannot be generalized to other contexts, reflecting only the analyzed reality of an emerging economy.

Practical implications: The results of this research can guide management strategies and strengthen Brazil's developing economy. The validated challenges offer clear direction for strategic planning, investment, team training, and action prioritization, accelerating the logistics sector's transition to Industry 4.0 with AI and ISO/IEC 42001 certification.

Originality/Value: Although there are numerous discussions about the adoption of artificial intelligence, debates about its impact in the organizational context, especially in relation to ISO/IEC 42001, are still scarce, especially in emerging countries such as Brazil, so the originality of the study lies in filling this gap in the literature, by validating challenges in the logistics sector considering the opinion of professionals who work in this area.

Keywords: ISO/IEC 42001; Artificial Intelligence; Logistics Management; Organizational Challenges; Data Security.

1 INTRODUCTION

Organizational management plays an important role in the logistics sector, where efficiency and precision are key factors in operational performance (Abouzid and Saidi, 2023). According to Parfenov et al. (2021) modern logistics requires an integrated and strategic approach, where organizational leaders must balance process optimization, cost reduction and customer satisfaction. Therefore, faced with a complex and dynamic context, managers and their teams face

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the challenge of coordinating a variety of internal and external activities in a highly competitive and globalized environment (Ransolin et al., 2024). In order to achieve a strategic and adaptable approach to the fluidity of the 21st century, companies need to exploit the potential of technologies and stay ahead of emerging market challenges (Tsang et al., 2022).

In this sense, more recently, the importance of Artificial Intelligence (AI) in the organizational context has emerged. AI as technology offers opportunities to improve operational efficiency and strategic decision-making related to logistics challenges (Sadeghi et al., 2024; Sharifmousavi et al., 2024). By analyzing data in real time, patterns can be identified, future demands can be predicted, and decisions can be made based on accurate and up-to-date information (Wu and Liao, 2023). Furthermore, through machine learning, AI systems are able to adapt over time, continually refining their operations, automating processes and increasing their accuracy and effectiveness. However, the successful implementation of AI in logistics management requires not only investments in technology, but also a change in cultural and organizational structure to ensure employee acceptance and collaboration (Wubineh et al., 2024).

However, the transformation in the way companies operate needs to be accompanied by robust governance and ethical alignments, since it involves accessing, using and distributing data from different sources in masse, generating new statistical correlations and new processes all the time (Sarkar et al., 2024; Siqueira and Lara, 2020). Corporate governance is related to operational performance and technological innovations, since it is necessary to preserve the rights and interests of its stakeholders while seeking the success of the company's results in an ethical and fair manner (Ma et al., 2024; Maheshwari et al., 2024). This creates a demand for regulatory and normative standards that level out the actions carried out within organizations considering ethical guidelines for competitiveness in the market, allowing for the sustainable development of results through the infinite possibilities presented by technology (Booyse and Scheepers, 2024).

Considering this need, the ISO/IEC 42001 standard has emerged as a response to establish international guidelines for the management of artificial intelligence systems in organizations. According to Long et al. (2020) and Yuan et al. (2023) this standard defines requirements for the establishment, implementation, maintenance and continual improvement of an Artificial Intelligence Management System, aimed at ensuring the effectiveness, security and transparency of AI systems. Compliance with ISO/IEC 42001 demonstrates an ethical and responsible commitment to AI, generating stakeholder confidence and competitive advantages. The application of the standard is not limited to a specific sector and can benefit various types of organizations, contributing to the responsible advancement of AI in society (Li et al., 2024; Peretz-Andersson et al., 2024; Yang, 2024).

Although ISO/IEC 42001 provides a framework for managing artificial intelligence systems, there is a notable lack of studies addressing the challenges of adopting ISO standards in various organizational contexts. Academic literature and practical research have yet to explore the barriers and difficulties faced by organizations when implementing ISO standards (Hirata et al., 2023). In this vein, Budayan and Okudan (2022) point out the lack of a clear framework for implementing total quality management (TQM) in ISO 9001-certified construction companies, revealing that these difficulties are shared for implementing different types of certifications. In addition, Zhu et al. (2018) highlights the need for research to fully understand the challenges to adopting ISO standards, emphasizing the importance of detailed research to develop effective implementation strategies. Therefore, there is a demand for investigations that validate challenges encountered by companies when implementing ISO/IEC 42001.

Specifically, it is worth highlighting the Brazilian logistics sector, which is characterized by its complexity and geographical diversity, as well as facing challenges related to infrastructure, regulation and competitiveness (Bonfim et al., 2013; Bouzada, 2012; de Faria et al., 2024; Guha et al., 2024). Logistics companies in Brazil operate in a dynamic environment, where transportation efficiency and supply chain management are important for gaining competitive advantage (Guarnieri et al., 2015; Santos and Ogunseitan, 2022). Corroborating this logic, the comparative study by Beier et al. (2022), which analyzed Brazil in comparison with other countries such as China and Germany, found that, despite a relatively advanced implementation of Industry 4.0 technologies, Brazil still faces significant challenges, justified by the fact that the digital transformation in Brazilian industrial production requires robust governance, clear incentive policies and a critical analysis of the alignment of technologies with strategic and sustainable objectives.

Thus, considering the Brazilian logistics sector, the importance of inserting new technologies such as AI and the challenges inherent in this context, this research is guided by the following question: "What challenges can Brazilian companies face in the logistics sector in adopting ISO/IEC 42001 in their processes?". Therefore, the main objective of the study was to conduct exploratory research to systematically analyze and statistically validate the challenges to the adoption of the ISO/IEC 42001 artificial intelligence system in the Brazilian logistics sector, based on the

contribution of industry professionals.

2 LITERATURE REVIEW

2.1 ISO standards

ISO (International Organization for Standardization) is an independent, non-governmental entity whose role is to standardize, standardize and publish international standards with the aim of improving compliance, efficiency and safety in companies. ISO standards contribute to innovation, support organizations in adopting best practices, quality management and sustainability, and consequently increase their competitiveness in the global market through certifications. In Brazil, the entity responsible for representing ISO is the Brazilian Association of Technical Standards (ABNT), while the National Institute of Metrology, Standardization and Industrial Quality (INMETRO) determines the guidelines that Accredited Certification Bodies (OCCs) must follow when obtaining certifications such as ISO 9001 and 14001 (Maekawa et al., 2013).

Faced with the growing role of AI in organizations, ISO 42001 has emerged as an important milestone for establishing clear and robust guidelines for the management of AI systems (Bouanba et al., 2022). This international standard establishes detailed specific requirements that cover everything from the implementation to the maintenance and continuous improvement of AI systems, with the aim of ensuring efficiency, safety and transparency (Thiers and Harned, 2024). In the organizational context, adopting ISO/IEC 42001 not only demonstrates an ethical and responsible commitment, but also confers competitive advantages by ensuring that the practices adopted are in line with recognized international standards (McIntosh et al., 2024). In addition, the standard is applicable to various sectors, extending its positive impact on society by promoting a balanced approach between technological innovation and social responsibility (Thomas et al., 2024).

2.2 AI challenges in the context of standards

In this context, starting the analysis of challenges related to the human capital of companies, in order to conduct operations using Artificial Intelligence, it is essential to have professionals available who are previously qualified to do so. Chen et al. (2024) points out the natural impact of AI on the labor market, since it requires a higher level of technical and higher education qualifications; however, in developing countries such as China - and Brazil - the majority of the workforce available is made up of frontline or basic operational workers. While Schuldts and Gröger (2022), in their study evaluating the level of maturity of the integration of the ISO System for Geometric Product Specification and Verification (ISO GPS) in Germany, reinforce that the low percentage of familiarity with the standard is due to the lack of professionals with mastery of the skills and knowledge prerequisites, the integration of a technology-based ISO system requires the maturity of the employees involved to implement it and have the capacity to manage it with quality. In agreement, Ahmad et al. (2022) points out the challenges faced by energy companies in transforming their activities with AI, and raises the need for a significant number of employees with technological skills so that there can be an effective, simple and innovative transformation, but at the same time reports that there is not a vast market of qualified professionals to meet this demand.

When dealing with an ISO standard, Schuldts and Gröger (2022) state in their research applied to the case of ISO GPS that knowledge of the standard's structure is one of the factors that defines the company's level of maturity in applying the requirements to processes, and the aim of knowing the maturity model is to visualize the company's current performance in the desired area and identify barriers to be overcome. In an application of the content analysis method to a collection of case studies of ISO 50001-certified organizations, Fuchs et al. (2020) found that one of the challenges most cited by companies was the gap in knowledge and familiarity with the requirements of the ISO standard, and then pointed out that the standard, published in 2011, is relatively new compared to 9001 or 14001 in terms of propositions and application guidelines in the literature. In addition, Franchina et al. (2023) in their study on ISO 9001, raise as a challenge the knowledge of the employees of the companies analyzed about the QMS (Quality Management System) - which guides the standard - and their need to overcome it in order to perform activities in accordance with the requirements of the system and the standard.

Ahmad et al. (2022) presents various AI technologies, such as algorithms, machine learning and artificial neural networks, in three areas of the energy sector; it is understood that it is a challenge to have knowledge and selectivity in the ideal technologies for each area, since there are different demands, volumes of data and degrees of complexity in each one, while facing a countless variety

of available technologies. Barnova et al. (2023) in their research on the use of AI in brain-computer interfaces in medicine, state that individual cases must be studied and developed in a targeted manner, which brings to those responsible for the area of AI and machine learning in the respective segment the challenge of knowing in depth and evaluating the possibilities generated by crossing different technologies within a system. In addition, Stogiannos et al. (2024) in their study on the implementation of AI in the field of radiology, point to the use of frameworks - standards that facilitate the creation, organization and maintenance of systems - to guide the use of AI by radiologists and other healthcare professionals, i.e. using knowledge stored by the company to support the development of skills of the professionals involved in the process.

However, Scaife (2024) in his study on the use of Artificial Intelligence in predictive maintenance comes to the conclusion that the middle to top leadership of the company must be involved in the process of building the AI system, because without support and favorable decisions to do so, a significant barrier is imposed, even though there are other necessary inputs for AI. Fuchs et al. (2020) also show that in 14% of the ISO 50001 adoption case studies analyzed, the lack of support from managers is cited as one of the challenges faced by companies. From the perspective of analyzing the various leadership styles in the context of the merger process between companies, Almada and Policarpo (2016) conclude that when the leadership stance is not constructive during a change process, it will itself become a challenge for the company.

Stogiannos et al. (2024) highlight the importance of formal and standardized training for staff. These authors carried out research into radiography in which they addressed the application of artificial intelligence, highlighting the challenges and opportunities found in the implementation of AI based on a survey of radiologists in England. Corroborating this understanding, Franchina et al. (2023), with their study on the barriers to implementing ISO 9001 in clinical trial centers, illustrates that having an active training program focused on the standards established by the norm is a challenge for establishments seeking to adopt ISO. Likewise, Ahmad et al. (2022) discusses the advantages of artificial intelligence in the workplace, specifically in the energy sector, and for companies to be able to take full advantage of these tools, it is necessary to have a trained workforce and overcome the challenge of keeping them up to date.

Similarly, with regard to the challenge of employee adherence to transformations in company processes, Fuchs et al. (2020) show that resistance and difficulty in educating leadership teams were identified in almost a third of the studies analyzed on ISO 50001. Considering the context of adapting functions and maintaining jobs, Chen et al. (2024) adds that employees within a company that is in the process of transforming to automation with AI must be willing to overcome the adaptation barrier to avoid replacing the workforce. Almada and Policarpo (2016), applying the situation of a merger between companies, contribute to the analysis of the dimensions of resistance - cognitive, emotional and intentional - and expose that the process of responding to changes in the company is a common challenge in companies, according to their particularities in each dimension.

The analysis of the challenges for validating ISO/IEC 42001 in the Brazilian logistics sector reveals the need to address both the human and technological aspects related to the internal infrastructure of organizations. When referring to the integration of management systems as a challenge, Ahmad et al. (2022) points out that the effective integration of the various energy system technologies, including automation and control, is one of the main obstacles in the implementation of AI, since compatibility between legacy systems and new AI technologies is extremely important to ensure successful implementation. Di Vaio et al. (2023) reaffirms that supply chain management is complex, involving various actors, processes and systems, integrating existing systems with AI solutions requires a holistic and coordinated approach across the organization, and emphasizes that integration is challenging due to heterogeneity, the need for cultural and social adaptation, and the investments required. In this vein, Sadeghi et al. (2024) add and relate transparency and agility in decision-making as fundamental factors for cyber resilience, requiring harmonious integration between Artificial Intelligence and existing management systems.

Furthermore, when analyzing challenges related to companies' infrastructure, it is important to validate that information and data flows are clear. The analysis reveals that, during the implementation of the ISO 50001 standard, many organizations faced significant challenges, including insufficient data related to the area of application, highlighting that solving this challenge was critical to guiding the process of implementing the standard (Fuchs et al., 2020). For Di Vaio et al. (2023), the emphasis on digitalization as a means of significantly improving data analysis implies that for effective use of artificial knowledge, organizations need efficient data processing systems and high-quality data. According to Villa-Henriksen et al. (2020), diversity of data sources results in systems of varying units, structures and nomenclatures, which impairs operability between environments, thus negatively impacting communication protocols, system integration and data sharing become critical for effective implementation of artificial intelligence.

Furthermore, as highlighted by Booyse and Scheepers (2024), company size and maturity

emerge as challenges for AI system implementation, because while larger companies may have the financial and human resources to invest in AI technologies, such as advanced software and hardware and qualified human capital, smaller companies may face significant obstacles due to financial and training constraints. Schuldt and Gröger (2022) reiterate that due to the complexity of the geometric product specification and verification system (ISO GPS), especially with the inclusion of mathematical descriptions, references, 3D specifications and manufacturing and measurement rules, small and medium-sized companies face difficulties in understanding and decoding this system. Following this line of reasoning, Henderson and Ruikar (2010) add that the size and maturity of companies directly influences their ability to deal with technological and cultural changes, such as the implementation of advanced technologies like AI, reinforcing that mature companies have more financial and human resources to invest in technologies and manage change processes.

Furthermore, the difficulty of standardizing processes is intrinsically linked to technological implementation, as described by Henderson and Ruikar (2010) the lack of clear standards can increase uncertainty among employees, hinders effective communication and coordination between the parties involved in implementing technology and can undermine the efficiency and effectiveness of technological implementation, making it more difficult to achieve the desired objectives. For Scaife (2024), this scenario is due to the inconsistency and lack of uniformity in operations, the efficient integration of technologies, such as AI, is hampered by the lack of standardization, which can result in conflicts between old systems and new technologies, difficulty in understanding and, consequently, acceptance of the new technology by employees. In a study proposed by Stewart et al. (2004), it is highlighted that non-standardized processes have a significant impact on the implementation of technology, especially in the construction industry, interoperability between different applications and organizations hinders communication and data exchange, which slows down the adoption of information technology-based technologies.

In addition to the challenges already mentioned, the management of documentation and standard operating processes emerges as an obstacle to the implementation of technology, as highlighted by Franchina et al. (2023) when relating to the Quality Management System, the creation and maintenance of documentation and standard operating processes in the standards of the norm are essential to ensure regulatory compliance, the quality of processes and the reliability of results in the implementation of technology in clinical research centers. Linked to this, applied to the context of digital holography technology (Zhong, 2024), which combines medical sensors and artificial intelligence, operational process documentation provides clear guidelines and standardized protocols for interpreting data and ensuring the effectiveness of the technology, keeping them up to date is fundamental for regulatory compliance and the quality of medical procedures.

When addressing an ISO standard, Fuchs et al. (2020) emphasize in their research on the implementation of ISO 50001 that the absence of a Long-Term Strategy negatively impacts both the implementation of technology and the ISO standard itself. Without a comprehensive strategy, organizations face challenges in communicating the benefits of ISO 50001 and securing the necessary commitment for its effective implementation, potentially leading to inadequate resource allocation and cultural resistance. According to Peretz-Andersson et al. (2024), the lack of a long-term strategic plan is common among small and medium-sized enterprises, negatively affecting the implementation of Artificial Intelligence. This compromises the transition to a more efficient, data-driven operations model. Scaife (2024) reiterates that the use of AI for predictive maintenance in facilities can optimize monitoring, system operations, and provide data-driven recommendations, but its efficient implementation requires ongoing strategic commitment, adequate resource allocation, and employee training.

Moreover, technological limitations significantly influence the implementation of advanced technologies and ISO standards, particularly in the energy sector, as illustrated by Ahmad et al. (2022) in their study on the digitalization of this industry. They highlight the integration of energy management systems and smart substations, which depend on Artificial Intelligence for equipment and consumption monitoring. However, slow adaptation by companies to new technologies, high demand for computational capacity, and lack of trust in AI predictions due to systemic uncertainties and unforeseen events are major obstacles. According to Fuch et al. (2020), technological limitations have a significant impact on the implementation of ISO 50001 in the energy sector, hindering the adoption of advanced technologies and modern management systems. Challenges such as security in smart manufacturing, the need for interconnected networks with secure communication, and incompatibility between legacy protocols and modern devices impede coordinated and cost-effective operations. To Sadeghi et al. (2024), using regression analysis, examined variables requiring rigorous checks to ensure the validity and reliability of the experimental design. Through regression models and hypothesis testing, significant relationships were identified, emphasizing the importance of technological advancements such as explainable

artificial intelligence (XAI) in strengthening cyber resilience in the supply chain.

Regarding external infrastructure challenges, Stogiannos et al (2024) in their research within hospital environments, report that data security is a significant challenge for the implementation of Artificial Intelligence in processes handling sensitive data. Vast online databases are needed to feed AI systems, but companies are concerned about exposing internal information to risks such as cyberattacks. Similarly, Ahmad et al. (2022) address challenges in developing AI tools, particularly ML algorithms for control in the energy sector, including the risks companies face in data protection during this process. In their research on AI technologies in decision-making processes, Sadeghi et al. (2024) elucidate that the demand for more comprehensible and reliable technologies arises from the barrier imposed by managers' lack of confidence in how their data is protected. For example, deep learning processes require large volumes of detailed company data, increasing concerns about data security.

In addition, Sadeghi et al. (2024) also identify the transparency of AI systems as a challenge when they are outsourced. The lack of understanding and visibility into how these technologies operate makes it difficult for companies to adopt new processes. Stogiannos et al. (2024), in their research with radiology professionals, highlight concerns regarding data privacy and access by AI companies during implementation. Although most professionals trust data protection laws and express minimal concern, some respondents remain uneasy about how clearly their information is being used. In this context, Booyse and Scheepers (2024), in their study on barriers to AI adoption in decision-making, emphasize the need for organizations to ensure responsible AI adoption by appointing supervisors capable of overseeing governance and ethics during the development process, a criterion identified as lacking in the analyzed companies.

Embedded in a network of stakeholders involved in the process, Maragno et al. (2023) discuss, from the perspective of AI implementation in public services, that one of the main challenges to overcome is aligning and securing support from external stakeholders. This includes technical competencies, data collaboration, and ensuring joint progress of activities. Similarly, Ahmad et al. (2022) in the context of the energy industry, emphasize the need to involve all links in the supply chain to ensure process fluidity, effective AI implementation, and cybersecurity for all stakeholders' data. A barrier arises when any party does not adhere to the new activity models.

Finally, in the context of external challenges to companies, Lee et al. (2024) address the implementation of Artificial Intelligence in the orthodontics segment, highlighting that the lack of legislative standards poses a challenge for organizations intending to adopt AI in their processes, as there is no official regulatory framework to ensure data protection. Regarding the use of technologies like ChatGPT, Nazir e Wang (2023) discuss the advantages, disadvantages, and challenges of AI-based technologies, particularly emphasizing the ethical challenges related to user privacy and preventing the spread of misinformation generated by algorithms. Similarly, Maragno et al. (2023) report in their exploratory study on AI adoption, societal concerns about laws and regulations controlling the use of technology. They highlight that new systems are developed more rapidly than new laws, and the lack of robust legislation limits the effective development of these technologies.

Regarding the financial resources needed to implement ISO/IEC 42001, Di Vaio (2023) suggests that implementing digitalization practices and artificial intelligence requires financial investments for infrastructure, as well as intangible resources such as time, effort, and human skills. They also emphasize the need for public policies to support AI technology implementation and digital knowledge management systems. Moreover, Fuchs et al. (2020) observe that implementation costs are often a determining factor in adopting energy management systems like ISO 50001. These costs include initial infrastructure investments, such as acquiring measurement equipment and energy monitoring systems, as well as ongoing operational costs, such as employee training and system maintenance. Aligned with this, Scaife (2024) stresses that to efficiently operationalize Artificial Intelligence, a robust technological infrastructure is necessary.

Installing and maintaining this infrastructure entails high initial costs, both in terms of hardware and software. In this context, the cost of maintaining technological systems is a relevant factor impacting organizations' decisions to adopt advanced technologies like AI. This involves significant financial investments, managing organizational change, providing employee retraining, and ensuring transparency and compliance with ethical and regulatory standards (Booyse and Scheepers, 2024). In Okonkwo et al. (2023), the research highlights that ongoing operational and maintenance costs are a critical barrier for companies seeking to adopt advanced technologies. It underscores the importance of considering not only acquisition costs but also the long-term costs associated with maintaining and operating these systems. Villa-Henriksen (2020) emphasizes that continuous maintenance and associated costs can directly affect the economic viability of implementing new technological solutions. The introduction of smart devices, such as Android mobile phones, necessitates hardware and software updates to ensure efficient operation, thereby increasing maintenance costs.

Additionally, as noted by Franchina et al. (2023), the implementation and maintenance of a Quality Management System (QMS) compliant with ISO 9001:2015 present significant financial and logistical challenges for organizations, particularly clinical research centers. The costs and logistics of annual audits require considerable investment, while the ongoing need for process improvements adds further financial pressure. Despite these challenges, the benefits include enhanced processes, more effective corrective actions, and more robust risk management.

3 METHODOLOGICAL PROCEDURES

The research strategies adopted in this study included a literature review and a survey, conducted in five distinct stages: (a) a literature review focusing on identifying challenges in the implementation of Artificial Intelligence and the adoption of ISO standards in the logistics sector; (b) the development of a research instrument (questionnaire) based on the challenges identified in the literature review; (c) conducting the survey with professionals in the field; (d) data analysis and validation using the Lawshe method; and (e) establishing discussions of the results, conclusions, and proposals for future research.

The literature review utilized scientific databases such as Web of Science, ScienceDirect, and Emerald. The objective of this stage was to identify articles that provide a foundation for the systematic use of technologies in the logistics sector and the challenges associated with adopting ISO/IEC 42001 Artificial Intelligence Standards. The searches were performed using specific terms and combinations, including: Artificial Intelligence, ISO, ISO/IEC 42001, Logistics, Supply Chain, Management System, Implementation, Corporate Culture, Change, Improvement, Companies, Challenges, Barriers and Difficulties. This search resulted in the selection, full reading, and analysis of 21 articles related to the challenges of adopting and utilizing ISO/IEC 42001 in the logistics sector (Table 1).

Subsequently, a questionnaire was developed based on the challenges identified in the literature. For each challenge associated with the adoption of ISO/IEC 42001, professionals were asked to respond using a 3-point scale: 1 - Overcoming this challenge is essential for adopting ISO/IEC 42001 in the logistics sector. 2 - Overcoming this challenge is important but not essential for adopting ISO/IEC 42001 in the logistics sector. 3 - Overcoming this challenge is not important for adopting ISO/IEC 42001 in the logistics sector.

For data collection, professionals were contacted via email and social media. The questionnaire, accessible through an online link generated on the Google Forms platform, was sent to 300 professionals in the logistics sector in Brazil. A total of 31 responses were received, representing a response rate of 10.33%. The low response rate obtained is average for survey-type studies conducted in Brazil. Factors such as respondents' time constraints, low perception of the study's immediate relevance, and an overload of similar requests may be possible causes for this limitation. Therefore, it is important to highlight a potential risk of non-response bias, since individuals who chose to participate may have different characteristics, perceptions, or levels of interest than those who did not respond. However, regarding the application of Lawshe's method, it is argued that the technique predominantly values the expertise of specialists in evaluating the content and perspectives considered in the validation process. Furthermore, it is emphasized that strategies were adopted to increase participation, such as sending individualized invitations, periodic reminders, and guaranteeing the confidentiality of responses. Finally, the exploratory nature of the study is reiterated, emphasizing that the results should be interpreted with caution, especially regarding their generalizability, and future investigations with larger samples and higher response rates are recommended to strengthen the evidence presented.

Regarding the profile of respondents, 19% were supervisors, 19% analysts, 19% specialists, 16% coordinators, 13% professors, 6% directors, and 6% held other positions. Geographically, 58% were from the North region, 19% from the Northeast, 16% from the Southeast, and 6% from the South. Educationally, 55% held postgraduate degrees, while 45% had only undergraduate degrees. Regarding experience, 39% had less than 5 years in the field, 39% had 5–10 years, and 23% had over 10 years.

Following data collection through the survey, the Lawshe method was employed in accordance with the guidelines of Lawshe (1975) and the recommendations Marinho et al. (2023) and Ayre and Scally (2014). This method is commonly used in exploratory studies to validate barriers, obstacles, benefits, challenges, and other aspects within a specific context, considering the opinions of experts and decision-makers (Lawshe, 1975; Moreira et al., 2023), as was done in this study. For validation, the Lawshe method involves classifying criteria into three categories: "essential," "important but not essential," and "not important".

To apply the method, the Content Validity Ratio (CVR) was initially calculated for each questionnaire criterion (Equation 1). The formula presented in Equation 1 is used to determine the

degree of agreement among experts on the relevance of each item, indicating whether it should be retained or excluded from the instrument.

Equation 1 - Content Validity Ratio

$$CVR = \frac{ne - \frac{N}{2}}{\frac{N}{2}} \quad (1)$$

Where "ne" represents the number of experts who considered the criterion as "essential," and "N" is the total number of experts who participated in the survey. CVR values range from -1 to +1, with -1 indicating complete disagreement and +1 indicating complete agreement (Ayre and Scally, 2014). According to Lawshe (1975), when evaluating the possible outcomes of the procedure, if more than 50% of respondents perceived the criterion as "essential," the CVR was positive. However, if fewer than 50% of respondents indicated the criterion as "non-essential," the CVR was negative. A CVR of zero indicated that half of the experts considered the criterion "essential," while the other half did not.

Subsequently, for further analysis of the method, the mean (Equation 2), standard deviation (Equation 3), and variance (Equation 4) were calculated to better understand the distribution of responses and the consistency among the experts. In these equations, "n" corresponds to the number of respondents, and "p" represents the probability of considering the item as essential.

Equation 2 - Mean

$$\mu = n \cdot p \quad (2)$$

Equation 3 - Standard deviation

$$\sigma = \sqrt{\sigma^2} \quad (3)$$

Equation 4 - Variance

$$\sigma^2 = \mu \cdot (1 - p) \quad (4)$$

Thus, based on these parameters, the $CVR_{critical}$ was calculated (Equation 5), serving as a "cut-off" indicator that, based on the obtained value, determines whether the item under analysis will be validated or not. For the calculation of $ne_{critical}$ (Equation 6) used in Equation 5, a significance level of $z=1.96$ and a standard normal distribution of 5% were adopted, as required by the method (Lawshe, 1975). In this way, it was possible to validate the challenges related to the adoption of ISO/IEC 42001 AI in the Brazilian logistics sector.

Equation 5 - CVR Critical

$$CVR_{critical} = \frac{ne_{critical} - \left(\frac{N}{2}\right)}{\frac{N}{2}} \quad (5)$$

Equation 6 - necritical

$$ne_{critical} = \mu + z \cdot \sigma \quad (6)$$

Finally, with the validation of the challenges, the results were analyzed, debates were established in light of the literature, theoretical and practical contributions were outlined, and the study's final conclusions were presented.

4 RESULTS AND ASSOCIATED DISCUSSIONS

4.1 Challenges in adopting ISO/IEC 42001 AI identified in the literature

From the review of the articles, 20 challenges related to the adoption of AI under ISO/IEC 42001 in the organizational context were identified in the literature. These challenges were listed and

organized in Table 1, where codes were assigned to each challenge, along with their descriptions and the main corresponding references.

Table 1 – Challenges in adopting ISO/IEC 42001 AI identified in the literature

Code	Challenges	Description	References
D1	Team Training	<ul style="list-style-type: none"> - Enable employees to use technologies according to the standard guidelines. - Investment in maintaining training programs. - Formalization and standardization of training. 	(Ahmad et al., 2022; Franchina et al., 2023; Stogiannos et al., 2024)
D2	Integration of Management Systems	<ul style="list-style-type: none"> - Process alignment among stakeholders. - Standardization and information security. - Process flows standardized to comply with the standard. 	(Ahmad et al., 2022; Sadeghi et al., 2024; Di Vaio et al., 2023)
D3	Availability of AI Professionals	<ul style="list-style-type: none"> - Need for innovation and simplification. - Qualified management. - Investment in skilled professionals in a growing market. 	(Ahmad et al., 2022; Chen et al., 2024; Schuldt and Gröger, 2022)
D4	Information and Data Flow	<ul style="list-style-type: none"> - Cleaning up information flows. - Definition of inputs and outputs for each process. 	(Fuchs et al., 2020; Di Vaio et al., 2023; Villa-Henriksen et al., 2020)
D5	Company Size and Maturity	<ul style="list-style-type: none"> - Adaptation to reality. - Consideration of current conditions and future expansion. 	(Booyse and Scheepers, 2024; Schuldt and Gröger, 2022; Stewart et al., 2004)
D6	Difficulty in Process Standardization	<ul style="list-style-type: none"> - Volume of information and processes. - Compliance with legislation and company requirements. 	(Henderson and Ruikar, 2010; Scaife, 2024; Stewart et al., 2004)
D7	Documentation/POP Management	<ul style="list-style-type: none"> - Create and keep documentation updated according to standard requirements. 	(Franchina et al., 2023; Zhong, 2024)
D8	Understanding the ISO Standard	<ul style="list-style-type: none"> - Access and incorporation of the standard. - Guidance. 	(Franchina et al., 2023; Fuchs et al., 2020; Schuldt and Gröger, 2022)
D9	Leadership Engagement/Commitment	<ul style="list-style-type: none"> - Cultural drivers. - Incorporate principles into top management. 	(Almada and Policarpo, 2016; Fuchs et al., 2020; Scaife, 2024)
D10	Resistance to Change from	<ul style="list-style-type: none"> - Process changes to align with 	(Chen et al.,

	Employees	reliability. - Development of team maturity. - Disruption of habits.	2024; Fuchs et al., 2020; Scaife, 2024)
D11	Lack of Long-Term Strategy	- Structured strategies with growth perspectives to sustain system implementation aligned with the standard.	(Fuchs et al., 2020; Peretz-Andersson et al., 2024; Scaife, 2024)
D12	Technological Limitations	- Need for infrastructure to adequately support AI. - Investment and maintenance. - Regional and local limitations.	(Ahmad et al., 2022; Fuchs et al., 2020; Sadeghi et al., 2024)
D13	Knowledge about AI Technologies	- Reference materials for using technology in internal processes. - Diversification of applications. - Ensuring secure origins for compliance.	(Ahmad et al., 2022; Barnova et al., 2023; Stogiannos et al., 2024)
D14	Infrastructure Implementation Cost	- Quoting options in the market. - Cost and contract management.	(Fuchs et al., 2020; Scaife, 2024; Di Vaio et al., 2023)
D15	Technology System Maintenance Cost	- Fixed costs. - Need for system stability.	(Booyse and Scheepers, 2024; Okonkwo et al., 2023; Villa-Henriksen et al., 2020)
D16	Annual Audit Cost	- Contractual costs for certification and annual external audits. - Application of internal audits.	(Franchina et al., 2023)
D17	Data Security	- Implementation of a closed and reliable system. - Investment in data storage technologies. - Compliance and data safety.	(Ahmad et al., 2022; Sadeghi et al., 2024; Stogiannos et al., 2024)
D18	Transparency of AI Provider Companies	- Requirement for documentation and contracts. - Data protection and governance. - Ethics and understanding of risks.	(Booyse and Scheepers, 2024; Sadeghi et al., 2024; Stogiannos et al., 2024)
D19	Resistance to Change from External Stakeholders	- Collective network development. - Regional context of companies.	(Ahmad et al., 2022; Maragno et al., 2023)
D20	Lack of Legislative Standardization	- Regulation and protection for companies and consumers.	(Lee et al., 2024; Maragno et al., 2023; Nazir and Wang, 2023)

The literature highlights the challenges listed in the context of adopting ISO/IEC 42001 AI as

fundamental elements to be overcome to ensure effective implementation aligned with organizational objectives. The need for formal training and process standardization indicates that technical and operational preparation is crucial for integrating the standard into business practices. Similarly, challenges related to the availability of specialized professionals and resistance to change emphasize the importance of strategic management that prioritizes continuous training and cultural adaptation within organizations.

Additionally, financial issues, such as the high costs of system maintenance and annual audits, point to the necessity of robust financial planning with strategies that balance initial investments and long-term benefits. Technological limitations and the absence of legislative standards strengthen the argument for building a reliable infrastructure that ensures data security and regulatory compliance. These challenges, as discussed in the literature, reveal that adopting ISO/IEC 42001 AI requires not only technological resources but also profound organizational changes supported by integrated management and governance strategies.

While numerous challenges related to the adoption of ISO/IEC 42001 AI are highlighted in the literature, it is essential to consider the need to validate them to assess the impact of this adoption in specific contexts. In this study, the validation was conducted within the logistics sector, considering the reality of Brazil, a country characterized by its emerging economy.

4.2 Validation of challenges using the Lawshe method

According to the adopted procedures, the CVR was calculated for each challenge analyzed in this study. Subsequently, the critical $CVR_{critical}$ was determined, resulting in a coefficient of 0.352. Thus, challenges with coefficients equal to or higher than the calculated critical CVR were considered validated, while those with lower coefficients were considered not validated. The results, including the list of validated and non-validated challenges based on the opinions of logistics experts, are presented in Table 2.

Table 2 – Challenge validation using Lawshe method

ISO/IEC 42001 AI Challenges	N. of responses "Essential"	Content Validity Ratio (CVR)	CRVcritical = 0.352
D1 - Team training	26	0.677	✓
D2 - Integration of management systems	23	0.484	✓
D3 - Availability of AI professionals	17	0.097	X
D4 - Information and data flow	25	0.613	✓
D5 - Company size and maturity	13	-0.161	X
D6 - Difficulty in standardizing processes	25	0.613	✓
D7 - Documentation/POPs management	18	0.161	X
D8 - Understanding of ISO standards	20	0.290	X
D9 - Leadership incentive/commitment	26	0.677	✓
D10 - Resistance to change by employees	26	0.677	✓
D11 - Lack of long-term strategy	20	0.290	X
D12 - Technological limitations	23	0.484	✓
D13 - Knowledge of AI technologies	13	-0.161	X
D14 - Cost of infrastructure implementation	16	0.032	X
D15 - Cost of maintaining technology systems	17	0.097	X
D16 - Cost of annual audits	12	-0.226	X
D17 - Data security	27	0.742	✓
D18 - Transparency of AI provider companies	23	0.484	✓
D19 - Resistance to change by external stakeholders	15	-0.032	X
D20 - Lack of legislative standards	22	0.419	✓

Legend: ✓ Validated, X Not validated.

As observed in Table 2, out of the 20 challenges analyzed using the Lawshe method, only 10 were validated according to the opinions of logistics professionals in the Brazilian context. These challenges correspond to: D1 - Team training, D2 - Integration of management systems, D4 - Information and data flow, D6 - Difficulty in standardizing processes, D9 - Leadership incentive/commitment, D10 - Resistance to change among employees, D12 - Technological limitations, D17 - Data security, D18 - Transparency of AI provider companies, and D20 - Lack of legislative standards.

The detailed analysis, followed by discussions and debates in light of the literature regarding the validated and non-validated challenges, is presented below.

5 ASSOCIATED DISCUSSIONS

Analyzing the challenges validated by the study, team training is recognized as a critical issue, involving the preparation of professionals in both ISO standards and AI-based management systems. Without adequate knowledge and foundational guidance for implementing new processes, businesses may face significant short- and long-term impacts (Franchina et al., 2023). Stogiannos et al. (2024) further emphasize that guiding professionals through digital transformation requires a solid learning structure and investments to foster company development and implementation success. The commitment of organizations to training their employees must be prioritized.

The challenge of system integration is also considered crucial to overcome. AI in business processes involves the interconnection of data networks, systems, and work environments. For consistent and reliable information, all elements must be properly connected (Di Vaio et al., 2023). In decision-making processes, a failure can have significant impacts on operations and outcomes, as outputs need to be reliable to effectively support tasks (Sadeghi et al., 2024). Therefore, efforts to integrate systems, standardize processes, and address potential errors are essential before adopting the ISO standard.

Information and data flow clarity, as a validated challenge, highlights the necessity for companies to solidify their internal structures. The quality of data and processing flow ensures consistency, reliability, and accuracy (Di Vaio et al., 2023). These attributes are prerequisites for successful standard implementation, as clear processes and accurate, organized information accelerate the adoption process, as discussed by Fuchs et al. (2020) in the context of ISO 50001. Without accessible essential data or well-defined flows, transformation and standardization processes will not be effective.

The difficulty in standardizing processes represents a significant obstacle. The absence of clear operational standards in logistics organizations is a critical factor that can compromise ISO/IEC 42001 implementation. Lack of standardization hinders team communication, reduces operational efficiency, and increases the complexity of integrating the standard's requirements into existing processes. Henderson and Ruikar (2010) note that every organization has unique cultural, operational, and human characteristics, and the lack of uniformity in processes generates uncertainties among employees, complicating coordination and the adoption of new technologies like AI. Additionally, Scaife (2024) highlights that the absence of standardization exacerbates challenges in integrating legacy systems with modern technologies, resulting in operational inconsistencies and undermining process reliability.

Leadership plays a fundamental role in the process, and lack of involvement and proactive engagement is a significant barrier. Leaders who lead by example drive success, while their absence can contribute to structural failure (Almada and Policarpo, 2016). Although the implementation process may be slow and challenging, leaders must be the primary supporters during development to ensure a smooth transition and continued success post-implementation (Scaife, 2024). Recognizing the lack of leadership involvement as a valid challenge underscores the importance of senior-level commitment to advancing AI standardization systems and their active participation in the process.

Resistance to change among employees is another significant challenge in implementing and adopting ISO/IEC 42001, especially in the dynamic environment of the Brazilian logistics sector. Resistance to technological and procedural changes among staff can hinder the acceptance of new AI management systems, delaying organizational adaptation and compromising the standard's effectiveness. (Scaife, 2024) highlight that employee resistance was identified in nearly one-third of studies on ISO 50001, often driven by uncertainties about how changes would impact their roles and job stability. Complementing this view, Chen et al. (2024) emphasize that in companies undergoing AI automation, it is crucial for employees to overcome adaptation barriers to avoid conflicts and resistance that can hinder transitions.

The validated challenge of technological limitations significantly impacts ISO/IEC 42001

implementation in the Brazilian logistics sector. AI adoption relies on robust and compatible technological infrastructure, often constrained by challenges such as insufficient computational capacity, lack of interoperability between old and new systems, and the need for secure communication networks. Ahmad et al. (2022) observe that adopting AI in the energy sector faces similar challenges, such as integrating smart substations and applying machine learning algorithms. These barriers demonstrate that slow adaptation to innovations limits the projected benefits. Additionally, Fuchs et al. (2020) note that incompatibility between outdated protocols and contemporary technologies complicates the implementation of advanced standards like ISO 50001, a relevant issue for ISO/IEC 42001 as well.

The challenge of data security is critical for effectively implementing ISO/IEC 42001, particularly in the logistics sector, where AI systems heavily rely on large volumes of sensitive data. The absence of adequate security measures exposes organizations to risks such as data breaches, cyberattacks, and loss of stakeholder trust. Stogiannos et al. (2024) emphasize that in environments handling sensitive data, such as healthcare, data protection in AI systems is central to adoption. Similarly, Ahmad et al. (2022) highlight that during the development of AI tools, data protection challenges become critical as they involve ensuring the integrity and confidentiality of the information used.

Regarding AI provider transparency, validating this barrier indicates insufficient knowledge about how information and data are processed within these technologies. Booyse and Scheepers (2024) argue that explaining the functioning and decision-making of AI systems is still challenging, requiring detailed audits and access to processing cores. Ensuring transparency is a key factor in improving AI acceptance, fostering clarity and trust in its use (Sadeghi et al., 2024).

For the validated challenge of lack of legislative standards, the absence of clear and comprehensive regulations complicates ISO/IEC 42001 implementation in the Brazilian logistics sector. The lack of specific governance standards for AI creates uncertainties for organizations and stakeholders, affecting trust in the ethical and safe use of the technology. Lee et al. (2024) highlight that in AI applications for orthodontics, the absence of solid legislative frameworks raises concerns about data protection and appropriate use, hindering business adoption of innovations. Complementing this perspective, Nazir and Wang (2023) discuss how regulatory gaps can lead to ethical and operational issues, such as misinformation and privacy violations in AI systems, exemplified in technologies like ChatGPT. In the ISO/IEC 42001 context, establishing legislative standards that provide legal security and specific guidelines for AI management is essential for fostering responsible and sustainable adoption, offering greater clarity to organizations and technology providers.

The remaining challenges that were not validated through the applied method should not be disregarded in future considerations and analyses. The validation results presented here emphasize that the currently non-validated challenges are not immediate priorities for logistics professionals. As the sector evolves and prioritized weaknesses are addressed, these other challenges may be considered in subsequent plans aimed at continuous improvement.

5.1 Implications for theory and practice

The exploration, validation, and interpretation of the challenges related to this topic contribute to both theoretical knowledge and practical applications in the market. Regarding theoretical contributions, the research results enrich the literature by highlighting the challenges validated by active professionals in the market within the reality of an emerging economy, specifically the Brazilian logistics context. This is ensured by the Lawshe method, with its systematic and statistical validation approach, providing a solid foundation for knowledge in this area. In doing so, it supports researchers by offering insights into a subject not yet deeply explored in the literature, delving into specific challenges to explain them or propose solution models, thereby strengthening the foundational knowledge available for the development of emerging economies, such as Brazil.

For practical applications, the results of this research can assist in implementing management strategies and strengthening the sector within Brazil's developing economy. In terms of strategic planning, investment allocation, team training, monitoring of indicators, and prioritization of actions within companies, the validated challenges offer a well-grounded direction that can lead to faster and more effective impacts in the logistics sector, aiding the transition to Industry 4.0 with AI and certification under ISO/IEC 42001. Consequently, the contributions generated provide support to the entire chain of stakeholders for business development within the analyzed context.

6. CONCLUSIONS

This study achieved its objective by identifying the challenges related to the adoption of ISO/IEC 42001 based on existing literature and a survey conducted with logistics professionals in Brazil,

whose data were analyzed using the Lawshe method to obtain results. This allowed for a contextualized understanding of the challenges inherent to adopting the standard in the Brazilian logistics sector, contributing to the advancement of knowledge on the topic as well as a more detailed comprehension of these challenges. Furthermore, the results can support the development of practical solutions aimed at overcoming these challenges.

The results highlighted key challenges validated by professionals in the field, including the need for specialized training, integration of management systems, process standardization, leadership incentives, and addressing resistance to change. Additionally, critical aspects such as technological limitations, data security, and the transparency of AI provider companies were identified as priorities to ensure compliance with the standard. The lack of legislative standards also emerged as a significant challenge to implementing ISO/IEC 42001.

However, despite achieving the proposed objective, this study has certain limitations. As exploratory research, the results reflect only the analyzed context and cannot be generalized to other regions or realities where the sample used in the analysis is not present. In other words, the research is limited to the reality of Brazil's logistics sector, a country still characterized as an emerging economy.

For future studies, it is proposed to conduct detailed research on the role of public policies and financial incentives in adopting ISO/IEC 42001 in the Brazilian logistics sector. Investigations analyzing how government regulations can support the implementation of the standard are important for understanding the impacts of specific policies on safety and efficiency in logistics management. Additionally, comparative studies across different sectors, such as manufacturing and technology, could provide innovative perspectives on variations in approaches and challenges in adopting ISO/IEC 42001, identifying practices that could be adapted to the logistics sector. Finally, it is suggested that another survey be conducted involving more professionals from different regions in order to increase the sample size and make the results more robust and generalizable.

REFERENCES

- Abouzid, I. and Saidi, R. (2023), "Digital twin implementation approach in supply chain processes", *Scientific African*, Elsevier B.V., Vol. 21 No. July, p. e01821, doi: 10.1016/j.sciaf.2023.e01821.
- Ahmad, T., Zhu, H., Zhang, D., Tariq, R., Bassam, A., Ullah, F., AlGhamdi, A.S., et al. (2022), "Energetics Systems and artificial intelligence: Applications of industry 4.0", *Energy Reports*, Vol. 8, pp. 334-361, doi: 10.1016/j.egy.2021.11.256.
- Almada, L. and Policarpo, R.V.S. (2016), "A relação entre o estilo de liderança e a resistência à mudança dos indivíduos em um processo de fusão", *REGE - Revista de Gestão*, Vol. 23 No. 1, pp. 10-19, doi: 10.1016/j.rege.2015.11.002.
- Ayre, C. and Scally, A.J. (2014), "Critical values for Lawshe's content validity ratio: Revisiting the original methods of calculation", *Measurement and Evaluation in Counseling and Development*, Vol. 47 No. 1, pp. 79-86, doi: 10.1177/0748175613513808.
- Barnova, K., Mikolasova, M., Kahankova, R.V., Jaros, R., Kawala-Sterniuk, A., Snasel, V., Mirjalili, S., et al. (2023), "Implementation of artificial intelligence and machine learning-based methods in brain-computer interaction", *Computers in Biology and Medicine*, Vol. 163, p. 107135, doi: <https://doi.org/10.1016/j.combiomed.2023.107135>.
- Beier, G., Matthes, M., Guan, T., Grudzien, D.I. de O.P., Xue, B., Lima, E.P. de and Chen, L. (2022), "Impact of Industry 4.0 on corporate environmental sustainability: Comparing practitioners' perceptions from China, Brazil and Germany", *Sustainable Production and Consumption*, Vol. 31, pp. 287-300, doi: <https://doi.org/10.1016/j.spc.2022.02.017>.
- Bonfim, Y.P., Ferreira, V. da R.S. and Caetano, M. (2013), "a Logística E O Agronegócio Em Goiás: O Caso Da Soja", *Revista de Gestão*, Elsevier Masson SAS, Vol. 20 No. 4, pp. 557-573, doi: 10.5700/rege515.
- Booyse, D. and Scheepers, C.B. (2024), "Barriers to adopting automated organisational decision-making through the use of artificial intelligence", *Management Research Review*, Vol. 47 No. 1, pp. 64-85, doi: 10.1108/MRR-09-2021-0701.
- Bouanba, N., Barakat, O. and Bendou, A. (2022), "Artificial Intelligence & Agile Innovation: Case of Moroccan Logistics Companies", *Procedia Computer Science*, Vol. 203, pp. 444-449, doi: 10.1016/j.procs.2022.07.059.
- Bouzada, M.A.C. (2012), "Jogando' Logística no Brasil", *Revista de Gestão*, Elsevier Masson SAS, Vol. 19 No. 4, pp. 647-668, doi: 10.5700/rege483.

- Budayan, C. and Okudan, O. (2022), "Roadmap for the implementation of total quality management (TQM) in ISO 9001-certified construction companies: Evidence from Turkey", *Ain Shams Engineering Journal*, Faculty of Engineering, Ain Shams University, Vol. 13 No. 6, p. 101788, doi: 10.1016/j.asej.2022.101788.
- Chen, K., Chen, X., Wang, Z. ao and Zvarych, R. (2024), "Does artificial intelligence promote common prosperity within enterprises? —Evidence from Chinese-listed companies in the service industry", *Technological Forecasting and Social Change*, Elsevier Inc., Vol. 200 No. January, p. 123180, doi: 10.1016/j.techfore.2023.123180.
- de Faria, C.H.F., Almeida, J.F.F. and Pinto, L.R. (2024), "Simulation–optimisation approach for sustainable planning of intermodal logistics in the Brazilian grain export industry", *Decision Analytics Journal*, Elsevier Inc., Vol. 10 No. December 2023, p. 100388, doi: 10.1016/j.dajour.2023.100388.
- Franchina, V., Stabile, S., Cenna, R., Mannozi, F., Federici, I., Testoni, S., Sinno, V., et al. (2023), "ISO 9001:2015 standard implementation in clinical trial centers: An exploratory analysis of benefits and barriers in Italy", *Contemporary Clinical Trials Communications*, Vol. 33, p. 101104, doi: 10.1016/j.conctc.2023.101104.
- Fuchs, H., Aghajanzadeh, A. and Therkelsen, P. (2020), "Identification of drivers, benefits, and challenges of ISO 50001 through case study content analysis", *Energy Policy*, Vol. 142, p. 111443, doi: 10.1016/j.enpol.2020.111443.
- Guarnieri, P., Sobreiro, V.A., Nagano, M.S. and Marques Serrano, A.L. (2015), "The challenge of selecting and evaluating third-party reverse logistics providers in a multicriteria perspective: a Brazilian case", *Journal of Cleaner Production*, Vol. 96, pp. 209–219, doi: 10.1016/j.jclepro.2014.05.040.
- Guha, S., Upadhyay, A. and Gupta, M. (2024), "Understanding the impact of technology investments on financial performance among Latin American supply chains", *The International Journal of Logistics Management*, doi: 10.1108/IJLM-01-2024-0048.
- Henderson, J.R. and Ruikar, K. (2010), "Technology implementation strategies for construction organisations", *Engineering, Construction and Architectural Management*, Vol. 17 No. 3, pp. 309–327, doi: 10.1108/09699981011038097.
- Hirata, R., Ialnazov, D.S. and Mieno, F. (2023), "Corporate governance characteristics of Japanese manufacturing companies and ISO 14001 adoption by their subsidiaries in Thailand", *Current Research in Environmental Sustainability*, Elsevier B.V., Vol. 6 No. June, p. 100236, doi: 10.1016/j.crsust.2023.100236.
- Lawshe, C.H. (1975), "A quantitative approach to content validity", *Personnel Psychology*, Vol. 28, pp. 563–575.
- Lee, M.K., Allareddy, V., Rampa, S., Elnagar, M.H., Oubaidin, M., Yadav, S. and Rengasamy Venugopalan, S. (2024), "Applications and challenges of implementing artificial intelligence in orthodontics: A primer for orthodontists", *Seminars in Orthodontics*, Elsevier Inc., Vol. 30 No. 1, pp. 72–76, doi: 10.1053/j.sodo.2024.01.005.
- Li, X., Rong, K. and Shi, X. (2024), "Situating Artificial Intelligence in Organization: A Human-machine Relationship Perspective", *Journal of Digital Economy*, The Authors, No. November 2023, pp. 1–6, doi: 10.1016/j.jdec.2024.01.001.
- Long, G.J., Lin, B.H., Cai, H.X. and Nong, G.Z. (2020), "Developing an artificial intelligence (AI) management system to improve product quality and production efficiency in furniture manufacture", *Procedia Computer Science*, Elsevier B.V., Vol. 166, pp. 486–490, doi: 10.1016/j.procs.2020.02.060.
- Ma, Y., Rahim, N.S., Panatik, S.A. and Li, R. (2024), "Corporate Governance, Technological Innovation, and Corporate Performance: Evidence from China", Pre-Proof.
- Maekawa, R., Carvalho, M.M. de and Oliveira, O.J. de. (2013), "Study on ISO 9001 certification in Brazil: mapping the motivations, benefits, and difficulties", *Gest. Prod.*, Vol. 20 No. 4, pp. 763–799.
- Maheshwari, P., Kamble, S., Kumar, S., Belhadi, A. and Gupta, S. (2024), "Digital twin-based warehouse management system: a theoretical toolbox for future research and applications", *The International Journal of Logistics Management*, Vol. 35 No. 4, pp. 1073–1106, doi: 10.1108/IJLM-01-2023-0030.
- Maragno, G., Tangi, L., Gastaldi, L. and Benedetti, M. (2023), "Exploring the factors, affordances and constraints outlining the implementation of Artificial Intelligence in public sector organizations",

- International Journal of Information Management, Elsevier Ltd, Vol. 73 No. June, p. 102686, doi: 10.1016/j.ijinfomgt.2023.102686.
- Marinho, S.S., Rego Neto, A.G., Fernandes, R.M., Silva Melo, A.C., Lourenço Bastos, L. dos S. and Martins, V.W.B. (2023), "Validation of sustainability indicators in the energy sector considering their relationship with the UN SDGs: analysis of an emerging economy country using the Lawshe method", *International Journal of Energy Sector Management*, doi: 10.1108/IJESM-10-2023-0010.
- McIntosh, T.R., Susnjak, T., Liu, T., Watters, P., Xu, D., Liu, D., Nowrozy, R., et al. (2024), "From COBIT to ISO 42001: Evaluating cybersecurity frameworks for opportunities, risks, and regulatory compliance in commercializing large language models", *Computers & Security*, Vol. 144, p. 103964, doi: 10.1016/j.cose.2024.103964.
- Moreira, P.A., Fernandes, R.M., Avila, L.V., Bastos, L. dos S.L. and Martins, V.W.B. (2023), "Artificial Intelligence and Industry 4.0? Validation of Challenges Considering the Context of an Emerging Economy Country Using Cronbach's Alpha and the Lawshe Method", *Eng*, Vol. 4 No. 3, pp. 2336–2351, doi: 10.3390/eng4030133.
- Nazir, A. and Wang, Z. (2023), "A comprehensive survey of ChatGPT: Advancements, applications, prospects, and challenges", *Meta-Radiology*, The Authors, Vol. 1 No. 2, p. 100022, doi: 10.1016/j.metrad.2023.100022.
- Okonkwo, C., Okpala, I., Awolusi, I. and Nnaji, C. (2023), "Overcoming barriers to smart safety management system implementation in the construction industry", *Results in Engineering*, Elsevier B.V., Vol. 20 No. September, p. 101503, doi: 10.1016/j.rineng.2023.101503.
- Parfenov, A., Shamina, L., Niu, J. and Yadykin, V. (2021), "Transformation of distribution logistics management in the digitalization of the economy", *Journal of Open Innovation: Technology, Market, and Complexity*, Elsevier Masson SAS, Vol. 7 No. 1, pp. 1–13, doi: 10.3390/joitmc7010058.
- Peretz-Andersson, E., Tabares, S., Mikalef, P. and Parida, V. (2024), "Artificial intelligence implementation in manufacturing SMEs: A resource orchestration approach", *International Journal of Information Management*, Elsevier Ltd, Vol. 77 No. March, p. 102781, doi: 10.1016/j.ijinfomgt.2024.102781.
- Ransolin, N., Saurin, T.A., Clay-Williams, R., Formoso, C.T. and Rapport, F. (2024), "A knowledge framework for the design of built environment supportive of resilient internal logistics in hospitals", *Applied Ergonomics*, Vol. 116 No. January 2023, doi: 10.1016/j.apergo.2023.104209.
- Sadeghi, K.R., Ojha, D., Kaur, P., Mahto, R. V and Dhir, A. (2024), "Explainable artificial intelligence and agile decision-making in supply chain cyber resilience", *Decision Support Systems*, Elsevier B.V., Vol. 180 No. January, p. 114194, doi: 10.1016/j.dss.2024.114194.
- Santos, S.M. and Ogunseitan, O.A. (2022), "E-waste management in Brazil: Challenges and opportunities of a reverse logistics model", *Environmental Technology & Innovation*, Vol. 28, p. 102671, doi: 10.1016/j.eti.2022.102671.
- Sarkar, B.D., Sharma, I. and Shardeo, V. (2024), "A multi-method examination of barriers to traceability in Industry 5.0-enabled digital food supply chains", *The International Journal of Logistics Management*, doi: 10.1108/IJLM-01-2024-0010.
- Scaife, A.D. (2024), "Improve predictive maintenance through the application of artificial intelligence: A systematic review", *Results in Engineering*, Elsevier B.V., Vol. 21 No. December 2023, p. 101645, doi: 10.1016/j.rineng.2023.101645.
- Schuldt, J. and Gröger, S. (2022), "The assessment of the ISO GPS system implementation with a GPS maturity model", *Procedia CIRP*, Elsevier B.V., Vol. 114 No. March, pp. 197–202, doi: 10.1016/j.procir.2022.10.027.
- Sharifmousavi, M., Kayvanfar, V. and Baldacci, R. (2024), "Distributed Artificial Intelligence Application in Agri-food Supply Chains 4.0", *Procedia Computer Science*, Elsevier B.V., Vol. 232 No. 2023, pp. 211–220, doi: 10.1016/j.procs.2024.01.021.
- Siqueira, D.P. and Lara, F.C.P. (2020), "Quarta Revolução Industrial, Inteligência Artificial E a Proteção Do Homem No Direito Brasileiro", *Revista Meritum*, Vol. vol 15 ed, pp. 300–311, doi: 10.46560/meritum.v15i4.8223.
- Stewart, R.A., Mohamed, S. and Marosszeky, M. (2004), "An empirical investigation into the link between information technology implementation barriers and coping strategies in the Australian construction industry", *Construction Innovation*, Vol. 4 No. 3, pp. 155–171, doi: 10.1108/14714170410815079.

- Stogiannos, N., O'Regan, T., Scurr, E., Litosseliti, L., Pogose, M., Harvey, H., Kumar, A., et al. (2024), "AI implementation in the UK landscape: Knowledge of AI governance, perceived challenges and opportunities, and ways forward for radiographers", *Radiography*, The Author(s), Vol. 30 No. 2, pp. 612–621, doi: 10.1016/j.radi.2024.01.019.
- Thiers, F.A. and Harned, Z. (2024), "The Emerging Role of ISO 42001 Certification in Fostering the Deployment of Responsible Generative AI Healthcare Solutions", pp. 1–5.
- Thomas, C., Roberts, H., Mökander, J., Tsamados, A., Taddeo, M. and Floridi, L. (2024), "The case for a broader approach to AI assurance: addressing 'hidden' harms in the development of artificial intelligence", *Ai & Society*, Springer London, No. 0123456789, doi: 10.1007/s00146-024-01950-y.
- Tsang, Y.P., Yang, T., Chen, Z.S., Wu, C.H. and Tan, K.H. (2022), "How is extended reality bridging human and cyber-physical systems in the IoT-empowered logistics and supply chain management?", *Internet of Things (Netherlands)*, Vol. 20 No. June, doi: 10.1016/j.iot.2022.100623.
- Di Vaio, A., Latif, B., Gunarathne, N., Gupta, M. and D'Adamo, I. (2023), "Digitalization and artificial knowledge for accountability in SCM: a systematic literature review", *Journal of Enterprise Information Management*, doi: 10.1108/JEIM-08-2022-0275.
- Villa-Henriksen, A., Edwards, G.T.C., Pesonen, L.A., Green, O. and Sørensen, C.A.G. (2020), "Internet of Things in arable farming: Implementation, applications, challenges and potential", *Biosystems Engineering*, Vol. 191, pp. 60–84, doi: 10.1016/j.biosystemseng.2019.12.013.
- Wu, L. and Liao, X. (2023), "Intelligent Machine Evolutionary Algorithm Learning Based on Artificial Intelligence", *Procedia Computer Science*, Elsevier B.V., Vol. 228, pp. 1016–1022, doi: 10.1016/j.procs.2023.11.133.
- Wubineh, B.Z., Deriba, F.G. and Woldeyohannis, M.M. (2024), "Exploring the opportunities and challenges of implementing artificial intelligence in healthcare: A systematic literature review", *Urologic Oncology: Seminars and Original Investigations*, Elsevier Inc., Vol. 42 No. 3, pp. 48–56, doi: 10.1016/j.urolonc.2023.11.019.
- Yang, Y. (2024), "Application of wearable devices based on artificial intelligence sensors in sports human health monitoring", *Measurement: Sensors*, Elsevier Ltd, Vol. 33 No. June 2023, p. 101086, doi: 10.1016/j.measen.2024.101086.
- Yuan, Y., Chaffart, D., Wu, T. and Zhu, J. (2023), "Transparency: The Missing Link to Boosting AI Transformations in Chemical", *Engineering*, Chinese Academy of Engineering, doi: 10.1016/j.eng.2023.11.024.
- Zhong, W. (2024), "Measurement: Sensors Application of artificial intelligence digital holography technology based on medical sensors in the development of medical image fusion", *Measurement: Sensors*, Elsevier Ltd, Vol. 33 No. March, p. 101146, doi: 10.1016/j.measen.2024.101146.
- Zhu, L., Johnsson, C., Varisco, M. and Schiraldi, M.M. (2018), "Key performance indicators for manufacturing operations management - Gap analysis between process industrial needs and ISO 22400 standard", *Procedia Manufacturing*, Elsevier B.V., Vol. 25, pp. 82–88, doi: 10.1016/j.promfg.2018.06.060.

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