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Towards a Balanced Scorecard enhanced by Artificial Intelligence: new perspectives for the Supply Chain

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Abstract. Modern supply chains operate in an environment marked by uncertainty, complexity, and increasing pressure to be sustainable. While the Balanced Scorecard (BSC) remains a widely used strategic tool, its limitations are becoming apparent in the face of these new challenges. This article analyzes how artificial intelligence (AI) can enhance the BSC to strengthen its management capabilities. Through a systematic and bibliometric review of recent literature, our results show that AI can improve data collection and analysis, anticipate performance, optimize internal processes, and integrate social and environmental dimensions. A comparative table between the classic BSC and the AI-enhanced BSC highlights these developments. The study concludes that the convergence of BSC and AI is a major lever for increasing the agility, resilience, and sustainability of supply chains, while raising issues related to data quality and ethical governance.

Keywords: *Balanced Scorecard; Artificial Intelligence; Supply Chain; Flexibility; Agility; Management Control.*

1. Introduction

In an era of globalization, digital transformation, and increasingly complex operational environments, supply chain (SC) management has become a key strategic challenge for organizations. (Ivanov & Dolgui, 2021) (Gunasekaran & Yusuf, 2002). The Balanced Scorecard (BSC), as a multidimensional management tool, has long been used to align strategic objectives with operational actions. (Kaplan & Norton, 2005), particularly in SC management. However, the limitations of the BSC in uncertain and highly dynamic environments highlight the need for its evolution (Chalmeta & Barqueros-muñoz, 2021). At the same time, artificial intelligence (AI) is now emerging as a powerful lever for improving decision-making, forecasting, and process optimization in the SC (Kamble & Gunasekaran, 2020) (Ali et al., 2024).

This raises a key question: *How can artificial intelligence help overcome the limitations of the traditional Balanced Scorecard to optimize the strategic and operational management of modern supply chains?*

In this context, the main objective of this literature review is to understand how the integration of AI can enhance the effectiveness of the BSC in the strategic and operational management of the supply chain. More specifically, it aims to: (1) identify recent scientific contributions

addressing the relationship between AI, BSC, and SC; (2) categorize the contributions of AI to the evolution of management control tools; and (3) analyze the impacts on the performance, resilience, and agility of supply chains.

To achieve these objectives, the article adopts a progressive structure: the first part is devoted to the conceptual framework, exploring the relationships between AI, BSC, and the supply chain; the second part presents the methodology used, including the criteria for selecting articles and the analysis tools; the third section presents the results from descriptive, bibliometric, and thematic perspectives; finally, the summary discusses the theoretical and managerial implications, proposes research perspectives, and concludes with a general conclusion.

2. Conceptual framework

a. The integration of Artificial Intelligence (AI) into supply chain management (SCM)

Artificial intelligence (AI) is emerging as a strategic lever in supply chain (SC) management, given the complexity of logistics, instability of demand, global disruptions, and sustainability challenges. It enables the analysis of large volumes of data, the generation of accurate predictions, and the guidance of decisions in real time (Zhang et al., 2020), (Pournader et al., 2021).

In demand planning, machine learning algorithms outperform traditional approaches by modeling complex behaviors and integrating weak signals (Zhang et al., 2020). This accuracy improves flow synchronization and reduces uncertainty.

AI also optimizes inventory management through hybrid models combining neural networks and genetic algorithms. It facilitates the automation of replenishment, real-time visibility, and the reduction of costs associated with overstocking and shortages (Pournader et al., 2021).

In logistics, IoT sensors, computer vision, and routing algorithms enable warehouse management automation and delivery optimization. AI also improves environmental performance by reducing emissions (W. Liu et al., 2022).

In predictive maintenance, it detects anomalies upstream, limits unplanned downtime, and reduces maintenance costs. The authors (Zampini et al., 2025) highlight its positive impact on the manufacturing industry.

AI also strengthens the resilience of supply chains. The authors (Ivanov & and Dolgui, 2021) show that by integrating simulation tools, it can anticipate disruptions and respond quickly to crises.

However, its integration poses technical, human, and ethical challenges: infrastructure, skills, algorithmic transparency, and data governance.

In short, AI is not just a technological tool: it embodies a new paradigm in the design and management of supply chains, conditioning their performance, agility, and capacity for innovation.

b. Integrating the Balanced Scorecard (BSC) into supply chain management (SCM)

The Balanced Scorecard (BSC), developed by Kaplan and Norton (1992) (Kaplan & Norton, 2005), is a powerful strategic tool for evaluating organizational performance, offering a holistic view that goes beyond simple financial measures. In the context of supply chain management (P. Liu & Zhang, 2017), the BSC allows for the integration of several dimensions of performance, including financial, customer, internal processes, and learning and growth perspectives. This multidimensional approach helps companies align their operational activities with their strategic mission, thereby facilitating effective management and better decision-making (Pakurár et al., 2019).

The BSC is particularly important for supply chain management because it establishes a clear vision of long-term objectives while measuring essential aspects beyond simple financial

results. It allows companies to track important non-financial criteria, such as customer satisfaction and internal process efficiency, all of which are key determinants of supply chain performance (Sadki et al., 2023). For example, a study on hospitals uses the BSC to monitor the performance of the hospital supply chain, demonstrating the importance of this tool in optimizing resource management.

Another study highlights the application of the BSC in the shipbuilding industry, combined with multi-criteria decision-making (MCDM) techniques such as the Fuzzy Analytical Network Process (ANP) (Gavalas et al., 2022). This approach allows performance to be evaluated from four BSC perspectives, illustrating the direct impact of the BSC in improving competitiveness and performance in complex industrial sectors.

The BSC is not limited to traditional industrial sectors, but also plays a key role in more specific contexts such as the vaccine supply chain (VSC). In the context of future pandemics, it is used to identify critical performance objectives and assist in the evaluation of various dimensions, including the sustainability and efficiency of logistics operations, by combining methodologies such as DANP (decision-making trial and evaluation laboratory based analytic network process) with fuzzy techniques (SFS) (Rai & Bera, 2025). This application demonstrates how the BSC can be adapted to evaluate the performance of complex and urgent systems, such as those associated with critical supply chains during health crises.

One of the major advantages of the BSC is its ability to link supply chain performance to organizational strategy. By establishing a continuous feedback system, it enables all members of the organization to understand their role in business processes and how these processes can be improved to achieve overall strategic objectives (Pakurár et al., 2019). This strategic dimension of the BSC is important to ensure that the actions of the various actors in the supply chain are aligned with long-term organizational objectives.

In addition, the BSC plays a key role in managing sustainability within supply chains. By integrating social, environmental, and ethical measures, the BSC can be transformed into a Sustainability Balanced Scorecard (SBSC), which helps assess companies' performance in terms of sustainability and reinforce responsible practices throughout the supply chain (Córdova-Aguirre & Ramón-Jerónimo, 2024). A case study of Peruvian SMEs shows how the BSC can be applied at a local level to assess sustainability and improve supplier performance in an extended supply chain (Córdova-Aguirre & Ramón-Jerónimo, 2024).

In summary, according to several studies, the Balanced Scorecard (BSC) is an essential tool for improving supply chain performance. It enables a comprehensive assessment of performance by integrating financial and non-financial measures, while aligning the organization's strategic objectives. Its application varies across sectors, from resource management in hospitals to process optimization in shipbuilding, to the management of critical supply chains during pandemics. The BSC facilitates not only continuous process improvement, but also the integration of sustainability concerns into supply chain management practices.

3. Methodology

We adopted a methodology combining a systematic review of the literature and a bibliometric analysis in order to structure the exploration of existing work and better understand the research dynamics in this field, in accordance with the recommendations of Xiao and Watson (2019) (Xiao & Watson, 2019). This approach ensures transparency and accuracy in identifying research trends and existing gaps, while providing an in-depth view of the interactions between the Balanced Scorecard (BSC), artificial intelligence (AI), and supply chain management.

Bibliometric analysis, carried out using VOSviewer software, allows for the synthesis of a large volume of bibliographic data in order to highlight emerging trends, collaboration networks between authors, and keyword co-occurrences. At the same time, the systematic review aims to summarize and synthesize the conclusions of existing research on the subject.

a. Search chain

The Scopus database was chosen because it is the largest database of scientific articles in management and engineering (Collins et al., 2021). It is widely used for systematic reviews of the literature in these fields and guarantees extensive, high-quality coverage of relevant publications.

The search was conducted between January 2025 and February 2025. To ensure a relevant selection of articles, we first conducted a search using the exact terms of our research question, namely ("Balanced Scorecard" AND "Artificial Intelligence" AND "Supply Chain"). This query identified only 12 articles, which was insufficient for an in-depth analysis. In order to expand our database, we then tested the query ("Balanced Scorecard" AND "Artificial Intelligence"), which yielded 81 articles, but without guaranteeing an explicit link to the supply chain. Faced with this limitation, we adopted a more inclusive approach by incorporating synonyms and related terms for each key concept. We used the following expanded query: ("Balanced Scorecard" OR "Performance Measurement System" OR "Strategic Control Systems") AND ("Artificial Intelligence" OR "Machine Learning" OR "Big Data") AND ("Supply Chain" OR "Logistics" OR "Operations Management").

Thanks to this reformulation, 56 articles were identified, constituting the initial database for our analysis.

b. Inclusion criteria

To ensure the relevance of the selected publications, we applied several inclusion criteria:

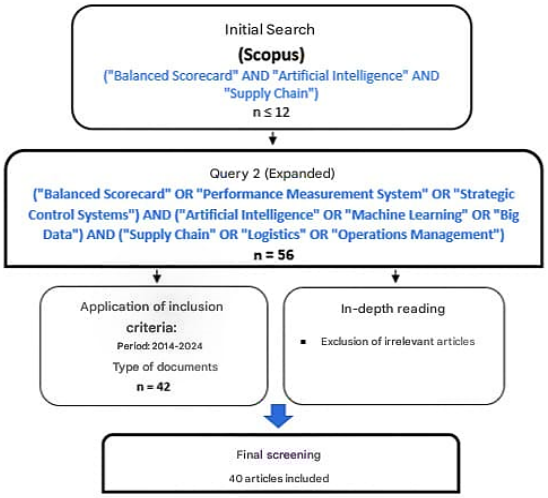
- Publication period: Only articles published between 2014 and 2024 were selected, in order to reflect recent developments in AI and management control.
- Document type: We only included articles from scientific journals and conference proceedings, thus ensuring high academic quality.

After applying these criteria, 42 articles were selected. A thorough reading of the titles, abstracts, and conclusions then allowed us to exclude studies that did not directly address our issue or strayed from our research focus.

In the end, 40 publications were included and subjected to a purification process using the Zotero bibliographic management software.

Figure 1 summarizes the different phases of the research, indicating the number of publications included at each stage.

Figure 1. Diagram of the research phases



Source: Authors' own work

c. Analyses

Two types of analysis were carried out to exploit these 40 articles:

- Bibliometric analysis: Mapping of keyword co-occurrences with VOSviewer to visualize research trends and relationships between key concepts.
- Content analysis: An in-depth review of the publications enabled us to synthesize the results according to the identified research areas, highlighting synergies and prospects for the evolution of AI-enhanced BSC in the context of the supply chain.

This methodology allows us to offer a clear vision based on the interactions between the Balanced Scorecard, artificial intelligence, and supply chain management, while identifying emerging trends and avenues for future research.

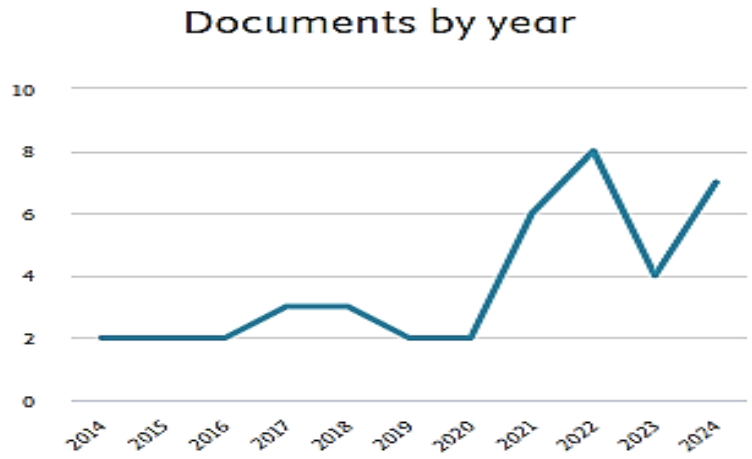
4. Results

a. Descriptive analysis

This section aims to provide an initial overview of the distribution of publications, analyzing their distribution along two complementary axes: on the one hand, the annual evolution of published works, and on the other hand, their dissemination by country.

Observation of the temporal evolution of articles, as shown in the figure, reveals relatively stable scientific production between 2014 and 2020, with a limited number of publications each year. However, a significant increase is observed from 2021 onwards, peaking in 2022 with (n = 8) publications, followed by a recovery in 2024 (n = 7).

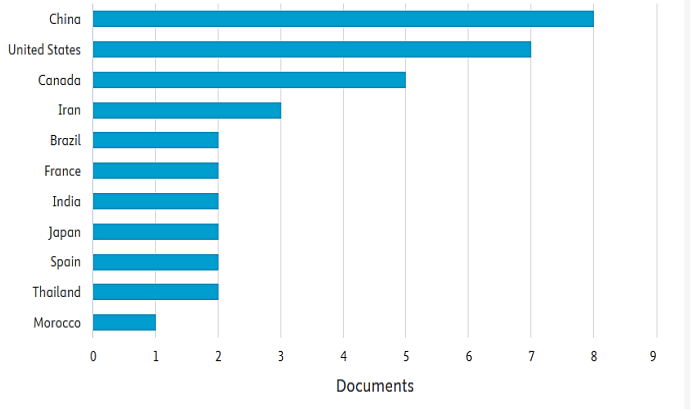
Figure 2. Distribution of publications by year.



This trend can be partly attributed to the COVID-19 crisis, which highlighted the vulnerabilities of supply chains and accentuated the need for innovative solutions. In this context, the rise of artificial intelligence and its integration into strategic management tools such as the Balanced Scorecard (BSC) has sparked growing interest, explaining this upward trend in scientific publications.

Figure 3 illustrates the geographical distribution of authors who have published articles on the integration of AI into the Balanced Scorecard for supply chain management. This analysis identifies the countries most active in this field of research and highlights disparities in scientific output.

Figure 3. Distribution of publications by country

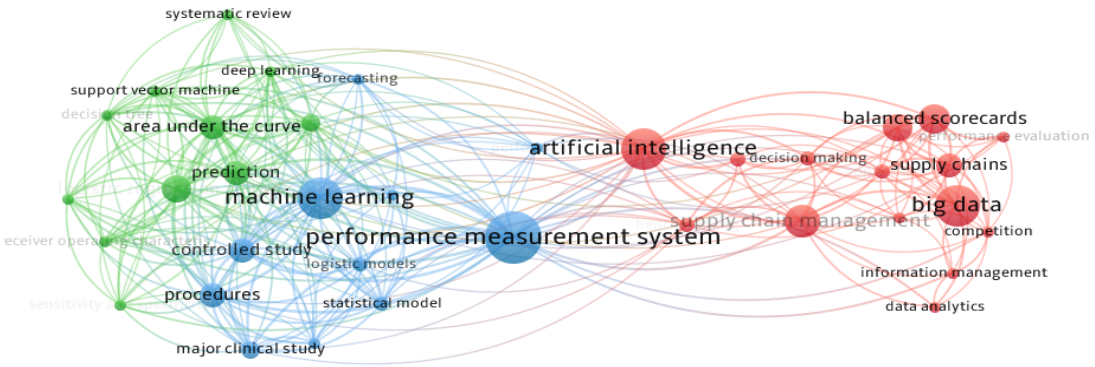


The graph shows the distribution of scientific publications by country on the integration of AI into the Balanced Scorecard for supply chain management. China, the United States, and Canada dominate this field with the highest number of publications, reflecting their lead in research and innovation. In contrast, Morocco ranks last with only one contribution, highlighting a lag in exploring this topic. This finding underscores the need to further develop Moroccan research in this strategic area to strengthen the competitiveness of local businesses.

b. Bibliometric analysis

The co-occurrence network of keywords present in the publications was visualized using VOSViewer software. As shown in Figure 4, 46 keywords with at least 3 occurrences were selected from 663 keywords extracted from the analyzed publications.

Figure 4. Keyword co-occurrence network with VOSViewer



The size of the nodes and font is proportional to the importance of the keywords in the corpus. The lines connecting the nodes indicate the co-occurrence between two keywords, meaning that they appear frequently together in publications. The stronger the link, the more significant the relationship between these terms.

The analysis reveals three main thematic groups. The first, in green, focuses on machine learning and related techniques, such as deep learning, prediction, and support vector machines. The second, in blue, focuses on performance measurement systems and their methodologies (logistic models, statistical models, procedures). Finally, the third, in red, focuses on balanced

scorecards, supply chain management, and big data, highlighting the application of AI technologies in optimizing supply chain management.
These results show a strong interaction between artificial intelligence and performance management tools, confirming researchers' growing interest in integrating balanced scorecards and AI into modern supply chain management.

c. Thematic analysis of study results

i. The contribution of AI to the Balanced Scorecard for the Supply Chain

The integration of artificial intelligence (AI) into performance measurement systems, particularly the Balanced Scorecard (BSC), represents a major advance for strategic supply chain management. AI improves the ability to assess and optimize performance by leveraging vast amounts of data, thereby facilitating decision-making and aligning strategies with organizational objectives.

- *The Balanced Scorecard as a tool for evaluating supply chain performance*

Introduced by Kaplan and Norton (P. Liu & Zhang, 2017), he BSC is a widely recognized tool for measuring performance across four perspectives: financial, customer, internal processes, and learning & growth (Holimchayachotikul et al., 2014). Its application to the supply chain has been gradually expanded to provide a more comprehensive and strategic overview (Abu-Suleiman et al., 2004). However, despite its effectiveness, the traditional BSC has certain limitations, including an excessive focus on top-down measures and a lack of formal implementation methodology (Abu-Suleiman et al., 2004).
To address these challenges, adaptations of the BSC have been proposed, notably the Sustainable Balanced Scorecard (SBSC), which incorporates sustainability dimensions(Chalmeta & Barqueros-muñoz, 2021). This evolution makes it possible to analyze the impact of decisions on the economic, social, and environmental aspects of the supply chain, while leveraging advanced techniques such as big data analysis to generate more accurate and predictive indicators (Goga et al., 2024).

- *The integration of AI into the Balanced Scorecard :*

AI plays a key role in improving BSC in supply chains by facilitating data analysis and decision-making. For example, the use of artificial neural networks (ANN) and the GM (1,1) model makes it possible to accurately analyze and predict key performance indicators (KPIs) (Ali et al., 2024). In addition, combining BSC and big data provides a better understanding of trends and allows strategies to be adapted to market developments (Kamble & Gunasekaran, 2020) (Mushtaha & Alsmairat, 2023).
AI also contributes to the optimization of supply chains by identifying more effective strategies, improving supplier selection, and strengthening resource management (B. Liu et al., 2023). The dynamic balanced scorecard (DBSC) is a major advance in this field, integrating system dynamics (SD) and big data analysis to adapt strategies in real time (Nazari-Ghanbarloo, 2022). This approach enables companies to continuously evaluate their performance and improve their resilience to disruptions.

- *AI and the Balanced Scorecard from a sustainability and innovation perspective:*

AI and BSC are also used to promote an eco-friendly and socially responsible supply chain, particularly in the healthcare sector (Adel et al., 2024). A strategic framework based on AI and aligned with the Sustainable Development Goals (SDGs) makes it possible to evaluate and manage hospital performance using appropriate indicators. In addition, low-carbon supply chains and smart cities benefit from the integration of the BSC for more efficient and sustainable management (C. Cui et al., 2018).
Finally, customizing the BSC for the supply chain involves adapting its perspectives by integrating advanced analytical tools, models such as SCOR, and business intelligence

technologies (Abu-Suleiman et al., 2004). However, certain limitations remain, including a lack of stakeholder involvement and a continued strong focus on short-term financial aspects.

ii. The benefits identified by studies

The integration of AI into the Balanced Scorecard (BSC) brings several significant benefits to supply chain management, including improved decision-making, optimized resources, and enhanced operational sustainability.

First, AI plays a key role in improving the decision-making process. Supply chain performance measurement systems (SCPMS) facilitate the evaluation of the effectiveness and efficiency of operations, thereby supporting the implementation of strategy at various levels (Amoozad Mahdiraji et al., 2023). Thanks to artificial intelligence techniques, companies can better orchestrate their supply chain, improve the customer experience, and increase their competitiveness by optimizing costs.

Second, AI tools help make the supply chain more flexible and responsive to market uncertainties. The use of unconventional AI methods, such as expert systems and fuzzy logic-based models, makes it possible to simulate complex decisions and optimize the evaluation of uncertain criteria (Pokorny et al., 2017). In addition, big data and predictive analytics facilitate the management of strategic information, making it possible to anticipate trends and better adapt the supply chain to market developments (Chalmeta & Barqueros-muñoz, 2021).

AI also plays an important role in sustainability and resource optimization. By improving the efficiency of logistics processes and reducing unnecessary inventory, companies can optimize resource utilization while maintaining a high level of customer satisfaction (Ali et al., 2024). The automation of flows and the elimination of low value-added activities thus contribute to better overall supply chain performance, particularly for SMEs (Goga et al., 2024).

Finally, the application of AI in strategic supply chain management is not limited to economic and operational aspects. Recent studies show that collaborative human-artificial intelligence promotes more creative solutions that are better suited to societal needs, particularly in the health and sustainable development sectors. In particular, hospital supply chains digitized using AI can improve social well-being and promote more environmentally responsible management (Adel et al., 2024).

Thus, recent research confirms that integrating AI into the BSC improves not only supply chain performance management, but also its resilience, sustainability, and strategic alignment with new economic and societal challenges.

iii. *The limitations and challenges of integrating AI into the BSC*

The integration of artificial intelligence (AI) into the Balanced Scorecard (BSC) presents significant opportunities, but it also faces several limitations and challenges.

Most of the articles in our database highlight the opportunities offered by the integration of AI into performance management systems, particularly the Balanced Scorecard (BSC). However, an in-depth analysis also reveals several limitations and challenges associated with this integration.

One of the main challenges is the need for interaction between AI capabilities and human skills to ensure that the humanistic dimension of social innovation is taken into account (Adel et al., 2024). Without this collaboration, the relevance of the solutions proposed by AI could be compromised, particularly when it comes to achieving social and strategic objectives in performance management.

Furthermore, the research context on the application of disruptive technologies, including AI, in supply chain performance measurement systems (SCPMS) is still under development (Amoozad Mahdiraji et al., 2023). The lack of solid theoretical and empirical foundations is a major obstacle to its adoption in the BSC, particularly in sensitive sectors or in times of crisis.

Data reliability and quality are another key challenge. If AI relies on insufficient, inaccurate, or inconsistent data, BSC performance could be affected, compromising the relevance of analyses and strategic decisions (P. Liu & Zhang, 2017) (Pokorny et al., 2017). In addition, AI-based systems, particularly those using fuzzy logic, are highly dependent on the precise formulation of rules and the management of uncertainty, which can complicate their integration into the BSC framework.

The integration of AI into the BSC is also limited by the difficulties of interoperability between information systems and the fragmentation of data sources in supply chains (Abu-Suleiman et al., 2004). Data heterogeneity and the lack of common standards make data aggregation and analysis more complex, which can affect the effectiveness of AI models applied to the BSC.

With regard to sustainability, the application of AI in the BSC to assess the sustainable performance of supply chains faces several limitations. The use of big data for sustainability can be hampered by the lack of standardized methods for translating analyses into concrete actions (Chalmeta & Barqueros-muñoz, 2021). In addition, AI models, which are often data-intensive, can be ineffective when data is scarce or unreliable (Ali et al., 2024).

Finally, the integration of AI into BSC raises economic and ethical questions. The initial investment in AI can be significant, especially for SMEs, and accurately measuring the return on investment remains a challenge [22]. In addition, increasing automation in performance management could lead to organizational resistance and questions about the place of humans in decision-making processes.

In summary, our analysis of articles from the database highlights that, despite advances in AI in improving performance management tools, its integration into the BSC still faces several challenges. These include data quality, the need for a hybrid approach combining artificial intelligence and human expertise, and methodological and ethical limitations. These aspects must be taken into account to ensure the effective and relevant adoption of AI-powered BSC.

5. Summary of results: The contribution of AI to the BSC in the context of the supply chain

The analysis of the 40 selected articles provided a better understanding of the potential contribution of artificial intelligence (AI) to the optimization of the Balanced Scorecard (BSC) in the context of supply chain (SC) management. However, it is important to note that only 18 articles clearly and comprehensively address our research question by explicitly exploring the integration of AI into the BSC applied to SC. The others provide partial answers, addressing either the AI-SC link or the BSC-SC link, without fully connecting the two. Finally, some publications, although not directly addressing our research question, offer relevant ideas and perspectives related to our general theme.

Overall, the results show that integrating AI into the BSC represents a strategic advance in addressing the complex challenges of the modern supply chain. Several major contributions emerge from the studies reviewed :

- ***Data collection and analysis***

AI, particularly through Big Data Analytics, enables the collection and analysis of large amounts of data from various sources, both internal and external to the supply chain, which is a major asset for the BSC (Kamble & Gunasekaran, 2020).

These authors show that AI enables a better understanding of real-time performance and links strategic data to clear performance indicators within the BSC framework. Furthermore, reference (Chalmeta & Barqueros-muñoz, 2021) indicates that sentiment analysis on social media, for example, can enrich the customer perspective of the BSC by providing qualitative data on satisfaction, thus offering a more nuanced view.

- ***Predicting and anticipating performance***

AI techniques, such as machine learning, are used to predict future supply chain performance

based on historical data and current trends. The authors of reference (Sanchez-Gonzalez et al., 2022) emphasize that these predictive models make it possible to anticipate potential risks or opportunities, thereby strengthening managers' ability to respond proactively. The use of neural networks for forecasting in supply chains is also highlighted by (Ali et al., 2024), which reports higher prediction accuracy compared to traditional models.

- ***Optimization of internal processes***

AI is also a driver of optimization for internal supply chain processes. According to article (Adel et al., 2024) AI can identify inefficiencies in operations management processes, improve the flow of goods and information, and make the supply chain more environmentally friendly by optimizing OSCM (Operations and Supply Chain Management) processes. Furthermore, (Zahoor et al., 2021) explains that AI enables real-time decision-making, which enhances the responsiveness and efficiency of operations.

- ***Strengthening the focus on learning and growth***

AI contributes to the BSC's learning and growth perspective by facilitating the identification of the skills and knowledge needed to improve supply chain performance. Reference (Chalmeta & Barqueros-muñoz, 2021) shows that AI can analyze performance data to identify best practices and growth strategies. This enriches organizational learning and supports innovation, which are important for the long-term success of the supply chain.

- ***Support for strategic decision-making***

AI plays a key role in supporting informed strategic decision-making. Reference (Ali et al., 2024) explains that AI enables leaders to make more accurate decisions based on reliable data, in line with the strategic objectives of the BSC. AI-based simulations, as highlighted in (Sanchez-Jimenez & Salais-Fierro, 2021), make it possible to assess the impact of different strategies on BSC KPIs, thus offering a more dynamic and predictive approach to strategic management.

- ***Integration of sustainability***

The integration of sustainability into the BSC through AI is another key aspect. Reference(Goga et al., 2024) highlights that AI can be used to measure the environmental impact of supply chain activities and adjust objectives accordingly.

For example, data analysis can help predict and reduce carbon emissions as part of the Sustainable Balanced Scorecard (SBSC). AI also facilitates the identification of innovative solutions to improve eco-responsible practices in the supply chain, as highlighted by (Adel et al., 2024).

- ***Improved collaboration and communication***

IA facilitates collaboration and communication between supply chain stakeholders, which is essential for effective management. The reference (Zahoor et al., 2021) indicates that AI systems enable greater transparency in information sharing, which helps align the actions of supply chain partners with the objectives defined in the BSC. These systems also promote stakeholder engagement through optimized collaborative tools.

Despite these advantages, several limitations still hinder the smooth integration of AI into the BSC:

- Lack of solid theoretical foundations : Article (Amoozad Mahdiraji et al., 2023) emphasizes that work on AI in SC performance measurement systems (SCPMS) is still in its infancy, with a lack of a structured theoretical framework.
- Data reliability : Article (L. Liu, 2022) points out that AI-based models are highly dependent on data quality. Incomplete or biased data can compromise results.
- Sensitivity to inaccuracies : Article (Pokorny et al., 2017) points out that AI systems are vulnerable to input errors, poorly defined rules, and uncertain knowledge, which can affect the validity of the indicators generated in the BSC.

- Need for human supervision : Article (Adel et al., 2024) emphasizes the importance of collaboration between human and artificial intelligence to ensure ethical and socially responsible decisions.

In summary, most studies reaffirm the transformative role of AI in the use of the BSC, strengthening its analytical, strategic, and sustainable dimensions. However, the integration of these technologies requires careful consideration of technical and human limitations. This summary highlights the advances made, but also the challenges that need to be addressed in order to fully exploit the potential of AI in supply chain performance management via the BSC. In order to better visualize the contributions identified in our review, we propose a comparative table that highlights the key differences between the classic Balanced Scorecard and the Balanced Scorecard enhanced by artificial intelligence. This table summarizes our findings and highlights the major changes brought about by AI in the strategic and operational management of supply chains.

Table 1. Comparison between the classic balanced scorecard and the AI-enhanced balanced scorecard (AI-BSC)

BSC dimensions	Classic Balanced Scorecard	AI-enhanced Balanced Scorecard (AI-BSC)
Data collection and processing	Limited financial and operational data, often static	Analysis of large volumes of data (Big Data), real time, integration of internal and external data
Customer Perspective	Traditional customer satisfaction measurement and feedback	Predictive analysis of customer behavior (AI, sentiment analysis, social media)
Internal processes	Monitoring of static performance indicators (efficiency, quality, deadlines)	Dynamic optimization using AI algorithms (reduction of inefficiencies, workflow automation, predictive maintenance)
Learning and growth	Training and human capital development measured using traditional indicators	Automated identification of key skills, organizational learning based on data analysis, and strategic recommendations
Financial outlook	Tracking costs, revenues, ROI, margins	Financial performance prediction using AI models (neural networks, predictive models), scenario simulation
Resilience and flexibility	Low ability to adapt to disruptions	Anticipating crises and adapting quickly through simulation, predictive analytics, and modeling
Sustainability (SBSC)	Limited integration of social and environmental aspects	Advanced monitoring of environmental and social impacts via AI, alignment with SDGs, real-time sustainability assessment
Strategic decision-making	Based on past indicators and periodic reports	Proactive, predictive, and real-time decision-making thanks to AI and multi-criteria decision support systems

Source: Authors' own work

a. Theoretical and managerial implications

The integration of artificial intelligence (AI) into the Balanced Scorecard (BSC) enriches supply chain management by offering advanced capabilities for data analysis, performance prediction, and process optimization. Theoretically, it allows the role of the BSC to be redefined by introducing more dynamic and predictive perspectives, while integrating sustainability objectives. From a managerial perspective, AI helps managers make more informed decisions,

improve the efficiency of internal processes, strengthen collaboration within the chain, and better manage risks while promoting a responsible and sustainable approach. These contributions underscore the importance of adopting advanced technologies to meet the complex challenges of modern supply chains.

b. Research prospects

Future research prospects could focus on further integrating management control tools with artificial intelligence to improve strategic and operational supply chain management. The application of AI, particularly through machine learning and big data, could improve performance prediction, optimize internal processes, and strengthen strategic alignment while promoting sustainability. In addition, it would be relevant to study its impact on strategic decision-making and collaboration within supply chain networks in order to strengthen competitiveness and resilience in the face of global challenges

6. Conclusion

This systematic and bibliometric review analyzed the evolution of management control systems (MCS), and more specifically the Balanced Scorecard (BSC), in response to the growing demands of modern supply chains. An examination of a corpus of 40 articles from the Scopus database shows that, although only 18 fully address our research question, all of the studies provide useful insights into the interactions between BSC, artificial intelligence (AI), and supply chains.

The results highlight that SCGs are an essential lever for aligning strategy and operations, and that the integration of AI marks a major advance by strengthening data collection and exploitation, performance forecasting, and continuous process optimization. This convergence contributes to increasing the resilience, agility, and sustainability of supply chains.

However, several limitations remain, including the lack of in-depth empirical studies, the limited exploration of the role of AI-enhanced BSC in crisis contexts, and challenges related to data quality and governance. These findings call for further research to concretely assess the contribution of AI in different industrial sectors and organizational contexts.

In summary, this study provides an up-to-date synthesis of knowledge and highlights the need to rethink management control tools in the era of digital transformation in order to support the overall performance and competitiveness of supply chains.

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8. Appendices

Table 2. Analysis of the relevance of articles for the integration of ai into the balanced scorecard and supply chain management

Article	Response to the issue	Contents
(Bailly et al., 2022)	Partial response	The paper focuses on comparing the performance of logistic regression and deep learning models in a biomedical context.
(Wang et al., 2022)	Partial response	The article focuses on highway accident prediction and the use of machine learning for this field, unrelated to Balanced Scorecard or supply chain management.
(Adel et al., 2024)	**Yes**	The article proposes a Balanced Scorecard (BSC) adapted to the context of Egyptian hospitals integrating AI to evaluate a green and socially innovative OSCM strategy. However, AI is used more to evaluate the results of BSC integration rather than to transform the process of setting objectives or analyzing performance in the modern supply chain.
(Amoozad Mahdiraji et al., 2023)	Yes	The article proposes an integration of AI (through Industry 4.0 technologies) into the Balanced Scorecard (BSC) to improve supply chain performance assessment. AI is suggested for use within the BSC framework, but the article does not specifically elaborate on how it can enrich its use in modern supply chain management.
(P. Liu & Zhang, 2017)	Yes	The article proposes an improvement of the traditional Balanced Scorecard to integrate the specificities of Big Data. It explores the use of AI (neural networks and genetic algorithms) for performance evaluation in a Big Data environment, thus enriching the Balanced Scorecard for the modern supply chain with analysis and prediction methods adapted to the complexity of the data.
(Zahoor et al., 2021)	No direct answer	The article explores SCPMS and their adoption in Industry 4.0 with a focus on IoT and big data, but does not specifically address the integration of AI with the Balanced Scorecard for modern supply chain management.
(DeCenso et al., 2018)	Partial answer.	The article uses AI techniques to improve risk adjustment of hospital outcomes, but does not link to the integration of AI into the Balanced Scorecard for modern supply chain management.
(Mello et al., 2014)	Yes	The article discusses the link between big data and performance measurement systems.
(Pokorny et al., 2017)	Yes	The article mentions the use of expert systems and fuzzy logic.
(Chang et al., 2015)	Yes	The article mentions the use of the Balanced Scorecard for the analysis of supply chain networks.
(L. Liu, 2022)	Partial response	The article proposes a supplier evaluation framework based on the Balanced Scorecard, but does not discuss the application of AI to improve this method in modern supply chain management.

Article	Response to the issue	Contents
(Mushtaha & Alsmairat, 2023)	Yes	The article discusses the impact of big data and supply chain capabilities on the Balanced Scorecard and sustainability.
(Nakagawa et al., 2018)	No answer	The article focuses on machine learning for medical diagnosis, unrelated to Balanced Scorecard or supply chain management.
(Nazari-Ghanbarloo, 2022)	Yes	The article proposes a model combining the Balanced Scorecard with system dynamics for performance measurement.
(Pyrzowski et al., 2024)	No answer	The article focuses on EEG biomarkers to predict post-traumatic epilepsy and does not mention the Balanced Scorecard or artificial intelligence in relation to supply chain management.
(Sanchez-Jimenez & Salais-Fierro, 2021)	No direct answer	Although the article discusses the use of AI in a performance measurement system, it does not mention the integration of AI into the Balanced Scorecard for modern supply chain management.
(Venkatesh et al., 2015)	No answer	The article focuses on the application of machine learning for medical diagnosis by breast ultrasound, without mentioning the Balanced Scorecard or supply chain management.
(Teniwut, 2013)	Yes	The article discusses the use of the Balanced Scorecard to analyze the performance of the fisheries agribusiness supply chain.
(Jiang et al., 2021)	No answer.	The article discusses the use of machine learning algorithms to predict the prognosis of advanced schistosomiasis, but does not discuss BSC or AI in supply chain management.
(Abu-Suleiman et al., 2004)	Yes	The article mentions the BSC in the context of R&D budget allocation
(B. Liu et al., 2023)	Yes	This article mentions the use of BSC to evaluate the performance of e-commerce platforms in supply chain finance.
(Maydanova & Ilin, 2019)	Yes	The article mentions AI and BSC as part of the digital transformation of the shipping industry.
(Mello et al., 2014)	No answer.	The article focuses on the impact of big data on performance measurement systems, without addressing AI or BSC in modern supply chain management.
(Mello & Martins, 2019)	No direct answer.	The article examines the impact of big data analytics on performance measurement systems, but does not directly address AI, BSC, or modern supply chain management.
(Charkha & Jaju, 2020)	Partial answer.	This article proposes a decision support system for supply chain performance measurement using BSC, but AI is not mentioned as integrated into BSC to address modern supply chain challenges.
(H. Cui, 2021)	No answer.	The article focuses on assessing the performance of low-carbon supply chains using the Balanced Scorecard, but AI is not mentioned or integrated into this model.
(C. Cui et al., 2018)	Partial answer.	The article discusses the use of machine learning algorithms in a Balanced Scorecard-based assessment system, but does not elaborate on

Article	Response to the issue	Contents
		how AI enhances the use of the BSC in modern supply chain management.
(Holimchayachotikul & Leksakul, 2017)	No direct answer.	Although the article uses a neuro-fuzzy approach and particle swarm optimization techniques for performance prediction, it does not address the integration of AI with the Balanced Scorecard for modern supply chain challenges.
(Farchi et al., 2024)	No answer.	The article uses an artificial neural network to predict sustainable supply chain performance, but does not discuss the integration of AI with the Balanced Scorecard for modern supply chain management.
(Hui, 2022)	No answer.	Although the article mentions the Balanced Scorecard and the big data environment in agricultural logistics, it does not mention AI or its role in improving the Balanced Scorecard for modern supply chain management.
(Kamble & Gunasekaran, 2020)	Yes	The article analyzes performance measures in supply chains based on Big Data and predictive analytics.
(Hosseini et al., 2016)	No answer	The article focuses on developing a lexicon for evaluating discussions about service levels in public transport, but does not address AI, the Balanced Scorecard, or modern supply chain management.
(Holimchayachotikul et al., 2014)	Yes	The article mentions the use of the Balanced Scorecard to improve supply chain performance
(Sanchez-Gonzalez et al., 2022)	Yes	The article deals with digitalization and AI in shipping companies.
(Goga et al., 2024)	Yes	The article discusses the impact of AI on the forklift industry, using the BSC and ESG framework
(Ali et al., 2024)	Yes	The paper proposes an AI methodology combining a neural network (ANN) and a gray GM(1,1) model to improve KPI prediction in supply chain management. It explicitly uses the Balanced Scorecard (BSC) and demonstrates how AI improves decision-making by reducing prediction error.
(Chalmeta & Barqueros-muñoz, 2021)	Yes	The article explores the use of Big Data Analytics (BDA), a technique close to AI, to improve sustainability assessment in supply chains. It discusses enriching the Balanced Scorecard with external data for improved decision-making.
(Katayama & Kobayashi, 2022)	No answer.	The article deals with the application of machine learning in immunology and biological sequence analysis.

Source: Authors' own work