

Serhii Kovalskyi*Faculty of Social and Humanities,**Khmelnytsky Institute of Social Technologies of the Open International University**of Human Development "Ukraine", Khmelnytsky, Ukraine**E-mail: sergkovals@ukr.net**ORCID: <https://orcid.org/0009-0005-9340-7364>*

Innovative Management Models in the Window Business: Optimization of Production, Logistics, and Installation under Market Growth

Abstract

The rapid growth of the construction industry and high demand for bespoke building solutions have made structural inefficiencies and failures in the context of window manufacturing companies more apparent, particularly the coordination between the production, logistics, and installation processes. To mitigate these challenges, this study devised the Integrated Window Operations Framework (IWOF), a process-oriented management model aimed at improving operational alignment and scalability. This study reinterprets existing research on digital supply chains, logistics optimization, and Industry 4.0 technologies through a lens of system-level integration based on a qualitative analytical methodology through a structured literature synthesis. Analysis indicates the window business is structurally inefficient due to stage fragmentation rather than technological limitations. Logistics is the primary coordinating mechanism, and real-time data visibility is demonstrated to be a required condition for successful integration. This analysis shows that digital technologies can improve performance only when integrated into a unified operating framework, and that scale lies in modular integration rather than enhanced volume generation. IWOF is a theoretical development for practice, broadening the concepts of supply chain integration to encompass process synchronization in construction-linked manufacturing systems. This research helps organizations move towards a faster, more resilient, and sustainable growth model in changing markets.

DOI: <https://doi.org/10.30525/2500-946X/2026-2-6>

1 Introduction

The window manufacturing industry occupies a unique position at the intersection of industrial production and construction services. It is a very different environment from that of other manufacturing industries, where operations have to take advantage of controlled environments. Furthermore, window businesses must integrate their production processes to match with project installation that occurs outside the company and includes external employees.

This dichotomy presents a high level of operational complexity, especially in such conditions where growth is more apparent, tailor-made project needs arise and schedules demand constant adjustment. The construction industry has been growing, and the requirement for efficient and scalable models of industrial operations in similar industries has only increased. Yet many window firms still face the need for fragmented management where

production, logistics and installation are viewed in different silos.

This disunity results in ongoing inefficiencies such as scheduling errors, non-delivery, idle stock, and installation issues. Digital supply chain management and Industry 4.0 technologies in recent times has opened up new possibilities to strengthen coordination and performance. Among others, such as big data analytics, Internet of Things (IoT), cloud-based systems foster real-time data exchange in real time, improve visibility, and advance predictive decision-making as emphasized in literature (Alvarenga et al., 2023; Anaba, Kess-Momoh & Ayodeji, 2024; Li, Chen & Guo, 2025).

These capabilities are especially important in the context of construction given the uncertainty and interdependence of operations (Ding, Jie, 2025). In the light of these changes, however, previous research has been mostly concerned with technological solutions rather than structural integration. Though the flow of information is enhanced by digital tools, it

Keywords

window manufacturing, supply chain integration, Industry 4.0, logistics optimization, process synchronization, operational scalability

JEL: M11, L23, O32, M21, D24



This is an Open Access article, distributed under the terms of the Creative Commons Attribution CC BY 4.0

does not solve the problem of misalignment as to how production should meet installation.

The same is true for logistics optimization models, which consider delivery efficiency but do not tend to take into account their role in coordinating the entire operational system. This presents a serious gap between theory and practice: the lack of a process-based management model that combines all the phases of a process in a single system (Masłowski, 2025). This void is even more pronounced in the window business, in which performance is key to business continuity, and this requires manufacturing output to be harmonized with construction schedules.

To this end, this study describes the Integrated Window Operations Framework (IWOFF), a conceptual model which seeks to establish production, logistics and installation in a common operating organization. The following question will be addressed in this research:

How can integrated, system-wide management models enable more efficient and scalable operations for window business, in the context of market growth?

The research has two contributions. By strengthening supply chain and operations management theory by adopting a structural approach to process integration. Second, it offers a practical perspective that businesses who wish to boost performance and scale up operations in construction-driven areas can utilize.

2 Literature Review

It has led to a literature of study exploring how the digital technologies are creating transformations in the industrial and construction related supply chains. However, with advances in digital supply chain management, logistics optimization, Industry 4.0, etc., the operational combination of production, logistics, and installation has not been well realized in various industries such as window manufacturing. This section critically analyzes the literature to identify both established knowledge and structural gaps that necessitate the development of an integrated management model.

2.1 Digital Transformation and Supply Chain Integration

With that in mind, the transformation in supply chains towards digital ecosystems is driving a paradigm shift in how operation systems are organized and managed. Digital transformation enables real-time exchange of information, predictive analytics and increased coordination among the actors within the supply chain (Li, Chen & Guo, 2025). Moreover, such features are especially vital when faced with uncertain and interdependent environments like manufacturing in construction.

One of key themes in the literature is supply chain visibility in supply chains, defined as monitoring materials, processes and the flow of information

throughout the system. Visibility is positively linked with increased responsiveness, reduced disruptions, and enhanced decision-making (Khattab et al., 2025). Likewise, digital technologies enhance supply chain resilience as companies are better able to anticipate risks and reduce them by means of a data-based approach (Alvarenga et al., 2023).

But, while digital integration enhances coordination at the information level, the literature indicates a major weakness: integration is more commonly framed as information connection rather than alignment of processes. That is to say, several studies focus on the technological interoperability of tools but ignore how tactical systems – such as during production and on-site implementation – are structurally synchronized.

This limitation is particularly true in construction-linked industries where the operations are at a wider level than at the factory setting, and extend its impact on project performance.

2.2 Industry 4.0 Technologies and Operational Performance

Industry 4.0 technologies (Internet of Things (IoT), big data analytics, cloud computing, and automation) are widely regarded as key enablers of supply chain performance. These technologies enable real-time monitoring, process automation, and enhanced decision-making capabilities, thereby improving efficiency and flexibility (Rad et al., 2022).

Evidence shows that Industry 4.0 technology adoption can enhance:

- Operational efficiency
- Process transparency
- Supply chain responsiveness
- Risk mitigation

In addition, the combination among an array of technologies has a synergistic impact in the marketplace by empowering firms to improve complex systems through a combination rather than by separating parts (Masłowski, 2025; Spieske & Birkel, 2021). The industry advances not with standing, the literature shows that adopting a technology simply does not lead to results.

Furthermore, the effectiveness of Industry 4.0 is reliant on a good fit between the organization and its operations, reengineering for new processes, and the incorporation of new technologies within its normal operation structures (Tortorella, Giglio & van Dun, 2019). This understanding is particularly important regarding window manufacturing, considering the fact that it is more complex than product lines as far as logistics and installation are concerned. An absence of a unified operational framework limits the potential advantages of digital technology.

2.3 Big Data Analytics and Decision-Making in Supply Chains

Big data analytics has become a core capability that can be used in the supply chain. It allows businesses

to access large volumes of data to determine trends, and to inform decisions at various operational levels (Mageto, 2021).

Numerous empirical studies indicate that organizations with robust analytics capability deliver better supply chain performance in the following segments:

- Demand forecasting accuracy
- Inventory optimization
- Resource allocation
- Process efficiency

Moreover, big data contributes to supply chain agility, as it increases visibility and enables swift response to changes in demand or operational conditions (Rahman et al., 2024). In construction contexts, big data is an important enabler of integrating complex and project-based operations. The presence of analytics in the supply chain processes ensures better synchronization of production outputs to on-site needs (Egwunatum, Anosike & Ihekweme, 2026).

According to the literature, data integration, infrastructure needs and organizational readiness are challenges that also appear (Khattab et al., 2025). More importantly, it does not automatically solve structural disconnections between operational stages, even while data analytics improve decision-making.

2.4 Logistics Optimization in Construction and Manufacturing Systems

Logistics is among the key components of supply chain performance, especially in industries where production has to be synchronized with external activities. Logistics-based delays, poor synchronization, and lack of planning are among the key factors for disruption in construction supply chains (Polusmiak, Pavliuk & Kosach, 2024). Among optimization models, recent studies stress the significance of the following models:

- Just-in-time (JIT) delivery approaches
- Algorithms for routing optimization
- Dynamic scheduling systems

They are effective at increasing the speed and accuracy of delivery, reducing costs, and improving overall system efficiency (Zhang et al., 2024). And researches on integration with production, logistics, have shown that the scheduling of manufacturing activities in accordance with delivery activities can significantly enhance the performance (Buhaievskiy & Petrenko, 2025; Gu, 2024; Lu, Chuah, Xia & Gary, 2025).

This is very true in the area when products are custom built and shipped directly to project sites. The rapid industrialization of offsite projects is increasing the need for logistics. These models move complexity off the construction site and into the supply chains, therefore making coordination of production and delivery a key success factor (Nesarnobari et al., 2025).

Notwithstanding these developments, the literature primarily describes logistics as a supporting role, while

not a focus towards linking through operating parts. This leaves a conceptual void in regards to the use of logistics as a strategic coordination mechanism.

2.5 Supply Chain Risk, Uncertainty, and Resilience

In construction-related industries, for instance, the frequency and impact of supply chain disruptions are growing in recent years. Project unpredictability, external dependencies, and environmental uncertainties also lead to operational instability (Anaba, Kess-Momoh & Ayodeji, 2024; Ding, M. J., & Jie, F. (2025).

Digital supply chains provide enhanced resilience through the ability to:

- Real-time monitoring
- Predictive analytics
- Scenario simulation

For instance, the business models for digital twins are to model with diverse conditions, the supply chain in order to support better decisions and risk reducing (Ivanov et al., 2019; Lu, Chuah, Xia & Gary, 2025). Indeed, research underlines that supply chain resilience is determined by visibility, flexibility, and integration (Cordon, 2023; Gu, 2024). Companies that can adapt their operations on the fly are better prepared for disruptions.

Yet, the literature highlights that resilience is frequently framed in a reactive narrative, emphasizing a disruption response over systemic design (Mohsen, 2023). There is little conversation around how supply chain structures can be redesigned to reduce vulnerability in their own right by design.

2.6 Identified Research Gap and Conceptual Direction

The literature analysis reveals a number of significant gaps:

1. Operational stages are fragmented. Producing, logistics, and execution (installation) are often considered as independent fields in the existing research, with no operational model for their management.

2. Overemphasis on technology rather than structure. Despite an extensive body of research on digital technologies, few studies have investigated their integration into integrated operational systems.

3. Under-theorization of logistics as an integrator. Logistics is seldom conceived as a central coordinating mechanism between supply chain stages.

4. Absence of industry-specific models. There is insufficient understanding of how the window business, which encompasses both manufacturing and construction, performs its specific operations.

These deficiencies suggest a need for a structural process-based organizational model comprising production, logistics, and installation. Consequently, it is proposed in this paper to introduce a custom analytic

framework – The Integrated Window Operations Framework (IWOF) – that is aimed at:

- Align operational stages
- Allow for real-time coordination
- Provide scalability in construction-driven markets

We suggest and operationalize this framework in the following methodology section.

3 Methodology

By systematically synthesizing literature and developing a conceptual model, this study employs a qualitative analytical methodology. Unlike traditional literature reviews that aim only to summarize existing knowledge, this analysis takes on a framework-driven analytical spirit, where the insights based on prior studies are systematically reorganized for building an industry-specific operational model.

3.1 Development of the Integrated Window Operations Framework (IWOF) – Author Contribution

To supplement the identified gaps, such as fragmented processes across production, logistics, and installation, this study has established the Integrated Window Operations Framework (IWOF) as the core analytical contribution. Drawing a line through these three domains, the Integrated Window Operations Framework (IWOF) conceptualizes the window business as a continuous, multi-layered operational system (See Figure 1):

1. Production Layer – comprising manufacturing processes, customization, and order processing
2. Logistics Layer – including transportation, delivery scheduling, and routing coordination
3. Installation Layer – involving on-site assembly, project alignment, and final execution

These layers are linked by a central digital coordination environment which allows real-time data

exchange between them, visibility of their operating, and the ability to dynamically synchronize all operational activities. The framework is theoretically based on the literature regarding supply chain integration and digital transformation research, which highlight visibility, coordination, and adaptability as performance determinants (Alvarenga et al., 2023; Li, Chen & Guo, 2025; Lu, Chuah, Xia & Gary, 2025). But IWOF builds on these ideas and introduces a process-focused integration framework, instead of only technological connectivity.

3.2 Analytical Application of the Framework

The IWOF is used as an interpretive prism to review the literature and to find structural inefficiencies in the window business. More precisely, the model is employed to assess:

- The degree of alignment between production output and installation requirements
- Logistics as a coordinating mechanism across operational stages
- The impact of digital technologies on cross-stage synchronization and decision-making

This model does not study technologies or processes in isolation, but also provides for a general system-level insight into operational performance and demonstrates interdependencies and bottlenecks for the whole workflow.

4 Results

Using the IWOF indicates that window business inefficiencies are more structural and systemic than technological. The results are classified based on the three foundational layers of the framework, and their interrelationships (See Figure 2).

The first important discovery was that the misalignment of production and installation processes is the main point of operational

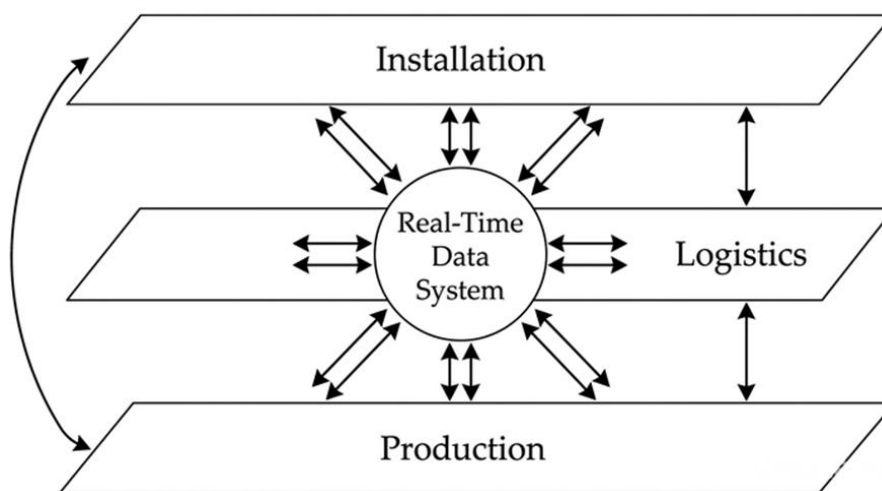


FIGURE 1 Integrated Window Operations Framework (IWOF)

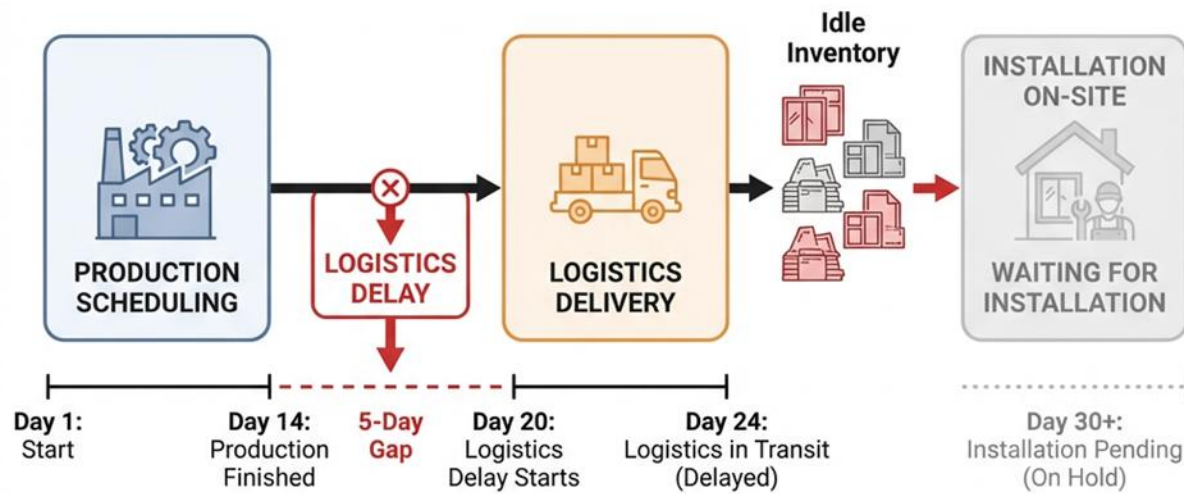


FIGURE 2 Process Flow / Real Operation

inefficiency. Production planning is based on internal manufacturing timetables, installation relying on external construction timetables. The absence of synchronization leads to early production, late site installations, and holding of unused stock.

Secondly, the analysis shows that logistics layer is the indispensable coordination mechanism of the system. If a logistics function exists separately in the system, the timing of deliveries will be inconsistent and reactive. When integrated, however, into a unified coordination structure, logistics allows for temporal alignment between production output and installation readiness, greatly lowering delays and rescheduling.

Third, the results suggest that the real-time data visibility is the facilitating point for cross-layer integration. Enterprises having centralized data systems can dynamically modify their production schedules, optimize their delivery courses and synchronize installation activities. On the other hand, less openness in data and limited data availability results in fragmentation of decision making and lack of responsiveness.

Fourth, IWOFF also shows that the constraint for achieving operational scalability is process-rigidity not capacity or production. Expansion businesses tend to increase output, yet they fail to restructure control arrangements leading to inefficiencies across logistics and install stages. Scalable operation is only possible if the processes are modular, synchronized throughout all the layers.

Fifth, disruptions propagate from one layer to the next, a series of cascading consequences is recognized in this framework. Logistics scheduling suffers as a result of production delays, which cause an eventual disruption to installation schedules. The lack of integrated control mechanisms means that such disruptions cannot be detected early and resolved.

The results also reveal that applying digital technologies does not in itself address operational inefficiencies. The efficacy of these solutions is based on their harmonization in an integrated system. Technologies applied in isolation improve local performance but fail to optimize the system as a whole.

Such findings generated through the Integrated Window Operations Framework (IWOFF), which will serve as a structured explanation of operational inefficiencies in the window business and serve as a foundation for both theoretical and practical advancements. This section discusses these findings in relation to previous studies and how the current research contributes to the present literature, highlighting the ways in which this framework adds to existing knowledge in supply chain management and construction industry manufacturing.

4.1 Structural Integration: Supply Chain theory and failure of the missing value chain dimension

The first key takeaway of the results is that inefficiency inside the window venture is structural, not

TABLE 1 IWOFF-Based Identification of Operational Inefficiencies and Optimization Levers

IWOFF Layer	Identified Issue	System-Level Impact	Optimization Lever
Production	Schedule misalignment	Inventory buildup, delays	Dynamic planning
Logistics	Reactive coordination	Delivery inconsistency	Integrated routing
Installation	External dependency	Timeline disruption	Synchronized scheduling
Cross-layer	Lack of visibility	Fragmented decisions	Central data system
System-wide	Process rigidity	Limited scalability	Modular integration

technological. Literature on digital transformation and supply chain performance has drawn much attention (Alvarenga et al., 2023; Li, Chen & Guo, 2025), but it assumes that better data sharing will automatically cause operational alignment.

But the findings problematize this assumption, confirming that data visibility on its own does not rectify process misalignment. The IWOFF demonstrates this when pointing out that without an embedded process integration of production, logistics, and installation, even the most sophisticated digital systems cannot address inefficiencies (Mohsen, 2023). This places the framework in the frame of reference of supply chain integration theory as a process-oriented extension rather than informational connectivity.

4.2 Reconceptualising the role of logistics: from being a mere provider of support to being a facilitator

A primary contribution of this study is revolutionizing logistics in terms of the way it is conceptualized. Current construction and manufacturing research acknowledges logistics as a key enabler of efficiency, but typically treats it as a downstream or supporting function (Lu, Chuah, Xia & Gary, 2025; Polusmiak, Pavliuk & Kosach, 2024; Zhang et al., 2024).

Based on their findings, the IWOFF shows logistics takes a completely different role; instead, it acts as the temporal and operative interface between production and installation. This indicates that logistics does more than just convey products and services; it is the central organising body facilitating a coordinated response system-wide. This re-reading extends present logistics theory by making it a central node of operation stages, especially in the case of project sectors.

4.3 Embedded Role of Industry 4.0 Technologies within IWOFF

The results validate our earlier discussion on the fact that digital technologies markedly improve operational performance, but only if incorporated into an integrated framework. This is consistent with literature that suggests the value created by convergence and coordination of Industry 4.0 technologies together (Rad et al., 2022).

Within the IWOFF structure:

- Big data analytics supports predictive planning and dynamic scheduling
- IoT technologies enable real-time tracking capability for materials and processes
- Scenario modelling and disruption management is enabled due to the advantages of digital twins and simulation tools (Ivanov et al., 2019).

But the results suggest an important nuance:

Technology improves integration – not supplants it. There are limited conceptualisations for this in the literature, where the adoption of technology is often

equated with operational enhancements at scale. The IWOFF provides clarity that technologies need to be embedded structurally in coordinated processes to create system-level benefits.

4.4 Scalability as Integrative Ability

A further important contribution is provided in the scalability debate. The classic view perceives scalability as greater production capacity or the growth in resources. The results show, in the window business, growth is inhibited, not by limits imposed under production but by coordination inefficiencies across stages of operation. This introduces modular scalability, in which you can scale up by duplicating your integrated operational units, not simply increasing capacity in an isolated unit. These findings match with studies about Industry 4.0 that focus on flexibility and adaptability (Tortorella, Giglio & van Dun, 2019) even when it extends this knowledge by tying scalability specifically to the ability to integrate processes.

4.5 System-level risk propagation and the generation of resilience

The IWOFF offers an alternative view of risk and resilience as well. Existing literature shows that visibility and flexibility are key aspects that help mitigate supply chain disruptions (Cordon, 2023; Ding, M. J., & Jie, 2025).

These studies, however, typically involve a single stage or external risks. The research shows that in the window business, risks have system-level interconnections. Disruptions in production move through logistics and finally to the installation process. This domino effect illustrates the need for system-wide collaboration and early detection efforts. The IWOFF helps contribute to resilience theory by linking these interdependencies, promoting a structural approach to disruption prevention rather than a reactive stance.

4.6 Validation of the Integrated Window Operations Framework (IWOFF)

It is important indeed that while the scope of analysis, method and framework are sound, there exist limitations to the integration of the whole IWOFF framework of windows in the IoT context. The paper provides a valid description and consistency of the operational and structural analysis of Window Operations Framework (WOF) concepts.

For these reasons, the contributions can be briefly summarized as follows:

- It presents a three-layer model comprising the complete process continuum
- It reshapes logistics as a core coordinating function
- It integrates digital technologies into a process-oriented structure
- It defines scalability as a function of system integration

- It describes risk propagation along inter-layer dependencies

Although the framework is a theoretical boost and a means to optimally use the system by filling the gaps identified in the literature.

5 Conclusion

This study shows that inefficiencies operating in the window business mainly come due to fragmentation in the processes of production, logistics, and installation. This is supported by the design and implementation of the Integrated Window Operations Framework (IWOFF) to give this information a structure by which to analyze and improve these inefficiencies.

These results demonstrate that technological adoption alone is not sufficient for optimizing

operations, as operational stages must be sequenced into a unified operating framework. Logistics become a central coordinating mechanism while the real-time visibility of data gives process-to-process dynamic synchronization.

Moreover, the research proves that scalability is only possible through modular integration not with an expanding level of production. The IWOFF's contributions are to the existing literature by applying supply chain integration theory to process-level synchronization in relation to construction-linked manufacturing. And it makes practical sense by making it easy for businesses to determine ways they can improve efficiency, resilience, and growth with a clear framework.

Future work should focus on empirical demonstration of this theoretical framework and explore its applicability across other industries characterized by similar operational structures.

References

- [1] Alvarenga, M. Z., Oliveira, M. P. V. D., & Oliveira, T. A. G. F. D. (2023). The impact of using digital technologies on supply chain resilience and robustness: the role of memory under the covid-19 outbreak. *Supply Chain Management: An International Journal*, 28(5), 825–842. <https://doi.org/10.54254/2754-1169/140/2024.GA18772>
- [2] Anaba, D. C., Kess-Momoh, A. J., & Ayodeji, S. A. (2024). Optimizing supply chain and logistics management: A review of modern practices. *Open Access Research Journal of Science and Technology*, 11(2), 020–028. <https://doi.org/10.53022/oarjst.2024.11.2.0083>
- [3] Buhaievskiy, M., & Petrenko, Y. (2025). Planning and optimization models in ready-made concrete production and logistics. *Radioelectronic and Computer Systems*, 2025(2), 264–279. <https://doi.org/10.32620/reks.2025.2.17>
- [4] Cordon, Carlos (2023) : The surprising developments of digital supply chains to raise resilience in the face of disruptions, ADBI Working Paper, No. 1383, Asian Development Bank Institute (ADBI), Tokyo. <https://doi.org/10.56506/KPJD9061>
- [5] Ding, M. J., & Jie, F. (2025). Mitigating the supply chain uncertainties and risks in the construction projects: Case studies of Australian construction projects. *Cleaner Logistics and Supply Chain*, 16, 100237. <https://doi.org/10.1016/j.clscn.2025.100237>
- [6] Egwunatum, S., Anosike, N. M., & Ihekwe, M. N. (2026). Weighing on the Capabilities of Big Data Analytics for Sustainable Supply Chain Management in Construction Projects. *Journal of Sustainability*, 2(1). <https://doi.org/10.55845/jos-2026-2183>
- [7] Gu, X. (2024). The Role of Digital Techniques in Supply Chain Resilience: Exploration in the Logistics Sector. *J. Bus. Res*, 134, 103–115.
- [8] Ivanov, D., Dolgui, A., Das, A., & Sokolov, B. (2019). Digital supply chain twins: Managing the ripple effect, resilience, and disruption risks by data-driven optimization, simulation, and visibility. In *Handbook of ripple effects in the supply chain* (pp. 309–332). Cham: Springer International Publishing.
- [9] Khattab, S. A., Al Shaar, I. M., Alatyat, Z. A., & Abu Zaid, M. K. (2025). Big data analytics capability and green supply chain: Does supply chain visibility and agility matter? *Journal of Information Systems Engineering and Management*, 10(36s), e24684376.
- [10] Li, P., Chen, Y., & Guo, X. (2025). Digital transformation and supply chain resilience. *International Review of Economics & Finance*, 99, 104033. <https://doi.org/10.1016/j.iref.2025.104033>
- [11] Lu, J., Chuah, S. C., Xia, D. M., & Gary, J. (2025). The development of the modern logistics industry and its role in promoting regional economic growth in China's underdeveloped northwest, driven by the digital economy. *Economies*, 13(9), 261. <https://doi.org/10.3390/economies13090261>
- [12] Mageto, J. (2021). Big data analytics in sustainable supply chain management: A focus on manufacturing supply chains. *Sustainability*, 13(13), 7101. <https://doi.org/10.3390/su13137101>
- [13] Masłowski, D., Deptuła, A., Ulbrich, W., Kocur, Ł., & Łapka, M. (2025). Identification and minimization of risks in the logistics processes of a window blinds manufacturing company using PHA and TPM.

- [14] Mohsen, B. M. (2023). Impact of artificial intelligence on supply chain management performance. *Journal of Service Science and Management*, 16(1), 44–58. <https://doi.org/10.4236/jssm.2023.161004>
- [15] Nesarnobari, S., Shahzad, W. M., Babaeian Jelodar, M., & Sutrisna, M. (2025). Offsite construction supply chain management: a scientometric analysis and systematic literature review. *Architectural Engineering and Design Management*, 21(3), 467–490. <https://doi.org/10.1080/17452007.2024.2381497>
- [16] Polusmiak, Yu., Pavliuk, T. & Kosach, I. (2024). Project management in the construction industry: identification of logistical problems and ways to optimise them. *Management and Entrepreneurship: Trends of Development*, 4(30), 69–78. <https://doi.org/10.26661/2522-1566/2024-4/30-06>
- [17] Rad, F. F., Oghazi, P., Palmié, M., Chirumalla, K., Pashkevich, N., Patel, P. C., & Sattari, S. (2022). Industry 4.0 and supply chain performance: A systematic literature review of the benefits, challenges, and critical success factors of 11 core technologies. *Industrial Marketing Management*, 105, 268–293. <https://doi.org/10.1016/j.indmarman.2022.06.009>
- [18] Rahman, M. A., Saha, P., Belal, H. M., Ratul, S. H., & Graham, G. (2024). Big data analytics capability and supply chain sustainability: Analyzing the moderating role of green supply chain management practices. *Benchmarking: An International Journal*. Advance online publication. <https://doi.org/10.1108/BIJ-10-2024-0852>
- [19] Spieske, A., & Birkel, H. (2021). Improving supply chain resilience through industry 4.0: A systematic literature review under the impressions of the COVID-19 pandemic. *Computers & industrial engineering*, 158, 107452. <https://doi.org/10.1016/j.cie.2021.107452>
- [20] Tortorella, G. L., Giglio, R., & van Dun, D. H. (2019). Industry 4.0 adoption as a moderator of the impact of lean production practices on operational performance improvement. *International Journal of Operations & Production Management*, 39(6/7/8), 860–886. <https://doi.org/10.1108/IJOPM-01-2019-0005>
- [21] Zhang, C., Jiang, J., Xia, C., Fu, Y., Liu, J., & Duan, P. (2024). Dual-objective optimization of prefabricated component logistics based on JIT strategy. *Scientific Reports*, 14(1), 31267. <https://doi.org/10.1038/s41598-024-82689-w>

Received on: 29th of April, 2026

Accepted on: 11th of June, 2026

Published on: 30th of June, 2026