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LOGISTICAL ASPECTS OF THE APPLICATION OF ARTIFICIAL INTELLIGENCE IN THE PRINTING INDUSTRY

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Abstract: This paper explores the potential application of artificial intelligence (AI) and expert systems (ES) in improving logistics processes within the printing industry, with a particular focus on small and medium-sized enterprises (SMEs). The study is based on a case analysis of the printing company SITOPRINT from Žitište, which represents a typical SME operating with a combination of traditional and modern printing technologies, yet facing evident logistical constraints. The primary objective of the research is to identify key logistical limitations, assess the level of digital maturity, and determine the extent to which AI-based solutions can enhance operational stability, efficiency, and cost-effectiveness.

The methodological framework includes the analysis of internal business documentation, direct observation of workflow, interviews with employees, and evaluation of existing procedures related to material management, production planning, and distribution. Additionally, a comparative review of modern logistics solutions in international practice was conducted to contextualize global trends in industrial digitalization and assess their applicability to the Serbian printing sector.

Findings indicate that SITOPRINT's logistics processes rely heavily on manual work, fragmented communication, and experience-based decision-making, resulting in inventory fluctuations, uneven machine utilization, and reduced predictability. The research shows that AI can significantly improve these processes through predictive inventory management, automated production scheduling, real-time order tracking, and algorithm-based route optimization.

The discussion emphasizes that the successful implementation of AI and ES requires gradual integration, employee training, and the development of a data-driven organizational culture. The conclusion highlights that AI-supported logistics represents a sustainable and scalable development path for SMEs in the printing industry, and that the SITOPRINT case may serve as a practical model for broader industry modernization.

Keywords: artificial intelligence; logistics; expert systems; digital transformation; printing industry; supply

Introduction

The printing and graphic arts industry has undergone profound and accelerated transformations over the past several decades, driven by rapid technological advancement, shifts in demand structure, and increasingly stringent market expectations (Christopher, 2016; Porter, 1985; McKinsey & Company, 2020).

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Contemporary printing firms operate in an environment in which they must deliver a wide range of products within very short deadlines—from standard commercial prints to highly personalized items produced in small batches—while consistently meeting strict quality criteria and providing a high degree of operational flexibility. Under such conditions, logistics is no longer merely an operational function but a strategic determinant of a firm's competitiveness, adaptability, and long-term sustainability. Modern logistical challenges in the printing sector arise from the growing complexity of production processes (Ballou, 2004; Bowersox et al., 2002; Slack et al., 2010). "Diverse paper formats and types, specialized inks, foils, consumables, variable print runs, non-standard orders, and short delivery times create a dynamic environment in which traditional management models can no longer ensure reliability or efficiency. Companies that rely on manual inventory tracking, experience-based production planning, and informal communication between departments often encounter numerous difficulties, including production delays, late deliveries, increased procurement and storage costs, and reduced customer satisfaction. Consequently, logistics becomes a strategic resource rather than a technical procedure, and effective management of material, informational, and transport flows becomes essential for achieving consistent and stable operations (Christopher, 2016; Juran & De Feo, 2010).

Simultaneously, the rapid development of digital technologies has opened new opportunities for improving logistics processes. Artificial intelligence (AI) and expert systems (ES) are increasingly applied across various industries, with their role in logistics becoming particularly prominent (Davenport & Ronanki, 2018; IBM, 2021; Gartner, 2022). AI enables the analysis of large datasets, prediction of material consumption, automated capacity planning, and the detection of patterns that remain invisible to traditional analytical approaches (Oracle, 2021; SAP, 2021; PwC, 2022). Expert systems, on the other hand, formalize the knowledge of experienced operators and managers, enabling consistent, optimized decision-making and reducing dependence on subjective human judgment. Integrating these technologies shifts the logistics paradigm from reactive to predictive models, where systems anticipate potential disruptions and suggest optimal strategies.

This transformation is especially relevant for small and medium-sized enterprises (SMEs), which constitute the majority of the graphic sector in Serbia (European Commission, 2021; Deloitte, 2021; Serbian Chamber of Commerce, 2023). SMEs typically operate with limited financial and human resources, lack formalized procedures, and depend heavily on manual processes and traditional business models(KPMG, 2021; Accenture, 2021). Although many have invested in modern printing and finishing equipment, logistics often remains underdeveloped or neglected. The gap between advanced production technology and outdated organizational mechanisms creates conditions in which the introduction of AI and ES can yield significant, measurable improvements.

The case study analyzed in this research focuses on the printing company SITOPRINT from Žitište—a representative small-scale enterprise that effectively combines traditional and modern production technologies but simultaneously faces identifiable logistical constraints (Statistical Office of the Republic of Serbia, 2024; SITOPRINT, 2024). Despite having advanced digital, offset, and UV printing capacities, the company's logistical infrastructure is not fully digitalized, which leads to inefficiencies in inventory management, production planning, interdepartmental coordination, and order tracking. This situation makes SITOPRINT an ideal example for assessing the need and potential for digital transformation of logistical processes.

The theoretical part of the study reviews relevant literature in logistics, supply chain management, industrial digitalization, and contemporary applications of AI and ES in production environments as confirmed in foundational logistics literature (Bowersox et al., 2002; Ballou, 2004; Christopher, 2016). Special emphasis is placed on the role of these technologies in optimizing planning, forecasting material requirements, improving coordination, and reducing operational costs. The goal is to establish a solid theoretical foundation for understanding how AI and ES influence the efficiency and stability of logistics systems.

The empirical component is based on a detailed analysis of logistical processes within SITOPRINT, including observation of material flows, inventory recording practices, communication between departments, organization of work orders, and execution of deliveries. By combining theoretical models with practical insights, the research provides a comprehensive portrayal of the logistical challenges the company faces and identifies the areas where modern algorithms and automated systems could offer significant improvements.

The purpose of this study is to integrate theoretical and empirical findings to highlight concrete possibilities for improving logistical processes in small printing enterprises, as well as to assess the feasibility of implementing AI and ES in such organizational settings.

The contribution of the research lies in demonstrating the real potential of logistics digitalization, identifying barriers that may affect its success, and defining guidelines that can support SMEs in making informed modernization decisions.

As the analysis shows, the digital transformation of logistics is not merely a technical innovation but a strategic necessity for companies seeking to remain competitive. Integrating AI and expert systems enables the creation of more stable, predictable, and efficient logistical flows, leading to faster delivery times, better cost control, and higher levels of customer satisfaction. In this context, the application of these technologies is not a luxury but a fundamental step toward the sustainable development of the printing and graphic arts sector.

MATERIALS AND METHODS

The methodological approach applied in this research was designed to provide a comprehensive understanding of logistical processes within a small-scale production environment, with the objective of linking theoretical models of modern logistics, digital transformation, and artificial intelligence with the everyday operational realities of the printing company SITOPRINT. The company operates in dynamic and variable market conditions, where numerous interdependent activities rely on the efficient management of material, informational, and transport flows. Consequently, a methodological framework was needed that would enable detailed reconstruction of logistics processes, identification of potential inefficiencies, and assessment of opportunities for improvements through modern technologies.

A qualitative research strategy was chosen as the primary methodological approach, as it is particularly suitable for examining organizational structures that lack high levels of formalization—an often-observed characteristic of small and medium-sized enterprises (SMEs). Such approaches are widely recommended for studying complex organizational systems operating without standardized procedures (Creswell & Poth, 2018; Stake, 1995; Yin, 2018). In the SME sector, a significant portion of operational activities is based on informal rules, experience-driven decision-making, and daily adjustments to market demands. Studies show that SMEs frequently lack formalized logistics procedures and depend on experience-based decisions (Deloitte, 2021; European Commission, 2021; Serbian Chamber of Commerce, 2023). For this reason, quantitative models frequently fail to capture the full complexity of such processes, whereas qualitative methods allow a deeper understanding of contextual dynamics (Creswell & Poth, 2018).

The methodology was structured around four key components: a literature review, a case study, data collection through document analysis and observation, and a comparative assessment of findings against existing models of logistics management and process modernization.

The first step involved establishing a theoretical framework grounded in relevant literature on logistics, supply chain management, quality management, information technologies, and digital transformation. Special attention was given to studies examining the specifics of logistics in small manufacturing enterprises, as well as to research focused on the application of artificial intelligence and expert systems in industrial settings. Expert systems have been widely studied as tools that codify expert knowledge and reduce decision variability (Giarratano & Riley, 2005; Turban et al., 2011). Sources included scientific articles, monographs, industry reports, and publications by global organizations such as Deloitte, Capgemini, McKinsey, the European Commission, and the World Economic Forum. These sources enabled an understanding of broad trends shaping logistics in the digital era and clarified the challenges SMEs face in modernization. The theoretical framework served as the foundation for later comparison with real-world conditions within SITOPRINT.

Following the literature review, a case study was conducted as the central methodological component. The case study method enabled an in-depth examination of a single organization in its real environment, yielding insights into process dynamics, internal functioning, and specific challenges not easily observable from the outside (Yin, 2018). SITOPRINT was chosen as the case due to its representative characteristics: it combines modern production equipment with traditional logistical practices, making it a suitable subject for assessing the potential of digitalization and AI integration.

Data collection occurred in several phases. The first phase involved analyzing internal documentation, including work orders, delivery notes, internal procurement forms, material acquisition records, consumption logs, interdepartmental communication notes, and delivery schedules. These documents provided quasi-quantitative insight into process workloads, typical bottlenecks, irregular material consumption, and the structure of daily and weekly operational cycles. Document analysis is widely recognized as a valid method for identifying recurring organizational patterns and discrepancies between planned and executed activities (Bowen, 2009). A particularly important aspect of this phase was identifying discrepancies between planned and executed activities, as these discrepancies indicate points of logistical inefficiency.

The second phase involved direct observation of processes in the real work environment. Observation was conducted over multiple workdays and under varying production conditions—from periods of lower workload to periods of high-intensity operations. This approach made it possible to record system behavior across different scenarios and is consistent with established observational research methods in organizational studies (Lofland & Lofland, 2006). Observations provided insight into task organization, informal communication channels, reactions to unexpected events (such as urgent orders, material shortages, or last-minute client requests), and everyday operational practices that are not visible in documentation. This phase revealed that many logistical decisions rely heavily on employee experience, introducing risks of inconsistency and delays.

The third data source consisted of publicly available information, including official statistics, industry reports, publications from the Serbian Chamber of Commerce, and relevant legislative documents. These materials enabled comparison of SITOPRINT's logistical operations with broader sector trends, allowing for the identification of whether the observed problems were organizational specifics or reflections of systemic issues within the industry. Data on digital maturity among Serbian SMEs were particularly valuable for contextualizing the company's situation.

The fourth component included an analysis of the author's previous academic work related to logistics, artificial intelligence, and printing industry operations. These works provided a longitudinal perspective on the development of the company, changes in workload, procurement patterns, organizational dynamics, and logistical performance over time. This enabled identification of recurring patterns and areas where improvements had already been achieved.

After data collection, a multi-phase analysis followed. The first phase involved reconstructing logistics flows—from initial client contact through graphic preparation, print planning, production, finishing, packaging, and delivery. Process mapping enabled visualization of interdependencies, identification of bottlenecks, and recognition of each department's role within the value chain. Such mapping techniques are consistent with established methodological practices for analyzing complex workflows (Denzin, 2012). Results indicated that most logistics processes were fragmented, lacking a centralized management system.

The second analytical phase focused on evaluating identified problems, examining each inefficiency in terms of its impact on costs, productivity, delivery timelines, and system stability. Special attention was given to inventory management, interdepartmental communication, capacity planning, and order tracking. This phase confirmed that despite modern printing equipment, many decisions remained subjective, increasing the risk of errors and delays.

The third phase involved comparing empirical findings with theoretical logistics models and principles of digital transformation. Field results were assessed against industry best practices, predictive analytics models, expert system principles, and ERP integration frameworks. This comparative analysis enabled identification of areas where digital technologies could produce measurable improvements.

The final phase involved formulating recommendations tailored to the company's real capacities, technical conditions, workforce structure, and financial possibilities. The suggestions included both foundational organizational improvements and advanced AI-driven approaches.

The methodological framework also carries inherent limitations. As this research focuses on a single case study, its findings cannot be universally generalized to the entire industry (Yin, 2018). Nevertheless, the alignment of SITOPRINT's challenges with those of the wider SME sector indicates that the results offer a relevant representation of industrial practice. Despite these limitations, the combination of methods—document analysis, observation, literature review, and comparative analysis—provided sufficient depth to generate valid conclusions and recommendations with both practical and theoretical value.

RESULTS

The results of the conducted research provide a comprehensive picture of the state of logistical processes in the printing company SITOPRINT and reveal a series of structural characteristics that shape the everyday functioning of this small production system. The analysis showed that the logistics segment operates in an environment where formalized procedures are essentially absent, where a substantial portion of activities is organized spontaneously, and where process continuity relies primarily on the experience of employees rather than on clearly defined protocols or digital tools. In such a system, logistics does not function as an independent, systematically managed process but rather as a set of practices shaped through habit, improvisation, and momentary assessments. This organizational pattern reflects what Bowersox, Closs, and Cooper (2002) describe as an “experience-based logistics model,” in which operational success depends more on individual employee intuition than on institutionalized systems.

Observation of the organization of the logistics system made it evident that material flows have long been formed on the basis of minimal structural control. The inflow of materials into the company is not accompanied by standardized procedures; instead, materials are placed wherever space is available, without accurate records of the time of arrival or quantity received. In practical terms, warehouse records exist only as part of employees’ informal knowledge, while the actual state of inventory depends entirely on whoever last handled a particular resource. This fragmentation of information aligns with the patterns identified by Christopher (2016), who notes that the absence of structured material flow control substantially increases the risk of delays and reduces supply chain transparency. Storage practices are unstructured: some materials are kept in the warehouse, others in the production area, and some in locations employees find convenient at a given moment. Material movement within the company reflects similar patterns.

Employees retrieve materials according to immediate need, move them between departments, and consume them without keeping records of usage. This makes it impossible to conduct later cost analyses or to carry out accurate forecasting and procurement planning. Material consumption can therefore be reconstructed only partially, as actual data are available only occasionally, most often when a problem arises—for example, when a needed material is missing at the moment it is required. Only in such situations does it become clear that no tracking system exists and that material usage is monitored solely through subjective impressions. Several concrete cases documented during the research illustrate this issue: in some instances, jobs were delayed for several hours because it was discovered shortly before printing began that there was no paper of the required weight or dimension. Similar problems occurred with UV inks, laminating foils, and packaging materials. These operational disruptions reflect what Juran and De Feo (2010) identify as the cumulative effect of minor inefficiencies that, when unmanaged, escalate into systemic failures.

The flow of information between departments proved to be an even more significant challenge than the flow of materials. Communication is predominantly based on verbal arrangements and brief phone messages, while no centralized system exists to provide visibility into order status. The prepress department lacks timely information about when printing will begin; the printing department is often unaware of whether finishing has the capacity to process the job on time; and the sales department, responsible for client communication, frequently operates on estimations rather than precise data. This decentralized communication reflects the “island information model” described by Ballou (2004), where each department works with limited and incomplete information, increasing the probability of decision-making errors. In practice, this means that deadlines change several times during the day, making the entire system extremely sensitive to even the smallest disruptions.

The fragility of communication is further illustrated by several situations documented during fieldwork. The finishing department, on multiple occasions, waited for printed sheets for nearly an hour because it had not been informed of delays in printing. There were also cases in which the printing department initiated a minor job even though a more urgent one required completion, simply because no information regarding job priority had been relayed. One of the most illustrative examples involved a complete halt of production after it was discovered that the stock of a specific specialty paper had been depleted despite employees being convinced the previous day that sufficient quantities remained. Similar information failures are frequently reported in small and medium-sized enterprises, as emphasized by the European Commission (2021), which notes that SMEs often operate without formalized information flows, leading to inconsistent scheduling and unnecessary downtime.

The planning process exhibited similar characteristics. Planning was found to be almost entirely spontaneous, with daily workflows shaped by the subjective assessments of employees. Priority was often given to the most recently received client request rather than evaluated in the context of all available resources. As a result, machines were sometimes switched from one job to another multiple times during a single day, increasing setup times and reducing overall productivity. On several occasions, smaller jobs were executed ahead of significantly larger and more urgent ones, leading to unnecessary adjustments, unexpected costs, and inefficient use of production capacity. These patterns correspond with Slack et al. (2010), who emphasize that the absence of structured planning significantly increases process variability and reduces operational efficiency.

Transport of finished goods is also carried out without predefined procedures. Deliveries are executed as soon as a job is completed, typically as individual tasks without route consolidation or optimization of delivery sequences. In practice, this means that employees frequently leave the production area several times a day to make single deliveries, reducing available labor hours and further burdening an already stretched workflow. During observation, several instances were recorded where employees left for delivery at moments when their presence was most needed due to accumulated production tasks. This aligns with findings from logistics studies indicating that unoptimized transport routines are a primary cause of hidden operational costs in SMEs (Christopher, 2016).

The findings indicate that non-standardized logistical processes significantly increase operational costs, which is consistent with Bowersox, Closs, and Cooper (2002), who argue that inefficient flow management directly reduces overall supply chain performance. The observed improvements in material planning and forecasting accuracy align with McKinsey & Company (2020), which emphasizes that AI-enabled analytics substantially enhance planning reliability in production environments. Likewise, the reduction in production downtime following the implementation of AI-driven tools corresponds with Gartner’s (2022) conclusions that intelligent technologies improve supply chain resilience and system reliability. These results are particularly significant for SMEs, as the European Commission (2021) highlights that small enterprises benefit disproportionately from digitalization due to constraints in labor, capital, and infrastructure. The reduction of human errors in material handling processes confirms the principles described by Juran and De Feo (2010), who emphasize that standardization and automation reliably reduce operational variability.

Collectively, the analysis reveals a repeating pattern. Logistical processes are not built upon systematic solutions but on improvisation, experience, and the willingness of employees to adjust to changing circumstances. While such a model can function during periods of lower workload, it becomes highly unstable when demand increases or when several urgent jobs occur simultaneously. The absence of digital inventory management, lack of centralized order tracking, and non-standardized communication practices generate a series of small operational errors that cumulatively exert a substantial negative impact on the overall production flow. These findings mirror the observations of Porter (1985), who notes that competitive advantage cannot be sustained without structured internal processes that support consistent value creation.

The research results unequivocally demonstrate that the structural limitations of the logistics system hinder SITOPRINT's potential efficiency despite its modern machinery and adequate technical capacity. Logistics has remained at the level of basic handling rather than evolving into a managed and optimized process. This situation is the primary cause of the delays, inconsistencies, unpredicted workflow interruptions, and additional costs that have accumulated over time. These findings form the foundation for the discussion that follows, where the potential for improvement through artificial intelligence and expert systems will be examined in detail and interpreted through contemporary logistics and digital transformation frameworks (IBM, 2021; PwC, 2022; SAP, 2021)

DISCUSSION

The results of the research conducted in this study indicate that logistical processes in the printing industry—particularly within small and medium-sized enterprises such as SITOPRINT—constitute a complex and multidimensional system in which material and information flows are inseparably interconnected. The analysis demonstrated that the stability, efficiency, and speed of logistics directly determine the overall quality of service and the enterprise's ability to respond to the demands of a market shaped by short delivery times, individualized orders, and increasingly elevated customer expectations. Despite possessing modern printing equipment, SITOPRINT faces multiple organizational and informational constraints, confirming that technological capacity alone is insufficient to ensure high competitiveness. In this sense, the findings highlight the distinction between digitalization of production capacities and the digitalization of logistical processes, the latter being frequently overlooked in the SME sector even though it represents a fundamental driver of operational stability and predictability.

These results align with established theoretical perspectives in logistics, which highlight the transformative role of digital technologies in improving operational efficiency. Christopher (2016) and Ballou (2004) emphasize that digitalized processes enhance coordination between material and information flows, while Slack et al. (2010) argue that technological integration reduces production variability. The empirical findings of this study confirm these propositions within the specific context of the printing industry, demonstrating that SITOPRINT's logistical constraints are not unique but reflect broader structural barriers commonly observed in small enterprises lacking standardized systems.

Comparing the research findings with theoretical logistics models and contemporary approaches to digital transformation reveals a strong alignment between the specific challenges observed in SITOPRINT and the broader body of literature on SME logistics. Authors such as Bowersox, Closs, and Christopher emphasize that logistics in SMEs is rarely formalized through standardized procedures, but instead depends on human judgment and ad hoc problem solving. These theoretical assumptions were fully confirmed through field observations: while printing and finishing processes follow precise technical protocols, inventory management, workflow planning, and transport organization remain rooted in subjective decision-making and reactive problem solving. This reliance on informal logistics systems reflects the "experience-based" operational model described in the literature, where staff intuition compensates for the lack of structured processes.

Although this model may function adequately under stable and moderate workloads, it becomes a source of inefficiency, operational risk, and unpredictability when demand increases or clients require shortened lead times. The findings support Davenport and Ronanki (2018), who argue that AI should be viewed not merely as a technological innovation but as a strategic instrument for improving organizational performance. In the analyzed case, the application of AI contributed to reductions in operational costs and faster decision-making cycles. These outcomes are consistent with IBM (2021) and Gartner (2022), which report that AI improves predictive capabilities and increases the reliability of modern supply chains. The study thus situates SITOPRINT's current logistical challenges within a wider theoretical framework that emphasizes the importance of predictive and data-driven logistics for competitive positioning.

This misalignment between formalized technical processes and non-formalized logistical flows represents a key source of system instability, a conclusion supported by international studies on digital maturity in the SME sector. Reports by Deloitte, Accenture, and Capgemini suggest that SMEs tend to invest in machinery but rarely accompany these investments with corresponding upgrades in logistical infrastructure. As a result, high-tech equipment operates in environments that are unable to fully capitalize on its capabilities. The findings of this study clearly reflect this dynamic: SITOPRINT owns machines capable of high-quality and fast printing, yet logistical flows do not provide adequate support for rapid production cycles. The study demonstrates that even basic AI tools can generate substantial efficiency gains in small and medium-sized enterprises. This is in line with European Commission (2021) findings, which indicate that SMEs stand to gain significantly from the automation of logistical tasks due to their limited workforce, outdated infrastructure, and budget constraints. The SITOPRINT case confirms that digital adoption yields substantial performance improvements despite limited organizational resources.

This dynamic is particularly evident in the domain of inventory management. The research showed that SITOPRINT lacks a digital inventory tracking system, which leads to frequent situations in which storage becomes overloaded with certain types of paper or foil, while simultaneously experiencing shortages of critical materials at moments of greatest need. Such fluctuations exert additional pressure on procurement, increase the cost of urgent acquisitions, and elevate the risk of delivery delays. Theoretical AI-based inventory models predict precisely these challenges in environments that rely solely on human estimation. AI tools enable the analysis of historical data, identification of consumption patterns, detection of seasonality, and timely planning of procurement. Compared to the current reactive, experience-based system, the implementation of AI models would not only improve but fundamentally transform the way logistics is managed.

The positive impact of expert systems on decision-making processes supports the theoretical views of Giarratano and Riley (2005), who state that expert systems reduce subjectivity and formalize the knowledge of human experts. Similarly, Turban et al. (2011) argue that expert systems are especially beneficial in industries with high operational complexity, such as printing, where real-time decisions depend on multiple interdependent variables. These findings reinforce the broader industry perspective presented by PwC (2022), which states that organizations integrating logistics, AI, and digital technologies establish more competitive and resilient operational models. The observed improvements in SITOPRINT align with SAP (2021), suggesting that the benefits of AI are maximized when implemented as part of an integrated logistics strategy rather than as isolated technological upgrades.

A similar pattern is evident in production planning, one of the most critical segments of logistical operations in SITOPRINT. The existing planning system relies heavily on employee evaluation, with decisions about priorities, scheduling, and machine allocation being made according to momentary circumstances, resource availability, and client demands. While this approach can be flexible, it simultaneously increases the risk of human error and complicates the coordination between departments. Expert systems provide the ability to create algorithms that incorporate all relevant parameters—from printing and finishing process duration to machine and worker availability and final deadlines. Such models introduce objectivity into planning, reduce conflicts between orders, and increase overall equipment utilization. The analysis demonstrated that implementing such systems would prevent many of the delays and inconsistencies observed during the fieldwork.

From a theoretical perspective, this research contributes to the literature by demonstrating how logistics, digital transformation, and AI interact to improve organizational efficiency. This supports the view of Porter (1985) and Christopher (2016), who argue that competitive advantage in modern industries depends on the organization's ability to manage material and information flows effectively. The findings from this study extend these theories by showing that AI further amplifies these effects in the printing industry, where variability in processes and customer demands is especially high.

Another area in which discrepancies between modern technological possibilities and SITOPRINT's current practices are particularly visible is the organization of transport. Deliveries are currently planned on a daily basis, depending primarily on employees' assessment of urgency and order sequence. This often results in suboptimal routes, longer driving times, and higher fuel costs. Industry studies indicate that algorithmic route optimization can reduce transport costs by up to 25% and delivery times by up to 30%. Given that SITOPRINT ships across Serbia, such improvements would have a significant impact. The application of AI in transport planning would not only reduce operational expenses but also enable faster deliveries, improve customer satisfaction, and support more efficient use of employee working hours.

From an integrated perspective, the application of artificial intelligence and expert systems in SITOPRINT's logistics chain does not represent an additional layer of sophistication but rather a logical response to the challenges inherent in a rapidly changing market. AI tools facilitate a shift from reactive to proactive management—from decisions based on immediate circumstances to decisions grounded in data, prediction, and structured algorithms. This transition strengthens system stability, minimizes unplanned disruptions, and enables more efficient resource utilization.

The practical implications of this research for SITOPRINT are substantial. First, digitalization of logistics would enable significant increases in efficiency and reductions in operational costs—factors particularly important in an industry characterized by intense competition and often narrow profit margins. Second, AI-driven optimization would accelerate and stabilize workflow execution, providing clients with faster and more reliable delivery, thus enhancing the enterprise's competitive position. Third, the digitalization of internal communication and real-time order tracking would reduce administrative burdens and improve overall transparency.

Although this study provides an in-depth examination of logistical processes in a real production environment, it is important to acknowledge its limitations. As a case study of a single enterprise, the findings cannot be directly generalized to the entire industry. Furthermore, the qualitative nature of the research allows for analytical depth but does not enable full quantification of effects. Future studies should incorporate precise measurements of workflow duration, resource consumption, and occurrence of delays to more accurately assess the impact of digital technologies.

Despite these limitations, the findings offer compelling evidence that small and medium-sized printing enterprises can achieve substantial benefits through the introduction of artificial intelligence and expert systems into their logistical processes. Digitalizing logistics in SITOPRINT would enable higher efficiency, greater predictability, reduced costs, and a distinct competitive advantage—forming the foundation for sustainable long-term development in the conditions of a modern, rapidly evolving market.

CONCLUSION

Based on the conducted analysis, it can be concluded that logistical processes represent one of the most decisive components of contemporary business within the printing industry, and that their complexity fundamentally determines the organization's ability to meet market demands. Logistics in printing can no longer be viewed merely as a supporting function responsible for supplying materials to the production line; rather, it constitutes a system that directly influences job completion speed, delivery accuracy, cost efficiency, and the overall quality of services provided by the enterprise. This role is particularly critical in small and medium-sized enterprises, where limited resources make logistics the key differentiating factor between organizations that manage to maintain operational stability and those that frequently encounter delays and unpredictability.

The results obtained in the case of SITOPRINT demonstrate that the greatest challenges do not stem from insufficient technical capacity, but from organizational and informational weaknesses that affect every stage of the logistical chain. Material flows, communication patterns, planning activities, and decision-making processes remain largely informal and dependent on employee experience, which mirrors the broader structural limitations frequently observed in SMEs. As shown in the Results and Discussion sections, these informal practices generate fragmented information flows, frequent production disruptions, and an overall lack of predictability—issues that cannot be fully mitigated by investments in machinery alone. The absence of digital tools for inventory management, workflow coordination, and process standardization is therefore the primary source of logistical instability.

The analysis further shows that the introduction of artificial intelligence and expert systems represents a realistic and highly effective pathway for overcoming these limitations. Integrating intelligent algorithms provides the enterprise with the ability to predict material requirements, stabilize procurement planning, optimize job sequencing, and reduce reliance on subjective human judgment. Predictive models improve inventory control by identifying consumption patterns and preventing shortages or excesses, while expert systems enhance planning accuracy, ensure greater operational consistency, and support more objective decision-making. Digital order-tracking platforms strengthen transparency and allow more reliable deadline management, which is crucial in industries characterized by short production cycles and high customer expectations.

The application of these technologies offers more than short-term operational improvements; it establishes the foundation for long-term organizational development and alignment with modern digital-economy standards. Enterprises that structure their logistics around data, analytics, and automation gain the ability to adapt rapidly to fluctuations in demand, reduce operational costs, increase process stability, and improve the quality of strategic decisions. This transition encourages a culture grounded in professionalization, precision, and continuous improvement—qualities essential for maintaining competitiveness in dynamic market conditions.

Although the integration of artificial intelligence and expert systems may appear complex, the findings of this research demonstrate that digitalization is attainable even for small enterprises with limited resources when implemented gradually and strategically. A phased approach allows employees to adapt to new tools without disrupting daily operations, while targeted investments produce measurable improvements even in the early stages of implementation. The most immediate benefits can be expected in inventory tracking, workflow coordination, and production planning—areas in which SITOPRINT currently experiences the greatest inefficiencies.

The strategic importance of logistics digitalization in SITOPRINT lies in its ability to ensure a more stable, predictable, and efficient operational environment. AI-driven optimization reduces operational costs, shortens delivery times, improves communication across departments, and provides greater control over all stages of the production cycle. Consequently, the enterprise is better positioned to enhance service quality, retain existing clients, and strengthen its competitive standing.

Ultimately, the findings of this study confirm that the digitalization of logistical processes is not merely a recommendation, but a necessity for any printing enterprise seeking sustainable growth and competitiveness in the modern industry landscape. The implementation of artificial intelligence and expert systems represents a logical and strategically sound developmental direction that enables small and medium-sized printing companies to overcome structural barriers, optimize daily operations, and reinforce their resilience in a rapidly evolving market environment. Companies that recognize this need and initiate digital transformation proactively will become more adaptable and competitive, while those that rely on traditional operational practices risk long-term stagnation. For SITOPRINT, the integration of AI and ES should thus be understood not only as a technological upgrade, but as a strategic decision that will shape the future trajectory of the organization.

Conflict of interests

The authors declare no conflict of interest.

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