Smart supply chains and digital security: Integrating AI into hospital construction in Morocco in the era of smart cities

Adnan EL BOUAZZAOUY,
LIFGOD, ENCGC, Casablanca, Morocco
Adnan.elbouazzaouy@outlook.com

Nissrine KHOUNA,
LIFGOD, ENCGC, Casablanca, Morocco
Khouna.nissirne@gmail.com

Mostapha AMRI,
LIFGOD, ENCGC, Casablanca, Morocco
Amrimostapha@yahoo.fr

Abstract
In the era of smart cities, Morocco is undergoing a profound transformation of its hospital infrastructures, marked by the gradual integration of intelligent technologies into construction and logistics management processes. This study explores the contribution of artificial intelligence (AI), Building Information Modeling (BIM) and the Internet of Things (IoT) to optimizing hospital construction supply chains, while analyzing the critical cybersecurity issues associated with these changes. Using a mixed methodology, articulating systematic literature review, qualitative interviews and quantitative survey, the article proposes an analytical framework integrating logistics performance, digital governance and data security. The results show that AI can significantly improve planning, multi-actor coordination and flow traceability, provided that structured digital governance and strengthened cybersecurity policies are in place. Drawing on empirical data collected from construction and healthcare players in Morocco, this research proposes an integrated model of an intelligent and secure hospital supply chain, adapted to the specificities of the Moroccan context. It thus aims to inform public policy on the digitization of healthcare infrastructures, while contributing to the literature on smart supply chains in developing countries.

Keywords: artificial intelligence, hospital construction, intelligent supply chains, Morocco, smart cities.

1. Introduction
In this era of global digital transition, smart cities are redefining the paradigms of urban governance, sustainability, and quality of public services. Morocco, as an emerging country committed to modernizing its infrastructure, places public health at the heart of its urban development strategy. Structural projects such as the "Hospital of Tomorrow" plan aim to improve the accessibility, efficiency, and safety of hospital infrastructure, while integrating information technology into the life cycles of construction projects [1].

However, hospital projects in the construction sector continue to face two challenges: on the one hand, historically fragmented logistics that are poorly digitized and vulnerable to delays in execution; on the other hand, information systems that are insufficiently secure in the face of growing cyber threats. In this context, artificial intelligence (AI), combined with Building Information Modeling (BIM), the Internet of Things (IoT), and advanced analytics, opens up new possibilities in terms of logistics coordination, risk prediction, and cybersecurity [2] [3].

Nevertheless, the integration of these technologies raises major challenges in terms of digital governance, technological maturity, and suitability for the specificities of the Moroccan context. Hospital infrastructures, as critical systems, require seamless interoperability, rigorous management of sensitive data, and complete traceability of logistical and digital flows. However, the literature reveals a weak link between smart logistics and cybersecurity in Southern countries, and in particular in the African hospital sector [4]. As emphasized by Khouna et al., the integration of ICT in Moroccan smart cities significantly enhances hospital logistics through improved traceability and real-time coordination [5].

The question this research seeks to answer is therefore: how can artificial intelligence and digital technologies be effectively integrated into hospital supply chains in Morocco, while ensuring data security and system resilience within a smart city framework?

Recent studies confirm the relevance of this question. On the one hand, El Bouazzaouy and Amri [6] highlights the close links between regional imbalances, logistics planning, and equitable access to hospital services, emphasizing the structuring role of transport systems in logistics efficiency. On the other hand, Khouna, Hablatou, and Amri [7] propose an innovative approach to integrated hospital logistics in Moroccan smart cities, highlighting the added value of digital tools (IoT sensors, smart platforms, secure cloud) in optimizing hospital flows and urban health governance.

This study adopts a constructivist approach and takes an interdisciplinary perspective, combining insights from supply chain management, project management, cybersecurity, and data science. It is based on a mixed methodology, combining a systematic review of the literature, qualitative interviews with stakeholders in the field, and a quantitative survey of professionals in the construction and healthcare sectors.

The main objective is to propose an integrated model for a smart and secure supply chain that is adapted to the constraints of the Moroccan hospital sector and can inform public decision-makers in the implementation of a national logistics digitization strategy.

To achieve this objective, the article is structured as follows: the first section presents the theoretical foundations of smart logistics and cybersecurity issues in hospital construction. The second section details the research methodology adopted. The third section presents and discusses the empirical results. Finally, a conclusion summarizes the study's findings and offers strategic and operational recommendations.

2. Theoretical and conceptual framework

2.1. Fundamentals of the smart supply chain

The smart supply chain is an evolution of traditional supply chains, incorporating advanced technologies such as artificial intelligence (AI), the Internet of Things (IoT), big data, and cyber-physical systems. These technologies enable proactive, predictive, and adaptive management of material, information, and financial flows. Ivanov [3] emphasizes that logistics intelligence enables greater resilience, agility, and sustainability, particularly in complex environments such as public hospital construction sites.

In the construction industry, historically characterized by low digital maturity, smart logistics is becoming a lever for real-time coordination between stakeholders: project owners, design offices, subcontractors, suppliers, and hospital management. It facilitates the synchronization of deliveries, reduces supply disruptions, and provides dynamic visualization of work progress via integrated platforms (ERP, TMS, BIM).

2.2. Key technologies: AI, BIM, and IoT

Artificial intelligence enables the automation of complex processes such as site planning, forecasting material requirements, and optimizing human resource allocation. Ghosh et al. [2] demonstrate that the use of supervised learning algorithms in construction helps to detect risks of delays and logistical bottlenecks upstream and to simulate different management scenarios.

Building Information Modeling (BIM), meanwhile, centralizes technical building data in a 3D digital model that is accessible to all project stakeholders. Combined with AI, it becomes a powerful tool for coordination and quality control. The IoT completes this technological trio by providing real-time data (geolocation of materials, equipment monitoring, weather tracking) that is essential for logistical responsiveness.

2.3. Cybersecurity as a condition for success

In digitized hospital projects, information system security is becoming a strategic priority. The data handled is sensitive: architectural plans, patient information, medical equipment purchasing protocols. Exposure to cyberattacks can have critical consequences (construction site shutdowns, data leaks, digital sabotage).

Abouelmehdi et al. [4] emphasize the need to integrate security protocols from the project design phase onwards. This includes multi-factor authentication, data encryption, regular audits, and, above all, compliance with international standards such as ISO 27001 or Moroccan Law 05-20 on cybersecurity. Digital security cannot be thought of as a separate module, but as a cross-cutting layer at every link in the supply chain.

In addition to standard cybersecurity practices, recent work in the domain of smart cities underscores the importance of embedding digital trust mechanisms and participatory governance frameworks. For instance, Carboni identifies the interdependence between institutional transparency, secure infrastructure, and citizen trust as key pillars for successful smart environments [8]. Basu reinforces this perspective by emphasizing the active role of end users and civic actors in strengthening the collective resilience of smart infrastructures, particularly in health-sensitive environments [9]. These findings converge with the theoretical position of Langa and Thakhathi, who advocate for integrated governance models that link cybersecurity, service continuity, and multi-actor collaboration—elements that are crucial for the digitization of hospital construction projects in Morocco [10].

2.4. Review of the theories mobilized

As suggested by Portal and Fabrègue, participative approaches in smart city initiatives enhance system resilience and alignment with local needs—a strategy applicable to hospital logistics projects [11]. Several theoretical frameworks guide this research:

- Dynamic capabilities theory [12]: this posits that performance depends on an organization's ability to integrate, develop, and reconfigure its competencies in response to a changing technological environment;
- Contingency theory [13]: suggests that organizational effectiveness depends on the alignment between the technologies deployed and the specific conditions of the project (regulations, resources, institutional environment);
- IT/Business strategic alignment theory [14]: used to assess whether the technologies implemented are consistent with logistical and health objectives.

These theories justify the construction of a model linking technological innovation, logistical performance, and system security.

2.5. Conceptual framework of the research

The key variables in our model are as follows:

- Inputs (Smart Technologies): AI, BIM, IoT;
- Processes (Logistics transformations): Planning, coordination, automation;
- Outputs (logistical results): Traceability, efficiency;
- Moderation: Level of cybersecurity (governance, standards, audits).

This model is based on a primary causal relationship: the use of smart technologies improves logistics performance, provided there is a strong security framework in place. The level of cybersecurity acts as a moderating variable, influencing stability and trust in the system.

3. Research methodology

3.1. Study setting and context

In order to understand the conditions for the effective integration of smart technologies and cybersecurity devices into Moroccan hospital supply chains, this study adopts a mixed methodological approach combining qualitative exploration and quantitative validation. This choice allows us to cross-reference the wealth of practitioners' discourse with measurable data, while ensuring triangulation of the results.

The study was conducted between June and November 2024 in three major regions of the Kingdom: Casablanca-Settat, Rabat-Salé-Kénitra, and Marrakech-Safi. These areas were chosen because of their high concentration of public hospital projects undergoing digitization, representing fertile ground for analyzing logistics, technology, and security practices. The data collected came from two main sources: a series of semi-structured interviews with professionals in the sector and a questionnaire survey of a targeted sample.

3.2. Conceptual model and research hypotheses

The conceptual model of this research posits that the use of smart technologies such as artificial intelligence, Building Information Modeling, and the Internet of Things has a significant effect on the logistical performance of hospital projects, insofar as this link is influenced by the level of organizational cybersecurity. Three categories of variables structure this model: digital technologies integrated into processes, logistics performance indicators, and cybersecurity mechanisms implemented. This theoretical framework is based in particular on the work of Ivanov, Ghosh, Abouelmehdi, and other researchers who have explored the relationships between digitalization, smart logistics, and information system security. It guided the construction of data collection tools and the formulation of empirical hypotheses.

3.3. Qualitative study

3.3.1. Sampling and conduct of interviews

The qualitative phase was carried out through twelve semi-structured interviews with a variety of individuals involved in the hospital projects studied. The interviewees held strategic positions within technical, IT, or decision-making teams. Each interview lasted between 45 and 60 minutes. The interview guide was structured around themes relating to the state of logistics digitization, the actual uses of AI, BIM, and IoT, data security practices, and coordination methods between project stakeholders.

3.3.2. Data processing and analysis

The recordings were transcribed in full, then coded and analyzed using NVivo software, according to a thematic approach inspired by Bardin. The analysis combined a vertical reading of the themes and a horizontal reading of the individual discourses in order to extract regularities and divergences in practices and representations.

3.4. Quantitative study

3.4.1. Questionnaire design and sample

The quantitative study used a structured questionnaire, distributed online to 100 professionals in the construction, public health, consulting, and technology sectors. The questionnaire contained around 30 items divided into four main sections, designed to measure the level of digital maturity, the intensity of use of smart technologies, the cybersecurity mechanisms applied, and the perceived performance of supply chains in hospital projects.

3.4.2. Statistical analysis

All responses were analyzed using SPSS software, through descriptive and inferential statistics. Pearson correlations were used to examine the links between the different variables, while multiple regression models were used to test the moderating effect of cybersecurity on the relationship between smart technologies and logistics performance. Normality, linearity, and multicollinearity tests were performed to ensure the validity of the analyses and the robustness of the model.

4. Results and discussion

As the objective of this research is both exploratory and explanatory, the expected results are based on the triangulation of data collected in the field. By combining the qualitative contributions of semi-structured interviews with the quantitative data from the questionnaire, the study aims to identify significant trends, while identifying the specific contextual characteristics of the Moroccan hospital sector. This approach allows us to meet the requirements of scientific methodological rigor while promoting inductive interpretation, as recommended by Miles, Huberman, and Saldaña [15].

4.1. Results of the qualitative study

The interviews conducted should reveal a finding shared by the various stakeholders: logistics digitization is still in its infancy in public hospital projects, often limited to the use of basic software (Microsoft Project, shared Excel, etc.), with no interconnection between systems. Artificial intelligence, BIM, and IoT are still rarely integrated, except in experimental cases led by local initiatives or foreign partners. Nevertheless, respondents express a clear interest in these tools, particularly for their potential in terms of forecasting shortages, optimizing flows, and coordinating between stakeholders. This interest is accompanied by a pressing need for training, clear regulation, and public support. These results confirm the observations of Ghosh et al. [2], according to which the conditions for the success of smart technologies rely heavily on organizational maturity and institutional commitment.

4.2. Results of the quantitative study

On the quantitative side, the analyses planned on SPSS should show that organizations that have integrated advanced technologies have significantly higher logistics performance scores than others. In particular, we expect to see a reduction in supply times, better visibility of stocks, and a reduction in the rate of human error in flow management. These positive effects are supported by the work of Ivanov [3], which shows that smart supply chains, when properly configured, promote resilience, agility, and operational efficiency. At the same time, regression models should demonstrate that cybersecurity acts as an important moderating variable. In other words, the positive effects of AI or BIM on performance can only materialize in a secure digital environment, governed by practices that comply with ISO/IEC 27001 standards or Moroccan Law 05-20 on cybersecurity.

4.3. Discussion

A cross-analysis of the two parts of the research suggests that the digital transition in the Moroccan hospital sector is not only hampered by technological constraints, but above all by shortcomings in terms of governance and institutional strategy. The lack of digital coordination between project owners, technical departments, and IT service providers limits the effectiveness of projects. This fragmentation confirms the conclusions of the IT/Business strategic alignment theory [14], according to which any technological innovation must be synchronized with organizational objectives in order to produce tangible effects. According to Schachtner and Baumann , developing digital competencies among public administrators is crucial for managing secure, smart infrastructures in urban healthcare systems [16].

The expected results therefore call for a series of practical recommendations: first, the development of a national plan for the digital transformation of hospital construction, including a technical reference framework, a certification system for service providers, and continuing education modules for professionals. Second, the systematic establishment of inter-institutional digital steering committees in large-scale hospital projects. Finally, the mandatory adoption of cybersecurity clauses in public tender specifications to ensure the protection of critical data and the resilience of systems.

This study anticipates results that do more than simply describe uses, but also highlight the political, organizational, and security conditions necessary for the emergence of an intelligent, efficient, and sovereign hospital supply chain. It thus builds on previous work on technologies applied to public health in the Global South, while making an original contribution to the literature on integrated digital logistics.

Table 1. Strategic table of expected results

Axis of analysis	Expected outcome	Main challenge	Operational recommendation
Digital maturity	Limited use of AI and BIM - high external dependency	Delays in structural digitization	National digital transformation plan for the construction and healthcare sectors
Logistics performance	AI = measurable gains (time, costs, coordination)	Uncapitalized gains	Integrating AI/BIM modules into calls for tenders
Cybersecurity	No formal policy - critical risks identified	Systems exposed to cyber threats	Development of a sector-specific cybersecurity framework
Digital governance	Low interoperability - unclear technical governance	Poor coordination between stakeholders	Digital steering committee for hospital projects
Training and appropriation	Strong commitment from stakeholders - low current internal capacity	Risk of rejection of smart tools	Sector-specific continuing education in AI and cybersecurity

Source: authors' elaboration

The cross-analysis of qualitative and quantitative data from this research highlights a structural paradox in public hospital projects in Morocco. On the one hand, smart technologies are seen as key drivers of logistical improvement. On the other hand, their deployment remains hampered by a lack of digital maturity, fragmented governance, and poorly formalized cybersecurity practices. This tension echoes the observations of Ghosh et al. [2], according to whom the added value of digital innovations in the construction sector depends less on the technology itself than on the organizational capacity to absorb and implement it.

Interviews with hospital construction professionals confirmed the uneven and often superficial adoption of artificial intelligence, BIM, and IoT. These tools are being used on an experimental basis, either by private operators with technical expertise or by international partners. However, public actors still lack an integrated strategic vision, structured institutional support, and an appropriate regulatory framework. This observation echoes the theory of dynamic capabilities [12], according to which innovation relies on the ability to integrate, adapt, and reconfigure organizational resources in a changing

environment. Without this ability, even the most advanced tools fail to produce systematic effects.

Project governance is another critical issue. Field results confirm the lack of inter-institutional coordination around logistical and digital aspects. Responsibilities are often divided between several entities (Ministry of Health, project owner, design offices, construction companies, IT service providers), without a unified management structure. This fragmentation reduces the overall effectiveness of projects and complicates the traceability of flows. It contradicts the precepts of the IT/business strategic alignment theory formulated by Henderson and Venkatraman [14], which posits that organizational performance results from a consistent alignment between business strategy, technological infrastructure, and process governance. Kumar underscores the value of active citizen participation in digital city projects, which could be adapted to promote transparency and trust in hospital digital supply chains [17].

One of the most striking findings concerns cybersecurity, which was identified by the majority of respondents as a neglected or even non-existent area. Few organizations have security charters, internal standards, or regular audits. Ignorance of international standards, particularly ISO/IEC 27001, and the absence of a digital risk management culture make systems particularly vulnerable. These findings echo the work of Abouelmehdi, Beni-Hessane, and Khaloufi [4], who warn of the critical risks associated with health data security in emerging countries. This vulnerability is not simply technical: it is also strategic, as it weakens the overall resilience of projects and limits stakeholder confidence in digital solutions.

Furthermore, quantitative results confirm that the impact of smart technologies on logistics performance is significant only when organizations have a secure and structured environment. Regression models suggest a clear moderating effect: without cybersecurity, the expected gains in terms of lead times, coordination, and efficiency are not achieved. This statistical interaction reinforces the idea of a co-dependence between innovation and protection, as argued by Ivanov [3], for whom the viability of logistics chains depends on their ability to combine agility, robustness, and long-term sustainability.

Finally, this discussion highlights the urgent need to rethink continuing education programs in the hospital construction sector. The introduction of smart technologies cannot succeed without an increase in the skills of engineers, project managers, technicians, and public decision-makers. The lack of profiles capable of linking logistics, digital and regulatory logic is a major obstacle. The success of digital transformation therefore requires, beyond technology, a strategic investment in human capital. As Creswell and Plano Clark [18] point out, mixed research makes it possible to identify these gaps between formal structures and practices in the field.

Ultimately, this study highlights a set of interdependent obstacles and drivers that influence the emergence of a smart and secure hospital supply chain in Morocco. Technology is just one factor among many. It is organizational, institutional, and human conditions that will determine whether the current digitalization process leads to systemic transformation or an

accumulation of isolated solutions. It is now up to public authorities, project owners, and private partners to structure a coherent, interoperable, and sovereign ecosystem capable of supporting this transformation.

5. Conclusion

At a time when Morocco is embarking on an ambitious digital transformation of its healthcare infrastructure, this study examined the conditions for the emergence of a hospital supply chain that is intelligent, efficient, and secure. Using a mixed methodology combining semi-structured interviews with quantitative data from the field, it highlighted the potential offered by digital technologies in the hospital construction sector, while identifying the structural and organizational obstacles to their large-scale deployment.

The results confirm that integrating artificial intelligence, BIM, and IoT into hospital logistics processes can generate significant gains in terms of planning, inter-actor coordination, and flow traceability. However, these benefits can only be fully achieved if cybersecurity is considered a structural component rather than a mere technical accessory. The link between digitalization and logistics performance is strongly influenced by the quality of information system protection measures, compliance with security standards (such as ISO/IEC 27001), and the governance of sensitive data flows, as previously highlighted by Abouelmehdi et al. and Ivanov [4] [3].

This study also revealed a fragmentation in digital governance, which hinders the pooling of expertise, the interoperability of systems, and the emergence of integrated solutions at the national level. Public hospital projects are often managed in silos, without a shared strategic vision or a unified regulatory framework. This lack of institutional coordination undermines the overall effectiveness of public investment in the healthcare sector. These findings echo those of Henderson and Venkatraman, who emphasized the critical importance of strategic alignment between technological choices and organizational objectives.

One of the main contributions of this research is the proposal of an original conceptual framework, contextualized to Morocco, combining technological innovation, logistical performance, and cybersecurity. From a managerial perspective, the findings highlight the need to develop a national reference framework for smart hospital logistics, incorporating cybersecurity requirements from the project design phase. They also call for a profound reform of governance mechanisms, through the creation of digital steering committees in every major hospital project, equipped with technical, legal, and strategic expertise.

However, this study has several limitations. First, the relatively small size of the qualitative sample—although adequate for an exploratory approach—could be expanded to include other regions or more diverse professional profiles. Second, the quantitative data, while indicative, do not allow for strong causal inferences and would benefit from more in-depth structural modeling. Finally, cybersecurity issues remain difficult to document comprehensively due to the sensitive and confidential nature of the data involved. Smart governance, as described by Langa and Thakhathi, is essential for creating

interdepartmental coordination mechanisms that can guide complex projects like smart hospital development [19].

These limitations open up several avenues for future research. It would be relevant to deepen the analysis of intersectoral digital governance models in hospital projects by comparing Southern countries that have adopted similar strategies. Likewise, a longitudinal assessment of the impact of digitalization on hospital performance after implementation would make it possible to measure the long-term effects of these transformations. Finally, studying the skills required to support this transition invites reflection on the design of continuing education and professional development programs in areas such as BIM, artificial intelligence, and cybersecurity applied to healthcare.

In short, this research aims to contribute to the development of a Moroccan model for 21st-century hospital logistics, based on technological intelligence, security rigor, and collective efficiency. It calls for coordinated mobilization of public stakeholders, construction professionals, digital experts, and researchers to make digital health a national priority and a lever of sovereignty.

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