The role of ICT in Moroccan smart cities: towards innovative hospital logistics

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Abstract

This article explores the role of information and communication technologies (ICT) in the development of smart cities in Morocco, with a particular focus on hospital logistics. It aims to demonstrate how the integration of ICT can transform logistics practices, improve the efficiency of hospital operations and address sustainability challenges in a rapidly evolving urban context. This theme is essential to support Morocco's efforts to modernize healthcare infrastructures and make the digital transition. The study draws on existing research on the impact of ICT in hospital logistics systems and on international smart city initiatives, while integrating analyses of specific examples in Morocco. It follows on from published work on the synergies between digitalization and public service performance. A qualitative methodology was adopted, combining documentary analysis and case studies of Moroccan smart city projects. Interviews with healthcare and logistics professionals provided practical perspectives on the challenges and opportunities associated with the use of ICT. The results reveal that integrating ICT into smart city hospitals enables better management of logistics flows, optimization of resources and enhanced coordination between players. These improvements contribute not only to the efficiency of care, but also to the resilience of hospital systems in the face of growing urban constraints. This study offers concrete guidelines for decision-makers and practitioners, highlighting the need for appropriate digitization policies. It also offers innovative thinking on the intersection between hospital logistics and intelligent urbanization, making a valuable contribution to research and practice in this field.

Keywords: Information systems, healthcare logistics, smart cities, digital transformation, infrastructure management.

1. Introduction

Smart cities constitute a revolutionary approach to urban planning and development. They incorporate technology, enhance sustainability and engage citizens to create a more efficient, sustainable and liveable urban environment [1]. At the same time, it is essential to address the associated challenges to ensure that the benefits of smart cities reach all citizens [2]. The future of smart cities looks promising, with technological advances and a growing emphasis on sustainability and citizen participation shaping tomorrow's urban landscapes [3].

Information and communication technologies (ICT) are, therefore, at the heart of the transformation of smart cities, defined as urban spaces using advanced technological

solutions to optimize resources, improve sustainability and meet citizens' needs. These cities integrate interconnected systems, such as the Internet of Things (IoT), smart sensors and digital platforms, to manage various sectors, such as energy, transport, education and, significantly, healthcare [4, 5]. The main objective is to provide more efficient public services while creating a sustainable and innovative environment for its inhabitants.

In Morocco, the transition to smart cities has become a strategic priority in the face of rapid urbanization and increasing pressure on existing infrastructures. Projects such as Rabat City of Light, Casablanca Smart City and Marrakech Smart City illustrate the country's efforts to align itself with global trends. However, these initiatives come with challenges, such as financing, technological adoption and the integration of services, particularly in the healthcare sector [6].

Hospital logistics, an essential component of smart city infrastructure, aims to guarantee the availability, quality and traceability of medical products, while optimizing processes linked to inventory management, transport and distribution. In the Moroccan context, the introduction of ICT in hospital logistics could resolve current shortcomings, such as delays in deliveries, wastage of resources and lack of coordination between players. For example, the adoption of IoT-based integrated management systems and real-time databases could enable proactive management of medical supplies and better responsiveness to health emergencies [7, 8].

This integration of ICT into hospital logistics, while still in its earliest stages in Morocco, represents a unique opportunity to improve the quality of care and support the sustainability objectives of smart cities. In particular, it could strengthen the resilience of healthcare infrastructures in times of crises, such as those observed during the COVID-19 pandemic, and meet the growing demands of an expanding urban population.

The aim of this article is to explore how ICT can transform hospital logistics in Moroccan smart cities. The following research questions structure our approach: How do ICT enhance the coordination and efficiency of logistics operations in hospitals? And what are the impacts of this transformation on the quality of care and the sustainability of hospital infrastructures? These questions build on theoretical frameworks developed in previous studies, notably those examining Internet of Things (IoT) applications in smart city infrastructures and logistics management systems.

Previous work reveals that smart cities adopting robust and reliable ICT achieve substantial benefits in terms of resource management, cost reduction and service improvement. These systems integrate sensors, IoT networks and digital platforms to monitor and optimize logistics flows in sectors such as healthcare, while meeting sustainability objectives.

2. Literature review

2.1. Concept of smart cities and ICT

Smart cities represent a modern approach to urban development, integrating information and communication technologies (ICT) to transform urban spaces into sustainable, connected environments focused on the well-being of citizens.

A smart city is defined as an interconnected urban entity in which infrastructure, public services and citizen interactions leverage ICT to optimize efficiency, reduce environmental impact and improve quality of life. The term refers to cities that use digital networks and data to coordinate urban systems, such as transportation, resource management and healthcare infrastructures [9]. In addition, by focusing on the use of real-time data from sensors and connected devices, we can continuously monitor and adapt urban services [10].

Smart cities rest on several essential pillars, namely; digital infrastructure, based on an integrated ICT network, including sensors, IoT platforms and communication networks such as 5G [11]; Big Data and Artificial Intelligence (AI), which enable the collection, processing and analysis of massive data to improve decision-making [12]; and citizen participation, by integrating digital applications and platforms enable increased interaction between citizens and local governments, fostering transparency and community engagement [4].

ICT plays a central role in the operation of smart cities. For example, the Internet of Things (IoT) facilitates communication between devices, enabling real-time management of infrastructures such as power grids or transport [13]; cloud computing provides a framework for storing and sharing large quantities of data, essential for analysis and coordination [14]; and smart grids such as energy or water management systems automatically adjust services according to need [15].

ICT enables smart cities to optimize public services, for example, by improving traffic management via intelligent transport systems; to reduce ecological footprints through efficient management of natural resources, notably via smart energy networks [16]; and to strengthen urban resilience where real-time data enables better preparation and response to urban crises, such as natural disasters or pandemics.

2.2. Hospital logistics in the context of smart cities

Hospital logistics in smart cities represents an interconnected system that leverages ICT to optimize resource management, improve healthcare services and respond effectively to citizens' needs. This integration is based on an approach focused on technological innovation and sustainability.

Hospital logistics covers a wide range of activities: supply management, patient flow planning, drug distribution and medical waste management. In a smart city context, these processes are enhanced by advanced ICT systems, such as the Internet of Things (IoT), artificial intelligence (AI) and shared databases [17]. These technologies optimize the availability and distribution of medical equipment, reduce delays in emergency transport flows thanks to real-time data [18], and improve the transparency and traceability of hospital resources [19].

Hospital logistics in the context of smart cities consists of inventory and supply management where cloud and IoT-based systems enable real-time tracking of stock levels and automation of replenishments [20], intelligent transport and delivery where optimized routing algorithms are used to deliver medical supplies to hospitals while minimizing costs

and emissions [21], and traceability and tracking of medical flows with RFID sensors and blockchain platforms that ensure complete traceability of drugs and medical devices [22].

The benefits of integration in smart cities lie in cost reduction, where digital systems reduce losses due to overstocking or drug obsolescence; increased efficiency, where AI-based platforms predict resource requirements, thus avoiding disruptions in hospital supply chains; and rapid response to health emergencies, where thanks to the interconnectivity of systems, hospitals can rapidly adjust their capacity in the event of major crises, such as pandemics [23].

Although Morocco is still in the development phase, initiatives such as Casablanca Smart City are laying the foundations for integrating these innovations into the hospital sector. E-health platforms could be used to coordinate flows between different medical establishments more efficiently.

2.3. Practical applications of ICT in hospital logistics: an international and Moroccan perspective

ICT has profoundly transformed hospital logistics, offering practical tools to improve the management of patient flows, medical resources and healthcare data. These practical applications vary according to international and national contexts, with initiatives adapted to local needs.

In advanced healthcare systems, ICT is being used to streamline hospital logistics operations through tools such as the Internet of Things (IoT), hospital information systems (HIS) and blockchain:

- Patient flow management: IoT systems are deployed in connected hospitals to monitor patient movements, reduce waiting times and optimize the use of hospital resources [24].For example, at the NHS (UK), centralized management platforms forecast bed requirements by analyzing admissions and discharges data [25].
- Tracking equipment and drugs: RFID (Radio Frequency Identification) technologies enable real-time management of medical inventories. These systems reduce human error and equipment loss, particularly in critical units [26]. Blockchain is also used to ensure the traceability of medicines and prevent counterfeiting. In Estonia, it is integrated into the national pharmaceutical supply chain to guarantee the quality of medical products.
- Medical transport planning: AI algorithms help optimize ambulance routes and medical supplies deliveries based on traffic density and urgency [27].
- Morocco is beginning to integrate ICT into its hospital infrastructures, with a particular focus on smart city initiatives.
- Digitization of hospital information systems (HIS): Several Moroccan hospitals, notably in Casablanca and Rabat, are using hospital management software (HIS) to centralize patient data, improve interdepartmental coordination and optimize inventory management [28]. In this way, the e-santé Maroc initiative aims to strengthen digital integration in the medical sector for more efficient services.

- Tracking medical supplies: ICT is being used to digitize the ordering and tracking of medicines in public hospitals. ERP (Enterprise Resource Planning) management systems are beginning to be adopted to automate these tasks [29].
- Public-private partnerships for IoT solutions: companies are collaborating with hospitals to introduce connected devices, particularly for tracking critical equipment and stocks of sensitive medicines.
- Prospects for medical transport: although the use of optimization algorithms is still limited, some pilot initiatives are testing logistics solutions for emergency transport in collaboration with local start-ups [30].

The benefits of ICT in these applications lie in cost reduction, where digital tools minimize inefficiencies in the management of medical resources; better patient care, where flow management systems reduce waiting times and free up time for care; and improved traceability and quality, where technologies like blockchain and IoT sensors guarantee the security of medical supplies.

2.4. Challenges of integrating ICT into hospital logistics

The integration of ICT into hospital logistics presents considerable opportunities for improving the efficiency and quality of medical services. However, a number of technical, organizational and financial challenges stand in the way of their adoption and optimal use:

- Technical challenges: namely, system interoperability, where hospitals often use heterogeneous information systems, making interconnection difficult. Medical data must be compatible across platforms to avoid information loss and ensure seamless integration [31]. For example, integrating an ERP (Enterprise Resource Planning) system with IoT devices requires common standards that are not yet universally adopted; cybersecurity where the multiplication of connected devices and data storage in the cloud increase the risk of cyberattacks. Attacks targeting medical data can lead to critical interruptions in hospital logistics [32]; insufficient technological infrastructure where in many countries, including Morocco, technological infrastructures, such as network coverage or connected equipment, remain insufficient, limiting ICT implementation [33].
- Organizational challenges: such as the lack of digital skills, from which hospital staff often lack the training to use ICT systems effectively, which can reduce their efficiency. Appropriate training programs are essential [34]; resistance to change, where the transition to digital systems leads to resistance from employees used to manual processes. This slows down the adoption of new technologies [35]; the complexity of hospital processes, where logistics management in hospitals involves critical and interdependent processes. Integrating ICT requires careful adaptation so as not to disrupt essential medical flows.
- Financial and legal challenges: include high installation and maintenance costs, hence digital systems, such as IoT platforms, ERP and cybersecurity solutions, involve high initial investments. Many facilities, particularly in developing countries, lack the necessary resources [36]; lack of government support, in Morocco, despite initiatives such as e-santé Maroc, budgets allocated to hospital digitization remain limited. This slows down the implementation of ICT in public

facilities [37]; and data protection issues where data privacy laws, such as the RGPD in Europe, impose strict constraints on the use of ICT. Hospitals must guarantee legal compliance while integrating innovative technologies [38].

- Challenges specific to the Moroccan context: regional inequalities which hospitals in rural areas often have fewer ICT resources and infrastructures than urban centers such as Casablanca and Rabat. A lack of collaboration between stakeholders means that better coordination between governments, hospitals and private companies is needed to overcome the obstacles to ICT adoption.

3. Methods

For this article, a qualitative approach was adopted to gain a better understanding of the dynamics and issues involved in integrating ICT into hospital logistics, particularly in the Moroccan and international context. This methodological choice enables us to explore perceptions, experiences and practices, while taking into account local and organizational specificities.

3.1. Study design

- Exploratory nature: This study aims to examine how ICT influence hospital logistics in various environments (smart cities, urban/rural hospitals) to identify emerging models.
- Analysis framework: The analysis relies on technology adoption theories, such as the Technology Acceptance Model (TAM), to explain the facilitating or blocking factors in ICT implementation.

3.2. Data collection techniques

- Semi-structured interviews: a series of interviews with healthcare personnel involved in information systems management. The aim is to explore their perceptions of the effectiveness of ICT and its impact on hospital logistics. Sample questions: What ICT tools do you use in your hospital? What challenges do you face when integrating ICT into your logistics processes?
- Literature review: a consultation of institutional reports, case studies, and recent academic articles to complement the qualitative data from the interviews.
- Field observations: visits to Moroccan hospitals integrating ICT solutions to observe digital logistics processes at first hand.

3.3. Selection of samples

- Sampling criteria: participants were selected according to their strategic role in hospital logistics (IT managers, logistics directors, administrative staff, nursing staff) and institutions, with an inclusion of public hospitals and a balanced distribution between urban and rural centers for a representative view.
- Sample size: around 15 to 20 participants, distributed as follows; 5 IT managers, 5 hospital logisticians, 5 administrative or medical executives.
- Geographic focus: Moroccan hospitals integrating smart city initiatives (Casablanca, Rabat).

3.4. Data analysis

- Thematic analysis: data were analyzed according to pre-established themes, such as perceptions of ICT effectiveness, organizational and technical challenges, and the impact of ICT on resource flow management.
- Data coding: NVIVO software was used for qualitative analysis to identify emerging themes.

4. Findings

4.1. Improving the efficiency of logistics processes

The integration of ICT in hospitals has enabled smoother management of resources, inventory and patient flows. Inventory management systems based on digital platforms have reduced inventory management errors, resulting in better availability of drugs and medical equipment. Hospitals that have adopted ERP systems have noted a reduction in operating costs, thanks in particular to better resource planning and more preventive management of equipment failures [33].

4.1. Technical and organizational obstacles

Despite these advantages, a number of obstacles remain. One of the major challenges identified is interoperability between the different systems used in healthcare establishments. A large proportion of Moroccan hospitals still use separate software systems that do not communicate effectively with each other, making it difficult to integrate new technologies [38].

Resistance to change among hospital staff also remains a major obstacle. Many players in the sector express concern about the need for training and the adaptation of existing practices to new technologies [31].

4.2. The impact of ICT on emergency management and medical logistics

In hospitals that have integrated advanced technologies, such as IoT sensors for real-time tracking of medical equipment, responses to emergency situations have improved. Reaction times in emergency departments have been reduced, leading to better management of critical situations, thanks to automatic alerts and real-time management of medical stocks [32].

4.3. Perception of hospital actors

The majority of professionals surveyed are optimistic about the future benefits of ICT, but stress the need for ongoing training and more robust institutional support to ensure successful adoption. In particular, hospital managers feel that investment in digital infrastructure needs to be stepped up, and done so systematically on a national level [35].
ICT offers considerable potential for optimizing hospital logistics in Morocco's smart cities, by improving process efficiency and reducing operational costs. However, their adoption remains limited by technical, organizational and financial challenges. Their successful integration will largely depend on the implementation of supportive public policies, the ongoing training of professionals and the improvement of the digital infrastructure.

5. Discussion

The discussion of this study highlights the implications of the results obtained, comparing them with global trends observed in the literature and international experience. It also identifies the prospects and limitations of Moroccan initiatives in this field.

5.1. ICT as a catalyst for transforming hospital logistics

ICT is recognized as a fundamental element in smart cities for optimizing urban processes, and its impact is particularly visible in the hospital sector. The results confirm that ICT, such as ERP systems and IoT sensors, enable integrated management of medical resources, reducing the logistical inefficiencies observed in traditional environments. This is in line with the findings of Bhuyan et al. (2020), according to which the adoption of digital solutions leads to greater responsiveness in hospitals.

However, in Morocco, although progress is being made, these transformations remain fragmented and largely dependent on the budgetary capabilities of institutions. This contrasts with developed countries such as Estonia, where digital systems are systematically integrated on a national level.

5.2. The challenges of ICT integration

Despite their potential, ICT integration remains hampered by technical, organizational and cultural challenges. These include:

- Limited interoperability: the digital systems adopted in different healthcare facilities are often not compatible, making it difficult to share critical data.
- Lack of training: results show that Moroccan hospital staff require intensive training to adapt to new technologies. Acceptance of the technologies depends heavily on the support offered by managers.
- Insufficient digital infrastructure: Moroccan hospitals still suffer from technological shortcomings, limiting their ability to take advantage of advanced solutions such as artificial intelligence (AI) and clinical decision support systems.

5.3. Comparison of international trends

A comparison of Moroccan experiences with international initiatives reveals significant differences:

- In Nordic countries, such as Finland, digital platforms are used to integrate not only hospitals, but also home care and pharmacies, promoting continuity of care. This model could inspire strategies in Morocco, particularly for hospitals in remote areas.
- In Asia, cities such as Singapore have adopted advanced IoT solutions for real-time monitoring of medical equipment, an area where Morocco is still in the experimental phase.

5.4. Perspectives for Morocco

The results of the study indicate that a coordinated national strategy is needed to maximize the impact of ICT on hospital logistics. This includes:

- Investment in infrastructure: upgrading ICT infrastructure is a priority, particularly in rural areas, to ensure equitable access to technologies.
- Public-private partnerships: the Moroccan government could collaborate with technology players to develop tailor-made solutions for hospitals.
- Human capacity building: targeted training programs need to be developed to meet the specific needs of hospital and administrative staff.

5.5. Contributions and limitations of the study

This study contributes to understanding the dynamics of digital transformation in Moroccan hospitals. However, it is limited to a qualitative analysis, which limits the generalizability of the conclusions. A complementary quantitative study would be required to validate the trends identified.

6. Conclusion

The integration of ICT into hospital logistics, particularly in the context of Morocco's smart cities, offers promising prospects for optimizing the management of healthcare services. The study highlighted the substantial benefits of ICT, particularly in terms of operational efficiency, cost reduction and improved quality of care.

In particular, digital systems such as ERP platforms, IoT solutions, and clinical decision support tools are enabling better management of logistics flows and boosting hospital facilities' responsiveness to growing needs. However, this digital transformation faces significant challenges, including system interoperability, lack of adequate training for staff, and still-limited infrastructure in many Moroccan regions.

Internationally, successful experiences in advanced countries offer concrete examples that Morocco could adapt to its own context, provided that current technical and organizational obstacles are overcome. In this respect, well-coordinated national strategies, based on public-private partnerships and human capacity building, are crucial to the success of this transition.

This study contributes to enriching the thinking on the role of ICT in hospital logistics and in Moroccan smart cities, but it also highlights the need for further research, particularly quantitative, to deepen the results obtained.

In conclusion, the optimal use of ICT in the hospital sector represents an essential lever for improving the resilience and efficiency of Moroccan healthcare systems, while supporting the objectives of sustainability and urban modernization.

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