Hospital 4.0 Maturity Assessment Model Development: Case of Moroccan Public Hospitals

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Abstract—**This paper presents a Hospital 4.0 Maturity Assessment Model based on the Industry 4.0 concepts. The self-assessment model defines current and target states of digital transformation by considering multiple aspects of a hospital and a healthcare supply chain. The developed model was validated and evaluated on real-life cases. The resulting model consisted of 5 domains: Technology, Strategy 4.0, Human resources 4.0 & Culture 4.0, Supply chain 4.0 management, and Patient journeys management. Each domain is further divided into several sub-domains, totally 34 sub-domains are identified, that reflect different facets of a hospital 4.0 mature organization.**

Keywords—**hospital 4.0, industry 4.0, maturity assessment model, supply chain 4.0, patient**

I. INTRODUCTION

The concept of Hospital 4.0 or Digital Hospital is the conceptualization of a transformation project in harmony with the digital revolution that is impacting the society and the healthcare system (Jonsson & Mattsson, 2016). Using digital technologies to support healthcare processes isn't just about technology (Forrester, 1958; Christopher, 1998; Benazzouz *et al.*, 2017a, 2017b). It's also and above all a question of expertise allowing the development of specific and adapted sectoral activities solutions. Then, a Hospital 4.0 is a: (i) communicating hospital for all internal and external actors, which includes the areas of hospital information systems (HIS) and e-health; (ii) smart building with the ability to track products and people, organize processes and inform, alert in the event of deviations or risks; (iii) medical-technical production and robotic and automated logistics: minimizing human intervention, accelerating flows, transport, and generating strong productivity gains. The concept of Hospital 4.0 corresponds to the adaptation efforts of hospital to a professional environment that is experiencing changes shaped by patient demand and technology (Stoltzfus, 2023). It refers to how a hospital transforms and creates its business processes, culture, and customer experiences or to modify existing ones, to meet changing business and market needs based on developments in the field of information and communication.

In the factory, the digital transformation in a hospital can be defined as a process that connects organizations (Frederico, 2021; Haddud & Khare, 2020) and allows interconnection between all objects: employees, machines, products, patients, suppliers, systems, etc. It therefore corresponds to the integration of all the actors in the healthcare Supply Chain (SC), in a single digital ecosystem by using technologies. These technologies can be traditional that have been well established for decades, such as EDI, electronic catalogs, RFID and AGVs or, recently, elaborate technologies like cloud computing, the IoT, big data analytics, 3D printing (Kosmol *et al.*, 2019), blockchain (Chang *et al.*, 2020), and artificial intelligence (Paschen *et al.*, 2020).

In Morocco, the COVID-19 situation has propelled the acceleration of the hospital digitalization, which is strengthening the healthcare system by making digital healthcare accessible throughout the entire country, reduces healthcare inequalities, improves the quality of healthcare provided and increases the well-being of citizens (The head of government, 2020; Raimo *et al.*, 2022). The importance of integrating Industry 4.0 concepts and implementing digital solutions in hospital management isn't attracting interest from academics. However, there are few studies that examined the hospital 4.0 and/or digital transformation maturity in the healthcare supply chains. Therefore, research studies haven't provided a bridge, or link between academia and real-world hospital. None of the studied maturity models in the literature evaluate the digital transformation of the hospitals in Morocco. In this context, we are interested in Moroccan public hospitals to diagnose and assess the digital transformation maturity by following a developed Hospital 4.0 Maturity Assessment Model.

This paper will first describe the research methodology used to develop the model. Next, it will introduce the model, including its constituent domains, sub-domains and levels of maturity. In the rest of the paper, we will present the results of the application and the evaluation of the model in 6 public hospitals. Finally, the paper will explain how it can be used in further developed.

II. RESEARCH METHODOLOGY

A. Research Gaps

Our research methodology included a literature survey that demonstrates viewpoints, methodological solutions and research results related to the study, primary data acquisition through a qualitative study carried out in Moroccan public hospitals to identify and classify risks related to the medical supply chain (Benazzouz et al., 2019) and data analysis. As this research was initiated to explore the models and tools for digital maturity of a hospital and hospital 4.0 maturity, the nature of this research was both exploratory and explanatory.

The digital maturity of a hospital, whatever its type, is an assessment of its degree of digital transformation (Maturity level). It is based on the analysis of not only uses: digital tools to manage relations between actors, collection and use of data to make decisions, digitization and integration of business processes, but also that of the ability to implement change: strategy and vision, planning, risk management, innovation, training, learning and continuous improvement. The description of each maturity level expresses when a certain level is reached. Domains depict different aspects of hospital 4.0 maturity and are derived from the application area. Sub-domains give a more granular view. Every sub-domain should contain a detailed description of each maturity level

From Table I, it is clear that Healthcare as a whole lack research in the area of digital maturity: only 6 models that are specific to assess the digital maturity of hospital.

TABLE I. MODEL & TOOL DESCRIPTIONS

Model/ Tool	Description
Digi.eval, (2020)	A free online platform, developed by Wifirst, helps to measure the digital maturity of healthcare establishments through around thirty questions relating to 4 dimensions.
DigiM Digital Maturity Model, (2021)	The DigiM tool evaluates the relative maturity of select health systems in the U.S by assigning numerical scores to individual digital programs implemented by health systems.
Global Digital Health Index (GDHI), (2016)	The Global Digital Health Index (GDHI) is an interactive web-based resource that aims to track, monitor, and assess the enabling environment for digital health throughout the world.
Health Information System Stages of Continuous Improvement Toolkit (HISS CIT), (2019)	The Health Information System (HIS) Stages of Continuous Improvement (SOCI) Toolkit was collaboratively designed to help countries or organizations holistically assess, plan, and prioritize interventions and investments to strengthen an HIS. The tool can be used in two formats: an Excel-based tool and a digital, app-based version of the tool available through the DHIS2 platform.
Health Information System Stages of Continuous Improvement Toolkit: Digital Assessment Tool Add-On Module, 2(020)	The digital version of the HIS SOCI tool is a web-based application used for assessment purposes. The app is based on the Excel-based toolkit.

	Based on an operational framework for the Capability Maturity Model, devised specifically for health care, the authors applied information use characteristics to define eight information systems maturity levels and associated technology infrastructure capabilities. These levels are mapped to user experiences to create a linkage between technology infrastructure and experience outcomes. Subsequently, specific technology capabilities are deconstructed to identify the technology features required to meet each maturity level.
Infrastructure Maturity Assessment Frame work (Patricia et al., 2019)	

B. Hospital 4.0 Maturity Model Assessment Development

In this literature review, there is not a unique model of digital maturity. Many hospitals around the world have developed their own models and tools. What most of these models have in common is a set of dimensions/domains, sub-dimensions/sub-domains and levels/ stages that correspond to digital engagement efforts (Table II).

There is a lot of research conducted on digital transformation in healthcare, however the digital transformation measurement in terms of the position and degree of digital maturity lack behind. Out of the 49 eligible articles, not one treats, uses, develops a digital maturity assessment model for public hospital in Morocco. Also, this is not a developed model centered on Industry 4.0 concepts. Furthermore, not all approaches provide adequate tools to apply the respective maturity model to a practical use case. With respect to the previously outlined prerequisites this showcases a clear deficiency in the current research. So, the rigor of the development process description is improvable for most digital maturity model. This supports the assumption that this field of research already provides interesting initial insights but that many future research possibilities are still to be worked upon.

TABLE II. DIMENSIONS AND LEVELS OF SELECTED MODEL

Model/ Tool	Dimensions/ Domains	Levels / Stages
Digi.eval, (2020)	1. The resident/establis hment relationship and e-reputation 2. Digital services for residents 3. Digital for staff needs 4. Digital in the face of Covid-19	Not specified
DigiM Digital Maturity Model, (2021)	1. Care management 2. Digital engagement: Patient and Provider 3. Enabling Technologies 4. Model & Governance	Level 1: Primary platform for digital engagement. Level 2: Digital initiatives focused on expanding virtual care. Level 3: Stand-alone digital health function. Level 4: Multi-year transformation strategy and investments.

Global Digital Health Index (GDHI), (2016)	1. Governance 2. Interoperability 3. Privacy and security policies 4. Workforce 5. Infrastructure	5 stages model, with Model 5 being the most deployed
Health Information System Stages of Continuous Improvement Toolkit (HISS CIT), (2019)	1. HIS leadership and governance 2. HIS management and workforce 3. HIS information and communication technologies (ICT) infrastructure 4. HIS standards and interoperability 5. HIS data quality and use	Stage 1: Emerging Stage 2: Repeatable Stage 3: Defined Stage 4: Managed Stage 5: Optimized
Health Information System Stages of Continuous Improvement Toolkit: Digital Assessment Tool Add-On Module, (2020)	1. HIS leadership and governance 2. HIS management and workforce 3. HIS information and communication technologies (ICT) infrastructure 4. HIS standards and interoperability 5. HIS data quality and use	Stage 1: Emerging Stage 2: Repeatable Stage 3: Defined Stage 4: Managed Stage 5: Optimized
Infrastructure Maturity Assessment Frame work (Patricia *et al.*, 2019)	1. Transport 2. Collaboration 3. Security 4. Mobility 5. Data Center	Level 1 : Administrative Level 2 : Tactical Level 3 : Fixed Level 4 : Mobile Level 5 : Externalized Level 6 : Integrated Level 7: Contextualized Level 8 : Orchestrated

Our hospital 4.0 Maturity Assessment is a self-assessment model to measure how well hospital publics in Morocco are supported by digital technology. The model does not end with a figure stating how well the hospital is digitalized; it uses the results to determine concrete areas of action and weaknesses that can be used for better planning and the sustainable realization of projects. For the structural design and development of the model, the methodological studies of (Ünal *et al.*, 2022; Borštnar & Pucihar, 2021; Çınar *et al.*, 2021; Valdez-De-Leon, 2016; Benazzouz & Auhmani 2023) were considered. By combining those guidelines, the development procedure for the digital maturity model was defined. Also, we derived the attributes from the literature review and the qualitative study carried out in Moroccan public hospitals to identify and classify risks related to the medical supply chain.

The final model consisted of five basic domains and 34 sub-domains associated with these five domains is conceptualized and formulated in Appendix A.

(1)   Technology: The Technology domain represents the extent to which the hospital 4.0 has implemented digital infrastructure, digital systems, technologies, and services that are usable and effective.

(2)   Strategy 4.0: The strategy domain represents the extent to which the hospital 4.0 has developed and implemented a strategic plan to achieve its goals and objectives. Also, this domain is described as the extent to which the hospital 4.0 possesses formalized and committed roadmap for the employment of digital technologies.

(3)   Human resources 4.0 & Culture 4.0: The human resources 4.0 and culture 4.0 domain assesses the extent to which internal actors of hospital 4.0 are digitally literate and motivated to leverage digital health systems. Also, it evaluates human resources competencies in digital transformation, the adoption of the institution, organizational values, and principles by the employees, and their willingness to take the company to a higher level.

(4)   Supply chain 4.0 Management: This domain assesses the extent to which external actors of hospital 4.0 are engaged and integrated in the processes of the digital transformation with the aim of increasing the efficiency and effectiveness.

(5)   Patient journeys Management: This domain assesses the extent to which patients are engaged and integrated in the processes of the digital transformation.

For the conceptualization the assessment levels, we based on the existing models in the literature. Then, four digital maturity assessment levels are proposed for each sub-domain according to the formulated and conceptualized domains (Appendix A).

- Level 0: The lowest hospital 4.0 maturity level (Digitalization not started) expresses the complete absence of the respective digital maturity sub-domains in the hospital 4.0.
- Level 1: In this basic hospital 4.0 maturity level (Initialing digitalization) the hospital has decided to move toward a hospital 4.0 organizations.
- Level 2: In this advanced hospital 4.0 maturity level (Integrating digitalization) the hospital's digital initiatives within the sub-domain are integrated to support digital transformation.
- Level 3: The highest hospital 4.0 maturity level (Full Digitalization) describes the state in which hospital 4.0 maturity sub-domains are self-sustainable on the highest possible development state.

III.   HOSPITAL 4.0 MATURITY ASSESSMENT MODEL VALIDATION ON THE REAL-LIFE CASES

The Hospital 4.0 Maturity Assessment Model has been developed so that hospitals systems of different sizes can be evaluated. Thus, a hospital can assess a process and, simultaneously, an entire service, in terms of digitalization. The application and use of the model brings important implications for practice research. For practitioners, first they should be aware of the specificities of their organization fit with the hospital environment and actors before implementing the Hospital 4.0 strategies. Second, the systematic review and assessment of the Hospital 4.0 maturity level of each domain and sub-domain should be used to build organization-specific road map. The Hospital 4.0

Maturity Assessment Model provides a vision of what a more mature digital Hospital looks like. However, the model is not prescriptive as to what is the best way to move up in the digital transformation scale. It also does not suggest that Level 3 is a requirement for all hospitals.

The Model was validated and applied on the six real-life use cases. Any case study, whether qualitative or quantitative, usually involves a representative sample of the population. To do this, the determination of the size and distribution of the sample must first take into account the characteristics of this population. Since this is a qualitative approach the size of the sample is not important, the essential is to have relevant and rich information (Benazzouz *et al.*, 2019).

For the data collection, we conducted interviews with the six public hospitals from different regions of Morocco. Each self-assessment was done individually. At the beginning of the interview, we made it clear that that anonymity was guaranteed in order to allow respondents to express themselves freely. The interviews lasted between one and two hours. The polar charts shown in "Figs. 1–6", were used for the analysis of the results. We can observe that the case of Hospital 6 was assessed as level 2 (Integrating digitalization) for the five domains: Technology, Strategy 4.0, Human resources 4.0 & Culture 4.0, Supply chain 4.0 Management and Patient journeys Management. Likewise, for Hospital 2, but in this case the Technology domain was rated as level 1(Integrating digitalization). For Hospital 1,3,4 and 5, we can observe that the Hospital 1 was very weak in two domains: Technology and Supply chain 4.0; while the hospitals 3 and 5 were rated as level 0 (Digitalization not started) in the Technology domain. The hospital 4 had the lowest levels on four domains: Technology, Strategy 4.0, Supply chain 4.0 Management and Patient journeys Management.
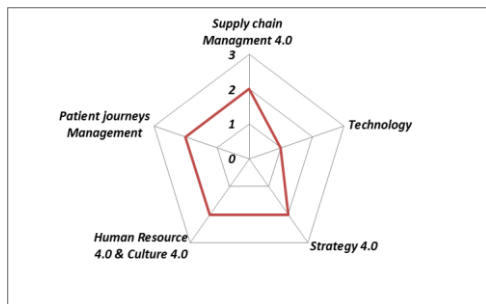

Figure 1. Polar chart for the assessment of the hospital 4.0 Domain and sub-domains-Hospital 1 Levels.
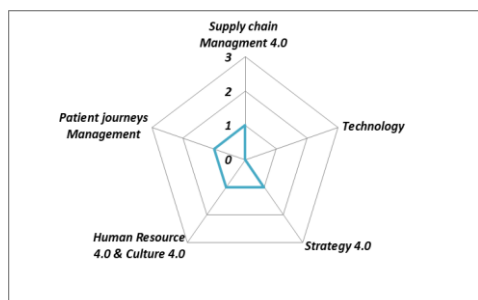

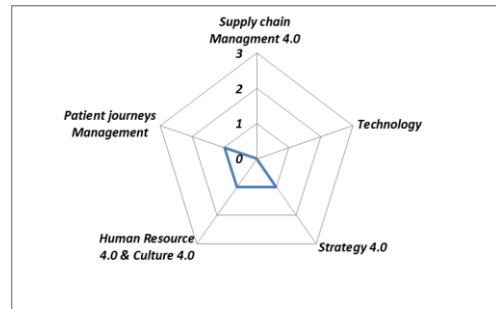Figure 2. Polar chart for the assessment of the hospital 4.0 Domain and sub-domains-- Hospital 2 Levels.

Figure 3. Polar chart for the assessment of the hospital 4.0 Domain and sub-domains -- Hospital 3 Levels.
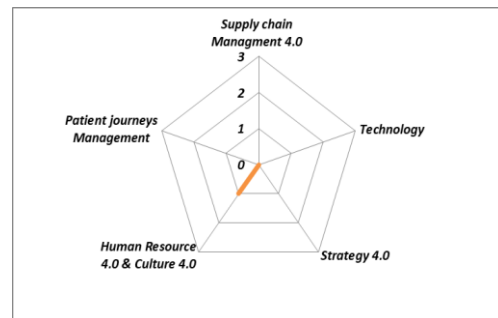

Figure 4. Polar chart for the assessment of the hospital 4.0 Domain and sub-domains -- Hospital 4 Levels.
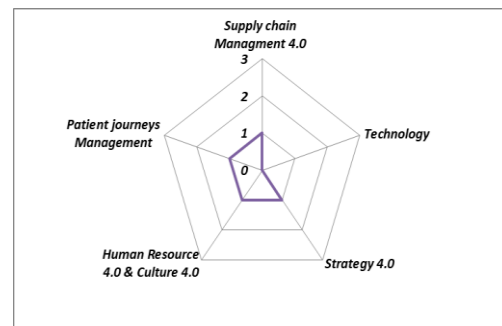

Figure 5. Polar chart for the assessment of the hospital 4.0 domain and sub-domains – Hospital 5 Levels.
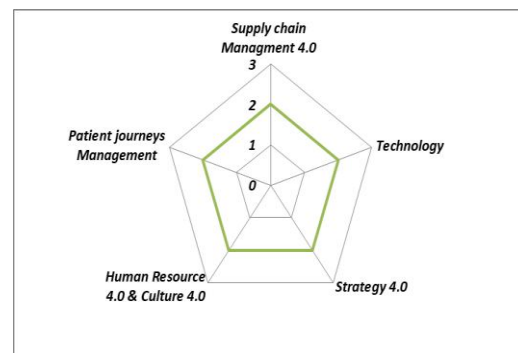

Figure 6. Polar chart for the assessment of the hospital 4.0 domain and sub-domains-Hospital 6 Levels.

IV. CONCLUSION

The Hospital 4.0 Maturity Assessment Model proposed in this paper is a self-assessment model for define current and target states of digital hospital maturity and help public hospitals in their digital transformation.

Compared to existing maturity models, the resulting Hospital 4.0 Maturity Assessment Model implements a holistic approach by considering multiple Industry 4.0 concepts and hospital aspects. The resulting model consisted of 5 domains: Technology, Strategy 4.0, Human resources 4.0 & Culture 4.0, and Supply chain 4.0 Management and Patient journeys management. Each domain is further divided into several sub-domains, totally 34 sub-domains are identified. These sub-domains can be evaluated based on 4 digital hospital maturity levels. The model was validated and applied on the six real-life use cases.

The uses of our model are multiple such as: The diagnosis and analysis of the current situation of the hospitals to provide a structured view of current and target positions; The definition of the current level of maturity, and as a guide through the digital transformation; the evaluation of a hospital's own position against a competitor or a peer (as a benchmarking tool); the identification of dysfunctions, in a hospital and in their internal and external supply chain, that may adversely affect the overall effectiveness of digital transformation efforts.

Finally, although the model was designed for public hospitals as a main actor in the healthcare supply chain, the framework may be of interest to other supply chain, especially those in industries.

APPENDIX A. HOSPITAL 4.0 MATURITY ASSESSMENT MODEL DEVLEPED

Domains	Sub-Domains	Level 0	Level 1	Level 2	Level 3
Supply chain Management 4.0	Blockchain End-to-end Visibility Method, Procedures and Workflows Management Suppliers Relationship Management (SRM) Risk Management Sustainable supply chain	▪ SC Actors don't have full visibility and transparency. ▪ Lack of secure data sharing and access between multiple SC actors. ▪ No formally SRM model is defined. ▪ No collaboration of suppliers in risks management.	▪ Some internal actors have transparency and control over how their data is used in the hospital. ▪ Needs in real time supplier data has been identified. ▪ No formal development model for manage relationships with suppliers.	▪ Data are sharing between internal and external actors of the hospital. ▪ All internal actors have transparency and control over how their data is used in the hospital. ▪ Real time supplier data is available but not used by all the actors.	▪ Data are sharing between internal and external actors of the hospital 4.0. ▪ All internal actors have transparency and control over how their data is used. ▪ Real time supplier data is used to maintain visibility across the SC 4.0. ▪ Standardizations of SRM model for various suppliers.
Technology	Additive Manufacturing Artificial Intelligence Augmented & Virtual Reality Big Data Cloud Computer Cyber security Digital Twin Internet of things (Lot) Robotics & Automation Predictive maintenance Simulation	▪ No technology tools used. ▪ No industrial concepts adapted.	▪ Only standard technology tools used. ▪ The hospital is taking initial steps in digital technology used.	▪ Technology architecture has been implemented. ▪ Some services are being integrated and supported by digital technology and related tools.	▪ Tools of digital technology are implemented and used, and industrial concepts are adapted across the hospital
Strategy 4.0	Care Planning & Control Innovation strategy Digital medical product-service systems Hospital 4.0 roadmap Hospital information system (HIS) integration Monitoring and decision support systems	▪ No explicit ▪ No explicit Hospital 4.0 roadmaps. ▪ Lack of an HIS integration.	▪ The hospital defines an initial digital vision. ▪ Innovation strategy is ▪ Only a simple information system used, no integrate.	▪ Planning to support and implement digital transformation are identified. ▪ The interconnection	▪ A common digital strategy is shared across the hospital. ▪ The Hospital 4.0 roadmaps are developed and drives the hospital direction and investments
Human resources 4.0 & Culture 4.0	Cultural transformation Learning Education & Training Involvement Knowledge	▪ Governance s ▪ The cultural transformation is not part of the values of the hospital.	▪ Governance structure on digital transformation is informally existing.	▪ Governance structure is defined but not fully transparent to all the human resources.	▪ Digital is fully embedded in the hospital 4.0 culture. ▪ The hospital processes and

	Governance structure	▪ Lack of training and education programs.	▪ There are conflicting messages about the importance of digital transformation in the hospital. ▪ Need of training and education programs is identified.	▪ Training programs are being adapted to align with digital strategy. ▪ Digital technologies still cause problem and confusion in use but the staff will succeed with it.	human resources are flexible and easily adapt to changes. ▪ All staff empowered to experiment with digital tools.
Patient journeys Management	Appointment management End-to-end patient experience Patient empowerment Patient's needs Prescriptions and Referrals management	▪ No use of the end-to-end patient experiences for identify existing problem and plan new patient services. ▪ Patient scheduling and appointment & Prescriptions and Referrals management are manual. ▪ Medical records of patients are treated manually. ▪ Patient can't control over decision and actions affecting their health.	▪ The hospital uses only standard IT tools used: MS Office, VBa applications…. To manage patient scheduling, ▪ Patient express the need to control over decision and actions affecting their health. ▪ Patients can be notified by email or phone message.	▪ Patient scheduling, appointment, prescriptions and referrals management are ensured by an HIS. ▪ The hospital use the end to end patient experiences for identify existing problem, improve and plan new patient services. ▪ The digitalization of patient's medical record is supported by a specific team.	▪ Patient portals are used to help patients securely view their health data, consult a healthcare provider, schedule their appointments and have a secure messaging for communication. ▪ Patient can control over decision and actions affecting their health. ▪ Real time access to electronic medical record via patient portals is insured.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Conceptualization, B.T. and A.K.; methodology, B.T.; validation, B.T. and A.K.; formal analysis, B.T.; investigation, B.T.; data curation, B.T.; writing—original draft preparation, B.T. and A.K.; writing—review and editing, B.T. and A.K.; visualization, B.T. All authors had approved the final version.

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