# Blockchain for electronic medical record: assessing stakeholders' readiness for successful blockchain adoption in health-care

Benedetta Nicolai, Salvatore Tallarico, Luisa Pellegrini, Luca Gastaldi, Giacomo Vella and Simone Lazzini

**Abstract**

**Purpose** – *This paper aims to provide a helpful tool for those who plan to implement blockchain-based solutions for the governance of the electronic medical record (EMR) in health-care settings. The goals are to identify each type of stakeholders involved in these projects and to clarify the relevance, to achieve success, of their readiness, intended as availability and ability to adopt blockchain.*

**Design/methodology/approach** – *The chosen methodology is a multiple case study on three initiatives that used blockchain to manage EMRs. This study relied on multiple sources of evidence. The primary data consisted of two rounds of semi-structured interviews with different informants. This study followed a grounded theory approach and performed within- and cross-case analyses.*

**Findings** – *This study identified the types of stakeholders – nodes and not-nodes – of the network and how their readiness level affects the implementation of blockchain-based projects applied to EMR. The nodes (e.g. patients and doctors) are pivotal in making the network working once this has been constructed. Out of the four readiness dimensions suggested by literature, motivational readiness, has the higher impact. Not-nodes stakeholders play a pivotal role in the project's pre-implementation phase. For them, structural readiness is the dimension with the higher relevance.*

**Originality/value** – *To the best of the authors' knowledge, it is the first time that a paper analyses the differences between nodes and not-nodes stakeholders of the blockchain network, in terms not only of type but also of readiness. Identifying the readiness level to implement successful projects is a fundamental step that has never been analysed in the health field.*

**Keywords** *Blockchain, Electronic medical records, Health-care organizations, Digitalization*

**Paper type** *Research paper*

Benedetta Nicolai is based at the Dipartimento di Ingegneria dell'Energia, dei Sistemi, del Territorio e delle Costruzioni, Università di Pisa, Pisa, Italy. Salvatore Tallarico is based at the Dipartimento di Economia e Management, Università di Pisa, Pisa, Italy. Luisa Pellegrini is based at the Dipartimento di Ingegneria dell'Energia, dei Sistemi, del Territorio e delle Costruzioni, Università di Pisa, Pisa, Italy. Luca Gastaldi and Giacomo Vella are both based at Dipartimento di Ingegneria Gestionale, Politecnico di Milano, Milan, Italy. Simone Lazzini is based at the Dipartimento di Economia e Management, Università di Pisa, Pisa, Italy.

## 1. Introduction

Health-care systems are currently trying to reconfigure and innovate their processes to achieve and maintain a continuous balance between quality improvement and cost rationalisation (Porter and Lee, 2013; Gastaldi *et al.*, 2015; AlOmari, 2021; Sharma, 2021). The digital transformation characterising the health-care sector nowadays (Antonacci *et al.*, 2017) offers important research opportunities from this viewpoint (OECD, 2016; Stefanini *et al.*, 2018; Gastaldi *et al.*, 2018).

More specifically, according to a recent report (Deloitte, 2020), electronic medical record (EMR) has a huge potential for boosting both efficiency and effectiveness in health-care delivery (Reina *et al.*, 2012). An EMR is a digital repository of patient data that is shareable within a hospital. Typical EMR systems incorporate features such as a clinical data

Received 31 December 2021
Revised 30 April 2022
Accepted 30 April 2022

repository, computerised patient records, decision support applications, integration with other systems and transaction processing capabilities (*Angst et al.*, 2010).

If EMR has an enormous potential to impact on hospital performance (De Benedictis, 2020), the results of its introduction are often well under expectations (Gastaldi *et al*, 2019). In this context, although there are differences among the requirements objectives, and developmental paths (Gastaldi *et al.*, 2012), there are three main criticalities characterising most of EMRs.

Firstly, the health structures often use not-homogeneous application architectures, even within their operating units, and the data extracted from different devices are heterogeneous. The resulting fragmentation generates inefficient coordination of care, difficulty of EMR interoperability and potential lack of essential information in case of emergency (Zhang *et al.*, 2018a; Yaeger *et al.*, 2019).

Secondly, patient information is generally contained in EMR, mainly organized within centralized systems and, for that reason, vulnerable to a single point of failure and information loss, due to natural disasters or information thefts following cyber-attacks (Yaqoob *et al.*, 2021).

Lastly, current data management systems cannot ensure transparency, reliable traceability, immutability, audit, privacy and security when managing EMR (Yue *et al.*, 2016).

Blockchain is an extremely innovative technology offering a wide range of integrated functions – such as data access flexibility, security, privacy, decentralized storage, transparency, immutability, authentication, disintermediation, verifiability, programmability, interconnection (Omar *et al.*, 2019; Hasselgren *et al.*, 2020) – through which address the three above issues (Chen *et al.*, 2019; Farouk *et al.*, 2020; Gordon and Catalini, 2018; McGhin *et al.*, 2019). It can simplify health data management operations (Islam *et al.*, 2019; Esposito *et al.*, 2018; Syed *et al.*, 2019; Chukwu and Garg, 2020) and allows unprecedented efficiency and interoperability (Balasubramanian *et al.*, 2021).

Indeed, blockchain is a decentralized digital ledger that offers the opportunity to record and share information (Hussien *et al.*, 2019) held through a series of nodes. Any entity connected to the blockchain can be classified as a node. Nodes are a critical component of the infrastructure of a blockchain because they act as further validation for the ledger, allowing anyone to transparently view transactions/data conducted or held on the network and their connection is described by blockchain architecture (Hussien *et al.*, 2019).

Despite the several benefits of blockchain, it is worth noting that the introduction of new and emerging technologies in any sector can rise challenges (Ratta *et al.*, 2021). The literature unison confirms that blockchain requires a strong synergy among stakeholders (Lee *et al.*, 2012). When implementing a blockchain project, it is essential to assess the stakeholders' readiness, i.e. the availability and capacity of the various stakeholders to adopt the new technology – both individually and collectively (Savage *et al.*, 2010).

However, to the best of our knowledge, the literature has neglected one important difference among stakeholders: all blockchain nodes can be stakeholders, but not all stakeholders are, in fact, nodes. This means that not each readiness dimension may be as important for every stakeholder and, hence, that not necessarily all the stakeholders should score high whatever the readiness dimension is analysed. To fill this gap, the research questions of this work are the following:

- Who are the stakeholders involved in the implementation of blockchain-based solutions for the EMR governance? Among them, who are the nodes of the blockchain network?
- How does nodes stakeholders' readiness and not-nodes stakeholders' readiness affect the implementation of blockchain-based projects applied to EMR?
- The paper is structured as follows. Section 2 presents a brief description of the theoretical background, while Section 3 explains the research methodology. The results of this work

are presented in Section 4; Section 5 discusses the implications and presents conclusions and suggestions for further research.

## 2. Background

In contrast to the current solutions for implementing the EMR, blockchain provides several potential improvements directly related to its architectural properties, such as data security, traceability and automation (Hasan *et al.*, 2021; Beinke *et al.*, 2019; McGhin *et al.*, 2019; Przhedetskiy *et al.*, 2019).

The literature has extensively investigated the benefits that blockchain can bring to the health-care sector (Badr *et al.*, 2018; Zhang *et al.*, 2018b; Kuo *et al.*, 2017). However, so far it has not focused enough on issues concerning the involvement of stakeholders in the projects' pre-implementation phase and on the motivational, ethical, technological, environmental and economical aspects that might affect their correct implementation (Beinke *et al.*, 2019). In this regards, two are the main issues.

Firstly, it is necessary to identify the stakeholders involved in this type of project. In particular, for blockchain-based projects, it should be remembered that the nodes represent the fundamental basis of the blockchain network. The importance of nodes within the blockchain infrastructure also lies in the role of ledger validators they assume (Hussien *et al.*, 2019). The typical nodes in the EMR management context include physicians, caregivers and nurses, therapists, pharmacists, clinics and hospitals, laboratories, care service and nursing homes, and patients (Beinke *et al.*, 2019). Each node wants to ascertain that data is secure, trusted and efficiently processed within a comprehensive, single, complete medical history (Burke, 2018).

Nevertheless, in addition to nodes, previous studies in health care have highlighted a plurality of stakeholders relevant for implementing blockchain-based solutions. For instance, governmental bodies (Bell *et al.*, 2018; Dhagarra *et al.*, 2019), business entities (Radanovíc and Likíc, 2018), regulatory bodies (Nugent *et al.*, 2016) and service providers (Kuo *et al.*, 2017) have sometimes been included as stakeholders.

However, while recognising the diversity in terms of type and interests between the involved actors, the literature identifies a wide spectrum of actors as stakeholders, without distinguishing whether they are nodes or not-nodes of the blockchain network. For instance, in a patient-centric project aimed at improving clinical record management, both the patients – i.e. the owners of clinical data – and hospitals – i.e. data managers – are undoubtedly stakeholders and nodes of the blockchain network. Conversely, even if recognised as a stakeholder aiming at both ensuring the privacy of its citizens and improving process efficiency, the government is not necessarily a node in the network.

Secondly, it is also necessary to consider the stakeholders' readiness for the proper implementation of blockchain-based projects (Ozturan *et al.*, 2019). Readiness is defined as the willingness of an actor to cope with a situation and perform a sequence of actions (Handayani *et al.*, 2021).

In the health-care sector, readiness refers to the willingness of stakeholders to anticipate changes brought by digital transformation (Khoja *et al.*, 2007). Furthermore, it is essential to evaluate the adoption of new solutions not only to save time and money but also to prepare a better architecture for future technological developments (Handayani *et al.*, 2021). With the readiness factor, the developers of blockchain-based solution can determine how the system should be developed or updated to suit the capabilities and characteristics of its users (Khatun *et al.*, 2015).

Focusing on the health-care context, Balasubramanian *et al.* (2021) suggest considering four different dimension of readiness – motivational, engagement, technological and

structural – and highlight their different impacts on the effectiveness of blockchain implementation.

Motivational readiness shows stakeholders' willingness to act to achieve a desire or goal (Kruglanski *et al.*, 2014) and it is necessary to appropriately address the changes concerning an existing service or circumstance (for instance, in clinical data management, the need to overcome problems related to the quality of service or privacy) (Balasubramanian *et al.*, 2021).

Engagement readiness gauges how much stakeholders can become aware of blockchain, are inclined to prefer blockchain-based solutions and actively debate the perceived blockchain benefits and adverse effects (Mauco *et al.*, 2019). Engagement readiness refers to the knowledge of new solutions and the explicit recognition of their benefits and potential challenges (Balasubramanian *et al.*, 2021). For blockchain, this includes knowing how to achieve results, the potential risks of current systems, the potential benefits, the difficulties associated with development costs and the risks of failure.

Technological readiness is the individual or organizational predisposition to embrace new technologies. Factors contributing to this type of engagement include, for instance, the availability and compatibility of existing hardware, software, networks, applications and other digital resources that facilitate the new technology (Khatun *et al.*, 2015; Mauco *et al.*, 2019; Balasubramanian *et al.*, 2021).

Structural readiness refers to the availability of not-technical resources – mostly temporal, financial and human – to be invested in adopting new processes or technologies (Snyder-Halpern, 2002; Balasubramanian *et al.*, 2021). Indeed, implementing blockchain requires valuable resources, such as time, money and people.

The relationship between the various kinds of readiness and the types of stakeholders involved in the implementation of blockchain-based projects – nodes or not-nodes – is essential in many regards:

- for defining the key stakeholders responsible for adopting the technology (Siyal *et al.*, 2019);
- for testing their technical knowledge and their awareness of the benefits and challenges related to the introduction of blockchain (Balasubramanian *et al.*, 2021); and
- for assisting each specific stakeholder in her decision-making regarding blockchain adoption (Vlachos *et al.*, 2019).

This is especially true in the health care because there are many different types of stakeholders, and the success of blockchain implementation is determined by the willingness of each of them to accept this new technology (Chukwu and Garg, 2020). However, the scientific debate does not indicate the level of readiness of each involved stakeholder (Razmi *et al.*, 2009) and this approach may not offer a comprehensive view (Li *et al.*, 2012). In addition, in the literature, we have only encountered three studies evaluating the readiness for blockchain adoption (Ozturan *et al.*, 2019; Vlachos *et al.*, 2019; Balasubramanian *et al.*, 2021), and only one of them in health care (Balasubramanian *et al.*, 2021). Therefore, we have scant evidence on the readiness levels of specific stakeholders that are necessary to provide the optimal conditions for blockchain-based EMR (Beinke *et al.*, 2019).

On a practical level, the lack of this information translates into the absence of tools to support health-care actors interested in creating data management solutions through the implementation of blockchain. Furthermore, systems that support information sharing involve various stakeholders with often conflicting interests. Failure to break down these

stakeholders into nodes and not-nodes could make the readiness assessment process inaccurate, hindering blockchain adoption.

## 3. Methodology

### *3.1 Case selection*

This paper deepens how the various readiness of nodes and not-nodes stakeholders affect the successful implementation of blockchain solution in governing EMR. As the knowledge in these domains is still limited, it becomes crucial to gather data by those people that are facing the phenomenon under investigation (Gioia *et al.*, 2013) "within its real-life context" (Yin, 2013). Thus, due to the phenomenon-driven (Eisenhardt and Graebner, 2007) nature of the research purpose, we performed a multiple, exploratory case study (Yin, 2013).

As a starting point for case selection, we used a database of initiatives developed worldwide since 2017. The database has been constructed within the research conducted by XXX (*details omitted for anonymous reviews*), an applied think tank in which two of the authors of the paper serve. Starting from this database, at the beginning of 2021 we selected multiple cases adopting a theoretical sampling (Eisenhardt, 1989) based on the following criteria. Firstly, we decided focusing on projects that concerned the application of blockchain to EMR. Then, to ensure a good integrity of evidence, we decided deepening only the projects that went beyond the simple phase of announcement to show real applications. The final sample resulted in five initiatives worldwide, testifying the novelty of the topic. Finally, we contacted the manager supervising each initiative, asking for his/her availability to be interviewed. The selection process ended with the identification of three cases, resumed in Table 1.

Hypertrust X-Chain is a blockchain-based, patient-centred solution suitable for personalized treatments (autologous cell therapy). The system provides an end-to-end solution to automate, streamline and secure the supply chain for customized treatments, and inform interested parties about upcoming auctions.

SAFE is a platform born from the "MedTech Acceleration" program of Maio Clinic and Arizona State University. Currently used for COVID-19, it was designed to diagnose and monitor sexually transmitted diseases and some common ailments. The platform connects patients, doctors and test providers through HealthCheck, an advanced smartphone and desktop application, which allows verification of vaccination status. SAFE has relied on Hedera Hashgraph, a distributed ledger technology evolving from blockchain, which offers the same benefits as blockchain without some of its limits.

Medicalchain is a platform built in 2018, allowing the safe and fast exchange and use of medical data, without compromising patients' privacy, thanks to asymmetric encryption. Health-care professionals, doctors, hospitals, laboratories, pharmacists and insurance companies can request permission to access and interact with medical records. The platform is based on the Hyperledger Fabric architecture and, through permissions, allows different access levels, with the patients directly controlling who can access which records and how long.

**Table 1** Summary of cases

| *Case* | *SAFE* | *MedicalChain* | *Hypertrust X-Chain* |
|---|---|---|---|
| Geographical area | USA | UK | Germany |
| Maturity level | Operative | Operative | Operative |
| Process | Data and document management | Data and document management | Data and document management |
| Blockchain reference | Hedera Hashgraph | Hyperledger Fabric | Hypertrust X-Chain |
| Access typology | Permissionless | Permissioned | Permissioned |

### 3.2 Data collection

To limit potential biases (Eisenhardt and Graebner, 2007) and gather stronger insights (Eisenhardt, 1989), we relied on multiple sources of evidence: as summarized in Table 2, we drawn on primary data, namely, semi-structured interviews, and secondary data, such as reports and policy documents, online news-articles and websites.

The primary data consisted of two rounds of semi-structured interviews (overall six) with three different informants, conducted between April 2021 and November 2021. For all cases, the first interview was with the manager supervising the blockchain project.

Firstly, we began the interviews by asking informants to briefly describe the project and to summarize the reasons and objectives behind blockchain application to EMR. These questions allowed us to identify the main features of each project, such as the services delivered, the functioning, the incentives and benefits of blockchain for data management, the role of the stakeholders engaged in its implementation and their readiness.

Data were simultaneously collected and analysed. This cyclical process allowed to gather new information based on the evidence arisen from previous interviews (Gioia *et al.*, 2010) and, following where the informants led us, we adjusted the protocol during the research. Therefore, the research increasingly focused on the role of stakeholders' readiness in blockchain-based project implementation. After this first round of interviews (one for each project), to achieve a higher "representativeness and consistency" (Corbin and Strauss, 1990) of the observations, we contacted the same managers, focusing on the number, type and role of stakeholders involved in the projects. In addition, they were asked to identify which readiness dimensions were considered a prerequisite – in the pre-implementation phase – for proper project implementation and to assess – during the operative phase – the achieved level of all dimensions (even those not considered a prerequisite) of readiness required to bring the project to success.

Each interview lasted at least one hour, was conducted using online tools (Microsoft Teams, Skype) by two of the authors, and was recorded and transcribed verbatim. The first two authors cross-checked data and shared their initial ideas (Bourgeois and Eisenhardt, 1988). The rest of the research team critically reviewed the observations. This approach allowed maintaining a high-level perspective (Gioia *et al.*, 2013).

Potential information bias was addressed in different ways. Firstly, all informants have been assured anonymity (Eisenhardt, 1989). Secondly, informants with diverse perspectives and roles were considered (Ozcan and Eisenhardt, 2009). Lastly, the interviews were complemented with archival and observational data (Bingham and Eisenhardt, 2011).

**Table 2** Data sources

| *Case* | *Primary data* | *Secondary data* |
|---|---|---|
| SAFE | 2 semi-structured interviews with the Chief Technology Officer of the Company | • Company website<br>• Company blog articles<br>• Press articles<br>• YouTube videos |
| MedicalChain | 2 semi-structured interviews with the Chief Executive Officer of the Company and project co-founder | • Company website<br>• Whitepapers<br>• Online articles<br>• YouTube videos |
| Hypertrust X-Chain | 2 semi-structured interviews with the Head of Innovation of the Company | • Company website<br>• Whitepapers<br>• Press articles |

### 3.3 Data analysis

The methodology adopted for data analysis followed the grounded theory approach (Glaser and Strauss, 1967). According to the recommendations for multiple case study theory building, within-case and cross-case analyses were performed (Eisenhardt, 1989; Eisenhardt and Graebner, 2007). The first and the second authors started by individually analysing the primary data, and triangulated these with secondary sources (Jick, 1979). Then, adopting an inductive approach (Saldaña, 2013), we coded the interviews to identify the preliminary concepts.

We then moved to a cross-case search, using replication logic across cases and clustering codes together in second-order themes. As suggested by Gioia *et al.* (2013), if all the researchers did not completely agree, we revised the analysis until we reached a consensus and we then defined the aggregate dimensions.

Once the cross-case analysis was ongoing, we cycled between case data, emerging concepts and dimensions and the academic literature to refine the emerging construct definitions, abstraction levels, construct measures and theoretical relationships (Gilbert, 2005). To converge on a parsimonious set of constructs, the authors focused only on the most robust findings (Andriopoulos and Lewis, 2009).

## 4. Results

During the interviews, informants confirmed that not all stakeholders were blockchain nodes and the substantial difference among the three projects is to be found in the number and type of nodes that make up the blockchain network. In SAFE, the network's nodes are mainly represented by laboratories, patients and physicians. In MedicalChain, hospitals are included as well, but there are not the laboratories, while in Hypertrust X-Chain, the network becomes even more extensive, incorporating a series of further stakeholders that concern, for instance, the drug supply chain.

Firstly, interviewees were asked which dimensions of readiness are prerequisites for implementing blockchain-based projects in the early stage. Furthermore, they provided a qualitative classification of readiness levels in low, medium or high. Figures 1–3 report these information for the three cases.

For cases that have identified hospitals as stakeholder nodes (MedicalChain and Hypertrust X-Chain), both motivational and technological readiness are judged as prerequisites. In both cases, the interviewees rated these two types of readiness at a medium level. This assessment is undoubtedly linked, on the one hand, to the strong urge for hospitals to improve the data management system, in terms of interoperability and safety (motivational readiness), and on the other hand, to the fact that, to implement blockchain-based projects, it is necessary to have adequate technological infrastructures (technological readiness).

For all three cases, the motivational readiness of patients and physicians, who are node-stakeholders, is considered as a prerequisite and evaluated, in most cases, high. This is due both to the need of patients to improve/resolve the pathology-related critical issues, and to physicians necessity of knowing the patients' complete clinical history, currently fragmented, to formulate appropriate diagnoses, as highlighted by the following quotes:

> *Physicians see a lot of issues, you know, with the current way things are done and it's inefficient and they don't get to have enough time and patience and things. So, physicians will be high, I think, and the patients are also high because, you know, mainly because of cost and inefficiency. (SAFE Chief Technology Officer)*

> *It's very frustrating when you are seeing the patient in your clinic and you don't have all of their medical information in front of you, because you are limited by what you have on your computer, but your computer doesn't show you when they went to this hospital or this clinic or spoke to this*

**Figure 1** Readiness assessment for SAFE solution

| | Stakeholder | Motivational readiness | Engagement readiness | Structural readiness | Technological readiness |
|---|---|---|---|---|---|
| Node | Physicians | ● * | ○ | ○ * | ● |
| | Patients | ● * | ○ * | ○ | ● |
| | Laboratories | ◑ | ○ | ◑ * | ◑ * |
| Not-node | Insurances | ● | ◑ | ◑ * | ◑ |
| | Care service and nursing homes | ● | ○ | ○ * | ● * |
| | Employers** | ● | ◑ * | ◑ | ◑ |
| | Blockchain providers | ● | ● | ● * | ● * |
| | Public authorities | ● | ◑ * | ○ * | ● |

**Notes:** ○ = low readiness; ◑ = medium readiness; ● = high readiness; * = dimension of readiness assessed as a prerequisite; ** = in this specific case the application is also used to certify the employee's state of health to return to work

**Figure 2** Readiness assessment for Medicalchain solution

| | Stakeholder | Motivational readiness | Engagement readiness | Structural readiness | Technological readiness |
|---|---|---|---|---|---|
| Node | Hospitals | ◑ * | ◑ | ○ | ◑ * |
| | Physicians | ● * | ○ | ◑ * | ○ |
| | Patients | ● * | ◑ * | ● | ● |
| Not-node | Laboratories | ● | ○ | ◑ * | ○ * |
| | Caregivers and nurses | ● * | ○ | ◑ * | ◑ |
| | Family and relatives | ● * | ● | ● | ● |
| | Blockchain providers | ● | ● | ● * | ● * |
| | Research institutes | ● | ● | ● * | ● * |
| | Public authorities | ◑ | ○ * | ○ * | ○ |

**Notes:** ○ = low readiness; ◑ = medium readiness; ● = high readiness; * = dimension of readiness assessed as a prerequisite

*doctor, so we want to create systems where the patients can carry the medical records with them, so, when they come to the appointment, they can just share their medical records with them and the physicians can review it on their computer, they can see everything and they add their consultation. (Medicalchain Chief Executive Officer)*

**Figure 3** Readiness assessment for Hypertrust X-Chain solution

| | Stakeholder | Motivational readiness | Engagement readiness | Structural readiness | Technological readiness |
|---|---|---|---|---|---|
| Node | Hospitals | ◑ * | ◑ | ◑ | ◑ * |
| | Physicians | ◑ * | ◑ | ○ | ○ |
| | Patients | ● * | ○ | ○ | ○ |
| | Laboratories | ◑ | ○ | ◑ | ○ * |
| | Pharmacists | ◑ | ○ | ◑ | ○ * |
| | Drug supply chain | ● * | ● | ● | ● |
| Not-node | Caregivers and nurses | ◑ * | ◑ * | ○ | ○ |
| | Therapists | ○ | ○ * | ◑ * | ○ |
| | Insurances | ○ | ○ | ○ * | ○ |
| | Blockchain providers | ● | ● | ◑ * | ● * |
| | Research institutes | ● | ● | ◑ * | ◑ * |

**Notes:** ○ = low readiness; ◑ = medium readiness; ● = high readiness;
* = dimension of readiness assessed as a prerequisite

The structural readiness of physicians is evaluated as a prerequisite because, in the preliminary phase, the medical staff must make available their resources (especially in terms of time) to understand and therefore use the full potential of blockchain. The reason why the structural readiness was rated low is the absence of resources to allocate to other projects that are not strictly related to patient care. Only after presenting an effective useful solution, physicians become well disposed towards blockchain, because they understand its benefits.

The engagement readiness, considered a prerequisite for some stakeholders (patients, caregivers and nurses, therapists, employers and public authorities), was classified as medium-low. This refers to the fact that blockchain solutions are still scarcely known in health-care. For this reason, the interviewees highlighted how it was necessary to carry out training courses to increase the awareness of the potential benefits associated with blockchain. As highlighted in Hypertrust X-Chain case:

> *For therapists it is low, according to our research, actually, there is not much, much pressure to change. But when a useful solution comes up and when they are instructed to make the most of its benefits, then they always feel good about having it. (Hypertrust X-Chain Head of Innovation)*

The cases agree in attributing a prerequisite role to the structural and technological readiness of laboratories, which was assessed as low because laboratories are not technologically equipped to use blockchain solutions. However, the level of structural readiness, classified as medium, guarantees sufficient resources to make up for this technological deficiency.

As far as caregivers and families are concerned, the dimension of readiness that was assessed as a prerequisite and high is mainly the motivational one. This is related to the fact that they need a safe solution able both to monitor the patient's health status and make decisions about therapies and care in his/her place in case of need.

Pharmacists and the drug supply chain are stakeholders nodes for Hypertrust X-Chain only. If the link with all dimensions of readiness is medium-low for the former, it is always high for the latter. Indeed, drug supply chain is interested in being ready and available to embrace new technologies and projects, keeping up with customer needs.

The structural readiness of insurances and public authorities are assessed as a prerequisite and low. For the insurances, it is not necessary to intervene to increase the level of the structural readiness because they do not have an active role in the implementation of blockchain-based projects. However, the opposite is true for the public authorities, who can unlock resources to be allocated to projects useful for the community. Triggers for increasing structural readiness level are not limited to simple training courses, but are also connected to environmental circumstances. An example is, for the SAFE case, COVID-19, which prompted the public authorities, whose structural readiness is both assessed as a prerequisite and low, to actively collaborate, find resources and remove the stakes to implement effective solutions in the shortest possible time. Another example is the WannaCry cyberattack, which directly involved 48 hospitals in the UK, raising the awareness of the national public authorities to support innovative projects aimed at data protection more decisively, as in the case of MedicalChain. Under normal conditions, the structural readiness is low. However, in these cases, unusual circumstances have created urgency and accelerated the implementation of innovative solutions such as blockchain, as highlighted by SAFE project manager:

> *But in our case with SAFE app, I remember with covid last year, everything was expedited or still is very expedited. So, the government is very, very motivated, you know, so motivated to do things and is reaching out to private organizations. And there's definitely more, you know, more of a kind of a sense of urgency. (SAFE Chief Technology Officer)*

As regards the blockchain providers, the three cases attribute all the types of readiness a high value, even when the respective dimension is not relevant (specifically motivational readiness and engagement readiness).

MedicalChain co-founder pointed out that a high level of technological readiness is assessed as a prerequisite in the early stage, but, actually, it is not a discriminating factor for implementing blockchain-based solutions. However, at an early stage, a low level of technological readiness cannot be considered an insurmountable obstacle because all hospitals within the same health system have potentially the same resources available to obtain an adequate technological level.

Finally, it is essential to underline that the technological readiness is the most complex of all readiness dimensions because there are multiple factors to consider, ranging from the digital skills of each stakeholder to the willingness to learn how using new solutions, up to pure technological complexity. For this reason, it is necessary distinguishing among the three cases. In the case of SAFE, the technological readiness of the stakeholders deemed as a prerequisite was classified as medium-high, because the solution relies on a user-friendly interface, so users (patients, medical and laboratory staff, and employers) are only required to use a smartphone; therefore, their technological readiness rates high. In the Hypertrust X-Chain case, in which both the number of nodes and the technological complexity are higher, the detected level of readiness is medium and only in the case of blockchain providers, high. Rather, in the MedicalChain case, the level of complexity is medium and the categorization of technological readiness for stakeholders is mainly medium-high and, only in one case, low.

## 5. Discussion and conclusions

The aim of this study is to provide a helpful tool for approaching blockchain-based projects in healthcare, with an emphasis on EMR. In addition, we propose to fill a gap in the literature which so far has not analysed the impact of nodes and not-nodes stakeholders' readiness on the implementation of blockchain projects.

From a theoretical viewpoint, our qualitative analysis confirmed what already highlighted by the scientific literature, i.e. the pivotal role readiness plays in implementing blockchain-based projects (Li *et al.*, 2012; Khatun *et al.*, 2015; Balasubramanian *et al.*, 2021; Handayani *et al.*, 2021). Blockchain is effective if key stakeholders involved in its introduction are ready and willing to use it. Being blockchain not owned by a single independent entity, all stakeholders must be part of the chain with a specific role. On this point our article makes a contribution by dividing the stakeholders between nodes and not-nodes. Specifically, the not-nodes are mostly the stakeholders who have a more active part in the project's pre-implementation phase, when technological and infrastructural investments, as well as cultural changes assume a critical role. Among them, we find the blockchain providers, the research institutes and government, which work together to develop solutions through which improving the quality of health-care. In contrast, the nodes play an essential role in making the network work, once it has been constructed. Among the nodes, we find entities such as patients and doctors who are the end-users of this solution.

The three investigated cases started unveiling how the readiness of each stakeholder, node or not-node, affects the implementation of blockchain-based projects applied to EMR. This step is crucial because it clarifies, on the one hand, which readiness dimensions must be considered before implementing a blockchain-based solution and, on the other, how the level of readiness of the involved actors can facilitate or hinder the implementation of these projects. Because the cases presented are successful, the interviewers' categorisation of readiness levels could be deemed a sort of "requirements level" necessary for an implementation to be successful.

Our study showed that the dimension of readiness that has the higher weight for not-nodes stakeholders is structural readiness. This result is connected to the active role that not-nodes play in the blockchain pre-implementation phase. A lack of resources is an obstacle to the effective implementation of the network.

Instead, as regards not-nodes stakeholders, motivational readiness is very significant when blockchain-based solutions are in place. Indeed, when users consider new applications that appear to help improving health-care quality, their readiness to adopt these applications will increase (Grandison and Sloman, 2000). This result is relevant, as the stakeholder nodes are the crucial entities of the blockchain network and will be the end-users of the applications. Therefore, the perceived usefulness of using the blockchain directly impacts the implementation of these solutions.

A low level of some dimensions of readiness, judged as a prerequisite in the early stage, could not hinder the implementation of blockchain-based solutions irrevocably. Actually, it is essential to increase or maintain at a sufficiently high level in the pre-implementation phase. On the one hand, the motivational readiness of the network nodes that are the solution end-users; on the other, the structural and technological readiness of not-nodes that play a role, active in implementing the project.

The main limitation of this work is related to the qualitative feature of the research that however is motivated by the small number of successful cases of blockchain-based projects in health care implemented so far globally. However, during the selection of the case studies, two other cases were identified which are in the operational stage, as far as we know:

- the UAE's Health Ministry's new blockchain platform (Peng, 2020); and
- the Department of Health and Human Services' blockchain-powered acquisition system (GCN Staff, 2018).

It could be interesting to either broaden the investigation, analyse these cases or gather more information with other interviews from the cases analysed in this paper.

## References


AlOmari, F. (2021), "Measuring gaps in healthcare quality using SERVQUAL model: challenges and opportunities in developing countries", *Measuring Business Excellence*, Vol. 25 No. 4, pp. 407-420.

Andriopoulos, C. and Lewis, M.W. (2009), "Exploitation-exploration tensions and organizational ambidexterity: managing paradoxes of innovation", *Organization Science*, Vol. 20 No. 4, pp. 696-717.

Angst, C.M., Agarwal, R., Sambamurthy, V. and Kelly, K. (2010), "Social contagion and information technology diffusion: the adoption of electronic medical records in US hospitals", *Management Science*, Vol. 56 No. 8, pp. 1219-1241.

Antonacci, G., Fronzetti Colladon, A., Stefanini, A. and Gloor, P. (2017), "It is rotating leaders who build the swarm: social network determinants of growth for healthcare virtual communities of practice", *Journal of Knowledge Management*, Vol. 21 No. 5, pp. 1218-1239.

Badr, S., Gomaa, I. and Abd-Elrahman, E. (2018), "Multi-tier blockchain framework for IOT-EHRS systems", *Procedia Computer Science*, Vol. 141, pp. 159-166.

Balasubramanian, S., Shukla, V., Sethi, J.S., Islam, N. and Saloum, R. (2021), "A readiness assessment framework for blockchain adoption: a healthcare case study", *Technological Forecasting and Social Change*, Vol. 165, p. 120536.

Beinke, J.H., Fitte, C. and Teuteberg, F. (2019), "Towards a stakeholder-oriented blockchain-based architecture for electronic health records: design science research study", *Journal of Medical Internet Research*, Vol. 21 No. 10, p. e13585.

Bell, L., Buchanan, W.J., Cameron, J. and Lo, O. (2018), "Applications of blockchain within healthcare", *Blockchain Healthcare Today*, Vol. 1, pp. 1-7.

Bingham, C. and Eisenhardt, K.M. (2011), "Rational heuristics: the 'simple rules' that strategists learn from process experience", *Strategic Management Journal*, Vol. 32 No. 13, pp. 1437-1464.

Bourgeois, L.J. and Eisenhardt, K.M. (1988), "Strategic decision processes in high velocity environments: four cases in the microcomputer industry", *Management Science*, Vol. 34 No. 7, pp. 816-835.

Burke, T. (2018), "The essential diversity of Blockchain Nodes – IEEE Blockchain Initiative Briefs", available at: https://blockchain.ieee.org/technicalbriefs/december-2018/the-essential-diversity-of-blockchain-nodes

Chen, L., Lee, W., Chang, C., Choo, K.R. and Zhang, N. (2019), "Blockchain based searchable encryption for electronic health record sharing", *Future Generation Computer Systems*, Vol. 95, pp. 420-429.

Chukwu, E. and Garg, L. (2020), "A systematic review of blockchain in healthcare: frameworks, prototypes, and implementations", *IEEE Access*, Vol. 8, pp. 21196-21214.

Corbin, J.M. and Strauss, A. (1990), "Grounded theory research: procedures, canons, and evaluative criteria", *Qualitative Sociology*, Vol. 13 No. 1, pp. 3-21.

De Benedictis, A., Lettieri, E., Masella, C., Gastaldi, L., Macchini, G., Santu, C. and Tartaglini, D. (2020), "Electronic medical record implementation in hospital: an empirical investigation of individual and organizational determinants", *Plos One*, Vol. 15 No. 6, pp. 1-12.

Deloitte (2020), "Digital transformation: shaping the future of European healthcare", available at: www2.deloitte.com/content/dam/Deloitte/nl/Documents/public-sector/deloitte-nl-shaping-the-future-of-european-healthcare.pdf

Dhagarra, D., Goswami, M., Sarma, P.R.S. and Choudhury, A. (2019), "Big data and blockchain supported conceptual model for enhanced healthcare coverage", *Business Process Management Journal*, Vol. 25 No. 7, pp. 1612-1632.

Eisenhardt, K.M. (1989), "Building theories from case study research", *The Academy of Management Review*, Vol. 14 No. 4, pp. 532-550.

Eisenhardt, K.M. and Graebner, M.E. (2007), "Theory building from cases: opportunities and challenges", *Academy of Management Journal*, Vol. 50 No. 1, pp. 25-32.

Esposito, C., De Santis, A., Tortora, G., Chang, H. and Choo, K.R. (2018), "Blockchain: a panacea for healthcare cloud-based data security and privacy?", *IEEE Cloud Computing*, Vol. 5 No. 1, pp. 31-37.

Farouk, A., Alahmadi, A., Ghose, S. and Mashatan, A. (2020), "Blockchain platform for industrial healthcare: vision and future opportunities", *Computer Communications*, Vol. 154, pp. 223-235.

Gastaldi, L., Lettieri, E., Corso, M. and Masella, C. (2012), "Performance improvement in hospitals: leveraging on knowledge asset dynamics through the introduction of an electronic medical record", *Measuring Business Excellence*, Vol. 16 No. 4, pp. 14-30.

Gastaldi, L., Pistorio, A., Appio, F.P. and Corso, M. (2018), "Managing the exploration-exploitation paradox in healthcare: three complementary paths to leverage on digital transformation", *Business Process Management Journal*, Vol. 24 No. 5, pp. 1200-1234.

Gastaldi, L., Mangiaracina, R., Miragliotta, G., Tumino, A. and Perego, A. (2015), "Measuring the benefits of tracking medical treatment through RFId", *International Journal of Productivity and Performance Management*, Vol. 64 No. 2, pp. 175-193.

Gastaldi, L., Radaelli, G., Lettieri, E., Luzzini, D. and Corso, M. (2019), "Professionals' use of ICT in hospitals: the interplay between institutional and rational factors", *International Journal of Technology Management*, Vol. 80 Nos 1/2, pp. 85-106.

Gilbert, C.G. (2005), "Unbundling the structure of inertia: resource versus routine rigidity", *Academy of Management Journal*, Vol. 48 No. 5, pp. 741-763, doi: 10.5465/amj.2005.18803920.

Gioia, D.A., Corley, K.G. and Hamilton, A.L. (2013), "Seeking qualitative rigor in inductive research: notes on the Gioia methodology", *Organizational Research Methods*, Vol. 16 No. 1, pp. 15-31.

Gioia, D.A., Price, K.N., Hamilton, A.L. and Thomas, J.B. (2010), "Forging an identity: an insider-outsider study of processes involved in the formation of organizational identity", *Administrative Science Quarterly*, Vol. 55 No. 1, pp. 1-46.

Glaser, B.G. and Strauss, A.L. (1967), *The Discovery of Grounded Theory: Strategies for Qualitative Research*, Aldine, Chicago (IL).

Gordon, W.J. and Catalini, C. (2018), "Blockchain technology for healthcare: facilitating the transition to patient-driven interoperability", *Computational and Structural Biotechnology Journal*, Vol. 16, pp. 224-230.

Grandison, T. and Sloman, M. (2000), "A survey of trust in internet application", *IEEE Communications Surveys & Tutorials*, Vol. 3 No. 4, pp. 2-16.

Handayani, P.W., Rima, I. and Pinem, A.A. (2021), "Mobile health readiness factors: from the perspectives of mobile health users in Indonesia", *Informatics in Medicine Unlocked*, Vol. 24, p. 100590.

Hasan, Q.H., Yassin, A.A. and Ata, O. (2021), "Electronic health records system using blockchain technology", *Webology*, Vol. 18 No. SI05, pp. 580-593.

Hasselgren, A., Kralevska, K., Gligoroski, D., Pedersen, S.A. and Faxvaag, A. (2020), "Blockchain in healthcare and health sciences: a scoping review", *International Journal of Medical Informatics*, Vol. 134.

Hussien, H.M., Yasin, S.M., Udzir, S.N.I., Zaidan, A.A. and Zaidan, B.B. (2019), "A systematic review for enabling of develop a blockchain technology in healthcare application: taxonomy, substantially analysis, motivations, challenges, recommendations and future direction", *Journal of Medical Systems*, Vol. 43 No. 10.

Islam, N., Faheem, Y., Din, I.U., Talha, M., Guizani, M. and Khalil, M. (2019), "A blockchain-based fog computing framework for activity recognition as an application to e-healthcare services", *Future Generation Computer Systems*, Vol. 100, pp. 569-578.

Jick, T.D. (1979), "Mixing qualitative and quantitative methods: triangulation in action", *Administrative Science Quarterly*, Vol. 24 No. 4, pp. 602-611.

Khatun, F., Heywood, A.E., Ray, P.K., Hanifi, S., Bhuiya, A. and Liaw, S.T. (2015), "Determinants of readiness to adopt mHealth in rural community of Bangladesh", *International Journal of Medical Informatics*, Vol. 84 No. 10, pp. 847-856.

Khoja, S., Scott, R.E., Casebeer, A.L., Mohsin, M., Ishaq, A.F.M. and Gilani, S. (2007), "E-health readiness assessment tools for healthcare institutions in developing countries", *Telemedicine and e-Health*, Vol. 13 No. 4, pp. 425-431.

Kruglanski, A.W., Chernikova, M. and Schori-Eyal, N. (2014), "From readiness to action: how motivation works", *Polish Psychological Bulletin*, Vol. 45 No. 3, pp. 259-267.

Kuo, T.T., Kim, H.E. and Ohno-Machado, L. (2017), "Blockchain distributed ledger technologies for biomedical and health care applications", *Journal of the American Medical Informatics Association*, Vol. 24 No. 6, pp. 1211-1220.

Lee, S.M., Olson, D.L. and Trimi, S. (2012), "Co-innovation: convergenomics, collaboration, and co-creation for organizational values", *Management Decision*, Vol. 50 No. 5, pp. 817-831.

Li, J., Ray, P., Seale, H. and MacIntyre, R. (2012), "An E-health readiness assessment framework for public health services–pandemic perspective", in *Proceedings of 45th HI International Conference on System Sciences, IEEE*, pp. 2800-2809.

McGhin, T., Choo, K.K.R., Liu, C.Z. and He, D. (2019), "Blockchain in healthcare applications: research challenges and opportunities", *Journal of Network and Computer Applications*, Vol. 135, pp. 62-75.

Mauco, K.L., Scott, E.R. and Mars, M. (2019), "Development of an eHealth readiness assessment framework for Botswana and other developing countries: interview study", *JMIR Medical Informatics*, Vol. 7 No. 3, p. e12949.

Nugent, T., Upton, D. and Cimpoesu, M. (2016), "Improving data transparency in clinical trials using blockchain smart contracts", *F1000Research*, Vol. 5, p. 2541.

OECD (2016), "Health at a glance: Europe 2016 – state of health in the EU cycle", available at: www.oecd.org/health/health-systems/health-at-a-glance-europe-23056088.htm

Omar, A., Bhuiyan, M.Z., Basu, A., Kiyomoto, S. and Rahman, M.S. (2019), "Privacy-friendly platform for healthcare data in cloud based on blockchain environment", *Future Generation Computer Systems*, Vol. 95, pp. 511-521.

Ozcan, P. and Eisenhardt, K.M. (2009), "Origin of alliance portfolios: entrepreneurs, network strategies, and firm performance", *Academy of Management Journal*, Vol. 52 No. 2, pp. 246-279.

Ozturan, M., Atasu, I. and Soydan, H. (2019), "Assessment of blockchain technology readiness level of banking industry: case of Turkey", *International Journal of Business Marketing and Management*, Vol. 4 No. 12, pp. 1-13.

Peng, T. (2020), "UAE health ministry debuts blockchain platform for Medical Data", https://cointelegraph.com/news/uae-health-ministry-debuts-blockchain-platform-for-medical-data

Porter, M.E. and Lee, T.H. (2013), "The strategy that will fix health care", *Harvard Business Review*, Vol. 91 No. 10, pp. 51-70.

Przhedetskiy, Y., Przhedetskaya, N., Borzenko, K. and Bondarenko, V. (2019), "Blockchain technologies in healthcare institutions: focus on security and effective cooperation with the government", *International Journal of Economics and Business Administration*, Vol. 7 No. 2, pp. 92-99.

Radanovíc, I. and Likíc, R. (2018), "Opportunities for use of blockchain technology in medicine", *Applied Health Economics and Health Policy*, Vol. 16, pp. 583-590.

Razmi, J., Sangari, M.S. and Ghodsi, R. (2009), "Developing a practical framework for ERP readiness assessment using fuzzy analytic network process", *Advances in Engineering Software*, Vol. 40 No. 11, pp. 1168-1178.

Ratta, P., Kaur, A., Sharma, S., Shabaz, M. and Dhiman, G. (2021), "Application of blockchain and internet of things in healthcare and medical sector: applications, challenges, and future perspectives", *Journal of Food Quality*, Vol. 2021, pp. 1-20.

Reina, R., Cristofaro, C., Lacroce, A. and Ventura, M. (2012), "Managing the knowledge interdependence with electronic medical record", *Measuring Business Excellence*, Vol. 16 No. 4, pp. 31-41.

Saldaña, J. (2013), *The Coding Manual for Qualitative Researchers*, 2nd Ed, Sage, Los Angeles.

Savage, G.T., Bunn, M.D., Gray, B., Xiao, Q., Wang, S., Wilson, E.J. and Williams, E.S. (2010), "Stakeholder collaboration: implications for stakeholder theory and practice", *Journal of Business Ethics*, Vol. 96 No. S1, pp. 21-26.

Sharma, S. (2021), "Co-creational leadership capability for driving health-care service innovation", *Measuring Business Excellence*, Vol. 25 No. 4, pp. 434-451.

Siyal, A.A., Junejo, A.Z., Zawish, M., Ahmed, K., Khalil, A. and Soursou, G. (2019), "Applications of blockchain technology in medicine and healthcare: challenges and future perspectives", *Cryptography*, Vol. 3 No. 1, p. 3.

Snyder-Halpern, R. (2002), "Development and pilot testing of an organizational information technology/systems innovation readiness scale (OITIRS)", *Proc AMIA Symp*, pp. 702-706.

Stefanini, A., Aloini, D., Benevento, E., Dulmin, R. and Mininno, V. (2018), "Performance analysis in emergency departments: a data-driven approach", *Measuring Business Excellence*, Vol. 22 No. 2, pp. 130-145.

Syed, T.A., Alzahrani, A., Jan, S., Siddiqui, M.S., Nadeem, A. and Alghamdi, T. (2019), "A comparative analysis of blockchain architecture and its applications: problems and recommendations", *IEEE Access*, Vol. 7, pp. 176838-176869.

Vlachos, A., Christodoulou, K. and Iosifs, E. (2019), "An algorithmic blockchain readiness index", *3rd Annual Decentralized Conference on Blockchain and Cryptocurrency*, Vol. 28 No. 1, p. 4.

Yaeger, K., Martini, M., Rasouli, J. and Costa, A. (2019), "Emerging blockchain technology solutions for modern healthcare infrastructure", *Journal of Scientific Innovation in Medicine*, Vol. 2 No. 1, p. 1.

Yaqoob, I., Salah, K., Jayaraman, R. and Al-Hammadi, Y. (2021), "Blockchain for healthcare data management: opportunities, challenges, and future recommendations", *Neural Computing and Applications*.

Yin, R.K. (2013), *Case Study Research Design and Methods*, 3rd Ed. Sage, Los Angeles.

Yue, X., Wang, H., Jin, D., Li, M. and Jiang, W. (2016), "Healthcare data gateways: found healthcare intelligence on blockchain with novel privacy risk control", *Journal of Medical Systems*, Vol. 40 No. 10, pp. 1-8.

Zhang, P., Schmidt, D.C., White, J. and Lenz, G. (2018), "Blockchain technology use cases in healthcare", in *Pethuru Raj, Ganesh Chandra Deka: Advances in Computers. First Edition*, Elsevier Academic Press, Cambridge, MA, pp. 1-41.

Zhang, P., White, J., Schmidt, D.C., Lenz, G. and Rosenbloom, S.T. (2018b), "FHIRChain: applying blockchain to securely and scalably share clinical data", *Computational and Structural Biotechnology Journal*, Vol. 16, pp. 267-278.

## Corresponding author

Benedetta Nicolai can be contacted at: b.nicolai1@studenti.unipi.it