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Blockchain-based vaccine passports: A multi-case analysis based on perceived risk facets

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Abstract:

The covid pandemic has heightened the need for uniformity across healthcare measures. As the healthcare standards in different countries can significantly vary, a homogeneous platform with standard regulations is required to examine and analyze relevant data. The lack of unanimous acceptance of the vaccines being used adds to the challenges of using such a platform. A blockchain-based vaccine passport can store, review, and verify vaccine data in a secure and scalable manner. If the proper architecture is put in place, it will save cost, time, and human intervention. But as much as there is an urgent demand for technology reinforcement, certain risks and concerns are associated with it. Following a secondary case study approach, this paper highlights the risks, benefits, and challenges of existing blockchain-based vaccine passports. The findings of the paper suggest Blockchain has the potential to transform the vaccine verification process as the shared distributed ledger can optimize data management. It will enhance the operational process, reduce cost and improve compliance. However, more attention needs to be given to the social, ethical, and regulatory risks of this neoteric initiative.

Keywords: blockchain, COVID, vaccine, passport, risks.

1. Introduction

The Covid-19 outbreak has put the world at a standstill. The imposed travel restrictions for safety affected multiple industries and resulted in an economic downturn in many countries. Many countries had to close their borders entirely or partially. Imposed travel restriction has affected international trade, global supply chain, and immigration. To restore pre-pandemic normalcy, countries need to resume domestic and international travel. Relaxing travel restrictions on people who have been vaccinated is the first stage of doing that (Beriain & Rueda, 2020). The technology that was developed to address these growing concerns is 'Vaccine Passport'. A vaccine passport refers to a printed or digital certificate with a QR code that can certify the vaccination status of an individual (Haque et al., 2021). The blockchain-based decentralized platform can instantly store and retrieve the vaccination details used to check the accuracy and authenticity of vaccination status. It can later be used for keeping records of other diseases as well. Therefore many countries and organizations have adopted vaccine passports that will allow people to work and travel around with attested proof of vaccination without compromising the safety of public health (Cao et al., 2020; Chaudhari et al., 2021; Chowdhury et al., 2020).

2. Rationale

Even within a short span of time, a wide range of research papers has intended to address the challenges associated with the global pandemic. The major areas of research have been focused on contact tracing

(Elmesalawy et al., 2020; Rajasekar, 2021; Shubina et al., 2020), vaccine distribution and management (Antal et al., 2021; Barakat & Al-Zagheer, 2021; Musamih et al., 2021), social distancing (Cao et al., 2020; Istomin et al., 2021), Covid diagnosis (Chowdhury et al., 2020; Maghdid et al., 2021; Udugama et al., 2020), immunity passport (Chaudhari et al., 2021; Eisenstadt et al., 2020; Hasan et al., 2020; Hernández-Ramos et al., 2021). In a vaccine passport, users are expected to have full control of their health data to share with appropriate parties, hence several papers that proposed a vaccine passport solution have used verifiable credential techniques and self-sovereign identity (SSID) to incorporate this feature (Eisenstadt et al., 2020; Hasan et al., 2020; Hernández-Ramos et al., 2021).

Blockchain is a growing field of study, and a diverse range of literature can be found on different aspects of blockchain. But in this multifaceted research field, feature analysis of existing blockchain services is untapped. Most articles featuring technological influence in vaccine passports are either too limited in scope or emphasize more concepts rather than implementation (Abd-Alrazaq et al., 2021). Many researchers have focused on the risk challenges and benefits of blockchain implementation from a general view (Atlam et al., 2018; Chang et al., 2020; Mackey et al., 2019; Osmani et al., 2021). But specific attention to adopted blockchain solutions such as vaccine passports is inadequate compared to the present context. This study will try to bridge the gap in sparse literature and highlight some of the key prospects and concerns of currently used vaccine passports worldwide. This research looks into the technical and ethical aspects of four blockchain-based systems that are currently operational in different countries. It also explores the use of perceived risk facets (Featherman & Pavlou, 2003) as an appropriate theoretical framework for analyzing the dynamic influences and outcomes associated with the implementation of blockchain-based vaccine passports.

3. Aims and research questions

The research will highlight the potential benefits, risks, and challenges of blockchain-based vaccine passports currently used worldwide. The research aims to address the following research question:

RQ1: What are the prospects and concerns of existing blockchain-based Covid vaccine passports?

4. Research Methods and Design

For this paper, the ‘embedded multiple case’ design approach suggested by Yin (1984) was followed. This approach involves multiple units of analysis. Multiple case design refers to the literal replication of logic, so the sample size consists of the number of cases needed to generate an effect (Yin, 1984). As demonstrated by Yin (2009) case study is a linear but iterative process. The linear process includes planning, designing, preparing, collecting, analyzing, and sharing (Yin, 2009). The reason for choosing multiple case studies for this research is to understand the factors that lead to more successful system implementation in one case compared to the others. As this study is focused on a comparative analysis of four systems to figure out which one is more fitted for the purpose, the multi-unit analysis highlights the parameters to analyze. For data collection and design, the research also takes help from the case study research method suggested by Cassell and Simon (2004). The exploratory research looks into secondary use case data for multi-case analysis. The four cases that were analyzed for this study are as follows:

1. IBM’s Digital Health Passport “Common Pass”
2. The Linux Foundation Public Health’s COVID-19 Credentials Initiative

3. The Vaccination Credential Initiative (Microsoft and Oracle) the International Air Transport Association's Travel Pass
4. EU Digital COVID Certificate.

The rationale for choosing these four technologies is they were identified as leading technologies in this field by expert examination of the vaccine passport of Ada Lovelace Institute, globally recognized for information system research (Ada Lovelace Institute, 2021). Moreover, these 4 technologies are the most successful and widely adopted technologies in the field that are currently in use. As they have been already implemented and achieved success to a high extent compared to other conceptual frameworks it is highly rational to review these technologies to propose future improvements.

4.1 Framework

This study followed the structure of the Type-II case study framework as shown in figure 1 (Reddy & Agrawal, 2012). The framework parameters are customized based on the research objective and positivistic research philosophy for this study:

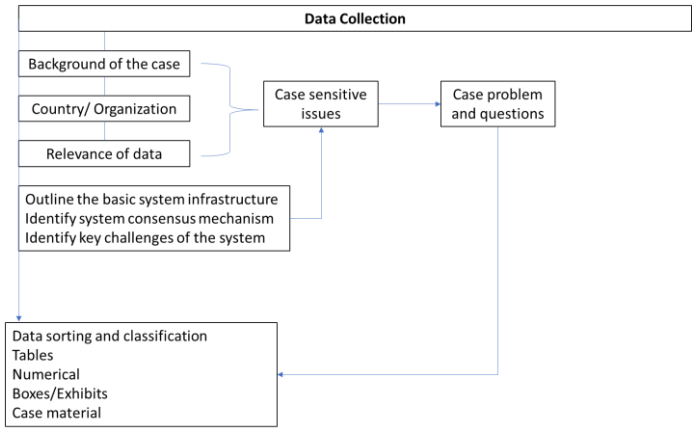


Figure 1: Case study design framework

4.2 Data collection

The secondary data was collected from multiple sources based on the availability of public data as shown in figure 2.

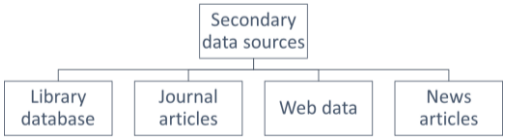


Figure 2: Secondary data sources

For the chosen solutions technical and marketing contents are available on the company website and Information Technology database accessible through the MacOdrum library (MacOdrum, 1942) of Carleton University and social, and ethical legal aspects are analyzed by collecting data from journal articles and news articles. The research did not include grey literature and maintained peer review articles as a selection criterion. The research concentrated on including high-quality peer-reviewed research articles, book chapters, conference proceedings, or preprints posing relevance to the research topic, other types of publications like conference abstracts, editorials, and commentaries were excluded

from the study for the limited coverage of the subject area. Based on the secondary sources the research is mainly focused on comparing the generic features of existing vaccine passports. In-depth technical analysis is out of scope due to the unavailability of data.

5. Comparative analysis of four vaccine passports

5.1 IBM's Digital Health Passport "Common Pass"

Background: IBM's digital health pass (IDHP) powered by blockchain technology can be used to verify health status without involving any third party. The IBM digital health pass named Excelsior Pass was launched on 25 March 2021 in New York (Androulaki et al., 2021). It consists of three main components the portal, wallet, and scanner. Vaccinated/tested users can visit the portal where they can get their Excelsior pass based on their vaccination/test status. Then the users can download the wallet application on their smartphones to store the credentials of the pass. The scanner is also an application business/authorized organizations can download and use to scan the QR codes of Excelsior pass to verify the vaccination status of an individual (Patel, 2021). One of the key features of this pass is the flexibility it offers to the managing organizations to select the criteria for assessing health status (Moskvitch, 2021).

Country/Organization: IBM, USA

System architecture: IDHP uses Hyperledger Fabric infrastructure that incorporates the following stages:

- *Issuer registration and onboarding:*

the first stage involves registering issuers in the Trusted Registry system. Administrative authorities register issuers who can issue different types of health certificates. First administrative authorities receive a request from issuers for system registration. Then after proper due diligence, the authorities proceed to the enrolment stage. In the enrolment process issuers receive X.509 certificates detailing issuing authorization. Then issuer generates a signing key pair providing the verification key to the trusted registry which later maps the issuer to its verification key (Androulaki et al., 2021).

- *Health certificate schema:*

It includes the set of fields that compose a digital health certificate. The schema fields can be modified by respective issuers. The schema definition is available to all verifiers(Androulaki et al., 2021).

- *Verification:*

Digital health certificates are issued in the form of QR codes. The verifier can scan the QR code with delegated app and verify the vaccination status.

Figure 2 shows a process diagram of the IBM digital health data verification process. Users need to reach out to an issuer of their choice and perform a Covid test or receive the vaccination. Then they receive a health certificate in form of a QR code. The QR code is generated with the signing key of the respective issuer. The QR code will be readily available in users' IDHP app. Users can print it out in the physical form as well (Androulaki et al., 2021).

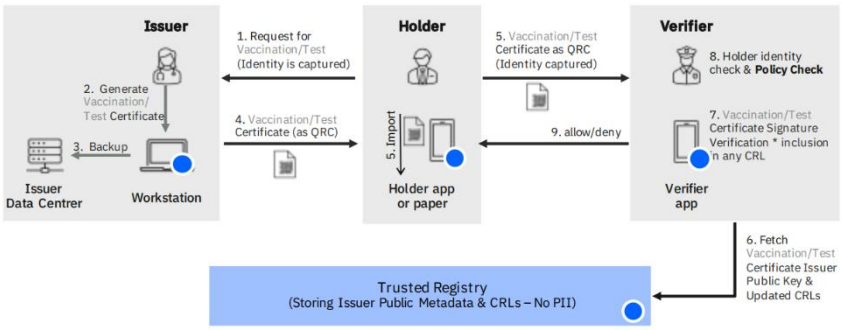


Figure 3: IBM digital health credential process diagram (Androulaki et al., 2021)

For verification, the subject/user gives access to their physical/digital QR code to a verifier who can scan the code and verify using the IDHP verifier app. The trusted registry gives the verifier access to the metadata related to the health certificate and also respective issuer details.

Consensus mechanism: The system uses traditional public-key encryption along with a digital signature. Authorized issuers generate digital key pairs that allow them to issue vaccine certificates. Verifiers send queries to the public registry to verify if a certificate was generated using authorized key pairs of issuers (Moskvitch, 2021).

Challenges: Vaccine supply chain is vulnerable to external threats like lack of automation, unsecure servers at the vendor's end, cyberattacks, etc (Quito, 2021).

5.2 The Linux Foundation Public Health's COVID-19 Credentials Initiative

Background: Covid Credential Initiative (CCI) was formed in April 2020. It's an open global community aimed at enabling interoperable use of privacy-preserving credentials for verifying health status. After nine months of developing Verifiable Credentials (VCs), CCI collaborated with Linux Foundation Public Health (LFPH). The combined effort facilitate the implementation of health credentials (Wilford et al., 2021). CCI brought together more than 300 technologists, healthcare professionals, and academics from more than 100 organizations to explore the potential of verifiable credentials. To advance this initiative in June 2021 LFPH launched the Global covid Certificate Network (GCCN) that will focus on data interoperability, security, and privacy concerns of vaccine passports.

Country/Organization: Linux Foundation Public Health (LFPH)

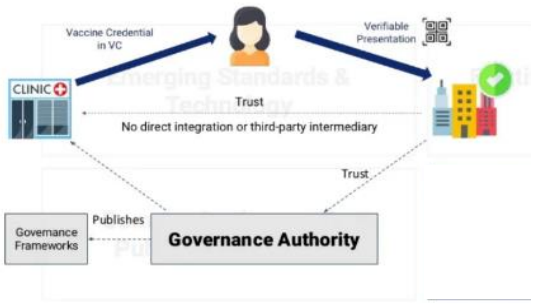


Figure 4: CCI operational process (Wilford et al., 2021)

System architecture: This system adopts a data minimization approach where a trusted issuer ensures the authenticity of the holder's vaccine credentials. Like IDHP there is no direct contact between issuer and verifier. Based on the vaccine credential the system generates a QR code that the verifier can scan and verify by querying the database (Wilford et al., 2021).

Consensus mechanism: The open-source trust management infrastructure will work on preparing a trust list to make a compilation of jurisdictions, regulations, and policies of different countries/organizations through a discovery mechanism (Whiting, 2022). If the certificate is issued from a valid source, then the verifier will be able to decrypt the certificate using a public key. This is a step forward toward the standardization process.

Challenges: It's still in the prototype stage and yet to be implemented on large scale.

5.3 The International Air Transport Association's Travel Pass

Background: After successfully completing the pilot phase with Singapore Airlines in March 2021, several airlines are planning to use International Air Transport Association's (IATA) Travel Pass. As of 26th April 2021 around 50 airlines signed up to trial this system. It comprises an app that allows users to create a secure digital version of an individual's passport in the app. On 15th April 2021, the app was launched on the Apple app store. Users can check travel regulations, upload their vaccine certificate and allow verifiers access to those certificates in the app. IATA travel pass can also inform users about the travel restrictions based on their travel date and flight details. It can also notify users whether they fulfill the requirement to fly (*IATA - Travel Pass Initiative*, 2021).

Country/Organization: International Air Transport Association (IATA)

System architecture: The architecture comprises four components. Figure 5 shows how the 4 modules work together as an integrated service (Otley, 2020).

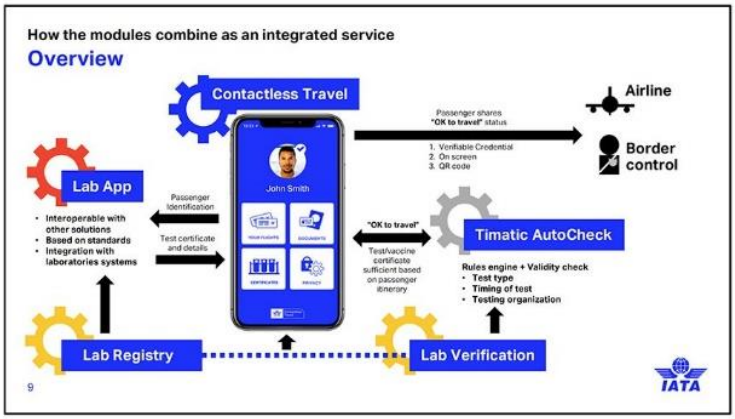
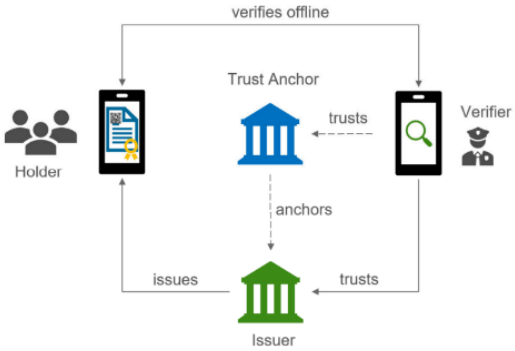


Figure 4: IATA travel pass modules (Otley, 2020)

- Global registry for health requirements that provides information about travel requirements, vaccine status, etc.
- Global registry for Covid testing/vaccination centers that has information of authorized labs and testing centers close to departure location.
- Lab app: this app allows authorized test centers to share test results and certificates with users in a secure environment.
- Travel app: this works as a digital passport module that allows users to store, share and upload their vaccine certificates



Consensus mechanism: The certificate uses Sovrin decentralized architecture of blockchain. However, it also has a centralized database for laboratories. Evernym has the ultimate control of issuing vaccine certificates as all laboratories delegate their private keys of encryption to Evernym (Lin, 2022).

Challenges: Lack of standardization regarding vaccine certificates (Sun et al., 2021).

5.4 EU Digital Covid Certificate

Background: The certificate was launched on July 1, 2021. The certificate has addressed the socio-ethical issues associated with vaccine passports and complies with General Data Protection Regulation (GDPR) to ensure data privacy (*EU Digital COVID Certificate*, 2022).

Country/organization: European Union

System architecture: Figure 6 shows the operational process of the EU digital certificae (*EU Digital COVID Certificate*, 2022). There are 3 main actors in the system (Fig 6).

Holder: a person having a digital or physical Covid certificate certifying vaccination status, test result, and relevant details.

Issuer: a government-authorized organization for issuing Covid certificates.

Verifier: different organizations that require a Covid certificate for their operation (i.e., custom offices, hotels, cinema halls, etc.).

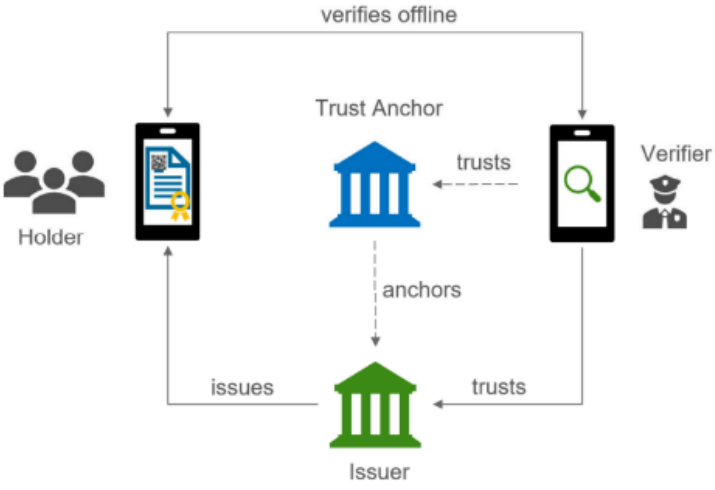


Figure 5: EU digital certificate system process (EU Digital COVID Certificate, 2022)

Consensus mechanism: This certificate uses cryptographic public keys to give access to sensitive data. each certificate carries a unique string that works as an identifier for the issuing authority (Mithani et al., 2021).

Challenges: The framework operates utilizing a public key infrastructure that creates regulatory concerns with GDPR requirements. Data saved in blockchain infrastructure is immutable so people might face restrictions to travel based on their earlier records that cannot be changed in the system (Montanari Vergallo et al., 2021). The summary of the cross-case analysis is shown in Table 1.

Vaccine passports	**IBM's Digital Health Passport "Common Pass"**	**The Linux Foundation Public Health's COVID-19 Credentials Initiative**	**International Air Transport Association's Travel Pass**	**EU Digital COVID Certificate.**
Background	Launched on 25 March 2021 in New York	Formed in April 2020	Launched on 15 April 2021	Launched on July 1, 2021
Country/ Organization	IBM, USA	Linux Foundation Public Health (LFPH)	International Air Transport Association (IATA)	European Union
System architecture	Hyperledger Fabric infrastructure	Data minimization approach where a trusted issuer ensures the authenticity of the holder's vaccine credentials	Sovrin decentralized architecture of blockchain	Decentralized blockchain architecture
Consensus mechanism	Public-key encryption along with a digital signature	Public-key encryption along with issuer validity	Private keys of encryption	Cryptographic public keys
Challenges	Lack of automation at user end, unsecure servers at the vendor's end, cyberattacks, etc.	Large scale implementation	Lack of standardization regarding vaccine certificates	Compliance with GDPR requirements

Table 1: Summary of cross-case analysis of chosen 4 technologies

6. Discussion

From the multi-case analysis following features were observed in all four systems that contributed to their success as vaccine passports:

- All four systems relied on decentralized blockchain architecture for data storing and sharing. Less dependency on centralized databases makes these systems highly scalable and less prone to cyberattacks
- All four systems designed their architecture based on 3 main actors: issuer, holder, and verifier, and created specialized portals for each of them
- Both physical and digital certificates were supported by system architecture in all four systems
- QR-code-based vaccine certificates were issued in all four portals that helped to ensure data anonymity and integrity
- Users have the ultimate control in all four systems to give access to their confidential health data
- The system required no direct interaction between the issuer and verifier. The identity of the issuer was embedded in the issued certificates which the verifier can use to authenticate the certificate

Based on the use cases of the four vaccine passports this study aims to analyze the attributes of vaccine passports based on perceived risk facets suggested by Featherman and Pavlou (Featherman & Pavlou,

2003). Perceived risk exerts a strong inhibiting influence on perceived usefulness and perceived ease of use. Perceptions of specific risk facets inhibit system evaluation and adoption trends among users which is important for the implementation of a vaccine passport. In table 2 the blockchain-based vaccine passports are analyzed based on perceived risk facets.

The key concern of all 4 systems is having full compliance with regulatory requirements. As the systems are constantly updated with hybrid blockchain architecture most of these concerns are expected to be minimized or resolved

Perceived Risk facets	**Concerns related to Blockchain-based vaccine passports**
Performance Risk	For concurrent requests, there are certain delay in the issuance of vaccine passports which needs to be resolved for making the system scalable (Wilford et al., 2021)
Financial Risk	Blockchain requires complex technical infrastructure hence, the implementation and maintenance require high investments (Nabil et al., 2021)
Time Risk	The use of a mobile app requires a user-friendly interface otherwise depending on the technical literacy it might be difficult for general users to be comfortable using the system (Hall & Studdert, 2021)
Psychological Risk	Hesitancy to get vaccinated, sharing health data across public platforms, reluctance towards new technology (Renieris, 2021)
Social Risk	Lack of access to authorized vaccines based on social inequality, lack of standardization in vaccine certificate requirements (Tsukayama, 2020)
Privacy Risk	Giving access to sensitive data across multiple platforms, the immutability feature of blockchain prohibits updating information but rather creates a new record for every update (Haque et al., 2021)
Overall Risk	Standardization of policies and regulations and ensuring uniformity in the entire process (Mishra, 2022; Renieris, 2021)

Table 2: Assessment of blockchain-based vaccine passports based on perceived risk facets

7. Conclusion

The peer-to-peer network of blockchain technology can ensure autonomous data transactions while maintaining transparency. The infrastructural support and legal obligations required for blockchain implementation and maintenance are significantly high. But considering the distinct advantages namely data authentication, interoperability, user control, and privacy blockchain technology gains a competitive advantage over other technologies currently being considered in the field (McGhin et al., 2019). Compared to the discussions in existing literature there have been very few implementations in the practical field to support the assumptions made by researchers (Mithani et al., 2021). An extensive review of the challenges and prospects of blockchain-based vaccine passports is imperative for the future development of vaccine validation and monitoring for safe travel resumption.

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