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Applications of blockchain for vaccine passport and challenges

Applications
of blockchain

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Abstract

Purpose – The purpose of this study is to investigate the applications of blockchain in vaccine passport solution. The world is facing an unprecedented situation because of the COVID-19 pandemic. Many countries have witnessed sporadic lockdown and travel restrictions and it has marred trade and tourism. As the mass vaccination has started the life is slowly and steadily returning to true normal. Various countries are issuing vaccination passports to manage the immunization information and validate it. To realize vaccine-passport's true potential, security and privacy concerns should be being taken care of. There is a need for studies to evaluate the emerging technology for the vaccine passport.

Design/methodology/approach – This study uses a mix of qualitative and quantitative methods to achieve its objective. This study uses a systematic literature review to analyze the potential of blockchain for vaccine passports. The case study of three different types of organizations implementing blockchain for vaccine passports was analyzed and results were presented. Last but not least, focus group discussion and search of secondary literature was to done to identify scientific, ethical and legal challenges associated with the use of vaccine passports. The method used for calculating the importance score of these challenges was analytical hierarchy process.

Findings – This study concludes that blockchain-based solutions are very suitable for vaccine passports and addresses the concern related to interoperability, privacy and security. The case study approach was used to elaborate the use of blockchain in three different options available for the vaccine. Last but not least, this study identifies the challenges faced by vaccine passport programs and suggests measures to overcome them. This study concludes that the ethical challenges associated with vaccine passports are more important and should be preferentially treated.

Research limitations/implications – This study is timely and will be helpful for policymakers in designing the vaccine passport programs. It gives valuable insight to decision-makers evaluating technologies for the development of vaccine passport programs. This study identifies nine challenges to be tackled to making a vaccine passport program successful.

Originality/value – To the best of the author's knowledge, this study is not able to find out a review on the use of blockchain technology for vaccine passports, and this study attempts to fill this gap. This study further discusses the cases of organizations that have implemented blockchain technology for vaccine passport programs.

Keywords COVID-19, Vaccine passport, Immunization certificate, Blockchain

Paper type Research paper

Introduction

Global health-care systems are facing an increased burden because of the outbreak of unpredicted threats of infectious diseases. The world has faced similar health-care emergencies in the recent past but the scale has been humongous this time (Wong *et al.*, 2015). The global health system is facing an unprecedented crisis because of COVID-19. Countries have imposed travel restrictions, and it has hampered global trade, educational,



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medical and leisure tourism. Many countries have started allowing travelers who are fully vaccinated. Some countries are contemplating the administration of booster doses to increase immunity against the mutation of the viruses. People from different countries of origin and destination will require different types of vaccination documents to travel. The quarantine rules for these travelers also vary. This makes the management of travel documents a complex and demanding exercise.

“The strong desires to return to normalcy coupled with the rollout of efficacious vaccines have intensified discussions of ‘vaccine passports’ – certifications of vaccination that reduce public health restrictions for their bearers” (Hall and Stoddert, 2021). The vaccine passport solutions also come with other names such as Travel Pass and Health Pass. These digital documents come in form of mobile apps holding information regarding the COVID-19 health status of travelers such as test results and vaccinations.

Some of the governments have come up with their solution for vaccine passports, whereas others rely on the solution developed by reputed non-government players. Many authorities and government have already pilot run their solutions and planning to roll out them at a larger scale. It is imperative to develop reliable and accurate certification for these health documents because counterfeit document has serious health concerns. Policymakers must harness the potential of new technologies for reliable documentation of vaccination. Fortunately, technology like blockchain is being seen as a solution for this demanding task. The technology has been in use for a while and has been successfully used in solving business problems (Upadhyay *et al.*, 2021a, 2021b). This paper reviews the extant literature to study the use of blockchain in vaccine passports. This study further identifies, categories, and priorities the challenges faced by vaccine passport applicability using a review of secondary literature and focus group input. Last but not least, this study discusses some use cases of vaccine passports from different players.

Literature review

Governments worldwide are rolling out mass vaccination programs and as of June 10, 2021, 2,156,550,767 vaccine doses have been administered. The governments, travel carriers and other organizations are devising a mechanism for COVID-19 vaccine passports. A vaccine passport is a document to provide greater mobility to vaccinated people and hence facilitates society’s reopening and a return to ordinary life. The major areas of implementation of the vaccine passports are international travel, returning to work (people working in essential services like health care, police, teacher, etc.), education (student migrating to other countries), attending sports event (Japan Olympic, UEFA euro 2020, Wimbledon, French Open, Copa America, etc.) and attending mass gathering (marriages, conferences, fairs, etc.).

Any vaccine passport program needs to perform on a certain yardstick to be deemed successful. Some of these measures are interoperability, addressing privacy concerns, achieving accuracy and ensuring equitability (Tanner and Flood, 2021). The present inequities may result in the future equitability of a vaccine passport. Vaccine passport is not a new concept; it has been there for a while. Erstwhile countries have made it mandatory for a traveler to carry vaccination documents for diseases like yellow fever. There are other instances of countries making it compulsory to get certain vaccines before visiting them. The strict requirement of a vaccine passport can make it disadvantageous for many sections of society. The implementation of the vaccine passport programs should be equitable, not excessively restrictive, and should respect human rights (Vanderslott and Marks, 2021; Phelan, 2020). It should be only used for facilitating fast lane travel without additional testing and mandatory quarantine. The vaccine passport programs should be as fair and unoppressive as possible (Hall and Stoddert, 2021). It can also work as an incentive to

overcome the vaccine hesitancy hence helpful in achieving herd immunity as soon as possible. As COVID-19 is here to stay for months, and it is not going to be the last pandemic of its kind, vaccine passports or digital health pass applications (apps) could be extensively adopted by health-care policymakers and administrators in the coming days.

A new technology that has immense potential in reliable documentation and verification is blockchain. “A vaccine passport concept with data encryption, such as blockchain technology, could lead a forward way for continuous market surveillance that captures real-world evidence for safety and effectiveness” (Tsoi *et al.*, 2021). It is a system of recording information in a way that makes it difficult or impossible to change or hack. It is a decentralized database managed by multiple participants also known as distributed ledger technology (DLT). In blockchain, transactions are recorded with an immutable cryptographic signature called a hash. Blockchain technology has distinct advantages, as it provides decentralization, accessibility, immutability and irreversibility (Vanderslott and Marks, 2021). It has many use cases in COVID-19 management such as the design of distribution system, privacy-preserving framework for social distancing and multidrone monitoring for COVID-19-appropriate behavior are to name a few (Ramirez Lopez and Beltrán Álvarez, 2020; Choudhury *et al.*, 2021; Alsamhi *et al.*, 2021). Tsoi *et al.* in their seminal paper observed that blockchain technology is becoming more and more mature in the health-care sector, especially for health records processing. They suggested a framework for the application of blockchain for vaccine passports and is depicted in Figure 1 (Tsoi *et al.*, 2021). In their proposed framework, the data can be stored decentralized in different organizations like vaccination authorities, hospitals, embassies, etc. This data can be verified with multilevel authentication. The verifiable credentials can be stored in a mobile device and connected to different data servers. The data should be end-to-end encrypted to safeguard the privacy and confidentiality of the users. The data can be reviewed and used by an authorized person with a single login.

This section analyses the adoption of blockchain in vaccine passports through the lenses of various established theories. Considering the blockchain is an innovative technology, and there is hesitation around its adoption in the vaccine passport programs. Rogers and Shoemaker (1971) observed that five attributes of innovation are largely involved to influence the adoption of innovation; relative advantage, compatibility, complexity, trialability and observability. Blockchain-based vaccine passports should have these five attributes to be accepted at a larger scale. The other theory, which can help us in understanding the acceptance of the blockchain-based vaccine passport, is the widely used technology acceptance model (TAM). According to this model, the perceived usefulness and perceived ease of using lead towards attitude towards using the technology and hence

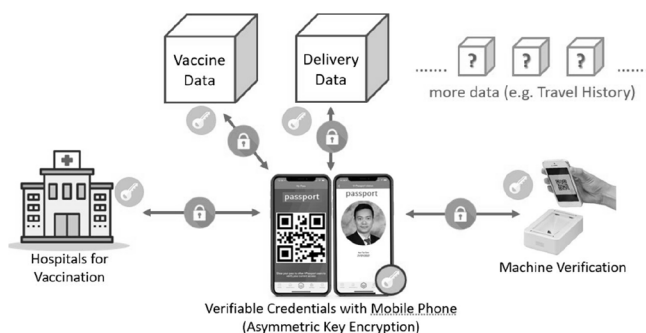


Figure 1.
Blockchain-enabled
framework for
vaccine passports

behavioral intention followed by actual use (Davis and Venkatesh, 1996). Goodhue and Thompson (1995) in their seminal work talk about task-technology fit. They observe that if the task requirement matches the technical characteristics, it eventually leads to technology use.

Considering the importance of blockchain in document verification and its management, this study reviews the extant literature to analyze its use for vaccine passports or immunization certificates. This study further discusses the case studies of vaccine passport programs using blockchain technology. Another objective of the study used is to identify and prioritize the challenges faced by the vaccine passport program and provide the measures to overcome those. The next section explicitly lists the research objectives, followed by methods, results, discussion and conclusion.

Research objectives

The study tries to answer the following research questions (RQ):

- RQ1.* How can blockchain technology be useful for governments in managing digital travel documents like vaccine passports?
- RQ2.* What are some leading use cases of vaccine passports using blockchain and what are their strengths and weaknesses?
- RQ3.* What are the challenges faced by vaccine passport programs?

Based on the above research questions, the research decided on the following research objectives (RO):

- RO1.* To perform a systematic review of literature for application of blockchain in COVID-19 vaccine passports;
- RO2.* To discuss the use of blockchain in vaccine passports using case studies of reputed governments and organizations; and
- RO3.* To identify and prioritize the challenges faced by vaccine passport programs and provide recommendations.

Methodology

For the first objective, this study used a systematic literature review (SLR); the details of the method used is discussed as below:

Design

This study adopted the approach of SLR to identify and select literature for review. The research question for the search was:

- RQ1.* What are the applications of blockchain in the COVID-19 vaccine passport?

This section lists the search strategy, inclusion and exclusion criteria, followed by data extraction for qualitative analysis.

Search strategy

This study reviews the databases EBSCOHost, PubMed and Google Scholar to find out the literature to be included in the review. The key search terms used to search were

“(Application OR Uses) AND (Blockchain) AND (CORONA OR COVID-19) AND (Vaccine OR Immunization) AND (Passport OR Certificate),” which produce a list of literature for screening.

Inclusion criteria

The SLR inclusion criteria were articles published in peer-reviewed academic journals, in the English language, included any discussion of the use of blockchain for vaccine certificate or immunization and published from August 2020 to the search date. Articles were excluded if they did not meet the above inclusion criteria, if the links were broken or if the content was paid on not available.

Screening process

The reviewer (VM) screened the title and abstract according to inclusion and exclusion criteria. The study uses the preferred reporting items for systematic reviews and meta-analyses (PRISMA) tool for screening literature to be included in the review. The PRISMA Statement helps authors improve the reporting of systematic reviews and meta-analyses. The strategy for the selection of the literature for review is listed in [Figure 2](#).

Data extraction

Finally, the study included ten papers for a detailed review. Following the full-text screening, the reviewer (VM) charted each article chosen for inclusion using the data extraction form to gather common and comparable information on each study.

Case study method

For the second objective, this study used the case study method a widely used approach in qualitative research. Case Studies help understand a phenomenon as they are down-to-earth and attention-holding. The major drawback of the case study approach is that the finding

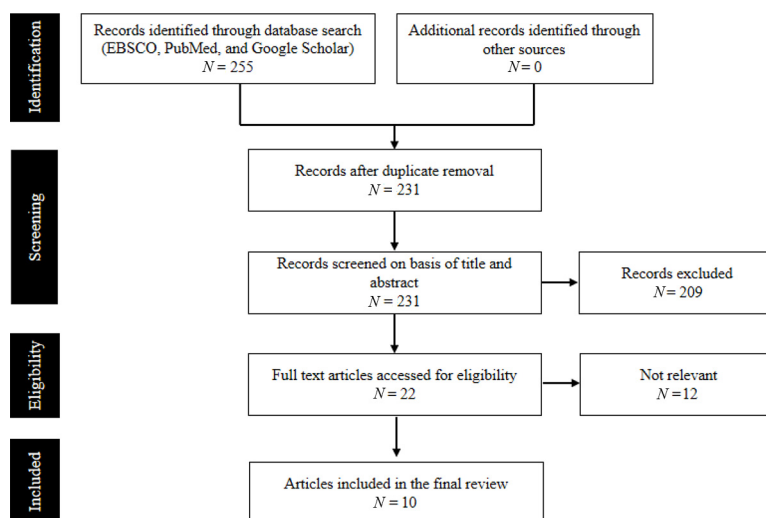


Figure 2.
PRISMA flow
diagram for literature
review

cannot be generalized. But Robert E Stake in his seminal paper claims that case studies are epistemologically in harmony with the reader’s experience and thus to that person as a natural basis of generalization (Stake, 1978). “Case Study investigates a contemporary phenomenon within real-life context when the boundaries between phenomenon and context are not evident and in which multiple sources of evidence are used” (Yin, 1992). This study uses three cases studies from three different types of organizations to investigate the use of blockchain in vaccine passports.

Analytical hierarchy process

For the last research objective, this study uses a search of secondary literature and focus groups to identify and categorize the challenges. The details of the focus group used for the study are listed in Table 1. To prioritize the challenges, the study further uses analytical hierarchy process (AHP).

AHP is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. It is a multicriteria decision analysis extensively used in engineering, social science, and management research. This approach was developed by Thomas L. Saaty in the 1970s (Tummala and Wan, 1994). The possible application of AHP range from selection, ranking and prioritization to importance score calculation and benchmarking (Mishra et al., 2018).

A focus group of six health-care professionals was created for identifying various challenges faced by vaccine passport programs. The focus group consisting of one researcher and five health-care professionals working in hospitals was formulated for the study. The method used for collecting the response and reaching a consensus was the Delphi method. The consensus about challenges was achieved in three iterations while it took two iterations to reach a consensus about AHP inputs (used for creating pairwise comparison matrix). The audience recruited for the pairwise comparison was asked to compare the challenges. The ranking was done as per the scale defined by Saaty listed in Table 2. If challenge C1 is preferred over challenge C2 by a preference score of 3, then challenge C2 is preferred over challenge C1 by a preference score of 1/3.

Table 1.
Details of the focus group used for the study

Expert	Qualification	Speciality	Experience (years)
Expert 1	MBBS, MD	Internal medicine	18
Expert 2	MBBS, MD	Internal medicine	10
Expert 3	MBBS, MD	Radiology	3
Expert 4	MBBS, MS	Gynecology	8
Expert 5	MBBS, MS	Surgery	8
Expert 6	BAMS	General physician	10

Table 2.
Preference score for pairwise comparison

Preference score	Definition
1	Equally important or preferred
3	Moderately important or preferred
5	Strongly important or preferred
7	Very strongly important or preferred
9	Extremely important or preferred
2, 4, 6, 8	Intermediate values, when compromise is needed

The steps used in the AHP are given below:

- Step 1. Defining the problem or goal of the study;
- Step 2. Develop a hierarchal framework for the AHP modeling;
- Step 3. Construct Pairwise Comparison Matrix [A] using the input of the focus group;
- Step 4. Calculation of the priority weight for the level [B];
- Step 5. Check the consistency of the judgment of the experts using the method discussed later in the study; and
- Step 6. Repeat Steps 1 to 5 for other levels.

To check the consistency of the judgment of the experts, the consistency ratio (CR) was calculated using the following steps:

- Step 1. The pairwise comparison matrix [A] was multiplied with the Eigenvector (Priority Vector) [B] to get a resultant vector [C].
- Step 2. The elements of matrix [C] were divided by the corresponding elements of the matrix [B] to get a vector [D].
- Step 3. The average of the sum of the elements of the vector [D] gives a value known as λ_{max}
- Step 4. The consistency index (CI) = $(\lambda_{max} - n)/(n - 1)$ was calculated.
- Step 5. Random index (RI) was taken from Table 3 for the number of criteria used in decision-making.
- Step 6. Finally, the consistency ratio CR was calculated using the following formula, $CR = CI/RI$. Usually, a CR of 0.10 (10%) or less is considered acceptable.

The goal of the study is to determine the importance score of challenges faced by vaccine passport programs. This study uses a three-level design of the problem as depicted in Figure 4. Our objective is to calculate the priority weights categories and hence the priority weights of nine sub-categories depicted in Figure 3.

This study first reviews the secondary research to gather pieces of evidence for the applicability of blockchain in the management of travel documents like vaccine passports. Then, this study delves into the use cases for the blockchain in vaccine passport and discusses their strengths and weaknesses. Based on the review of literature and input from

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 3.
Random index table
for AHP

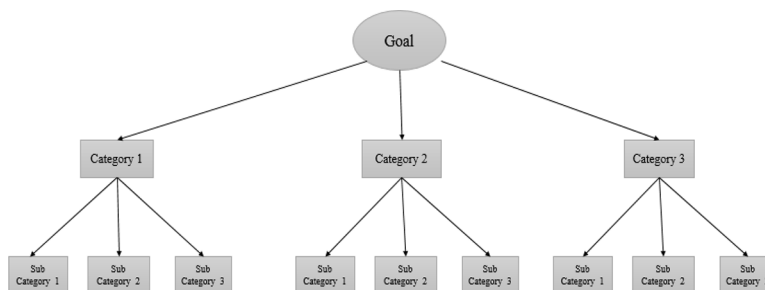


Figure 3.
Three-level
formulation of AHP
problem

the focus group, identify the possible challenges in the application of blockchain in vaccine passports and provide recommendations to overcome these challenges. Based on the research objectives of the study, the conceptual framework for the research is depicted in [Figure 4](#).

Results

The search of the keywords in the database resulted in 231 papers. These works of literature were reviewed for suitability based on title and abstract. A total of 22 pieces of works of literature were selected at this stage. On a detailed analysis of these works of literature, 12 were found not relevant and excluded at this stage. Finally, ten works of literature were selected for the detailed review, and the finding was presented in tabular form [Table 4](#).

Case studies

This section discusses three case studies, namely, International Air Transport Association (IATA) Travel Pass, IBM Digital Health Pass and Digital Green Certificate for a better understanding of the use of blockchain technology in vaccine passports.

IATA travel pass

In December 2020, IATA proclaimed that they are coming up with a new digital health credential solution (travel pass). Since then, many carriers are announcing the trial of this solution. It is primarily a mobile app that will facilitate a traveler to store and manage verified information about their health status, COVID-19 tests and vaccination information as per the requirements of the host countries and other organizations. This solution is proposed to be a part of the airline’s existing mobile application. This travel pass is essentially a tool for travelers, but it also communicates with governments, airlines, test centers and vaccination centers to ensure the veracity of the information. The proposed IATA travel pass is depicted in [Figure 5](#) ([Hannah, 2021](#)).

IATA is working closely with the International Airlines Group to develop four independent modules of the solution that can interact with each other. These four modules are global registry for health requirements, testing and vaccine requirements, lab at departure location module and digital passport module ([IATA, 2021](#)). Moreover, the travel pass solution is also to use the capabilities of IATA’s Timatic offering, which has provided credible solutions to airlines. This solution has been used by carriers to confirm whether a traveler is fit to travel. Travel pass uses decentralized blockchain technology and ensures that there is no central database. This arrangement ensures that it is not hacked to get the traveler’s information. The advantage of the blockchain technology traveler owns their data, which helps in building confidence in the system.

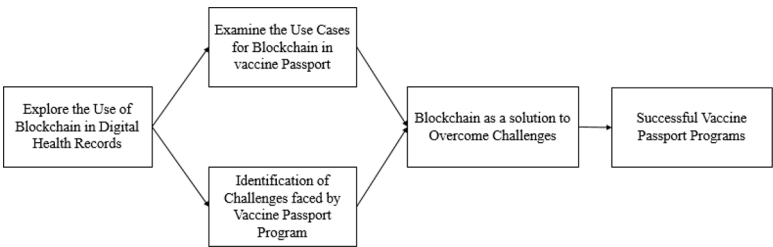


Figure 4.
Conceptual
framework used for
the study

Study	Methods	Objective	Outcomes
Tsoi <i>et al.</i> (2021)	Narrative review	Review of blockchain for vaccine passport	Vaccine passports constructed by blockchain technology should be used to overcome skepticism in global data sharing
Mithani <i>et al.</i> (2021)	Scoping review	Review of global vaccine certificate solution	COVID-19 vaccine certificates are being considered in 13 countries and are in place in three countries. All the solutions we identified are using blockchain technology
Hasan <i>et al.</i> (2020)	Case study	Development of Digital Medical Passport using Ethereum Blockchain	Ethereum blockchain-based solutions for medical are secure and cost-effective. The code used in the study is publicly available on GitHub
Abid <i>et al.</i> (2021)	Case study	Explore a promising solution for a secure Digital Health Certificate, called NovidChain	The evaluation shows that NovidChain provides better financial cost and scalability results compared to other solutions
Capece and Bazzica (2021)	Case Study	Propose a method for vaccination record management	This study concluded that the method can use blockchain to store the result of the test done and vaccination
Mbunge <i>et al.</i> (2021)	Letter to Editor	Analysis of emerging technologies for vaccination certificates and passports	The letter concludes there is no clear framework guiding the integration of blockchain technology in health systems and is imperative to develop framework and policies guiding it
Satria <i>et al.</i> (2021)	Narrative review	Review of the use of digital vaccine passport in bringing normalcy back	Blockchain has the potential to solve the challenges of security and privacy in a data-sharing system
Shuaib <i>et al.</i> (2021)	Systematic review	Analysis of blockchain in creating immunity credentials	Blockchain has effectively countered the issue of anonymity, accuracy and authentication issue and is very useful in creating vaccine passports
Garg <i>et al.</i> (2020)	Narrative review	Use of Blockchain-based solution for movement passes	Blockchain-based movement passes could be useful in reducing crowds in public places and promoting social distancing
Ricci <i>et al.</i> (2021)	Systematic review	Review of blockchain for COVID-19 contact tracing and vaccine support	This paper concludes that only a proper combination of blockchain technology with advanced cryptographic techniques can guarantee security and privacy-preserving applications in COVID-19 management

Table 4.
Results of the SLR
data analysis

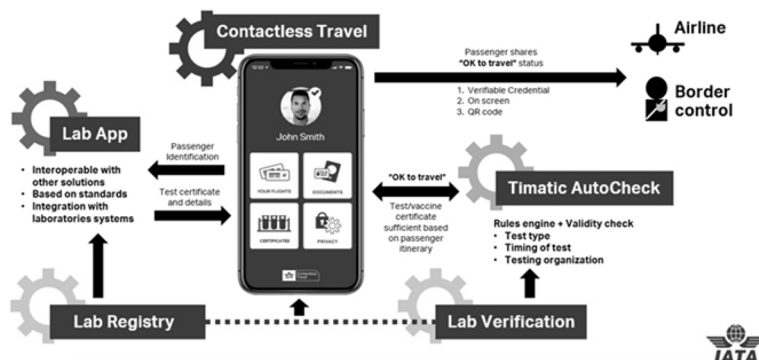


Figure 5.
IATA travel pass
working mechanism

Source: IATA (2021)

IBM Digital Health Pass

IBM Digital Health Pass is a digital wallet designed by IBM Watson Health, a leader in the digital health area. National Institute of Health of the US and Salesforce has joined hand for the trial phase of this solution:

Salesforce will provide individuals with -a verifiable and privacy-preserving way to manage and share their vaccination and health status in the wake of the COVID-19 pandemic via its Salesforce Work.com platform (Hannah, 2021).

Digital Health Pass is designed for various entities like issuers, individuals and verifiers. Like IATA's Travel Pass, it also uses blockchain technology to allow individuals to maintain control of their personal health information and share it in a way that is secured, verifiable and trusted. The key features of the Digital Health Pass are decentralization, open standards and secure verification. The solution uses blockchain technology to minimize the need to collect and store personal information. It also uses W3C standards across a global network to exchange and verify credentials data (IBM, 2021a, 2021b). The blockchain-powered Digital Health Pass Solution is depicted in Figure 6 (IBM, 2021a, 2021b).

As depicted in Figure 5, Digital Health Pass is a hybrid cloud solution having cloud-based applications to address the main requirements of credential generation, exchange and verification. The proposed solution uses mobile and cloud software development kits to fast-track solution development. The solution addresses standard use cases and can be customized for specific needs. IBM Watson claims that, through the use of blockchain technology, the digital health pass will be "verified, trusted and tamperproof" (IBM, 2021a, 2021b).

Digital Green Certificate

The European Commission is coming up with a vaccine passport solution being christened as Digital Green Certificate. The solution will enable travelers to freely move in the EU and avoid otherwise applicable quarantine restrictions. The document will provide proof that a traveler is vaccinated, tested negative for COVID-19 or recovered from the infection. Since the beginning of the pandemic, IOTA Foundation was working on the prototype of a vaccine passport solution that would allow people to prove that they have been tested negative in a trusted, secure and seamless way. IOTA is an open-source distributed ledger and cryptocurrency designed for the Internet of things. The IOTA foundation is working with

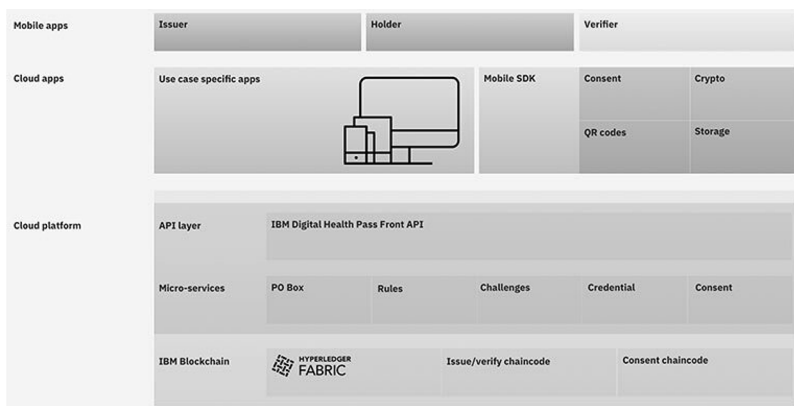


Figure 6.
IBM's Digital Health
Pass Solution

Source: Digital Green Certificates (2021)

Zebra Technologies to accelerate the deployment and availability of an open, secure and interoperable infrastructure for certificate creation and verification. The approach is secure, respectful of privacy, interoperable, open and inclusive. Like earlier discussed solutions Digital Green Certificate uses DLT for its decentralized and immutable solution. In near future, they are also planning to integrate the solution with evolving European Blockchain Service Infrastructure. The summary of the solution based on the immutability and scalability of the IOTA Ledger and its Decentralized Identity Protocol is listed in [Figure 7](#) (Digital Green Certificates, 2021).

Challenges faced by vaccine passport

This study used a search of the literature and focus group inputs to identify and categorize the challenges for the vaccine passport program. The list of the challenges is listed in [Table 5](#) (Osama *et al.*, 2021; WHO, 2021).

Based on the input from the focus group pairwise comparison matrix was created [A]. The matrix was normalized by dividing each cell by column total. Then, an average of the row was taken to get the priority vector [B]. Now, matrix [A] was multiplied with matrix [B] to get a matrix [C]. Now, each cell in [C] was divided by the corresponding value in [B] to get matrix [D]. The average of the elements of [D] gives λ_{max} , which is used to calculate the consistency index (CI). CI was divided by random index (RI) to get the consistency ratio. These steps were repeated for sub-categories scientific challenges, ethical challenges and legal challenges. The pairwise comparison matrix is listed in [Table 6\(a\)–\(d\)](#).

The priority weight of the three subcategories is given as scientific challenge (0.14), ethical challenge (0.71) and legal challenges (0.14). The local weights (priority) of the subcategory of challenges were calculated using the pairwise comparison matrix [Table 6\(b\)–\(d\)](#). These local weights were multiplied with respective category weights to calculate the global weight of the challenges (relative importance score) listed in [Table 7](#).

The CR for category weight calculation (0.006), scientific challenges weight calculation (0.012), ethical challenges weight calculation (0.007) and legal challenges weight calculation (0.007) were less than 0.10, hence in the acceptable region. The result of the study suggests that ethical challenges are more important and need to be overcome to make a vaccine passport program successful. The most important challenge into travel restriction, followed

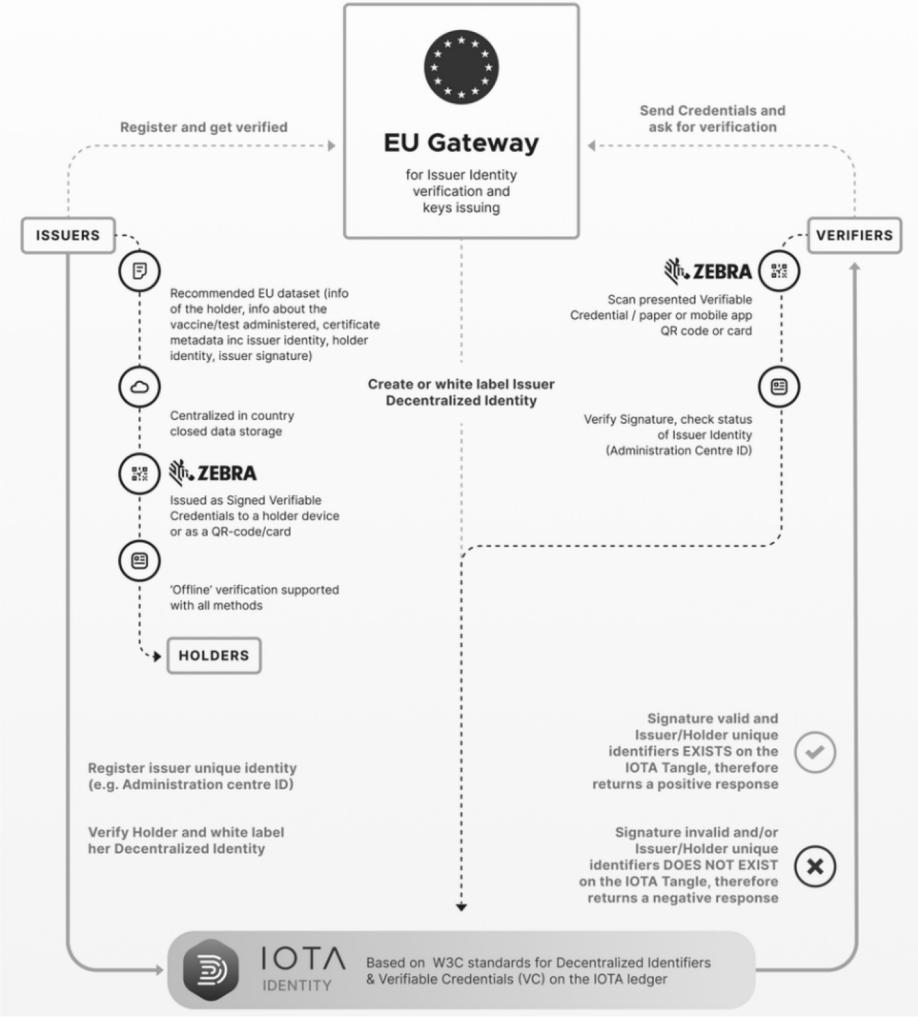


Figure 7.
Digital Green
Certificate

Source: IBM (2021a, 2021b)

by equity issues and access to technology. The least important challenge is the duration of protection. The finding of the study is summarized in [Figure 8](#).

Discussion

All selected literature in the study recommends the use of DLT like blockchain in the management of movement passes like vaccine passports. The reviewed papers have found the utility of blockchain in self-sovereign identity, an approach to digital identity that gives individuals control of their digital identities ([Shuaib et al., 2021](#)). [Abid et al. \(2021\)](#) in their paper explore a promising solution NovidChain and its application in vaccine

Applications of blockchain

Category	Sub-category	Description
Scientific challenges	Efficacy of vaccine	Efficacy of vaccine in curbing the transmission and protection against asymptomatic infections
	Duration of protection	Duration of protection and timing of the booster doses
	Potency against mutations	Efficacy of vaccines against possible mutants in other geographical locations
Ethical challenges	Equity issue	Limited access to vaccines and potential discriminations
	Travel restriction	Restriction of movement for unvaccinated people
	Access to technology	Exclusion of people without smartphones for digital vaccine passports
Legal challenges	Protection of privacy	Protection of the privacy of the data from potential miscreants
	Validity of documents	Challenges in validating the documents provided by the different stakeholders in different formats
	Forgery issues	Identifying the fake vaccination documents used for travel

Table 5.
List of challenges for vaccine passport

	Scientific challenges	Ethical challenges	Legal challenges
Scientific challenges	1	0.2	1
Ethical challenges	5	1	5
Legal challenges	1	0.2	1

Table 6(a).
Pairwise comparison matrix for category

	Efficacy of vaccine	Duration of protection	Potency against mutations
Efficacy of vaccine	1	3	1
Duration of protection	0.33	1	0.33
Potency against mutations	1	3	1

Table 6(b).
Pairwise comparison matrix for scientific challenges

	Equity issue	Travel restriction	Access to technology
Equity issue	1	0.33	1
Travel restriction	3	1	3
Access to technology	1	0.33	1

Table 6(c).
Pairwise comparison matrix for ethical challenges

	Protection of privacy	Validity of documents	Forgery issues
Protection of privacy	1	3	3
Validity of documents	0.33	1	1
Forgery issues	0.33	1	1

Table 6(d).
Pairwise comparison matrix for legal challenges

Table 7.
Weight of the
categories and sub
categories

passports. Ricci *et al.* (2021) in their paper conclude that only a proper combination of blockchain technology with advanced cryptographic techniques can guarantee secure and privacy-preserving applications such as travel passed. Thus the review of the literature suggested that there is evidence of the applicability of blockchain in the management of vaccine passports. The review of extant literature further suggested that to realize vaccine-passport’s true potential, security and privacy concerns should be being taken care of. The cases discussed in this study further confirm that the solutions developed using blockchain technology are decentralized, immutable and difficult to hack. The initial results on the use of these products are encouraging and will witness increased adoption once global travel opens. Thus, this study concludes that vaccine passports have a relative advantage over other solutions. The application comes in form of mobile apps, which makes it less complex and easy to try. Hence, we can conclude that higher diffusion of innovation is expected for these products (Rogers and Shoemaker, 1971). The vaccine passport solutions have high perceived usefulness for the users and make travel easy and at the same time it is easy to use. Hence, according to TAM, these vaccine passports solutions are expected to have a positive attitude for use and hence actual use of the vaccine passports.

Once it is established that blockchain-based vaccine passport solutions are suitable for managing travel documents, this study identifies challenges faced by the vaccine passport programs. There are three types of challenges associated with the vaccine passports program such as scientific challenges, ethical challenges and legal challenges. The study concludes that ethical issues are more important than legal and scientific issues related to

Categories	Challenges	Importance score
Scientific (0.14)	Efficacy of vaccine	0.060
	Duration of protection	0.020
	Potency against mutations	0.060
Ethical (0.71)	Equity issue	0.141
	Travel restriction	0.426
	Access to technology	0.141
Legal (0.14)	Protection of privacy	0.084
	Validity of documents	0.028
	Forgery issues	0.028

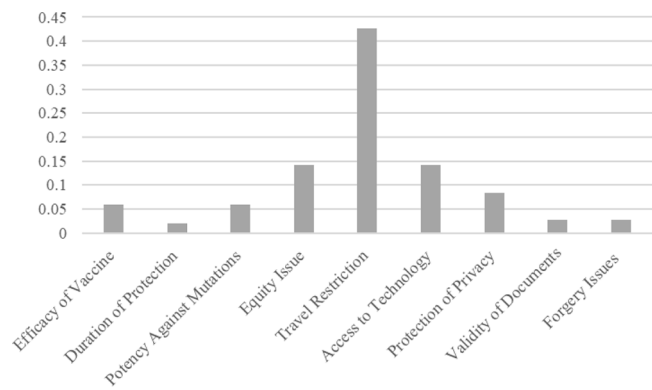


Figure 8.
Importance score for
challenges

vaccine passport programs. Blockchain technology-based solutions are useful in addressing legal challenges like protection of privacy, the validity of documents and forgery issues. The technical characteristics are unable to address ethical challenges like equity issues and unfair travel restrictions. The importance score for ethical challenges is far greater than legal and scientific challenges. This makes the role of international organizations like the World Health Organization (WHO) and GAVI (Vaccine Alliance) important in achieving equity and justice in vaccine passport programs.

Conclusion

Vaccination is being considered as a way to ease the travel restriction and bring global trades and tourism in true-normal. In light of mass vaccinations for COVID-19, countries are easing the restriction on travel for people who have been vaccinated or infected with the disease earlier. The travel companies are offering travel packages including the provision of jabs in their offerings. The countries are easing restrictions on the movements of vaccinated people in their countries.

Many countries have already announced plans for vaccine passports. The countries like UK and EU have started giving vaccine passports. But there are huge regulatory, ethical and technical challenges involved in the issue of these vaccine certificates, travel pass or digital health passes. For such a certificate or passport to work, it will require two things—access to a country's official records of vaccinations and a secure method of identifying an individual and linking them to their health record. Many policymakers are suggesting blockchain as one of the solutions to overcome these challenges. The review of the literature confirms the appropriateness of blockchain in the vaccine passport program. The case study discussions further suggest that DLT like blockchain are at the forefront for vaccine passport implementation. The review of literature also suggests that there is an ethical and security issue that needs to be addressed to realize the potential of blockchain in vaccine-passport management. The study also suggests that there are scientific, legal and ethical challenges to address for making a vaccine passport program successful.

Predictably, the concept of a vaccine passport or immunization certificates had led to a heated debate among people from all walks of life over its scientific evidence and ethical concerns. There may be a debate on the efficacy of the vaccines because the uncertainties remain over immunity responses and transmissibility after vaccination. Although the vaccination passport is not a new concept, as it has already been used for diseases like yellow fever, but the scale and complexity of the present pandemic are unprecedented. Historically socially marginalized groups are less likely to get the immunization; these people will be further marginalized because of the strict implementation of vaccine passports. Students in many countries are yet to be normalized; this will unfairly affect their travel for higher education. For people who are unable to be vaccinated because of their health status or religion, a vaccine passport regime could unfairly frustrate their return to normal life. The government should educate people to overcome vaccine hesitancy. Opinion leaders and religious leaders can act as catalysts in convincing people to get themselves vaccinated ([Jean-Jacques and Bauchner, 2021](#)). Vaccine equity is more important than vaccine passports. Vaccine passports should provide an incentive to overcome vaccine hesitancy. International agencies like WHO have a larger role to play in providing guidelines for the international travels and use of vaccine passports.

Research implications

As international travel is opening, the timing of this study is opportune. The study helps policymakers in designing the vaccine passport program for their country/organization. It

gives valuable insight to decision-makers evaluating technologies for the development of vaccine passport programs. The study further identifies nine challenges associated with vaccine passport programs. The prominent finding of this study is that ethical challenges are most important for the vaccine passport programs. The policymaker needs to address them to make a vaccine passport program successful.

Limitation and future directions

The experts selected for the focus group are on basis of the judgment of the researcher, this may result in some bias in the study. The study can use other multicriteria decision-making techniques such as Technique for Order of Preference by Similarity to Ideal Solution, ELECTRE or PROMETHEE. In case of uncertain data and imprecise knowledge about the phenomena, a future study can use fuzzy data in place of crisp data.

References

- Abid, A., Cheikhrouhou, S., Kallel, S. and Jmaiel, M. (2021), "NovidChain: blockchain-based privacy-preserving platform for COVID-19 test/vaccine certificates", *Software: Practice and Experience*, Vol. 52 No. 4, pp. 841-867, doi: [10.1002/spe.2983](https://doi.org/10.1002/spe.2983).
- Alsamhi, S.H., Lee, B., Guizani, M., Kumar, N., Qiao, Y. and Liu, X. (2021), "Blockchain for decentralized multi-drone to combat COVID-19 and future pandemics: framework and proposed solutions", *Transactions on Emerging Telecommunications Technologies*, Vol. 32 No. 9, p. e4255.
- Capece, G. and Bazzica, P. (2021), "Vpassport: a digital architecture to support social restart during the SARS-CoV-2 pandemic", *Sustainability*, Vol. 13 No. 7, p. 3945.
- Choudhury, H., Goswami, B. and Gurung, S.K. (2021), "CovidChain: an anonymity preserving blockchain-based framework for protection against covid-19", *Information Security Journal: A Global Perspective*, Vol. 30 No. 5, pp. 257-280, doi: [10.1080/19393555.2021.1921315](https://doi.org/10.1080/19393555.2021.1921315).
- Davis, F.D. and Venkatesh, V. (1996), "A critical assessment of potential measurement biases in the technology acceptance model: three experiments", *International Journal of Human-Computer Studies*, Vol. 45 No. 1, pp. 19-45.
- Garg, C., Bansal, A. and Padappayil, R.P. (2020), "COVID-19: prolonged social distancing implementation strategy using blockchain-based movement passes", *Journal of Medical Systems*, Vol. 44 No. 9, pp. 1-3.
- Goodhue, D.L. and Thompson, R.L. (1995), "Task-technology fit and individual performance", *MIS Quarterly*, Vol. 19 No. 2, pp. 213-236.
- Hall, M.A. and Stoddert, D.M. (2021), "'Vaccine passport' certification-policy and ethical considerations", *New England Journal of Medicine*, Vol. 385 No. 11, p. e32, doi: [10.1056/NEJMp2104289](https://doi.org/10.1056/NEJMp2104289).
- Hannah, B. (2021), "Vaccine passports - a guide to the different options", available at: www.businesstraveller.com/features/vaccine-passports-a-guide (accessed 14 July 2021).
- Hasan, H.R., Salah, K., Jayaraman, R., Arshad, J., Yaqoob, I., Omar, M. and Ellahham, S. (2020), "Blockchain-based solution for COVID-19 digital medical passports and immunity certificates", *IEEE Access*, Vol. 8, pp. 222093-222108, doi: [10.1109/ACCESS.2020.3043350](https://doi.org/10.1109/ACCESS.2020.3043350).
- IATA. (2021), "IATA travel pass initiative", available at: www.iata.org/en/programs/passenger/travel-pass (accessed 14 July 2021).
- IBM. (2021a), "How digital health pass works?", available at: www.ibm.com/watson/health/resources/digital-health-pass-blockchain-explained (accessed 14 July 2021).
- IBM. (2021b), "IBM digital health pass", available at: www.ibm.com/in-en/products/digital-health-pass (accessed 14 July 2021).

- Digital Green Certificates. (2021), "Digital green certificates: a decentralized and interoperable infrastructure", available at: <https://blog.iota.org/digital-green-certificates-a-decentralized-and-interoperable-infrastructure/> (accessed 14 July 2021).
- Jean-Jacques, M. and Bauchner, H. (2021), "Vaccine distribution—equity left behind?", *JAMA*, Vol. 325 No. 9, pp. 829-830, doi: [10.1001/jama.2021.1205](https://doi.org/10.1001/jama.2021.1205).
- Mbunge, E., Dzinamarira, T., Fashoto, S.G. and Batani, J. (2021), "Emerging technologies and COVID-19 digital vaccination certificates and passports", *Public Health in Practice*, Vol. 2, doi: [10.1016/j.puhip.2021.100136](https://doi.org/10.1016/j.puhip.2021.100136), (Oxford, England).
- Mishra, V., Samuel, C. and Sharma, S.K. (2018), "Supply chain partnership assessment of a diabetes clinic", *International Journal of Health Care Quality Assurance*, Vol. 31 No. 6, pp. 646-658, doi: [10.1108/IJHCQA-06-2017-0113](https://doi.org/10.1108/IJHCQA-06-2017-0113).
- Mithani, S.S. Bota, A.B. Zhu, D.T. and Wilson, K. (2021), "A scoping review of global vaccine certificate solutions for COVID-19", doi: [10.21203/rs.3.rs-334258/v2](https://doi.org/10.21203/rs.3.rs-334258/v2).
- Osama, T., Razai, M.S. and Majeed, A. (2021), "Covid-19 vaccine passports: access, equity, and ethics", *BMJ*, doi: [10.1136/bmj.n861](https://doi.org/10.1136/bmj.n861), 2021 Apr 1; 373: n861.
- Phelan, A.L. (2020), "COVID-19 immunity passports and vaccination certificates: scientific, equitable, and legal challenges", *The Lancet*, Vol. 395 No. 10237, pp. 1595-1598, doi: [10.1016/S0140-6736\(20\)31034-5](https://doi.org/10.1016/S0140-6736(20)31034-5).
- Ramirez Lopez, L.J. and Beltrán Álvarez, N. (2020), "Blockchain application in the distribution chain of the COVID-19 vaccine: a designing understudy", *Advance*, doi: [10.31124/advance.12274844.v1](https://doi.org/10.31124/advance.12274844.v1), Preprint.
- Ricci, L., Maesa, D.D.F., Favenza, A. and Ferro, E. (2021), "Blockchains for covid-19 contact tracing and vaccine support: a systematic review", *IEEE Access*, Vol. 9, pp. 37936-37950, doi: [10.1109/ACCESS.2021.3063152](https://doi.org/10.1109/ACCESS.2021.3063152).
- Rogers, E.M. and Shoemaker, F.F. (1971), *Communication of Innovations*, The Free Press, New York, NY, 1971.
- Satria, F.B., Khalifa, M., Rabrenovic, M. and Iqbal, U. (2021), "Can digital vaccine passports potentially bring life back to 'true-normal?'", *Computer Methods and Programs in Biomedicine Update*, Vol. 1, p. 100011, doi: [10.1016/j.cmpbup.2021.100011](https://doi.org/10.1016/j.cmpbup.2021.100011).
- Shuaib, M., Alam, S., Nasir, M.S. and Alam, M.S. (2021), "Immunity credentials using self-sovereign identity for combating COVID-19 pandemic", *Materials Today: Proceedings*, doi: [10.1016/j.matpr.2021.03.096](https://doi.org/10.1016/j.matpr.2021.03.096).
- Stake, R.E. (1978), "The case study method in social inquiry", *Educational Researcher*, Vol. 7 No. 2, pp. 5-8.
- Tanner, R. and Flood, C.M. (2021), "Vaccine passports done equitably", *JAMA Health Forum*, Vol. 2 No. 4, p. e210972, doi: [10.1001/jamahealthforum.2021.0972](https://doi.org/10.1001/jamahealthforum.2021.0972).
- Tsoi, K.K., Sung, J.J., Lee, H.W., Yiu, K.K., Fung, H. and Wong, S.Y. (2021), "The way forward after COVID-19 vaccination: vaccine passports with blockchain to protect personal privacy", *BMJ Innovations*, Vol. 7 No. 2, pp. 337-341, doi: [10.1136/bmjinnov-2021-000661](https://doi.org/10.1136/bmjinnov-2021-000661).
- Tummala, V.M.R. and Wan, Y.W. (1994), "Analytic hierarchy process (AHP) in practice: a survey of applications and recent developments", *Journal of Mathematical Modelling and Scientific Computing*, Vol. 3 No. 1, pp. 1-38.
- Upadhyay, A., Ayodele, J.O., Kumar, A. and Garza-Reyes, J.A. (2021a), "A review of challenges and opportunities of blockchain adoption for operational excellence in the UK automotive industry", *Journal of Global Operations and Strategic Sourcing*, Vol. 14 No. 1, pp. 7-60.
- Upadhyay, A., Mukhuty, S., Kumar, V. and Kazancoglu, Y. (2021b), "Blockchain technology and the circular economy: implications for sustainability and social responsibility", *Journal of Cleaner Production*, Vol. 293, p. 126130, doi: [10.1016/j.jclepro.2021.126130](https://doi.org/10.1016/j.jclepro.2021.126130).

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- Vanderslott, S. and Marks, T. (2021), "Travel restrictions as a disease control measure: lessons from yellow fever", *Global Public Health*, Vol. 16 No. 3, pp. 340-353, doi: [10.1080/17441692.2020.1805786](https://doi.org/10.1080/17441692.2020.1805786).
- Wong, G., Liu, W., Liu, Y., Zhou, B., Bi, Y. and Gao, G.F. (2015), "MERS, SARS, and Ebola: the role of super-spreaders in infectious disease", *Cell Host and Microbe*, Vol. 18 No. 4, pp. 398-401.
- World Health Organization. (2021), "Interim position paper: considerations regarding proof of COVID-19 vaccination for international travelers", available at: www.who.int/news-room/articles-detail/interim-position-paper-considerations-regarding-proof-of-covid-19-vaccination-for-international-travellers (accessed 30 June 2021).
- Yin, R.K. (1992), "The case study method as a tool for doing evaluation", *Current Sociology*, Vol. 40 No. 1, pp. 121-137.

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