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Blockchain Applications for the Police Task Force of IRI: A Conceptual Framework Using Fuzzy Delphi Method

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Abstract

Blockchain is one of the trending emerging technologies that enables immutable data storage over distributed ledgers. The fundamental features of blockchain technology, such as record and identity traceability and immutability makes it an attractive alternative for the state-of-the-art information systems. Thus, blockchain has found its way into various fields. In Iran, blockchain technology has been employed in different areas including: commercial mining platforms, secure exchange platforms, and innovative trustless projects. One of the main applications of blockchain is secure management of sensitive information, which makes it a suitable infrastructure for providing advanced control over data in police task forces. The motivation behind this research is to provide a conceptual framework for employing blockchain in law enforcement organizations by analysis and comparison of best practices in other countries and academic case-studies. We provide a systematic overview of case-studies by qualitative content analysis. Moreover, the reliability of our statistics is evaluated by Cohen's kappa coefficient roughly 0.64. Finally, the prioritized applications were evaluated by a 14 member experts panel through fuzzy Delphi method with a Kendall's Coefficient of Concordance of W=0.711, indicating high rates of agreement among members. To this end, "trustless authentication systems", "distributed data/resource/information management", and "inter-department integrated information systems" were selected as most valuable applications of blockchain for police task forces and law enforcement agencies in Iran.

Keywords: Blockchain applications; Police and law enforcement agencies; comparative study; content analysis.

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Introduction

During the past decade, blockchain has been one of the leading technologies in both industry and economy. For example there are many research employing blockchain to increase transparency and trustworthiness in supply chain e.g (Bamakan, 2021). Many studies state that blockchain is a revolutionary innovation in digital platforms (Saadatmand, 2019). Blockchain is consisted from multiple blocks that are chained to each other in a queue-like structure. Every block in a blockchain has unique identity and contains immutable information (Abeyratne, 2016). Therefore, stored data in the blockchain cannot be altered, removed nor updated (Madavi, 2019). Today, blockchain technology is extensively employed to provide trustless digital trading platforms in e-commerce (Glaser, 2017). This has attracted many users and industries to adopt their business with blockchain-based platforms (Gartner, 2016).

During the year 2020, police force of the Islamic Republic of Iran has deployed an innovation center in order to improve quality of its internal and public services by employing emerging technologies, such as big data analysis infrastructure, artificial intelligence center, and internet of things platform. According to their latest reports, the police department is planning on employing blockchain as one of the most innovative technologies for building smart police. To this end, since 2019, a feasibility study was started in the subject of "conceptual framework in applications of blockchain in police force of IRI". The framework was used as the foundation of prioritizing blockchain applications in police force and selected applications were handed-out to related units.

Without having a complete awareness from patterns of employing the technology, its development policies, and best practices worldwide, the possibility of impositioning different costs (in terms of time, man-power, and budget) significantly increases. Therefore, it is necessary to provide a conceptual framework to identify and select effective applications of blockchain technology in police force of IRI. Precisely, the main motivations behind this research are as follows:

- Better understanding of approaches and development patterns regarding employing blockchain technology in police departments, law enforcement agencies, and public security of different countries around the world.
- Decision making in the fields of development and employment of blockchain in territory of police force of IRI based on the best practices worldwide.
- Providing a decision support mechanism with the aim of identification and selection of blockchain development for its applications in police force of IRI.

The main goal of this research is to provide a comparative study of technical options available for blockchain to achieve "a conceptual framework for identification and selection of blockchain applications in police task force of Islamic republic of Iran", while

prioritization process of selected applications is based on fuzzy Delphi method. To this end, following questions are answered:

- What are the best practices in employing blockchain in police and law enforcement agencies in other countries? What were the main goal in each project?
- What is the conceptual framework for identification and selection of blockchain application in police task force?
- What is the importance and effectiveness of each technology in the provided framework? (according to the requirements and considerations of the target organization)
- In the followings, we highlight contributions of this work:
- To the best of our knowledge, this research is the first to provide a conceptual framework for blockchain applications in police task forces by systematic overview and analysis of its use-cases and best practices.
- This research focuses on limitations, considerations and requirements of a governmental department in Iran (the task force of IRI) through analysis of blockchain applications and their prioritization process. To this end, our findings are unique and valuable for the target organizations.

The rest of the paper is organized as follows. Section 2 provides literature review, while focusing on trends and applications of blockchain in governmental level. Section 3 overviews the research advancement framework and our methodology to achieve aforementioned research goals. Section 4 covers a wide range of case-studies and analyzes them from different points of view. Section 5 provides readers with detailed findings of this research. Finally, Section 6 concludes the paper, while emphasizing main findings of the research along with its limitations.

Literature Review

1. Trends of Blockchain Adoption in Financial and Non-Financial Applications

Emergence of cryptocurrencies and their various applications has been one of the biggest subjects in economy and financial industry. It is obvious that some of the fundamental features of blockchain are the main reason for its exponential growing interest in economy. As an example, blockchain distributes the control of transaction creation, identity verification and payment validation among users; this removes the necessary involvement of trusted third-parties in daily financial activities of users, which was required by traditional banking systems (Zheng, 2017). Distributing financial platforms and ecosystems over blockchain significantly reduces the initiation and maintaining costs (up to hundreds of million dollars) of traditional banking platforms (Lee, 2016; Peters, 2016).

Although bitcoin and other cryptocurrencies are most popular outcomes of blockchain technology; however, the technology can be employed in other applications to improve trust

and security levels compared to traditional centralized systems. Some studies strongly suggest that blockchain can be also considered as a building block for new generation of interactive internet system (Kosba, 2016). Blockchain can be employed as the underlying data infrastructure for governance systems and has been practically used in digital campaigns in many countries, such as UK, USA, Estonia, New Zealand, and Israel (van Engelenburg, 2017). In addition to transparency of transactions and trustless data infrastructure, some blockchains, such as Ethereum, allow execution of smart contracts on blockchain itself that improve scalability and functionality of the platform (Shah, 2019).

In a study back in 2019 by supervision of Arabsorkhi in ITRC (Arabsorkhi, 2020), effectiveness of blockchain key features in three areas: (1) insurance, (2) health, and (3) Governance evaluated. Table 1 presents a summary of the findings related to this research.

Table 1. Effectiveness of Blockchain Key Features in Selected Areas

(Lower numbers show higher effectiveness)

Area	Financial Interactions	Smart Contracts	Traceability	Data Storage	Digital Identity	Interactivity
Insurance	1	1	3	2	2	3
Health	2	1	1	1	1	1
Governance	3	2	1	1	1	1

In addition, most useful key features of the technology in other areas and industries were also identified (Arabsorkhi, 2020). Table 2 provides an overview in this regard. According to aforementioned findings and statistics, blockchain technology can be easily labeled as one of the most important markets in the past decade. The overall marketcap of blockchain-related industry has been predicted to be more than 20.55 billion dollars with a yearly growth rate of above 59%. The increasing amount of investment on blockchain projects allowed the technology to find its way in various markets such as finance, healthcare, e-commerce, media, and entertainment (Chernov, 2018).

Table 2. The Most Useful Blockchain Key Features in Different Industries

Area	Financial Interactions	Smart Contracts	Traceability	Data Storage	Digital Identity	Interactivity
Manufacturing industries (supply chain)	✓	✓	✓	✓	✓	✓
Educational and research activities				✓	✓	
Tourism and transportation industry	✓	✓	✓	✓	✓	
Decentralized markets	✓	✓	✓	✓		

2. Governmental applications of blockchain

Recent studies indicate that blockchain technology can help governments to improve public services to their citizens (Laskowski, 2017; Turkanovi¢, 2018), fight against fraud and scam (Hyvärinen, 2017; Archa, 2017), and to increase transparency and trustability of their public or organizational records (Liang, 2018; Xia, 2017). Blockchain can be directly employed in order to decentralize many authority-related public services improving scalability and reliability of the service in applications such as birth certificates and id-cards (Raju, 2017), property registration (NRI, 2015), digital public elections (Noizat, 2015; Yavuz, 2016), law execution (Peter, 2017), or personal data management (Zyskind, 2015).

In addition to aforementioned applications, many countries exploit the potential of blockchain in applications such as public security (Commission, 2015), law enforcement (Alketbi, 2018), and police public services (Zhang, 2018). Note that these applications are in the field of police and law enforcement agencies. To this end, there are multiple examples worldwide of different police and law related departments that have publicly invested in employing blockchain technology.

Methodology

In order to provide a conceptual framework for blockchain applications in police force, a comparative study of national and private acts in field is prepared in a systematic research framework as follows (Saadatmand, 2019):

Research methodology

This research is based on the traditional qualitative content analysis methodology, which is especially useful where quantitative methodologies are not possible. Therefore, qualitative content analysis can be viewed as a method for mental interpretation of the content of textual data, using categorization process of systematic coding and templates or design of known patterns (Saadatmand, 2019; ZareRezvan, 2021).

The reason behind the chosen methodology is the newness of the studied phenomenon (blockchain technology applications in police forces) and limited number of theoretical references in the field. Thus, in this research, we avoid using pre-selected categories and try to employ a data-driven approach to classify research findings. To this end, we described four independent related phases to progress research as is shown in Figure 1.

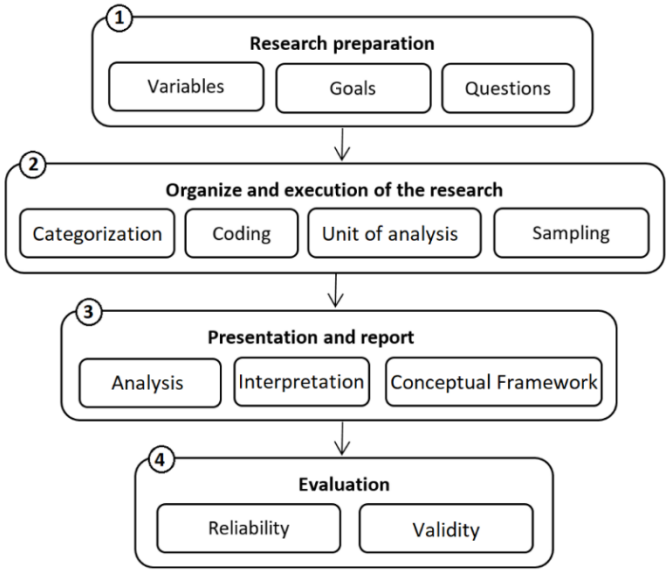

Figure 1. Research advancement framework

Moreover, in order to enrich the findings of the research, a subset of data analysis techniques is used in phase three of Figure 1. We provide comparative and strategic study of the findings using intra-case and inter-case analysis. In our comparative and strategic study, we follow goals higher than only describing each case-study and try to evaluate and prioritize blockchain applications for police and law enforcement agencies. Finally, in our intra-case and inter-case studies, we compare the point of view in police forces with reasons to ignore or select each application or blockchain feature (Saadatmand, 2019).

It is worth mentioning that Fuzzy modification method of Delphi (Cheng & Lin, 2002) was employed in order to identify and prioritize main application of the blockchain within the police task force of IRI. Suitable selection of the panel members is a very important phase of Delphi method. The higher knowledge of chosen members in the field, ensures the higher and more accurate Delphi analysis. Therefore, we focus on the knowledge in the blockchain field and academic ranks of the members for our selection (Linstone & Turoff, 2002). The Delphi method in this research is executed in three phases, which will be more detailed in Section "3.2. Sample" and Section "3.3. Data Collection and Analysis."

Sample

This research's sample includes public national and organizational reports of blockchain development and applications in police, law enforcement agencies in other countries. In order to ensure comprehensiveness of the research, we targeted and deeply analyzed more than 80 research and case studies. Moreover, in order to evaluate validity and reliability of the proposed conceptual framework (application of blockchain technology) within the mission

territory of the police task force of IRI, a professional panel of 14 experts including top universities professors (Tehran University (two members), Sharif University (three members), Amirkabir University (one member), Iran Science and Technology University (four members)) along with the blockchain experts from police force of IRI itself (four members), was formed. The panel members had the experience of nine strategic, technical, and developmental projects in the field of blockchain during past four years.

It is worth mentioning that three members of the experts team are employed in "Naji Research and Development Company" as "managing director", "deputy of software", and "deputy of information systems". Moreover, they have successfully defended their PhD thesis in the field of blockchain and are in charge of blockchain adoption program in police task forces of IRI. Nine members of the experts team are employed as scientific staff in top universities and have done multiple research on blockchain. Remaining two members are directors of ongoing blochchain-related projects in police task forces of IRI.

Data Collection and Analysis

The Unit of analysis in this research is the entire context of collected reports. After deciding unit of analysis, we design categories and subcategories of reports and identify research variables. By identifying technical fields and applications of blockchain in reports contexts and coding the gathered data, we can provide detailed analysis regarding areas of technology applications. In this methodology two main elements are present: (1) unit of analysis and (2) category of analysis.

The unit of Analysis is the smallest part of the document context that is measurable through research goals. The unit of analysis can include words, sentences, paragraphs, etc. according to the goal and type of the research. After defining analysis units of the research, it is necessary to demonstrate how the measured contents are categorized. Subjects of these categories are considered as analysis categories. Finally, units are categorized based on analysis categories to reach deliverable report statistics (Saadatmand, 2019).

The fuzzy modification method of Delphi (Cheng & Lin, 2002) was employed in order to evaluate and verify the proposed conceptual framework. To this end, three rounds of questionnaires and follow-up analysis were executed based on the 14 member expert panel. During the first round, semi-structured interviews (in the form of questionnaire) planned to analyze members' early opinion regarding each application of the blockchain in the police task force. In the second round of the fuzzy Delphi method, a list of applications was given to each member to prioritize. It is worth mentioning that this list was filtered out from the outcome of the first round. For the prioritizing questionnaire, we employed a 5 point Likert scale for each application with a triangular fuzzy number system (Rouhani, 2014) to emphasize the importance of each application. For the third round of fuzzy Delphi method, the same questionnaire was handed out to experts panel members with addition of the fuzzy

average of priorities given to each application in the second round. The outcome of this research was handed out to the police and law enforcement agencies as a conceptual framework.

Case Studies

Since the emergence of blockchain technology, there has been various efforts to employ and benefit from its potential for government and police applications. In this section, first, we discuss main applications of blockchain in literature based on our analysis categories. Later, we provide a generalized overview of publicly available blockchain adoption scenarios for police applications in foreign countries. Finally, we analyze different statistics regarding case studies to prioritize blockchain applications and features for police and law enforcement agencies.

Applications of Blockchain in Police Services

1. Chain of Custody based on Blockchain

Due to the immutable data structure of blockchain, every record of evidence submitted to the system has a complete log of accesses and interactions, which cannot be edited nor removed. To this end, no one will be able to corrupt any evidence through the process of a case in court or within police department itself. Moreover, such a system can also prevent human error or accidental data loss due to its distributed and immutable nature (Bonomi, 2018).

A blockchain-based chain of custody system can be shared within different departments including: police, jail and court. It can be employed in parallel, without any delay, and with complete transparency among departments. Therefore, entire process of a case from early inspections on the field of the crime with its evidence, until the decisions made by jury and execution of the punishments by department of justice can be transparently accessible through the system with suitable levels of transparency.

In order to implement a decentralized chain of custody, recent studies take advantage of smart contracts (Bonomi, 2018). In addition, to provide levels of transparency within a department or among other departments, different side-chains can be employed, where each department has its own private internally-accessed side-chain and automatically shared suitable information or evidence with the other parties.

2. Smart and Distributed Criminal Records System

Another obvious application of blockchain the field of police, is the criminal records system that can directly benefit from blockchain's distributed and immutable structure. With a criminal records system based on blockchain, no one can falsely edit or delete records of individuals without leaving a traceable log regarding such action. The launch of such system

also has great influence on society, since people sense that there is no escape from a record system with immutable data structure.

Many studies suggest employing side-chains in order to provide different levels of access to criminal records. For example, a rookie officer may have access to general criminal records of citizens but a more detailed information requires higher rank and closer interaction with the system. Another benefit of a blockchain-based criminal records system is the information security. Due to the distributed nature of blockchain, there is no single point of failure in the system and therefore, an attack or a failure in some servers do not result in any data loss. Moreover, such system provides more scalability in comparison with the traditional centralized criminal records systems.

3. Smart Traffic Control and Monitoring Based on Blockchain

An optimized traffic control system of an entire city requires a highly scalable platform. With exponential increase in the number of smart cameras and sensors in city streets and with more cars equipped with GPS and acceleration sensors, a very large and highly scalable data structure is required to handle such amount of data. The monitoring and controlling system must be able to collect all of the information possible without compromises on quality of the data and be able to provide real-time access to data on desired situations.

To this end, a smart traffic control and monitoring system must have a distributed infrastructure to be able to provide such scalability. In addition, the system must ensure correctness of incoming data and be able to handle information securely preventing any corruption or data loss. Such features can be fundamentally implemented within the system itself by employing a blockchain-based infrastructure.

4. Police Property and asset management system based on Blockchain

One of the main sources of wasted budgets in governmental departments is mismanagement of properties and assets of the department. Due to the high initial and maintenance costs of traditional database systems, it is not possible to keep digital records and logs of every property and asset within the department in a database.

However, blockchain technology can provide detailed and highly accessible record and logging system at low cost. Therefore, different governmental departments, and especially police, can benefit from keeping records of every valuable asset within the department. The immutability feature of the blockchain prevents any corrupted data and prevents many acts of fraud within department from the source of it.

5. Blockchain as a Platform for Document Management and Authentication

Employing blockchain as a platform for document management can provide different benefits to the police department as follows:

- **Inability to delete or change data**: In order to prevent fraud and different acts of corruption within the police department, blockchain's immutability can be highly suitable. If police department's internal documents are stored on a blockchain, there is no way to undo a submitted document to the system.
- **Undeniability**: Since submitted documents cannot be altered, every report on every case will be traceable by the authorities and officers will be responsible for their submitted reports.
- **Complete record of history**: Every update on a document will be recorded in the system as an additional version and therefore, the previous version of the document will still be accessed. Thus, such system can provide detailed and complete history of how a case was progressed until it got closed. Such history record, greatly decreases possibility of fraud within the police department.

6. Anonymity in cryptocurrency exchanges

One of the biggest advantages of decentralized cryptocurrencies over traditional fiat money system is that assets cannot be directly controlled by an authority. To this end, there are multiple techniques to keep currency transfers in black-listed organizations of Iran (such as Police department itself) anonymous. This feature helps different organizations to undo limitations forced by international sanctions (such as US sanctions). Besides international sanctions, anonymity of financial interactions within police department is important to hide certain relations among agents and hide their real identities for their general safety.

7. Distributed inter-organizational information system

Another interesting application of blockchain is to employ it as an information infrastructure for sharing data among different organizations. Due to the distributed nature of the blockchain, every device with certain rights can interact with the system. Therefore, a blockchain-based data-sharing system can have high scalability advantages over traditional systems.

Besides scalability and availability, a blockchain-based information system provides features such as: (1) immutability, (2) undeniability, and (3) full control over data share. These features make blockchain to be a suitable infrastructure for inter-organization information exchange platforms. As an example, an in-the-field officer may require to query some general information regarding a citizen, however, such access may require certain permissions from authorities in the current systems. But in a blockchain-based system, data is

categorized in different side-chains that have access to leveled information. To this end, there will be no permission requirements to access an already shared information on the blockchain. Note that the owner of the information has full control over what data it shares on different side-chains in the blockchain.

8. Confidential and classified information registration system

Handling and management of classified documents is one of the ongoing issues within any agency. Blockchain-based control systems can log immutable metadata regarding interactions with classified information. Moreover, immutability of the stored data itself ensures transparency of reports to the higher ranked authorities within the organization.

Public Government Case Studies

1. United States of America (USA)

Chronicled, Inc. is a blockchain and IoT technology company based in USA that offers different solutions to improve security and efficiency of everyday applications. One Chronicled products is CryptoSeal that is a blockchain-registered, tamper-evident adhesive seal strip for ensuring package delivery integrity (Cryptoseal, 2017). One of the main applications of such product is to manage and transport sensitive information and evidence in police departments. The product ensures physical integrity of delivered package and can be verified easily. On the other hand, it is cryptographically impossible to recreate an opened seal due to the fact that the data is timestamped on blockchain.

The Department of Homeland Security (DHS) Science and Technology Directorate (S&T) awarded a blockchain-based project with $199k back in 2016. The project focuses on safeguarding internet of things (IoT) devices from different adversaries by ensuring the integrity of the queried data from devices (DHS, 2016). A blockchain-based platform is used to store timestamped identity logs, lists of available updates, known security issues and granted authorities.

In 2017, IBM Watson publicly announced (IBM-Watson, 2017) the expansion of its federal work with US government by signing on with the Centers for Disease Control and Prevention from Food and Drug Administration. The project was focused on managing shared patient data over time and across various care settings on a blockchain-based platform to preserve users' privacy and secure private data.

The defense advanced research projects agency (DARPA) has started multiple security improvement projects based on blockchain technology (DARPA, 2019). One of the most notable DARPA projects is the experiments of creating an efficient and secure blockchain-based platform allowing personnel from anywhere to transmit secure messages or process transactions. The main application of such platform is to facilitate communication between

units and headquarters, and transmit information between intelligence officers and the Pentagon.

Another DARPA project using blockchain is to develop an unhackable code, based on the blockchain's unchangeable states property (DARPA, 2019).

Table 3. Blockchain Applications in Police and Their Employed Features

		Advantages over Traditional Systems	Employed Blockchain Features/Abilities				
			Side-chains	Immutability	Anonymity	Verifiability	Private chains
Police services based on blockchain	Chain of custody (CoC)	reliability, history record, automation		✓		✓	
	Smart traffic crash management	scalability, automation	✓			✓	
	Criminal history records	reliability, history record, automation		✓		✓	
	Integrated justice and law enforcement system	reliability, history record, scalability, lower latency	✓	✓	✓	✓	
	Smart traffic management	scalability, automation	✓			✓	
Blockchain applications inside department of justice and low	Data management system	distributed security, high controllability, privacy preserving	✓	✓		✓	✓
	Authentication system	distributed security, high controllability, privacy preserving, scalability		✓	✓	✓	
	Secure inter-organizational information system	distributed security, authentication, scalability	✓	✓			✓
	Privacy preserving & Anonymity	anonymity, privacy preserving, zero-knowledge authentication			✓		✓
	Resource management system	distributed security, high controllability, scalability	✓	✓		✓	

2. Europe

Recently, The European public sector is building its own blockchain services infrastructure (EBSI) and each member of the European Blockchain Partnership (EBP) - the 27 EU countries, Norway, Liechtenstein and the European Commission – will run their own full-nodes of the blockchain (Digital Strategy, 2020). The main use-cases of EBSI are as follows: 1) notarization, 2) diplomas and education credentials, 3) European digital identity, and 4) trusted data sharing.

Use-cases number 3 and 4 together implement a generic digital identity system that allows users to create and control their own identity across borders without relying on centralized authorities. On the other hand, citizens' authentication and traceability by authorities and police departments is increased due to the trustless and fully-accessible users' identity on blockchain, which is securely shared amongst authorities in the EU. Moreover, additional data, such as VAT identification numbers, are shared among businesses and one-stop-shops and also tax authorities to trace citizens' financial behavior.

3. Netherlands

Crystal-blockchain is a company in Netherlands that provides analytics and crypto transaction monitoring with solutions to streamline know-your-transaction (KYT) & anti-money laundering (AML) procedures (Crystal Blockchain, 2017). Their goal is to fill the lack of compliance in decentralized finance (DeFi) protocols. One of the main outcomes of such system is that financial tracking of suspicious accounts can be continued in a cross-chain manner. This can be very helpful for police and department of justice to track money laundry acts.

4. Singapore

Monetary authority of Singapore (MAS) has launched Project Ubin that is a collaborative project set up in 2016 involves a consortium of local banks, including DBS, UOB and OCBC. This helps securing national-wide financial information and produce a more trackable traces of financial criminality (MAS, 2016).

On the other hand, Blockchain Innovation Programme (SBIP) in Singapore is a governmentally funded project (almost $9 millions) that aims to improve different government services by employing blockchain technology. According to the latest news (Yang, 2018): "Singapore's government is positioning itself as a partner to blockchain developers and companies, with the goal of becoming a "crypto hub" that is more open to the technology than other countries."

5. United Kingdom (UK)

Recently, the UK parliament set up an all-party parliamentary group on blockchain (APPG) (Parliament, 2020). The APPG establishes a two-year agenda to foster blockchain-based solutions in the UK public sector by the end of 2022.

Back in 2018, former British minister for digital and the creative industries Margot James, stated that the British government is highly interested in investing on blockchain technology (Clarke, 2018). Moreover, James stated that: "We're investing over £10 million pounds through Innovate UK and our research councils to support Blockchain projects in diverse areas like energy, voting systems and charitable giving."

6. United Arab Emirates (UAE)

The government-funded project "smart Dubai" aims to fully implement vision of Sheikh Mohammed Maktoum for future of UAE (Smart Dubai, 2017). The project has piloted a blockchain for sharing public and linkable data among police, court, and Dubai Public Prosecution (DPP). As a sample application, the process of authorizing new citizen passports has been shortened into only one working day. Overall, although there are some government-funded projects are piloted through the country, the applications and required knowledge of developments in UAE seems to be low. Therefore, it is predicted that as same as previous technologies, UAE will finally end up on investing on foreign companies to build fancy blockchain-based infrastructures in the country.

7. Estonia

The government of Estonia is the world's leading in adopting to blockchain technology. One of the big projects in the government is development of court information system (KSI) blockchain that ensures global data integrity and privacy of the users. The KSI blockchain is employed directly in three larger national projects: 1) e-Law, 2) e-Justice, and 3) e-Police as follows.

1) **e-Law:** is a public and online access-point for the Estonian Ministry of Justice that allows citizens to review every draft law submitted since 2003.
2) **e-Justice:** is developed in order to improve efficiency of court in Estonia by automating procedures based on a blockchain information system (KSI).
3) **e-Police:** is a platform that provides officers almost instantaneous access to citizens' information. The available information includes: residency, photograph, contact information and driving license data.

8. China

The ministry of public security in China recently announced that they have developed a blockchain-based storage system for securely handling evidence collected during police investigations. The ministry's research arm filed a patent application in 2017 for a blockchain-based metadata handler system that stores metadata related to public information submitted to the cloud aiming to provide a transparent and tamper-proof deposition procedure (China officials, 2017). The intellectual property office in China notes that the main focus of the patent is to disallow any alteration after an evidence is submitted to the cloud, which provides a shared storage for different departments of the government.

On the other hand, China's national audit office, which is responsible for monitoring all government-related financial transactions, publicly announced that it is necessary to adopt to

blockchain technology with emphasizing scalability and transparency of the blockchain (China police, 2018).

Back in 2016, a national journal related to defense and science department of china published a short work on the possible military applications for blockchain (Lin, 2016), including:

1) Securing battlefield information
2) Weapons and equipment management
3) Smart military logistics
4) Covert intelligence incentives

9. Canada

Leonovus is one of the private companies that provide secure and reliable storage solutions with a guaranteed quality of service (Leonevus, 2017). One the recent solutions from Leonovus is a secure storage solution for managing sensitive information that is hardened via blockchain. The system ensures the correctness and integrity of data and their lifetime logs by inserting every access and transaction with data in a blockchain-based system. One of the main applications of such system is to host a tamper-proof chain-of-custody (CoC) between police and department of justice.

On the other hand, in the public sector of Canada, the government is trying out blockchain-based systems to improve transparency in government funding process. Precisely, National Research Council (NRC) in Canada is sharing information regarding funding and grants for its Industrial Research Assistance Program (NRC IRAP) in real time via the Catena Blockchain Suite. The blockchain-based real-time platform is built on a forked project from the Ethereum blockchain (Kalvapalle, 2018).

10. Russia

Since 2019, the Financial Communication Transfer System (SPFS) of Russia has started multiple blockchain-based projects to employ cryptocurrencies in order to circumvent US sanctions (Golstein, 2019). In other news, Russia's first deputy prime minister Andrey Belousov, stated that blockchain technology is one of the main researches that the Russian government prioritizes on near future. Moreover, he states that: "The task before us is to practically recreate a system of venture financing that attracts private capital and public-private partnership. Relevant proposals from industry have already come in."

11. Germany

The German Federal Ministry for Economic Affairs and Energy (BMWi) and the Federal Ministry of Finance (BMF) have recently published the "Blockchain Strategy of the Federal Government" stating their long-term roadmap to adopt to blockchain technology (BMWi, 2021). The published strategy plan includes different applications, such as social security and authorizing citizens. The main priorities in the strategy are as follows:

1) Ensuring financial stability and stimulating innovation
2) Advancing innovation by providing multiple industrial and academic fundings
3) Facilitating investment by putting reliable investment conditions in place
4) Harnessing digital technology to improve administrative services
5) Disseminating information: knowledge, networking and collaboration

Statistical Analysis

Table 4 provides a generalized statistics regarding included applications of blockchain in case studies. The table clarifies whether a countries public announcements have mentioned or included plans regarding a certain application of the blockchain. Moreover, in the final column of the Table 4, we provide number of reviewed scientific papers that included a plan on the classified applications.

As can be seen, some of the applications, such as privacy preservation and anonymity or smart traffic control, have got more attention in the academic society compared to the government interests. On the other hand, applications such as blockchain-based authentication systems have got high rates of attention in both governmental and academic fields.

The main reason behind such diversity, is the priorities of governments compared to the academic society. Although blockchain shows solid and highly scalable potentials on IoT and other innovative ecosystems, but the governments priorities at this decade does not include such innovations. As a generalization, we can conclude governments priorities lean towards increasing their controllability over their internal and public services.

Table 4. Statistics for Included Applications of Blockchain in Case Studies

		Countries										Total	Sci. papers
		USA	Canada	Russia	Germany	China	Estonia	UAE	UK	Singapore	Europe		
Police services based on blockchain	Chain of custody (CoC)			×				×	×	×	×	5	11
	Smart traffic crash management		×	×	×	×			×	×	×	3	5

	Criminal history records		×	×	×			×	×	×		4	5
	Integrated justice and law enforcement system							×		×	×	7	14
	Smart traffic management	×	×	×	×	×			×	×	×	2	5
Blockchain applications inside department of justice and low	Data management system					×		×	×			7	16
	Authentication system									×		9	20
	Secure database system							×	×	×		7	8
	Privacy preserving & Anonymity	×	×		×			×	×	×		4	14
	Resource management system			×				×				8	6
Total		5	4	2	4	7	10	3	4	3	6	10	56

In order to provide a more revealing analysis of Table 4 statistics, we provide the average percentage of included applications in each case study in Figure 2. The values in this figure are the average of both governmental and scientific case studies of Table 4. The higher rates in Figure 2 indicate higher overall interests within both governments and scientific society.

The most repetitive application suggestion for employing blockchain technology in police and law enforcement agencies is the "authentication system," which highly depended on immutability of data stored on blockchain. Moreover, applications in areas such as "resource management," "secure management systems," and "integrated justice and law infrastructures," are also included in more than forty percent of all case studies on average.

On the other hand, some innovative IoT infrastructures based on blockchain, such as "smart traffic control" did not get high statistical scores according to Figure 2. Furthermore, although tracking "criminal history records" on blockchain was a popular in governmental case studies, it did not get high attention in the academic society. For this specific application, we guess that the reason behind such diversity is the fact that employing blockchain for maintaining criminal history is a very straight-forward approach and does not give researchers any issues to solve and increase their contributions in the paper.

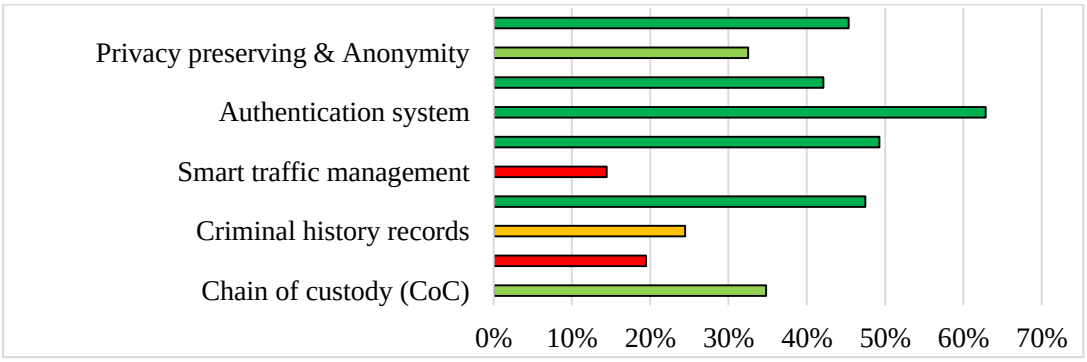

Figure 2. Average Percentage of Included Applications in Case Studies

We built a comprehensive questionnaire based on our qualitative analysis results for the 14 members of the experts' panel in order to evaluate practicality of available applications considering the mission territory of the police task force of IRI. After early classification and analysis of the responses in the third round, each application and its corresponding priority among others was represented, as is shown in Table 5.

Table 5 provides average priority given to each application by the experts panel members in both the second and the third rounds of the questionnaire and their corresponding difference. The red values present a decrease in the priority average. The difference between two rounds of questionnaire indicate the influence of final results on each individual, resulting on lower variance in the third round. According to Table 5 results, the highest priority was given to "authentication system" application with an average of 4.43 in the third round. The lowest priority was given to "smart traffic management" with an average of 3.01. The applications of "secure database management" and "smart traffic management" have seen the most increase and decrease of the priority between the two rounds, respectively. On the other hand, the priority of some applications, such as "secure data management," did not have any noticeable changes between two rounds.

Table 5. Blockchain Applications in Police from the Experts Panel Perspective

		Average priority given by members		Difference
		2nd round	3rd round	
Police services based on blockchain	Chain of custody (CoC)	3.12	3.03	-0.09
	Smart traffic crash management	3.07	3.05	-0.02
	Criminal history records	3.10	3.05	-0.05
	Integrated justice and law enforcement system	3.20	3.53	0.33
	Smart traffic management	3.12	3.01	-0.11
Blockchain applications inside department of justice and low	Data management system	4.30	4.30	0.00
	Authentication system	4.15	4.43	0.28
	Secure database system	3.07	3.45	0.37
	Privacy preserving & Anonymity	3.07	3.01	-0.06
	Resource management system	3.74	3.91	0.17

Results

According to the statistical reports in previous section, we conclude that in order to start serious investments on blockchain applications for police task forces of IRI, there are some fields that have should be considered with higher priority. Since our categorization of analysis is qualitative, we have measured the reliability and robustness of our findings using Cohen's kappa method (Cohen, 1960). To this end, according to our categories and percentage of each unit, the final Cohen' kappa coefficient is 0.64. This indicates that units of analysis and their corresponding categories in this research have reasonable inter-rater reliability. Figure 3 presents the proposed conceptual framework after analysis of case studies for application of blockchain technology in police and law enforcement agencies.

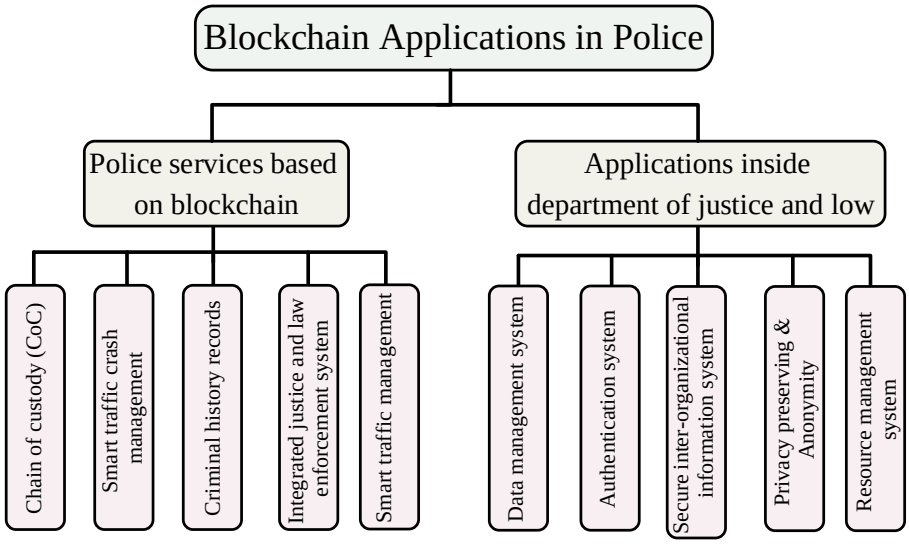

Figure 3. Conceptual Framework for Blockchain Applications in Police Task Forces and Department of Justice and Law

According to the qualitative findings (Figure 3), evaluation of the proposed conceptual framework for applications of blockchain in Police task force of IRI was done using the fuzzy Delphi method. Before examination process within the experts team, effective and key derivatives for blockchain adaption was analyzed in different levels of police task force of IRI. The results of analysis suggest that four subjects were highly desired by the polices are as follows: traffic, C.I.D, prevention, and public security and intelligence. According to these subjects, the priorities of blockchain applications were set by the fuzzy Delphi method through expert's team as follows: 1) police strategic issues, 2) important information and communication technology concerns of the chosen police forces, 3) management concerns of the police in activity domains, and 4) blockchain solutions for the aforementioned concerns. Based on these subjects, the experts team analyzed and prioritized ten major blockchain applications for police (Figure 3).

The number of rounds in the Delphi's fuzzy method highly depends on the concordance of opinions of experts panel members on overall analysis units. Moreover, Kendall's Coefficient of Concordance (W) was employed as the measurement for fuzzy Delphi method rounds. The selected measurement tool provides a decimal number between 0 and 1, with 0 indicating total independence, while score 1 presenting the highest amount of dependency (Nasiri, 2008). In the end of the third round of the executed fuzzy Delphi method, the Kendall's Coefficient of Concordance was calculated as W=0.711 using the SPSS software. This indicates that on average, members of the experts panel have reached to a general agreement on the prioritizing the applications of blockchain in police. Thus, the final candidate applications of the blockchain in police task force and department of justice and law of IRI are as follows:

1) **Blockchain-based authentication systems:** Due to the immutability of stored information on blockchain, one of the straight-forward applications of it within any system is the authentication process. It is worth mentioning that information related to authentication are usually limited and therefore are a suitable candidate to be directly put into the blockchain data blocks. This application has got highest rate of being included in our case studies and can easily remove limitations of current centralized authentication systems.

2) **Blockchain-based Data management systems:** Same as the case of authentication, different data types within police department have limited size and can be directly stored on blockchain. Besides immutability of stored data, blockchain can always provide complete interaction history of any stored data, which is a big advantage over current centralized systems. Such feature (i.e. immutability and complete history) provide higher traceability within the organization and prevents many fundamental sources of fraud inside departments.

3) **Resource management based on blockchain:** Another source of mismanagement and fraud within governmental departments is "resource allocation" process. Blockchain technology can provide cheap and highly scalable data management products for such applications. The main advantage of this approach is that no one can corrupt or alter data after it has been stored on blockchain. To this end, authorities can trace resources allocated to their workers within department.

4) **An integrated justice and law enforcement information system:** Blockchain provides ability to stablish a trustless shared information system within different organizations. To this end, one of the main and most referenced blockchain-based services for police and department of justice is an integrated justice and law enforcement information system. In such system, all evidences are entered on a blockchain-based chain-of-custody (CoC) and are tracked by both police and justice departments.

5) **Blockchain-based Secure database systems:** For other data types that may not be suitable to be directly stored on a blockchain (such as large media or bigdata), blockchain still can be employed to provide a trustless security to traditional databases. Every interaction to the database will be stored in the blockchain to have a complete log of data changes within the system. This approach also helps early integrations with blockchain in department level because there is no need to change previously stablished database mechanics in the system and blockchain will work as an attached logger to the entire system.

Conclusion

One of the main applications of blockchain is secure management of sensitive information, which makes it a suitable infrastructure for providing advanced control over data in police task forces. The goal of this research is to provide a conceptual framework for employing

blockchain in law enforcement organizations by analysis and comparison of best practices in other countries and academic case-studies. The reliability of the research statistics is evaluated by Cohen's kappa coefficient roughly 0.64 and the prioritized applications were evaluated by a 14 member experts panel through fuzzy Delphi method with a Kendall's Coefficient of Concordance of W=0.711, indicating high rates of agreement among members. To this end, "trustless authentication systems", "distributed data/resource/information management", and "inter-department integrated information systems" were selected as most valuable applications of blockchain for police task forces and law enforcement agencies in Iran. Moreover, final candidate applications of the blockchain in police task force and department of justice and law of IRI are blockchain-based authentication systems, blockchain-based data management systems, resource management based on blockchain, an integrated justice and law enforcement information system, and, blockchain-based secure database systems.

Finally, it is worth mentioning this research has following limitations, which can be solved in the future work:

- The overall level of interest in blockchain adoption from experts within the police task force of IRI is low, significantly due to the immaturity of the technology and high rates of structural changes that it requires. This limits their full support and engagement in the entire process of the research.
- The level of details in architecture and implemented products of the case-studies are limited, which makes it harder to provide a correct review while analyzing them.
- The difference in mission and overall goals between polices task force of IRI and its analogues foreign agencies adds up to the complexity of mapping blockchain applications in each organization.
- Since some of infrastructures and ICT services of police task force of IRI, already overlap with the five chosen applications of the blockchain for police; we provide principals and requirements, systematic architecture, its building blocks along with the adoption framework to reduce risks of building the practical solution based on blockchain technology.

Conflict of interest

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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