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INTEGRATION OF BLOCKCHAIN TECHNOLOGY INTO AUTOMOBILES TO PREVENT AND STUDY THE CAUSES OF ACCIDENTS

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INTEGRATION OF BLOCKCHAIN TECHNOLOGY INTO AUTOMOBILES TO PREVENT AND STUDY THE CAUSES OF ACCIDENTS

A Project

Presented to the

Faculty of

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In Partial Fulfillment

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by

John W. Kim

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ABSTRACT

Automobile collisions occur daily. We now live in an information-driven world, one where technology is quickly evolving. Blockchain technology can change the automotive industry, the safety of the motoring public and its surrounding environment by incorporating this vast array of information. It can place safety and efficiency at the forefront to pedestrians, public establishments, and provide public agencies with pertinent information securely and efficiently. Other industries where Blockchain technology has been effective in are as follows: supply chain management, logistics, and banking. This paper reviews some statistical information regarding automobile collisions, Blockchain technology, Smart Contracts, Smart Cities; assesses the feasibility of automobile collisions using Blockchain technology framework, and lastly includes some discussion in future studies of Blockchain technology.

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Thank you to the following people who have supported me in this journey: John Song, Conrad Shayo, Benjamin Becerra, Elisa Kim, and Rodney Reed.

DEDICATION

Thank you to my parents, family and friends who have contributed, supported, and believed in me.

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CHAPTER ONE

BACKGROUND

Automobile Collisions and the Benefits of Blockchain Technology

The world has evolved into a fast-paced environment consisting of information, logistics, technology, commerce, transportation, labor, procurement, and recreation. In each of these mentioned areas, there exists a need to ensure security and efficiency from start to finish. There are several methods that have been developed and still in development, to assure the certainty of satisfaction of everybody involved. One of the newest technologies to be introduced that can be implemented into every one of these areas is Blockchain technology. (Müßigmann, B. et.al.,2020).

Automotive collisions occur irregularly, in that they can occur more or less frequently at any given time – there is no set means as to how and why accidents occur. Blockchain technology will be the catalyst(s) to monitor all types of accidents.

In the interest of introducing Blockchain technology into the automotive industry; Blockchain technology is a new technology and can revolutionize the

automotive industry, as well as introduce other technologies to formulate the induction of setting precedence and a new foundation of safety, security, and encryption. Blockchain technology is already being used in several different industries such as supply chain management, information technology, software engineering, and transportation. The benefits of Blockchain technology in these four industries have all been beneficial and crucial to the success of each of the organizations involved. (Bodkhe, et.al, 2020). The induction of Blockchain technology into the automotive industry may provide and yield the similar benefits of success, as it has in other industries. Some of the benefits can include the following: Real-time transactional data pertaining to driver and vehicle activity, information pertaining to the driver's ecosystem, information pertaining to the vehicle's ecosystem i.e. its immediate surroundings (road conditions, cars, buildings, weather, pedestrians), the induction of Smart Cities, Smart Contracts, information transparency, participant(s)' transparency (Asamoah et al., 2020).

There are many cases and case studies available on Open Source (the Internet) which document the causes of car accidents. Any of the supply chain actors in the automobile manufacturing industry could contribute to eventual car accidents triggered by automobile defects. This culminating experience project will contribute to our understanding of how Blockchain technology could create Smart Contracts between supply chain players. Such Smart Contracts have the potential of identifying the supply chain partners who may have contributed to

automobile defects, and how they should be held responsible, accountable, and liable.

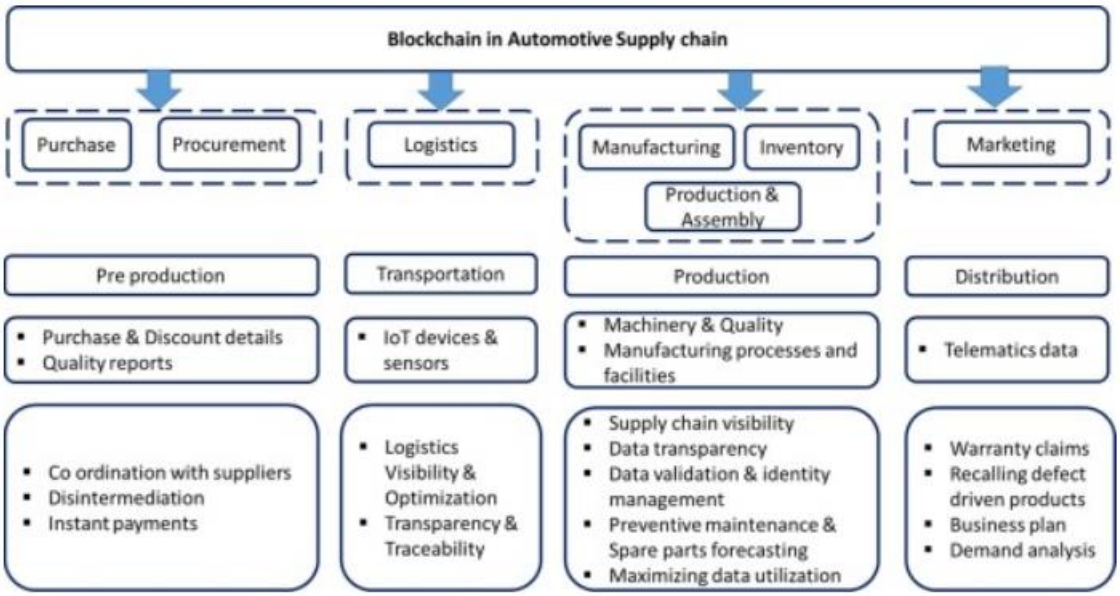
Automotive Supply Chain

There are key factors in the automotive industry supply chain that affect the overall usability, functionality, and safety in the manufacturing and ultimately the operation of vehicles. These key factors include factors such as raw materials, sourcing of materials, the vendors that process the raw materials into usable products such as car parts used to manufacture the cars.

Blockchain technology would work alongside IoT technologies such that the auto parts would have the IoT technologies embedded devices, sensors, and latency-free information systems into the auto parts. This network of IoT embedded devices can communicate with other devices for actuation, connecting and communicating via the internet – cloud computing network (Kasten, 2020).

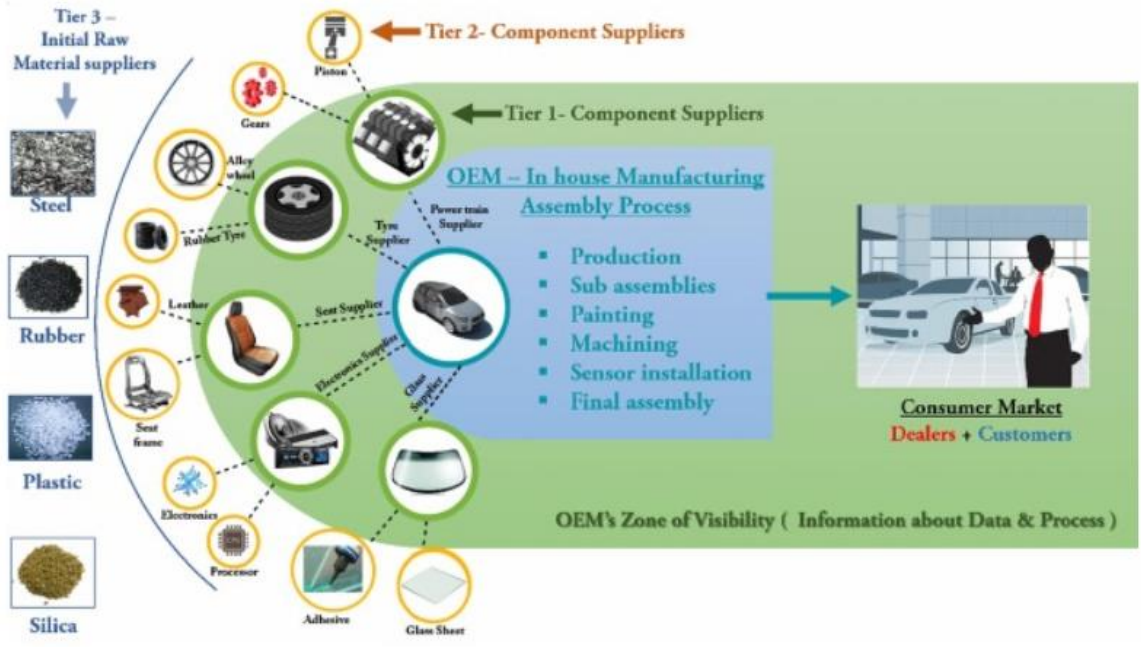
The automotive supply chain (ASC) is a sophisticated network, a make-up of a vast array of automotive parts along with other crucial key players (many of them stakeholders) consisting of the following: raw materials suppliers, independent distributors, independent dealers, government regulatory agencies and insurance companies. (Biswas & Gupta, 2019).

Figure 1. Framework: Blockchain in Automotive Supply Chain (Reddy, et. al, 2021).



By integrating IoT into conventional practices, there are incredible opportunities to create sources of logistical information across the supply chain (Rejikumar et al., 2019). This is where Blockchain technology can be used to create a common platform(s) for transparent supply chain(s). Below is an illustration of a typical ASC:

Figure 2. Typical Automotive Supply Chain (Reddy, et. al, 2021).



This is a graphical representation of three tiers of the ASC; starting at the tier 3 initial raw material suppliers, to tier 2 component suppliers, to tier 1 component suppliers and eventually the consumer market (consisting of dealers and customers).

There are several examples where Smart Contracts would prove to be very effective and efficient in the automotive supply chain and used in conjunction with the Blockchain technology. Some examples from the automotive industry include materials and/or workmanship related procurement practices that could have been prevented. Some of these companies include the following: Takata Corporation, Continental, and overall automotive procurement issues.

The Takata Corporation is a company that manufactures airbags for use in automobiles. Recently there was a recall of several million vehicles that were affected by faulty airbags manufactured by Takata Corporation. The main problem was due to the airbags being exposed to long periods very hot temperatures and/or humidity, which would cause the airbags to malfunction. The end result would be that the airbags overinflated or underinflated during an accident (NHTSA, 2015).

Continental Tire Co. had a fairly large recall of its tires due to overcuring tires during manufacturing, which could lead to the sidewall of the tires to break or the belt edge of the tire separating. As a result, if the tires do fail in this manner during operation of the vehicle, the driver can potentially lose control of the vehicle and crash (Barry, 2021).

The overall automotive supply chain operates on a global scale. There are vendors and suppliers that service all tiers in the automotive procurement process. The current Covid-19 pandemic is affecting automotive supply chain issues. One of the ideas discussed in an article published in SupplyChainBrain suggests is to develop more locations globally with resources. This would allow for faster processing times and reduce, if not eliminate the bottlenecks that naturally occur because of the time required to process and ship orders to their destinations (Sharma, 2020).

These are just three examples that can benefit from the inclusion of Smart Contracts. There is conflict that is created in the automotive supply chain.

Scarcity of supplies because of a lack global resources, manufacturing issues caused by mismanagement of parameters, and naturally occurring factors such as that of the defective airbags. There would not be any binding contracts and/or intermediaries to slow the process down. The Smart Contracts are designed with these features in mind.

Blockchain technology can address these issues of the past and present with its unique features of immutability, accuracy, and latency.

Automobile Accidents and Collisions

Some car accidents may be minor car accidents, often referred to as a "fender-bender" type of car accident. Some car accidents may involve more extensive damage, it may even involve driver(s) impairment (physical and/or otherwise). Some car accidents may involve several vehicles: a result of a chain-reaction – one vehicle being the sole culprit to the cause of the multi-vehicle car accident. The driver or person in charge of a vehicle must remain at the scene of the accident and provide information pertaining to them such as the driver's name, address, driver's license number, the name and address of the owner of the vehicle, and the registration of the vehicle. (Graesser, R., 1992)

According to a car crash statistics report provided by the California Highway Patrol (CHP) in 2017, on average a traffic crash was reported every 3

minutes – either a fatal or injury-related traffic crash. On average, one person was killed every 2 hours and 14 minutes resulting from a traffic crash. On average, one person was injured every 1 minute and 53 seconds resulting from a traffic crash.

Blockchain technology can be used to record pertinent information about what car(s) had the right of way, and some of the background information such as the date, time of day, outside temperature, weather conditions, road conditions, and visibility. Uncertainties such as who the vehicle belongs to, who was driving the vehicle, condition of the vehicle pertaining to mechanical functions and integrity, logistical aspects of the vehicle pertaining to time-stamped information of when and where each part of the vehicle was manufactured. (Rotună, C., et.al, 2019).

Problem Statement

In 2017, California Highway Patrol (CHP) reported that there is a car accident every 1 minute and 53 seconds, resulting in an average of one person being injured and every 2 hours and 14 minutes one person is killed resulting from a car accident.

Traditionally, after an accident, the involved parties are supposed to exchange information and file a report with the respective police agency(s). The traditional means of exchanging and reporting accidents may not always be effective due to uncooperative members of involved parties.

Something to remedy situations such as the aforementioned issues with car accidents and technology is Blockchain technology. It could be integrated into automobiles to monitor real-time activities to record information pertaining to each automobile.

Objective

The objective of this project is to look at some information about automobile collisions and what new technologies such as Blockchain technology, IoT, Smart Cities and Smart Contracts can be used to study the causes of automobile collisions and prevent automobile collisions from occurring.

The following research questions have been formulated based off of “Framework for Detemining Blockchain Applicability” (Scriber, 2018).

Research Questions

1. What factors will need attention to the automobile such as software updates, access to recorded information, who has access to what information at what level?
2. Will the participants in the Blockchain technology network agree to the terms of provided and discussed?
3. Is Blockchain technology compatible amongst an ecosystem of participants in differentiating classes?
4. What are the incentives for those who are participants in the Blockchain technology network, and will it be feasible to continue support of the Blockchain for an indefinite time?
5. What is required for Blockchain technology to be a prospective technology in the automotive industry?

Organization of the Study

This project is organized as follows: Chapter 1: Background information of the automotive supply chain, automobile accidents and collisions, problem statement, objective, and research questions. Chapter 2: Will discuss the literature review and discuss in detail what Blockchain technology is, what and how Smart Contracts are, Smart Cities and its make-up of the IoT infrastructure, and Blockchain technology applicability framework. Chapter 3: Will discuss materials and methods, a table is used to introduce some Blockchain applicability

terminology, a separate table is used to determine Blockchain criteria and applicability. Chapter 4 will discuss the results from the findings of the Blockchain applicability tables from Chapter 3. Some statistical facts about accidents and other uses of Blockchain technology is also discussed in Chapter 4. Chapter 5 contains a discussions, recommendations, and future directions section, which is commentary about the study.

CHAPTER TWO

LITERATURE REVIEW

What is Blockchain

Blockchain can be used to record information from the operator(s) of vehicles. Blockchain is a chain of events, originating from a starting point and adding onto and/or creating additional bits of information (Nofer, M., et. al, 2017), to record a history of events of the vehicle and its activity from the operator(s) and its outside environment. A blockchain consists of sets of data which are composed of a series in data packages, referred to as “blocks”, where the block builds a ledger of transactions. Each blockchain is further extended by additional blocks and build onto a list of historical transactions. Each block contains a timestamp, which is the hash value of the previous block, and what is known as a nonce which is a random number for verifying the hash. This hashing technology is to ensure security of the entire blockchain back to the very first block, known as the “genesis block” (Nofer, M., et. al, 2017). Blockchain technology is fairly new technology that is still being developed. Blockchain technology works in grouping historical information into blocks, processing cryptographic work, which is generally hashing, to characterize the information of each block and links the blocks to create a chain (Scriber, B. A., 2018). Blockchain works in as a network with other participants in the ecosystem who all check, confirm, and accept the work of each other. The result is a historical listing of transactions between these participants (Scriber, B. A., 2018).

Smart Contracts

One of the important functionalities for integrating Blockchain technology into cars is Smart Contracts. Smart Contracts is crucial for Blockchain technology in that they function in place of actual paper contracts used in real-world applications. Smart Contracts are able to do this by the use of programmed computer codes. These Smart Contracts work on agreements between two or more parties that every entity involved must fulfill their respective agreed upon promises.

These Smart Contracts are enforceable by law. What is unique about Smart Contracts is that there is no longer any need for intermediaries. The programmed computer codes work within a verified network within a decentralized blockchain network. The Smart Contracts also work with untrusted entities without commission fees that would otherwise be collected by outside agencies and minimize the time necessary for involved entities to process information and paperwork (Swan, 2015).

Smart Contracts are, in general, guidelines that must be met between participating devices with embedded Blockchain technology. According to researchers, Smart Contracts are complex algorithms used by the Blockchain technology to analyze preset agreements. (Viriyasitavat, Xu, Bi, & Hoonsopon, 2019). The use of Smart Contracts is applicable in several different fields. Smart Contracts is effective in use of several different fields in its ability to work in strict

protocols. The use of Smart Contracts is also efficient in that it enables the use of automated data-driven decisions (Xu, Zeng, Yang, & Shao, 2020).

Smart Cities

There are several issues that developed from the logistical aspects of human activity. The formation of such things as cities, big and small, scarcity of resources, traffic congestions, as well as outdated and/or deteriorating infrastructures have all given various reasons to develop Smart Cities (Borja, 2007; Marceau, 2008; Toppeta, 2010; Washburn et. al, 2009).

Smart Cities can be used in different context. Words such as digital or intelligent can be used in place of “Smart”, to refer to Smart Cities. Smart Cities can be used in describing urban developments (Hollands, 2008).

Some of the working definitions of a Smart City are as follows:

1. A city that sustains key factors and areas such as roads, bridges, tunnels, railways, subways, airports, waterways, communications infrastructures, water, power, major buildings, can optimize its resources, plan preventive maintenance activities, and monitor security aspects (Hall, 2008).
2. A city “connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city” (Harrison et. al, 2010).
3. Smart devices such as smart phones, IoT devices, networking equipment, laptop computers, tablet computers, Bluetooth technology can all be used

in conjunction to provide services in areas such as city municipalities, medical, social services, and logistical operations.

(Washburn et. al, 2009).

A Smart City is a collaboration of smart devices that is the very make-up of the network infrastructure. Smart computing is a new means of using computer hardware, software, and network technologies to provide real-time information via IT systems. Smart computing makes use of advanced analytics to make informed decisions and provide ever-changing, dynamic information (Washburn et. al, 2009).

Smart Cities would work in conjunction with Blockchain technology and IoT devices to communicate and exchange information amongst each other.

Blockchain Framework

This section will examine the contents of the five questions of the Blockchain Framework Applicability.

The first question is – What factors will this project require in updates and/or accessibility to information?

Blockchain technology does not require updates, Blockchain is unique in that the recorded information is immutable (Welfare, A., 2019). Blockchain technology will provide truth and trust, transparency, security, quality and certainty, and efficiency. Providing truth and trust means that information cannot ever changed. Each party has the exact same copy of the recorded information, this further enhances transparency and security (Welfare, A., 2019). Blockchain provides transparency, in that those who have access to this information (this would grant access according to levels of security), can see the information that is available and what it's being used for (Welfare, A., 2019). Blockchain provides security, the data is immutable and timestamped.

Blockchain creates an environment of quality and certainty, so the information can be entered from any source supporting IoT-enabled devices, from other information systems, API and/or otherwise. Blockchain technology also allows faulty information to be quickly corrected, to assist in helping fix any issue(s) with poor quality data (Welfare, A., 2019).

The second question is - Are all the requirements for all participants of Blockchain explained to and have consensus?

There are four areas of in which information transparency is very important, that may potentially affect different criteria of transparency: Participants, Victims, Users, and Curators (Bertino, E., et. al., 2019). Some mechanisms used in Blockchain-based transparency is as follows: Blockchain-Based Transparency Management and Blockchain-Based Ethics Management for Transparency (Bertino, E., et. al., 2019).

The mechanism used to record information into Blockchain technology works using a CRUD (Create, Read, Update, Delete) query platform protocol. The information recorded is copied along all other devices communicating within the network. The drivers of data transparency include: intake of information, the internal and external information available to those needing access to the information stored, and to those that will act as regulators to this information (Bertino, E., et. al., 2019).

The CRUD mechanism is an ethics support for information systems such as Blockchain. This mechanism is necessary as a result of opposing transparency of data. Some of the policies can be implemented as Smart Contracts, also to include transparency policies. This mechanism ensures that data is not biased, requests of information are processed, and the results support the ethical requirements of the Blockchain ledger. In the Blockchain system, the networked devices have access to a fully replicated history of activity, which

serves as the trusted append-only System of Record (SOR) type of query platform (Bertino, E., et. al., 2019).

The third question is - Does Blockchain technology compatible with participants in broad scale without limitations?

Blockchain technology is compatible amongst a broad scale of participants without limitations. The architecture will function under circumstances such as the following: Smart Cities, identification using smart devices such as personal smart phones, Internet of Things (IoT), and Smart Contracts (Rotuna, C., et. al., 2019). Smart Cities is defined as an environment for learning and educating, fusing the ideas of social populations and cultures into one rich in information technology; building the bridge of compatibility between humanity and information systems (Rotuna, C., et. al., 2019). Information must be gathered about the participants and exterior ecosystem such that everything is recorded and accounted, to serve as part of the algorithm. Each participant of the ecosystem serves as a driver to what is happening in real-time. The user(s) manage the application via a smart device and/or a computer. The information gathered from the participants will include attributes such as name, gender, date of birth, address, etc.; it will be through this information that the backbone of information and access to this information will be beneficial to the end-users. The user(s) are assigned different tiers of permission – mathematical calculations are performed to encrypt this information making it nearly impossible to decrypt

the information (Rotuna, C., et. al., 2019). Internet of Things (IoT) will be implemented to provide information services to the ecosystem i.e. participants, neighboring smart devices, immediate objects in ecosystem embedded with IoT. The infrastructure that is in use now is not up-to-date and it the cost to maintain the current infrastructure isn't beneficial. The current infrastructure is also prone to cyber-security risks. The cost to operate at the current infrastructure is cost-efficient.

Blockchain technology can be used to monitor and manage IoT information systems and other smart devices such as smart thermometers, cameras that are part of the cloud network, environmental quality sensors, etc., from potential exploits. Integrating a Blockchain information system can protect the exchange of data between IoT smart devices located tens of hundreds of kilometers away, in a Smart City, in real-time, without the need of a local city law enforcement agencies (Rotuna, C., et. al., 2019). (Rotuna, C., et. al., 2019).

The fourth question is - What are the benefits to the participants to support Blockchain long-term?

Blockchain technology is a fairly new and making its presence into different fields in applicability and usefulness as an important resource.
An information system, a cloud network, with a small number of participants is not very marketable and not efficient. For this reason, the higher the number of

participants to join in the Blockchain community, they better. The information gathered from the larger number of participants in the network would benefit everybody; contributing to pool of information and statistical analysis (Drobyazko, S., et.al, 2019).

The logistical procedures of the Blockchain technology has its foundations in the available technology per environment/ecosystem (Drobyazko, S., et.al, 2019). Blockchain technology is still in its infancy in development for the whole world. The percentage of Blockchain technology being implemented in will be determined by each environment, the current and forecasted needs, cost analysis, and technological infrastructure(s) (Drobyazko, S., et.al, 2019).

The fifth question is - What is the likelihood that this Blockchain technology will gain attention and attracting participants to provide a working model?

Considering that Blockchain is in its infancy stages, there is not enough information to forecast its success. Looking how Blockchain technology has impacted other industries such as supply chain management and procurement; the prospect is promising. The Blockchain network has its restrictions due to such factors as overhead costs, a working model still in development, network security, and a consensus to measure the number of participants active in the Blockchain network.

A study was performed involving a Byzantine Fault Tolerance protocol known as DRBFT, this study was on the Practical Byzantine Fault Tolerance (PBFT). The PBFT aims to analyze efficiency and integrity of the Blockchain network (Hao, X., et. al, 2018). The Byzantine Fault Tolerance is a consortium of “faults” or errors that may occur during the compilation of Blockchain technology. These faults include redundancies, economic factors, system vulnerabilities via malicious attacks, and software errors; amongst other faults (Hao, X., et. al, 2018).

The Practical Byzantine Fault Tolerance (PBFT) protocol was proposed by Castro and Liskov and published in 1999 (M. Castro, 2002). There are some characteristics of PBFT that presented concern for use in a closed environment Blockchain ecosystem. A Dynamic PBFT protocol was introduced as an alternative. The Dynamic PBFT protocol provides security and liveliness that the original PBFT protocol provides. The Dynamic PBFT protocol is based on a week synchrony assumption (Miller, A., et. al, 2016), which is a crucial to make it compatible in the environment of IoT devices. This protocol enables redundancies to act in a dynamic manner. It also doubles in providing security in erroneous nodes of information (Hao, X., et. al., 2018).

CHAPTER THREE

MATERIALS AND METHODS

A table was used to determine whether Blockchain is a suitable application in recording automotive information i.e., driving habits, driving style(s), date, day of the week, time of the day, the ecosystem in which the vehicle is in. To elaborate on what the ecosystem is, the ecosystem includes where the operator(s) and vehicle(s) are located geographically, physical and natural aspects such as neighboring buildings, trees, landscaping, date and time of day, current weather conditions; a “snapshot” of the scenario at the time of accident. The materials and methods used in the research include using the internet search engine Google, scholarly internet search engines including Google Scholar, and the Pfau Library provided by California State University, San Bernardino. This information, including some of the detailed keywords and phrases, can be found in the Appendix and will be presented to develop answers and/or considerations into the Blockchain framework. The full Blockchain framework requires assessing 10 domains (Table 1). However, before this larger scale study can be performed that will require field work, experimental studies, etc; a feasibility study using a reduced five question screener can be performed. The five questions for the Blockchain framework are as follows: 1. What factors will this project require in updates and/or accessibility to information? 2. Are all the requirements for all participants of Blockchain explained to and have

consensus? 3. Does Blockchain technology compatible with participants in broad scale without limitations? 4. What are the benefits to the participants to support Blockchain long-term? 5. What is the likelihood that this Blockchain technology will gain attention and attracting participants to provide a working model? (Scriber, B.A., 2018).

Table 1. Table Ref: A Framework for Determining Blockchain Applicability, Brian A. Scriber, CableLabs. IEEE Software July/August 2018

Table 1. A form for evaluating a blockchain's level of fit.

Architecture or blockchain characteristic	Example subjective suggested weighting	Weight (this column must add up to 100)	Subjective percentage of affirmation	Weight × affirmation
Immutability: Will the architecture never need the ability to execute a command with update or delete semantics?	12			
Transparency: Does the architecture require transparency between actors?	12			
Trust: Does the ecosystem currently lack trust between participants?	16			
Identity: Must participants and actors be mapped to their transactions, or do those transactions have a value to be claimed by a participant?	5			
Distribution: Can the implementation manage and afford distribution of nodes and participants? Does the system have multiple writers?	10			
Workflow: Would the addition of a distributed ledger simplify workflow?	5			
Transactions: Does the system follow a transactional model, or is the data transactional?	12			
Historical record: Is the project ready to assume the fiscal, legal, distributive, and cryptographic responsibilities of running this chain for an indeterminate time period?	8			
Ecosystem: Does the architecture support an ecosystem as opposed to a single company?	15			
Inefficiency: Will the architecture support a blockchain's security overhead, search limitations, and transactional verification model?	5			
Total percentage of fit:				

Table 2. Table Ref: A Framework for Determining Blockchain Applicability, Brian A. Scriber, CableLabs. IEEE Software July/August 2018

Table 2. Criteria for whether to choose blockchains.

Question	Considerations
Will this project require updates, mutability, or deletion of records?	Blockchains are inherently permanent. If the architecture requires anything other than rare additions of new blocks to invalidate prior blocks, the overhead of checking for revocations can have a significant negative impact in mature or large chains.
Is there agreement that all blockchain participants should be able to view and validate transaction details?	Distribution of blockchains and validation of transactions are critical. Without the use of obfuscating techniques that allow for transaction validation without viewing, the power of distributed trust in the chain would be lost to the single node that originally validated the transaction, which might not even be a permanent member of the chain.
Does this architecture fit well in an ecosystem of diverse participants?	For internal projects in which significant trust already exists, a database solution will likely be far more economically appropriate.
Are there adequate incentives for participants to continue to support the chain indefinitely?	From the economic and technical perspectives, support for the chain's future depends on the maintenance of that chain and storage of previous blocks (in many cases, active storage of all of them).
From an efficiency perspective, are there enough participants and sufficient complexity to buoy the consensus model, validate all transactions, and approve the authentication and authorization processes?	Here, the economic and technical considerations collide when you consider not only the long-term power, computation, backup, maintenance, and support requirements but also the changing landscape of adversarial engineering. Will the chain continually have enough positive influence in the consensus model to counteract negative actors and achieve Byzantine fault tolerance?

CHAPTER FOUR

RESULTS

Causes of Accidents in Southern California

Causes of accidents include: Not following laws/rules of the road set forth by the DMV and local law enforcement agencies. These include speeding, tailgating, not paying attention to the immediate surroundings while driving, reckless driving, road rage, distractions caused by electronic devices (i.e. cellphones, laptop computers, tablet computers, smartwatches, radio from car, GPS navigation from car and/or cellphone, etc.), car racing, impaired driving, impaired pedestrians, not signaling, sudden lane changes, erratic driving patterns. These accidents also include accidents at intersections and non-intersections, as well as right-of-way related traffic accidents (2017 California Quick Crash Facts. 2017 Annual Report California).

The information above is a report provided and published by the California Highway Patrol. The information pertaining to automobile collisions in residential and/or commercial areas is spread thin. The cause(s) of automobile collisions has several different factors. Human error(s), mechanical error(s), an environmental factor(s) and the ecosystem(s) in which the operator of the vehicle is in.

Blockchain In Logistics

Blockchain is currently being used in the areas of logistics to create a flowchart of sorts, to track the progress in the areas of transportation and/or procurement i.e., transportation: DHL (international travel), procurement: manufacturing of goods.

Blockchain can be embedded into the computer(s) system(s) of cars to enable event recording. Blockchain will function as a live black box, much like those found on commercial aircraft. The black box(es) on aircraft can be recovered and investigated in the event of aircraft crashes and/or aircraft mechanical/electrical failure.

Blockchain Feasibility In Collisions

Q1: Updates, mutability, or deletion of records

According to an article that further emphasizes the crucial information that a vehicle equipped with Blockchain technology has to offer; the Blockchain technology would work in and as network involving the five separate entities: the very user(s) of the cars, automobile insurance companies, law enforcement agencies, vehicle manufacturers, and vehicle repair providers (Gerrits, L., 2020). This very sophisticated network will work in sync along with the other IoT devices mentioned previously, to provide a state-of-the-art network infrastructure to the public motoring industry.

The Blockchain network will provide triangulation between the above-mentioned entities and thus these entities will record and update their business-related transactions as it relates to each individual entity. The information recorded pertaining to each vehicle and part of the Blockchain network will be immutable. Software updates will be administered via the administrator(s) of the Blockchain network, but each transaction within the Blockchain network already created cannot be modified – if needed an addendum can be added to recognize needed changes to already existing transactions of each Blockchain network activity log.

Q2: Are all the requirements for all participants of Blockchain explained to and have consensus?

To bring back into context the Blockchain technology framework, all participants using these automobiles with the Blockchain technology will need to agree to the terms and conditions such as who has access to viewing and validating transactional details. The end-users (namely the drivers of the Blockchain technology-enabled vehicles) will have direct access to the network that the Blockchain technology will operate under. For reference purposes, these four areas of data transparency is important: participants, Victims, Users, and Curators (Bertino, E., et. al., 2019). So these four entities will have access to viewing transactional details, but will not access to changing any of the details. This is especially crucial to why Blockchain technology would be so beneficial to

the automotive industry – its unique features of immutability, security, encryption and latency.

Q3: Blockchain technology compatible with participants in broad scale without limitations?

Blockchain technology is compatible with participants in broad scale without limitations. The Blockchain technology will coincide with technologies involving Smart Cities, Internet of Things (IoT), and Smart Contracts. Smart Cities is designed to be intrinsic, in that it can absorb information of the environment of population and dynamically modify its information systems as needed in real-time (Rotuna, C., et. al., 2019).

The Blockchain technology can be beneficial in that it cannot be altered outside of its unique operating parameters. The information recorded and provided to outside agencies such as law enforcement agencies, insurance companies, the network that the Blockchain network will operate on via Smart Cities, IoT, will prove to be very effective and nondiscriminatory.

Q4: What are the benefits to the participants to support Blockchain long-term?

Blockchain technology works off of the premise that there is a large number of participants. The larger the number of participants, the greater the availability of information to the IoT network and its surrounding ecosystem. The

Blockchain technology platform will operate on a buildup of local IoT networks. Too small of a number of participant would not make the Blockchain platform marketable and efficient, it would benefit each and every participant in the Blockchain network to support the Blockchain network indefinitely (Drobyazko, S., et.al, 2019).

The methodology to which Blockchain technology will be implemented is based on the classification of innovations in base technology by the level of readiness for adaptation (adoption) of this technology, based on two aspects that have a decisive impact on the development of basic technology and applications (Drobyazko, S., et.al, 2019).

The Blockchain technology can be invaluable in its immutability and use of Smart Contracts. These two key features alone is enough incentive for participants to support the chain indefinitely. It will reduce cost expenditures, save on time necessary for processing information, reduce and/or eliminate discrepancies resulting from human error, amongst other things.

Q5: Consensus model, validation of transactions, and process approval

Blockchain technology is still in its developmental stages. A consensus model cannot be created yet. Things such as validation of transactions, authentication and authorization processes would have to be introduced into the automotive field. From just the solely examining the Blockchain technology framework in its being effective, there was a study performed using known as the

Byzantine Fault Tolerance (BFT) protocol. The BFT is a consortium of “faults” or errors that may occur during the compilation of Blockchain technology. These faults include redundancies, economic factors, system vulnerabilities via malicious attacks, and software errors; amongst other faults (Hao, X., et. al, 2018). The BFT had its limitations and so a newer protocol, Dynamic PBFT, was introduced to allow redundancies to modify the information dynamically.

Table 3. Blockchain Technology Results of Questions and Criteria

Question	Passes criteria
Q1	Yes
Q2	Yes
Q3	Yes
Q4	Yes
Q5	Yes

CHAPTER FIVE

DISCUSSION AND RECOMMENDATIONS

Discussion

Based off of the analysis from the framework, Blockchain can be very effective because of its unique capabilities in immutability. Blockchain is unique in that those Blockchain participants may have reassurance of how a chain of events occurred and may benefit everybody involved, and not only to those of the operators of automobiles, but to those in the surrounding ecosystem(s). Blockchain benefits its participants and really is a developing technology that will be a universal application – a technology that can be applied to everything. From an efficiency perspective, it will be very effective as Blockchain technology is introduced and marketed into the mainstream markets, recognized for its uncanny capabilities.

Recommendations

The research conducted of Blockchain technology, automotive supply chain, and review of other publications of and/or relating to the areas of Blockchain technology, Smart Contracts, Smart Cities, IoT, and automotive supply chain, Blockchain technology will be the next wave of technology to be included into the automotive field. Blockchain technology will add onto and revolutionize the automotive industry. Currently there exists technology such as self-driving cars. Even these self-driving cars are not really fully autonomous.

There have been reports of minor to severe accidents caused from people relying on the auto autonomous self-driving feature of these cars. With the inclusion of Blockchain technology, it will add onto recording real-time activities within and around each vehicle equipped with the Blockchain technology, and reinforce safety, integrity and dignity to the automotive motoring public.

Future Directions

Development of software/firmware into automotive technologies to enable Blockchain technology into automobiles. What infrastructure needs to be built in addition to what already exists i.e. cloud computing, mobile technologies, smart cities, cyber security threats, networking infrastructure(s), etc. How will consumer privacy be protected and how will Blockchain technology be used in the automotive field. What effects will Blockchain have on industries such as automobile insurance, law enforcement agencies, logistical changes to the autobody collision repair industry, and supply chain processes to automobile companies such as Chrysler, Toyota, GM, Ford, Honda, Mercedes-Benz; how will copyright infringement (business law) be implemented, if any, amongst Blockchain and other industries i.e. automotive, aviation, rail, maritime, intermodal transport, procurement.

This study of Blockchain technology has provided several different advantages of implementing Blockchain technology into the automobiles. The logistics of Blockchain technology is precise, accurate and timely. After evaluating the five questions from the Blockchain Applicability Framework,

implementing Blockchain technology into automobiles can prove to be very effective in preventing automobile collisions.

Future studies in Blockchain technology include further applications of the 10-point Blockchain Framework – identifying specific strengths and weaknesses in the application of Blockchain technology.

APPENDIX

SOURCES USED, KEYWORDS USED IN SEARCHES

APPENDIX

Sources Used: Google Scholar, OneSearch (John M. Pfau Library, California State University, San Bernardino)

Keywords Used In Searches: Blockchain framework applicability, Blockchain immutability, Blockchain transparency, Blockchain trust, Blockchain identity, Blockchain distribution, Blockchain workflow, Blockchain transaction, Blockchain historical record, Blockchain ecosystem, Blockchain inefficiency, Byzantine fault tolerance, What is Byzantine fault tolerance, Traffic accident statistics, What information do I collect after a car accident, What is blockchain, History of the automobile, Automotive collisions blockchain mutability, Automotive collisions blockchain participants, Supply chain management and technology, What industries is blockchain being used in, Blockchain vehicle networks, Blockchain authentication for vehicle accident detection and notification, Blockchain network vehicle use case, Blockchain-based sharing services: what blockchain technology can contribute to smart cities, Integrating IoT and Blockchain for ensuring road safety: an unconventional approach, Automotive industry supply chain blockchain framework, Applications of smart contracts, Takata airbags recall, Tire safety recalls, automotive procurement issues, Smart cities.

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