AMERICAN UNIVERSITY OF BEIRUT

A BLOCKCHAIN FRAMEWORK TARGETING UNETHICAL PRESCRIPTION PATTERN OF INCENTIVE BASED PRESCRIPTION: APPLICATION AND PROOF OF CONCEPT

by
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ABSTRACT
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In the realm of medicine and the increasing unethical behaviors happening resulting in different medical crises has made the demand for a better transparent trusted mediator that can achieve the objective. Blockchain has been discussed and used as a potential solution for different financial and healthcare management, due to its ability to provide a trusted median between parties, transparency, and traceability. These features are important to provide a sustainable healthcare system that delivers solutions to patients and does not create new medical crises. We provide an analytical comparison between different solutions that have been implemented to resolve the problem. As well as presenting, providing, and validating our solutions capability in mitigating and limiting the unethical practices being done in the field.

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ABBREVIATIONS

PDMP	Prescription Drug Monitoring Program
BC	Blockchain
IOT	Internet Of Things
BCT	Blockchain Technology
COI	Conflict Of Interest
RD	Research and Development
ROI	Return on Income
ADHD	Attention-Deficit/Hyperactivity Disorder
IDE	Integrated Development Environment
DB	Data Base
ML	Machine Learning
UI	User Interface

CHAPTER 1

INTRODUCTION

In the realm of medicine, the understanding of ethics and prioritizing patients care over personal gain has been a significant concern due to the practices of doctors, and marketing representatives of pharmaceutical companies. The issue of overprescribing and incentivized prescriptions has been ongoing for decades now, and it has been proven and addressed in countless earlier research. Some programs are being applied to decrease the effect. However, a gap is still found due to incomplete data sharing, limited integration as well as its inaccessibility to the data as it is centralized (Buchmuelle, et al., 2020).

Awareness campaigns, regulations, and prescription drug monitoring programs (PDMP) have been set to eliminate the ongoing crises. Implementing only one of these options cannot be beneficial, as interventions should be taken by implementing more than one of the listed solutions (Chishlom-Burns et al., 2019). The PDMP has been implemented in the states and many studies were conducted to measure its effectiveness, but mixed outcomes were found (Rhodes et al., 2019).

The substance abuse and mental health services administration has revealed the highest misuse of nonmedical prescription drugs between adults of 18 and 25 age. Also, the percentage of medical students misusing stimulants varied between 5.2% to 47.4% (Samsha, 2019). The source for stimulants is peers or relatives as stimulants are considered easy and accessible prescription (Edinoff et al., 2022). As for these and other statistics that reflect the high use and misuse of stimulants it is raising concerns to be the next pandemic (Moustafa et al., 2022).

To bridge the gap this research will delve into providing a process to limit the unethical prescription of physicians influenced by the pharmaceutical industry. This process will have Blockchain (BC) which is the technology that will be used, integrated into the process due to its ability to overcome the incompetence of prescription monitoring program, enhancements will be applied to limit unethical behavior in prescription, as it has been proven that BC use can positively affect the ethical behavior of an organization (Chatterjee, et al., 2023). This technology will be used in the developed process as an open distributed ledger. As it can record transactions between parties efficiently and in a verifiable and permanent way (Spano et al., 2021).

After the development of the application the researcher will be measuring the improvement of the prescription pattern; by implementing a validation process to prove the applications ability in significantly decreasing the influenced prescriptions of doctors; as it leads to overprescribing (Yang, 2016), prescribing more expensive medications (Chao et al., 2022), delaying treatments (Liu et al., 2007), and their rationality (Brennan et al., 2006). The application can improve the situation of the listed problems. As well as capturing crisis in advance.

This paper includes 5 sections. The remaining sections include the technological background of the being established process. The second section will be discussing the previous work that have been done as a solution for the overprescription and incentivized prescription crises, the gap that is still found will be addressed, and a comparison will be done between the work being done and the work that have been done and followed. The third section will include the methodology of the research as well as a detailed description of the technology used. The fourth section will carry the

discussion of the procedure, limitations, and the gap. The fifth and concluding section will include the results of the paper, and further work that can be made.

1.1.Research Problem

Blockchain has proved its capability to improve various industries and companies, regardless of their size (Wong et al.,2020). Applications in different fields were applied and have proved their functionality and ability to enhance the system, such as internet of things (IOT), Energy, Finance, Healthcare, and Governance (Jaoude et al., 2019). However, there are still some obstacles that need to be overcome in order to successfully and effectively apply blockchain; some of these obstacles are the knowledge, and resources (Wong et al., 2020).

However, blockchain technology (BCT) is still considered a new phenomenon in many industries, as there are still research gaps that have not yet been covered. According to a research paper that have been done by extracting 41 primary papers from scientific database; Yli-Hummo et al., (2016) 80% of the papers focused on bitcoin system and less than 20% focused on the other industrial applications such as smart contracts.

Electronic prescriptions are key components and drivers of digital health, as they can increase the safety of patients, in the last decade they have increased in popularity worldwide (Aldughayfiq et al., 2021). However, the being used technologies are not providing the security standards that are needed for such sensitive data and this was verified by health insurance portability and accountability act (HIPAA). HIPAA has reflected the statistics of data breaches in its published journal as **Error! Reference source not found.** convey the data breaches have been increasing throughout the years,

showing that the used technologies are not providing high security measurements.

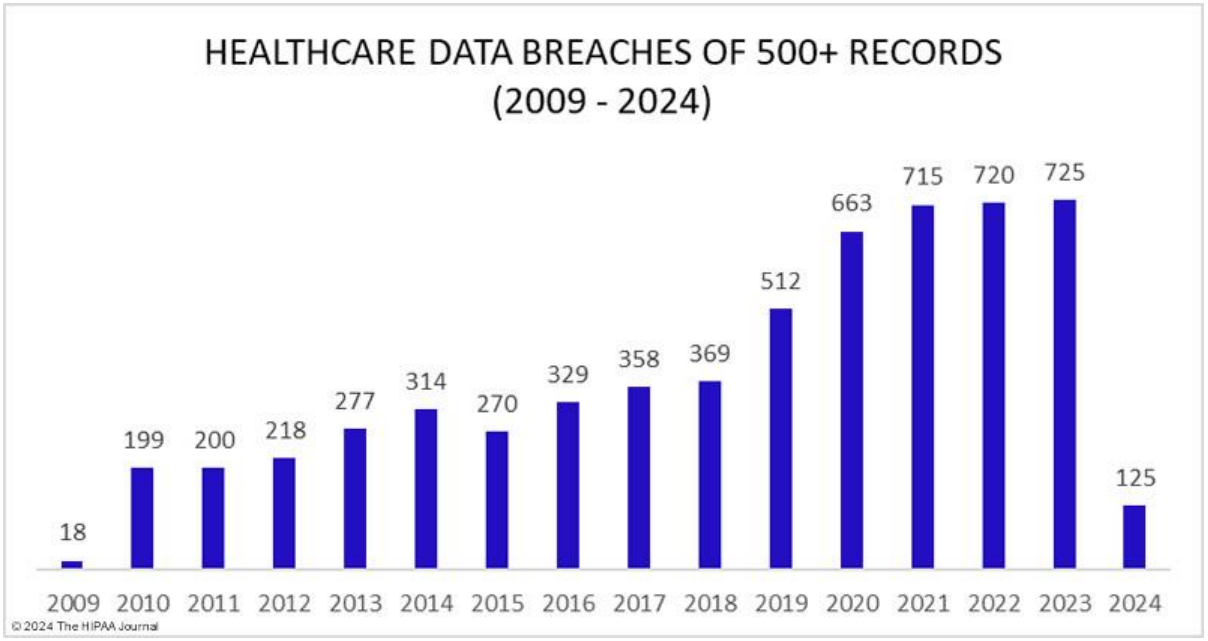

Figure 1. Healthcare data breaches (2019 - 2024)

As they have reported 725 data which is the highest number of breaches recorded since 2009, and due to these breaches 1350000 medical records have been breached at an average of 364,571 records a day, this can be seen in **Error! Reference source not found.** which was reported by HIPAA. It is important to mention that the number of breaches has been increasing over the years. This brings us to the importance of using an application that provides a better security measurement, traceability, transparency, audatabilty, and immutability these aspects will be discussed more in detail in this paper.

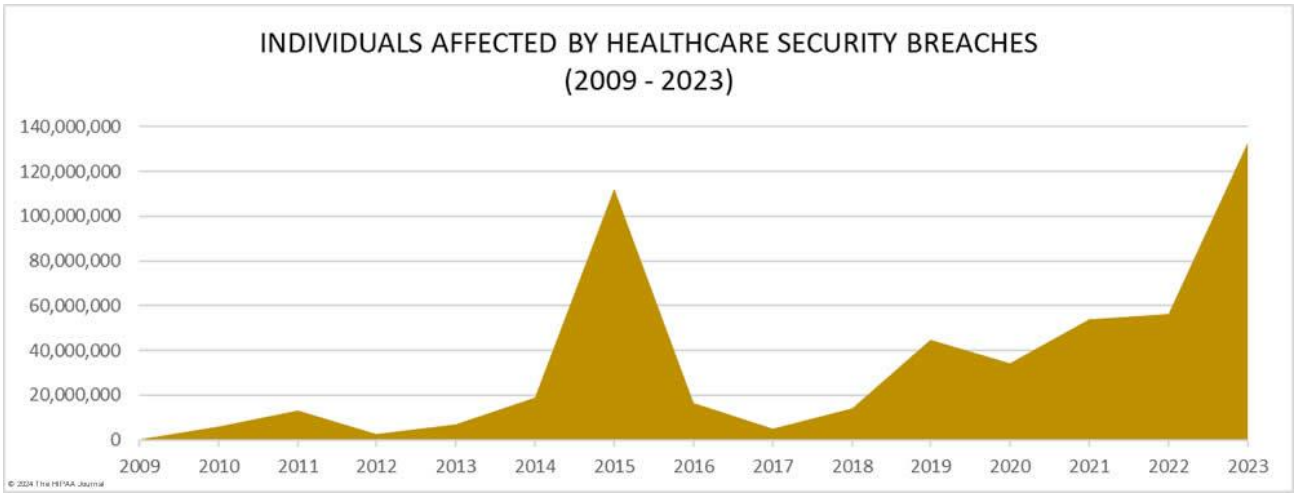

Figure 2. Individuals affected by healthcare security breaches (2009 - 2023)

Nonetheless, the being used approaches do not provide auditability, transparency, and traceability to the long-lived unethical practices being widely spread in the field. The overprescription practices fueled by incentives. These practices have been addressed by different approaches however, they failed in mitigating and limiting the mentioned unethical practices.

1.2.Research Purpose and Research Questions

The purpose of this thesis is to provide a secured and ethical technological solution to the problem of unethical prescriptions that is the root problem to additional other subsequence problems; the proposed technological frame that ensures safety to the data and security to the information of patients is a BC application. We will highlight in this thesis how BCT can facilitate more transparent sustainable medical transactions to protect the patient doctor relationship. To fulfill the research purpose the following research questions will be answered:

Questions:

- How can we implement Blockchain in the healthcare field to provide transparency in prescription issuing?
- Can smart contracts provide anti-incentive applications to eliminate the influence of pharmaceutical companies on physicians?
- Can the evaluation phase validate the efficacy of blockchain technology in mitigating incentive-based prescription practices within healthcare?

Hypothesis:

- Null Hypothesis (H0): Blockchain was not able to prove its ability in mitigating incentive-based prescriptions. The results obtained using BC were the same as the ones studied in the traditional healthcare system.
- Alternative Hypothesis (H1): Blockchain was able to prove its ability in mitigating incentive-based prescriptions. The results obtained using blockchain were significantly better than the ones studied in the traditional healthcare system.

1.3.Technological Background

1.3.1. Blockchain

As defined by IBM: BC is a shared, immutable ledger that eases the process of recording transactions and tracking assets in a business network. An asset can be tangible (a house, car, cash, land) or intangible (intellectual property, patents, copyrights, branding) (Nam et al., 2008). Virtually anything of value can be tracked and traded on a BC network, reducing risk, and cutting costs for all involved. BC is a chain of blocks with a decentralized and distributed network, each block having a digital signature (Monrat et al., 2019). The chain grows continuously when blocks are added to it. It has a simple structure; the first block genesis block has the data into it with a

calculated hash that acts like a unique identifier just like a fingerprint. This hash value will be used as a linkage with the next block. Also, each block has a timestamp to ease the traceback. This mechanism makes BC unique as any adjusting attempt will result in altering the cryptographic hash of the block. This is part of what makes BC unique in data recording as any change in the data of a block is impossible due to the computational difficulty involved in recalculating the block hash and keeping consensus across the network. **Error! Reference source not found.** sourced from Kakarlapudi and Mahmoud (2019) reflects the mechanism and details of BC were every block reference the previous block preforming an immutable chain.

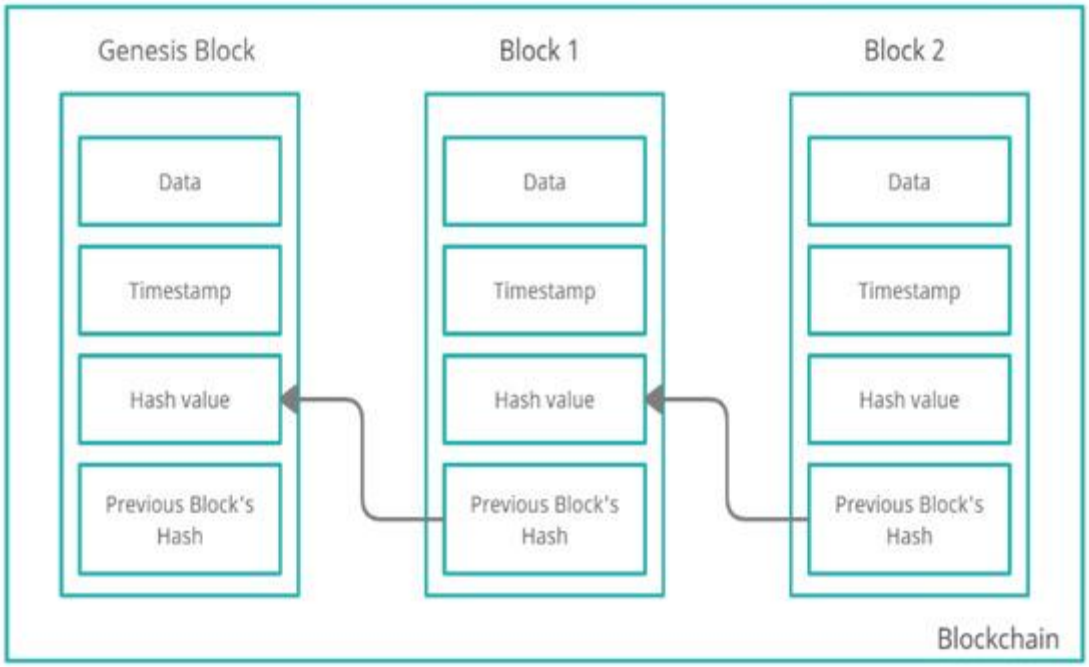

Figure 3. Genesis block in the blockchain, with illustration of block content.

BC in general is used to solve the problem of trust in a distributed system (Di Perro, 2017). The information is distributed validated and maintained by a network of computers, there is no need for a third party or authority. All data is secured and safe from manipulation, as no one can gain full control of the network, no edits or deletion

can happen as it is immutable. The nature of BC is built as a distributed ledger. BC has been used for more than ten years to complete monetary transactions between two parties without the need for intermediaries like banks or any other similar institution. Lately, a shift in the use of BC has occurred as now it is also being used as a distributed ledger for records. What makes BC a better possibility for medical records than traditional ones are that its design provides a better centralization around patients, it is also easily accessible by clinicians (Seaberg et al., 2021). In this research paper, the researcher will be using BC to propose and develop a decentralized application that allows physicians to prescribe medicine to patients. Moreover, it allows patients to check their medication prescriptions. This will allow different healthcare parties to connect using one secure consortium BC application. To be able to use the BC to record the transactions of prescriptions all prescribers, receivers and the assets included need to have an account that is named by a digital token as cited from the patients (Blackley et al., 2022). In **Error! Reference source not found.** the main features of BC are mentioned, described, as well as highlighting their relevance in the healthcare field.

Table 1. Blockchain features and benefits

Benefit	Description	In the field of prescription
Transparency	Transparency can be defined as a concept where specific information is accessible and apparent to counterparties and external observers	Transparency of doctors' prescriptions is important to increase trust, maintain accountability of actions, establish ethical behavior transparency as well as prevent conflict of interest between doctors' benefits and the patient's best interest as transparency can reduce ambiguity and vague behaviors.

Traceability	The role of traceability in a supply chain context is to identify components and the chronological order of supply chain activities. Knowing the location of a product improves quality control and can be used to ensure the authenticity of products.	Prescriptions are recorded in chronological order providing easy traceability of all prescriptions. Traceability is a focal point in healthcare as it is the solution for a lot of problems and can steer to the root of the problem.
Accountability	Refers to an actor's obligation to take responsibility for one's undertakings. Smart contracts in blockchain determine who is accountable for which actions.	As BC allows us to trace back the actions, knowing who is responsible and how it grew into the symptom this research is talking about incentive-based prescription1.
Auditability	Auditability refers to when an auditor who is not engaged in the process has the possibility to follow the audit trial.	Prescriptions cannot be tempered, edited, or deleted by any chance. the data is hashed into a serialized chain. This makes the data on blockchain reliable and dependable for future use, and this makes doctors know that if there is any unethical action being done everyone can see it as it is accessible to the public and it cannot be edited.
Consumer trust	By providing transparent and immutable information for inspection, the increased consumer demand for supply chain	All prescriptions will be available to the public making the prescription lifecycle available to be reviewed.

	transparency can be fulfilled. This results in increased consumer trust	
Data security	Instead of maintaining sensitive data on centralized databases, blockchain provides a secure, decentralized solution for the increasingly complex global supply chains.	The prescriptions will be available to the public to review. However, each doctor will have an ID formed from an alphanumeric unique username.
Governance decision	Consensus-based record validation removes the need for trusted intermediaries, which helps governance decisions in supply chains.	No need for a trusted intermediary as all data can be available to the public, instead of having some entities responsible for recording and maintaining the prescriptions. This job will be done by a trusted reliable technology (BC).
Immutability	The transaction data cannot be edited or tampered, with once the network has validated them.	All prescriptions are recorded and cannot be tampered with.
Transaction cost savings	By eliminating the intermediaries and automating transactions blockchain lowers the transaction costs.	There would be no need to buy or subscribe to any platform to keep a record of the prescriptions.
Trustless chain	By eliminating intermediaries and the need for human intervention, blockchain has the potential to replace personal trust with system trust.	Blockchain does not have a place for human intervention with the data recorded, making it impossible to interfere with the quality of the data. There is no need to have trust in the other party who is providing the service as the blockchain

		eliminates any interference from any pharmaceutical representative.

This research paper aims to build upon earlier research papers by providing a technological solution that implements Blockchain (BC). Transparency will be provided as BC will be used this will enhance trust in the healthcare industry. The proposed solution of implementing BC will introduce a new era to enhance the relationship between medical suppliers, healthcare providers, and patients. BC was chosen as a solution for its ability to revolutionize business models as it appeared to eliminate the middleman in business transactions (Nakamoto, 2008). In our application it will eliminate the pharmaceutical industry's influence on doctors' prescription behavior; as the BC provides transparency (Sunny et al, 2020). Also, it will supply a reliable data source for the prescription behavior of physicians to be analyzed and monitored persistently to detect problems in their early stages. In the next section, the literature review will discuss, compare, and criticize different approaches that have been implemented highlighting, proving and addressing the problem with the suitable solutions as well as the outcomes.

1.3.2. Smart Contract

Smart contract is a digital negotiation protocol used between two or more anonymous parties without the need for an intermediator to insure trust as it is a median were anything of value can be shared with no possibility of fraud (Samanta et al., 2021). The term “term smart contract” was coined by Nick Szabo in the 1990’s (Szabo, 1997). He has proposed to translate the clause of a contract into a code and embed them into a

software or hardware to be self-executed as visualized in **Error! Reference source not found.** (Brezitska, 2023), knowing that this will avoid accidental exceptions and malicious actions during performance (Zou et al., 2019). The objective and principle of this design is derived from the legal principles, economic theory, and theories of reliable and secure protocols (Szabo, 1997). They are stored on the blockchain making them verified, enabling automation in transactions (Berg et al., 2021).

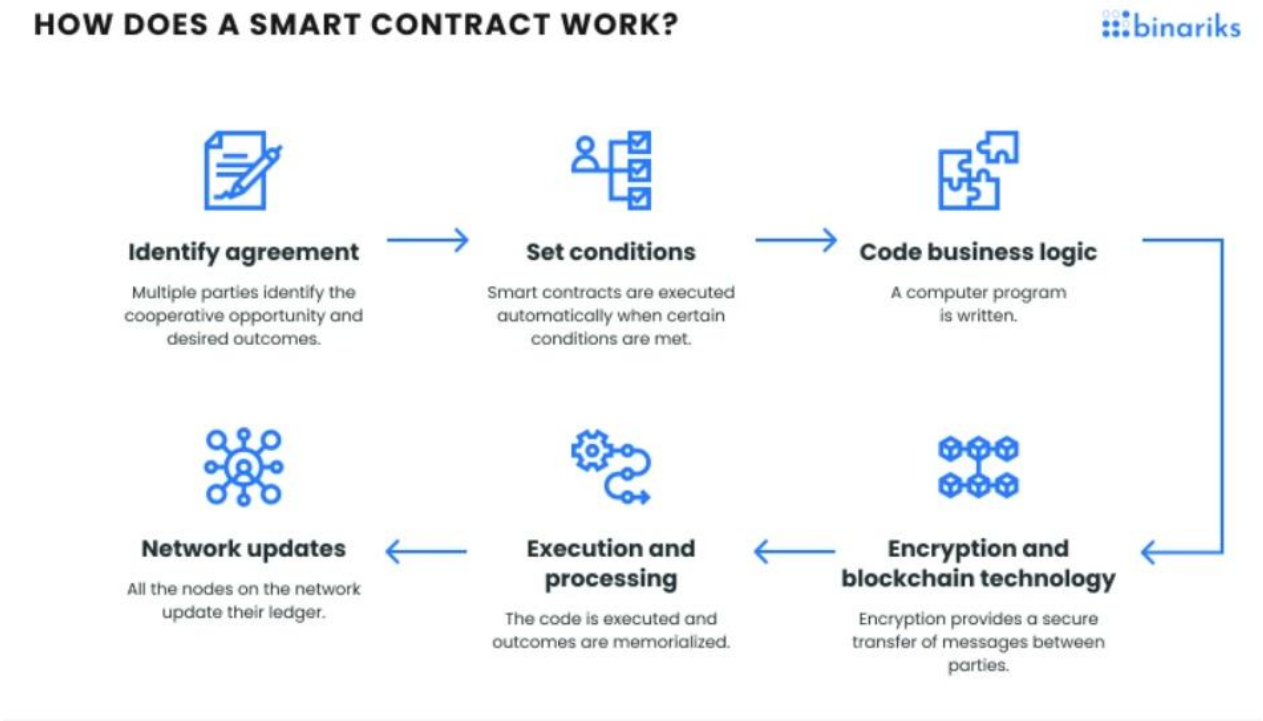

Figure 4. How does a smart contract work? (Brezitska, 2023)

In the previous section the problem was introduced, and an identification of the previous solutions and challenges has been discussed. The researcher has mentioned the ability of blockchain in solving the problem. Nonetheless the technological background has been introduced and explained. In the subsequent section, a comprehensive literature review will be included as it will discuss the existing applications that address the unethical behavior of prescription, and the outcomes of the unethical behaviors that

have been identified. This will provide the current state of knowledge available about the field.

CHAPTER 2

LITERATURE REVIEW

The healthcare business landscape has been raising concerns due to the relationship between the suppliers of medicine (pharmaceutical companies), and the healthcare providers (doctors/physicians). Part of these problems concern the financial incentives pharmaceutical companies give healthcare providers (Agha et al.,2022). These commercial ties can be traced back to at least the 1950s (Lichter, 2017). Nonetheless, these commercial ties have been growing rapidly as they have increased from $17.7 to $29.9 billion when comparing between 1997 and 2016 (Schwartz et al., 2019). In 2015 $2.4 billion was received by 48% of US doctors as industry payments (Tringale et al., 2017).

Agha and Zeltzer (2022) who have studied the effect of pharmaceutical payments in anticoagulant drugs showed that it has led to a significant and persistent increase in the volume of prescription. Nonetheless, their paper has contradicted the claims of pharmaceutical companies to improve the clinical adherence as the results have not shown any sign of it. It also highlighted the effect of peers in increasing the prescription of medications. The following methodology is based on administrative data as well as statistical method. In this paper we will be applying a blockchain process that will limit the influence of the marketing channels used on the prescriber's decision. Litcher (2017) noted that the ongoing relationship between the health care economy that is worth $3.2 trillion, and prescribers is a long lived one. And there have been many rules enforcement and programs that have shown impactful results in decreasing the conflict of interest (COI) between patients and their physicians. However, he also stated

that the aimed for output still needs work and experiments to choose the appropriate measurements as well as discard the irrelevant ones to ensure a trusted relationship that is accompanied with integrity to all parties of the system. This can be achieved through blockchain for its ability to provide integrity, transparency, and trust.

Incentives come in many shapes and forms varying from speaking fees, consultation, food and beverage, supporting research payments, compensation, travel, and lodging, which is considered part of the marketing strategy of the companies (Steinbrook, 2017). On one hand, some of these incentives are for educational and compelling causes; on the other, some raise concerns when they influence the decisions of healthcare providers. Nonetheless, the promotional activities of the pharmaceutical industry which are only directed toward physicians, exceed the spending on research and development (R&D) with a ratio of approximately double; this contradicts the industry claims. (Gagnon et al., 2008).

Steinbrook (2017) have shed the light on the industry payments for doctors in the US, as in 2015 95.5% of physicians have received food and beverages payment with a mean equal to $400, where these are the most frequent types of gifts received. However, it was highlighted that different gifts yielded different outcomes; for example, the speaking fees returned a greater percentage of branded medical prescriptions. Physicians have debated the claims of being influenced by such payments or gifts saying that they attend such events to further educated about the medications as they already prefer the brand. However, the data used by Steinbrook has shown; larger prescription rates have a proportional relationship with more expensive gifts. To conclude on the effect of industry largesse's on the behavior of physicians according to the American Medical Association Code of Medical Ethics cleared the issue by stating

“[g]ifts to physicians from industry create conditions that carry the risk of subtly biasing—or being perceived to bias—professional judgment in the care of patients.” Gagnon and Lexchin (2008), discussed the claims of the pharmaceutical industry claims of being interested and investing in the RD of medicine. However, the payment of marketing predominates the budget spent on RD. This is not being hidden by companies as the largest part of the marketing budget is being clearly labeled for promotion. However, the industry promotes they are research driven while they have promotion driven company.

Financial incentives create a fertile environment holding many problems, some of which are overprescribing, prescribing higher cost medications, and many more. Overprescribing is any prescription that was not necessary, or choosing costly medications for no valid reason (Yang, 2016). Also, incentive receivers in general tend to prescribe higher-cost medications (Chao et al., 2022). This was also reported by tuberculosis patients as they face higher costs when treated by incentive receivers, which also makes them susceptible to delay in receiving treatment (Liu et al., 2007), (Sharma et al., 2018). It has been proven that physicians face conflicting interests between their commitments to patients' care and receiving incentives as it is a myth that small gifts do not affect their behavior, since human behavior is not completely rational (Brennan et al., 2006), physicians persist in voicing myths to justify their partaking of industry’s largesse (Lichter, 2008). Moreover, incentivized healthcare providers may harm the patient’s trust in the healthcare providers (Trayer et al.,2022).

Chao and Larkin (2022) research paper have found that a change on the state level in the policy was able to make a disclosure of pharmaceutical payments for prescribing branded medications; and some cases there was a shift in prescriptions

toward unbranded medications. Their research paper disclosed the contradictory literature they had about the effect of disclosure; it was confirmed by the paper that disclosure is effective to reduce biased. Nonetheless, the research paper has mentioned that the disclosure federal policy does not require reporting free meals which is considered an incentive.

Sharma et al., (2018), have conducted a study to grasp a better understanding of the assassination between industry payments and prescribing costly medications. They have confirmed the correlation between both values; and stressed patients' rights of having a transparent relation with their physicians and being informed of any sponsorship or financial ties to the pharmaceutical industry. To achieve this outcome and close the gap the procedure suggested through the blockchain technology can perform it as it will be discussed and applied through this paper.

Trayer et al., (2022) did not deny the importance of the pharmaceutical industry in developing the drugs and medical devices. On the other hand, the researchers stated that it did not bring any little value for the patient care. On the contrary it has been proven that any little interaction between the industry and the physician leads to being influenced toward favoring their medications over the generic medications. Due to that the paper has stated the need for an interference as this behavior would not have been tolerated in any other field. Also the paper had mentioned some of the measurements that have been applied and criticized them due to not being enough. This leads to the importance of our paper which focuses on the application and process that will decrease harmful behavior, as well as validating it.

Yang (2016) has confirmed in her research paper that was based on empirical interviews with physicians in shanghai that hospitals have pushed doctors to prescribe,

as there was a benchmarking schema to encourage doctors to reach their prescription targets regardless of the efficacy and efficiency of the treatment. The paper argued the principle the Chinese health care follows, which is providing care based on profit. It has also been stated that in order to change the system and improve it, a crucial component should be achieved; which is setting a system to maintain growth and profit for the field before regulating any new regulations.

In 2004 the pharmaceutical companies spent $57.5 billion on promotion only in the United States (Spurling et al., 2010). This is not surprising since it has been estimated that in the late 90's, between $8000 and $13,000 were spent on each physician each year (Wazana, 2000). Incentivized prescription can be traced back to too many reasons other than increasing profit, such as the insufficient funds given to hospitals by the government. This has pushed hospitals to shift their dependency of income on to the sales of drugs (Yang, 2016).

Overprescription can vary in kinds; some are unnecessary prescriptions, other excessive dosage, prolong duration, polypharmacy and many more. The motive behind overprescription can be due to several reasons such as: incentives, patients demand, or diagnoses uncertainty. Misuse of medication is associated with inevitable risks as adverse reaction, hospitalization, death, addiction in the case where opioids were misused as it can lead to fetal overdose.

In the past 25 years there have been an emerging crisis (opioids pandemic) in the USA & Canada as it was responsible of the death of more people than of World War one and two combined. This has caught the eye of the Standford University of Medicine and The Lancet to assess an investigation which revealed many important points first that this epidemic is fueled by legally prescribed opioids. The crisis has generated $35

billion US dollars for Purdue Pharma. The prescriptions of its manufactured opioids were prescribed due to office visits offering a ranged amount (Humphreys et al, 2022). As in 2016 the pharmaceutical industry spent $20.3 billion dollars only in the US for marketing to the prescribers (Schwartz et al, 2019). The commission that was formed by Stanford University of Medicine and The Lancet has suggested some measurements to be enforced as well as the PDMP.

Humphreys et al., (2022) compared the opioid crisis to the tobacco crisis that emerged before from high-income countries to the international market to sustain their existing; it is important and crucial to put the regulations and sanctions to not export the crisis from the Americas to other countries. They also brought attention to the issue that many cases have been filed against the companies that are using fraudulent activities to increase over prescription. However, the court prohibited such activities in the US only. The crisis of opioids is not one of a kind and it has been repeated multiple and frequent times. This leads to the need to establish measurements that can limit the ongoing pattern of crisis. Humphreys paper suggested imposing policies. While in this paper we present a procedure that will have the ability to prevent these actions as the technology that will be integrated in the process has been validated for being transparent, traceable, accountable, and provides consumer trust as well as many other functional values that will be beneficial in the healthcare system to insure ethical behavior.

This crisis has been ongoing in the developed countries for years now and it is raising concerns from starting in the developing countries soon. This phenomenon is highly important as it has been seen in the opioids trend description which affects neurological functionality (Volkow et al., 2021). Also, it has been seen in the stimulants prescription as clinicians have been over diagnosing and prescribing stimulants for

attention-deficit/hyperactivity disorder (ADHD) patients (Moustafa et al., 2022). Moreover, the antibiotics overprescription has been addressed as a worldwide problem. It is still raising flags in many countries, and in 2016 the US had 30% of its antibiotic's prescriptions considered as non-necessary (Ferrara, 2017). The kinds of medications that are being overprescribed due to incentives extend furthermore.

According to Moustafa et al., (2022) paper that is shedding light on a new emerging crisis of ADHD overdiagnosis and overprescription that has been formulating in the past decades due to unmonitored prescription patterns. The pattern and number of prescriptions have been increasing for more than three decades, however between 2006 and 2016 the numbers have doubled. This crisis did not affect only people who were prescribed stimulants after being diagnosed only. But also have reached to their surroundings from friends and families as they were able to share their medications due to the overprescribed medications. Also, most abusers were able to bring medications from the surroundings.

Opioids, stimulants, and antibiotics were all mentioned in the literature review due to in common promotional schemas. However, they all have caused a crisis due to overprescribing, which is driven by incentives. These crises share some in common features; this highlights the importance of having the process being mentioned in this research to limit the effect of the pharmaceutical industry corruption, salespeople marketing behavior, and unethical behavior of physicians.

In contrast, Rahodes research paper has proved that there is no significance in the statistics between the range of opioid prescriptions and the application of the PDMP. The PDMP program was not denied the enriching outcomes and benefits in giving the ability to prescribers to check if they want. Nonetheless, there are some studies where

they reflected that the states that apply PDMP have higher rates of fetal and non-fetal overdose incidents. However, the prescription rate decreased after applying the program (Rhodes et al., 2019).

Nonetheless, regulations from the government have also failed in altering the physician's behavior. Even the FDA () which is the worlds most powerful regulatory agency its powers evolve around drug approval stage more than any other stage post marketing (Nachlis, 2018).

This research will propose a transformative solution to mitigate the business problems faced in the healthcare field. The problem is resembled by the influence of incentives given to doctors by suppliers to increase or shift prescriptions to certain medications. The link between the in-kind gifts/cash and the prescription pattern and volume has been proven (Mitchell et al., 2021), (Agha et al., 2022).

Blockchain should be a considerable solution by governments for many reasons; first the prescription drug monitoring program PDMP is only used for controlled medications, while there is more medications that are escalating in the prescription trends. Instead of using different measurements blockchain can be used to data recording and the integration of the regulations that will be enforced using the smart contracts. This will be discussed in the next section as the methodology for the research.

CHAPTER 3

METHODOLOGY

3.1. Framework Creation

The ethical problem that is being faced in the health care system; where marketers are explicit in the over prescription crisis that has been going on; Since their influence has been documented for effecting the physicians' decisions of what medication to prescribe, in what quantity, and for what reasons (Hadland et al., 2019). Also, the encouragement of some pharmaceutical companies for doctors to prescribe branded medication that are typically 30%-60% more expensive than their generic counterparts (Straka, Keohane, & Liu, 2017, as cited in Zarowitz, 2008). The mentioned problems have been covered in the conducted literature review, to explore the current research activities.

This section will explain and describe the solution employed to develop and implement a BC application to record data. The researcher will walk through the steps and stages needed to develop the framework that can be introduced as the solution to the problems that were yielded due to the unethical marketing strategies of pharmaceutical companies, hospital needs to generate money to maintain their continuity and operating due to the limited funds available, as well as doctors motives in generating more profits, gains, or even getting fundings for their research.

Based on the literature review conducted where we highlighted the long-lived problems despite the different approaches that have been used to handle and resolve the problem. As we criticized and learned. Now the methodology will cover how the gaps will be

approached and filled in, in order to decrease the influence of the unethical behavior of prescribers.

Five attributes will be covered in this section. First the backend, smart contract which includes all the rules, components and considerations that will be undertaken in the application. Third, the frontend which is the website that facilitates the interaction with the BC; user interface (UI). Fourth, subsection will cover the wallet used to verify the access to the interface. Finally, we will walk through the application and how it works.

3.2.Backend

In this section we will go over the development of the backend of the application. Node.js has been used as the runtime environment, it simplified the routing for HTTP requests, as well as incorporating authentication mechanism to ensure authorized access to each functionality of the UI. Api calls were made to call on the smart contract and interact with it. Overall, the backend encompasses various sets of features ensuring a solid and robust foundation of a powerful and user-friendly BC application.

3.3.Smart Contract

The contract is written with a solidity programming language that is used to code smart contracts, which provide a base for different parties to construct contract rules that are then enforced on the BC. This gives the opportunity of making transactions with

people we have no knowledge of or experience with, or we do not trust to be trusted without the need of mediators.

Solidity is a programing language like JavaScript in syntax. The development of the contract took place on an online integrated development environment Remix IDE, as it is a specific platform for smart contracts development. The process of writing, compiling, deploying, and testing was done on the mentioned website. This process provides the smart contract with a unique address that is composed of 160- bit identifier as provided in **Error! Reference source not found.**, and then it gets uploaded to the BC. Once it gets successfully uploaded it allows different parties to interact and invoke transactions (Wohrer et al., 2018).

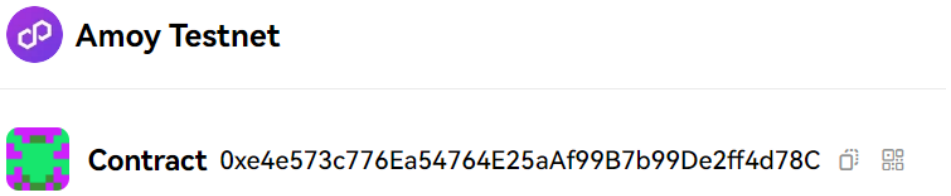

Figure 5. Deployment of the smart contract.

The targeted issue in this smart contract is to limit branded medications prescribed to patients, as they are mostly derived by incentives (Steinman et al., 2007). This has been activated by adding the "addPrescription function" where we included the 'if' statement to enforce doctors when they prescribe a branded medication the doctor is forced to give a generic alternative for the patient as **Error! Reference source not found.** shows. Otherwise, the prescription won't be submitted to the block. This can be seen below in the code provided.

```
function addPrescription( // this enforce every authorized prescriber to enter a generic medication
        address patientAddress,
        string memory normalMedication,
        string memory normalDosage,
        string memory brandedMedication,
        string memory brandedDosage,
        string memory age,
        string memory diagnoses) public onlyDoctor {
        patients.push(patientAddress);
        require(bytes(normalMedication).length > 0 && bytes(normalDosage).length > 0, "Normal prescription is required");

        if (bytes(brandedMedication).length > 0) { //However, here prescribers are not forced to be filled and thats why 'if' statment was used
            require(bytes(brandedDosage).length > 0, "Branded dosage is required with branded medication");
        }
```

Figure 6. Solidity code in remix enforcing the generic medication in every prescription.

3.4.Front End

For the interactive frontend, where users can use the BC application to make transactions we have used java script, html, CSS, with the integration of web3.ps which allows the interactions with the Polygon BC. This outlines the components of the frontend as it projects a friendly interactive interface for users to interact with the backend smart contracts.

HTML and CSS is used for constructing the components of the layout and features available. Then we used the java script to implement interactivity and functionality with the API backend to submit and retrieve the data. The API calls are responsible for communication between the backend and the front end. The use of web3.ps allows real-time interactivity between both ends. To allow a seamless system for doctors to use for submitting prescriptions and users to retrieve data. A graphic user flow diagram was designed to guide the creation of the frontend, as we have three different portals that can be accessed, the diagram is illustrated in **Error! Reference source not found.**. The diagram includes the scenarios possible when using the application. The login page can be used by three different kinds of users: admins,

prescribers, and patients. Different scenarios were mentioned and explained in the diagram.

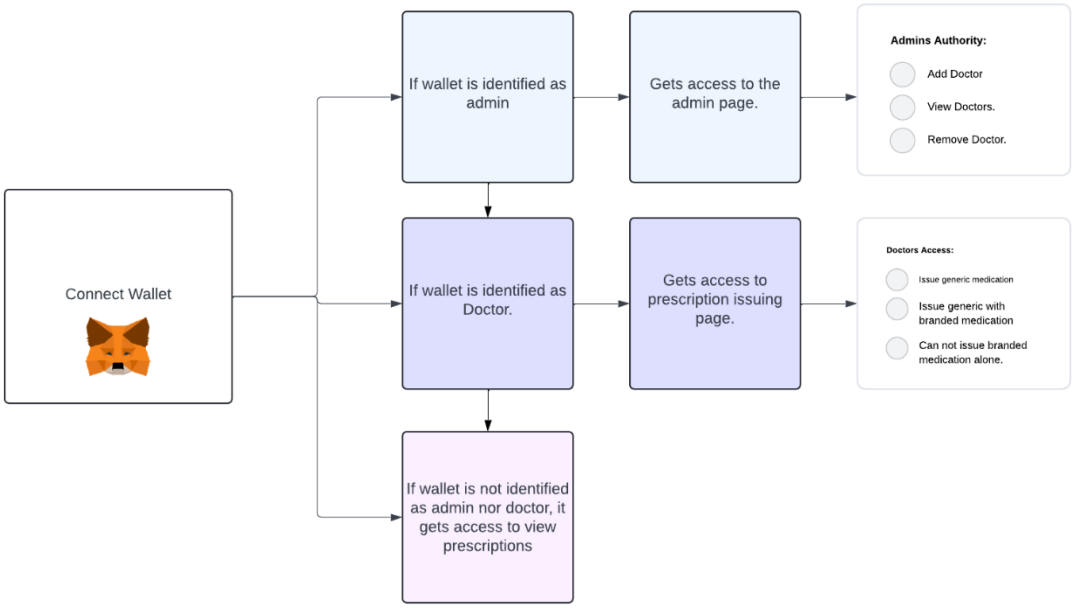

Figure 7. User interface flow diagram of the BC application solution.

Once testing was completed satisfactorily, the frontend application was deployed to localhost using vite, while the smart contracts were deployed to the ganache local blockchain using third web's cli. After deployment third web provides an interface for interacting with the smart contracts and to read stored state. Once the testing stage was completed while the smart contracts were deployed to the ganache local blockchain using third web's vite.

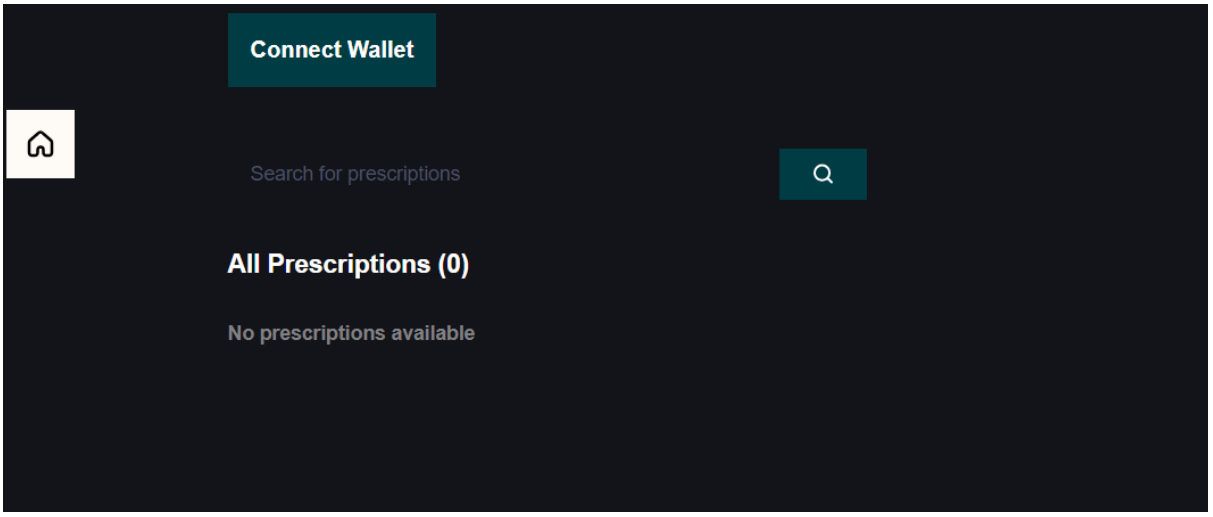

Figure 8. Streaming The Application On Vite-JavaScript Starter

3.5.User Verification: MetaMask

MetaMask provides a website extension to provide the function of using the Ethereum wallet, manage their accounts as well as the transactions. To be able to access the built application and interact with it safely. By leveraging the encryption capabilities that are provided with the front end we certify that prescribers' identities are verified and authenticated to enable them from making transactions on the block, which in this case are prescriptions. This functionality can ensure the association of doctors is fostering a proper framework among doctors that is able to provide privacy, security, high trust, and many other features that only BC can provide in this high functionality.

3.6.Application

First, to be able to use the website every user needs an ether wallet which has a public and private key. This can be provided through wallet software that can provide cryptographic addresses for users and private keys. Here we used MetaMask as seen in

Error! Reference source not found. as it provides an easy-to-use interface to manage accounts on the BC. And we have used Ganache to generate addresses.

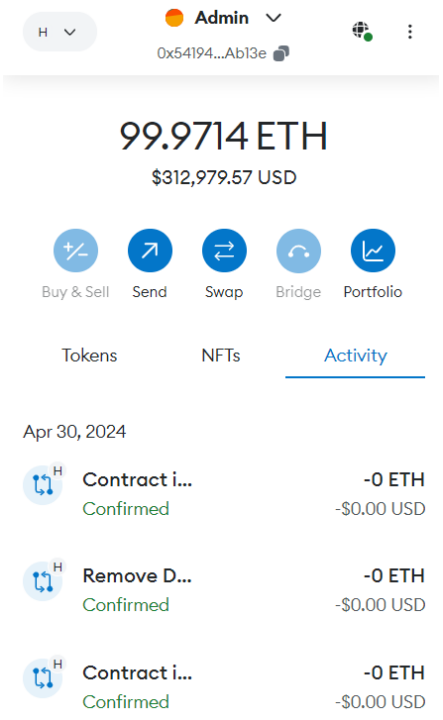

Figure 9. MetaMask Wallet

Private key works like the password, it is a mathematical encryption randomly generated 256-bit, formed from a 64-character hexadecimal string. This is an example of it: "0x64c89fb8ae25f72e66c2f78181b86e98bfa2130f0d2c6e6be3b9a501af7d1e8f". Then for the public key it is derived from the private key mathematically. However, we cannot derive private keys from public keys. This is a random example of a public key: "0x98bE382c1a72f0F3f1eD7A462bE3f83b8A6c54B9". Here in **Error! Reference source not found.** we use the private and public key that are managed through the digital wallet created before through Ganache.

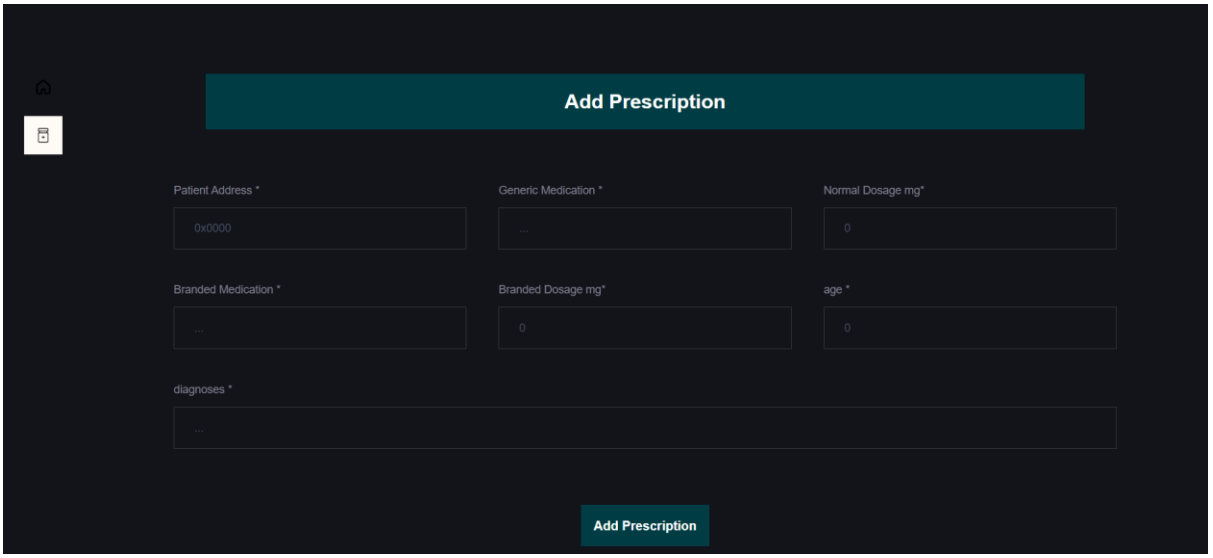

Figure 10. Doctor Login UI

This interface can be accessed by admins, doctors, and patients. All users need a wallet to login. The admin has the capability of adding admins, adding doctors, as well as removing doctors as seen in **Error! Reference source not found.**. Doctors can add prescriptions as seen in **Error! Reference source not found.**, viewing prescriptions, and retrieving prescriptions of patients **Error! Reference source not found.Error! Reference source not found.**.

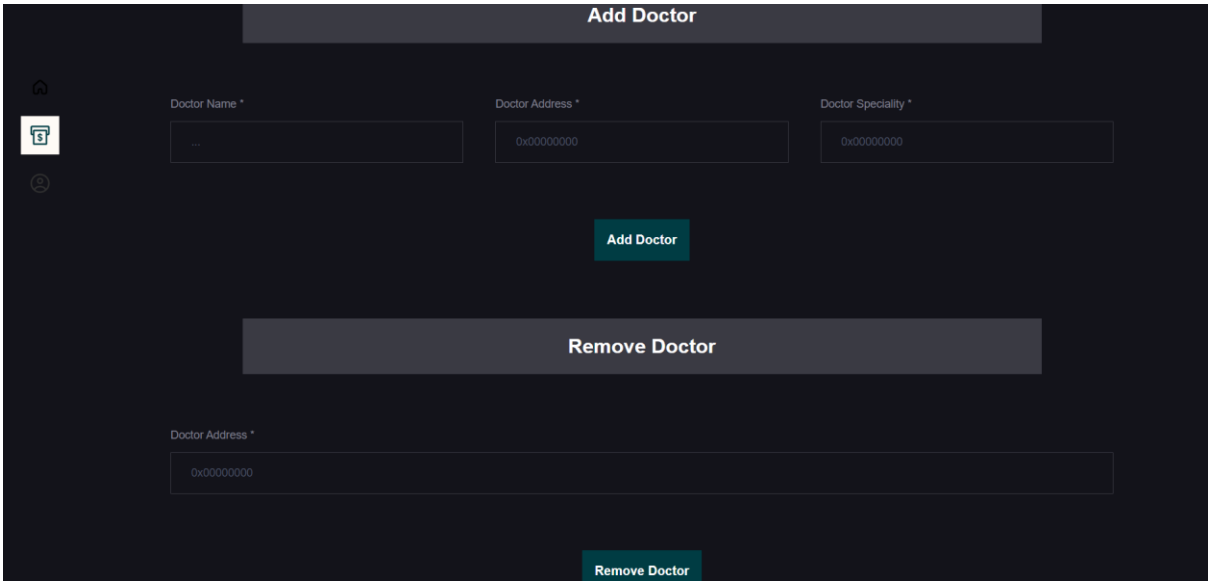

Figure 11. Admin UI.

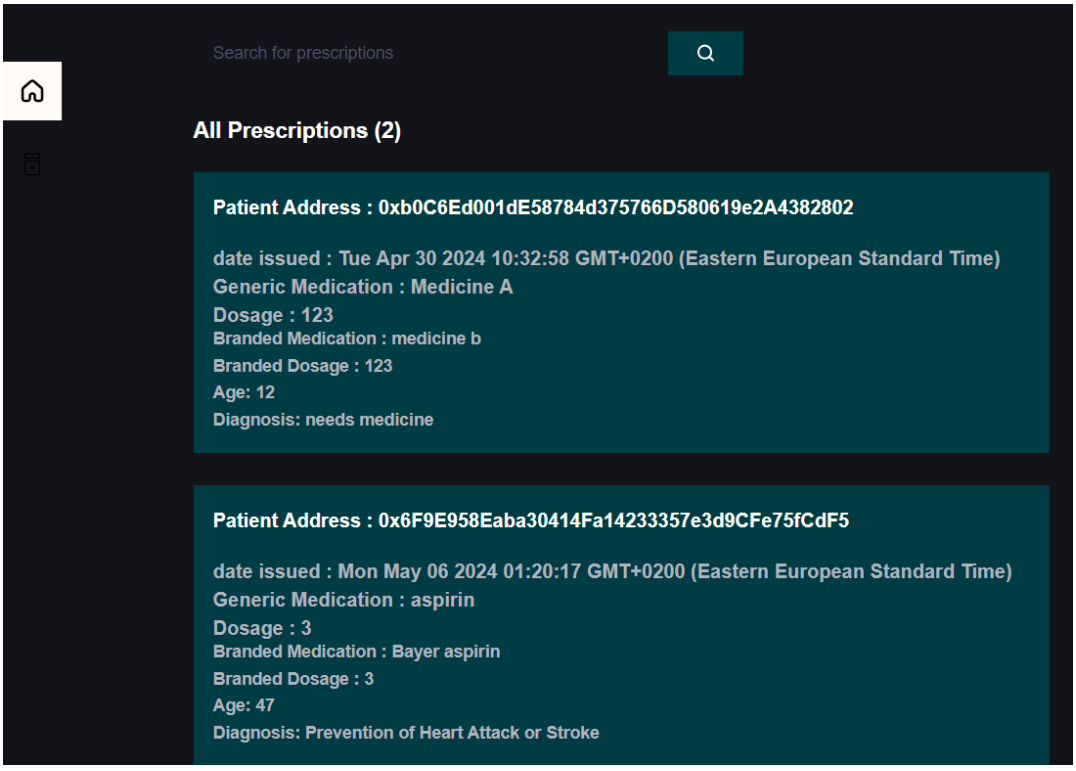

Figure 12. Retrieving Prescriptions

Patients can view prescriptions and retrieve prescriptions using the public

address of patients. By that they can retrieve all prescriptions with information of what medication they are taking, dosage, if the doctor has prescribed an additional branded medication, the age of the patient, and the diagnoses. This has been visualized in **Error! Reference source not found.Error! Reference source not found.**.

BC applications require crypto currency wallets. Since this application is for a testing purpose MetaMask and ganache were used to generate wallets to be used on the application.

CHAPTER 4

RESULTS & VALIDATION

The purpose of this thesis was to examine BC technology's possible applications in the healthcare sector and to highlight the importance and significance of the technology in making prescriptions. As this thesis acknowledges, BCT is not only restricted to the virtual currency bitcoin but is applicable to much more. Due to its features that provide security, transparency, traceability, accountability, auditability, and many other features are validated in the following section.

This section analyzes how BCT can facilitate the needed requirements for an ethical prescription practice, to mitigate the outcomes of the behaviors that are being done using the traditional prescription applications. The validation was broken down into two parts. The first part will include the answers to the research questions. The second part will include the hypothesis testing of the thesis, as they will be answered

within the analysis section.

4.1.Research Questions

RQ1: How can we implement Blockchain in the healthcare field to provide transparency in prescription issuing?

BC allows us to make transactions in a decentralized environment. Implementing it in the healthcare field with its capability to provide transparency will significantly enhance integrity and security of prescribing medications. Below we will demonstrate:

Decentralization: First, one of the important features of BCT is data decentralized in a consensus mechanism as well as being a distributed ledger having multiple nodes (a group of independent computers) maintaining a copy of the data achieving high security and giving all the application users the ability to access the data, to be extracted for analysis, and monitor. Hence, if one node from the BC goes down, the ledger can be retrieved from the other nodes of the BC. As **Error! Reference source not found.** shows each dot resembles a node, if one of the nodes in a distributed ledger goes down the other modes stay connected, and the data can be retrieved since it is available and accessible by all nodes.

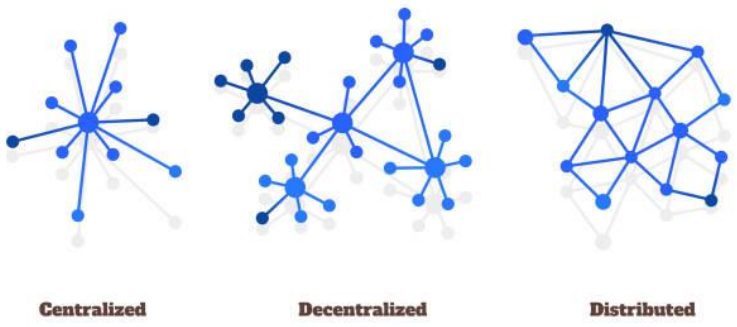

Figure 13. Centralized vs Decentralized vs Distributed network architecture

Encryption: Utilizing this technology for storing patients' records as each patient has encrypted digital identity on the blockchain, having all their prescriptions and diagnoses recorded with timestamp, also it shows who issued each prescription providing traceability to the data. This is reflected in **Error! Reference source not found.** as the information of the prescription is provided.

Figure 14. Transaction infotainment recorded on the block

This is provided due to it being chained as blocks in a chronological order, shared between nodes, as it is a peer-to-peer networking that disregards the importance or even relevance of having an authorized entity as a mediator where all nodes have the

same capabilities.

Nonetheless, this is validated by the cryptographic hashes of each transaction, then every two transactions, together forming a Merkle tree structure which is explained in **Error! Reference source not found.Error! Reference source not found.**, which ensures all transactions are tamper proof. No new transactions can be inserted into the block after it is hashed as any edit in it will change the hash value as it is encrypted.

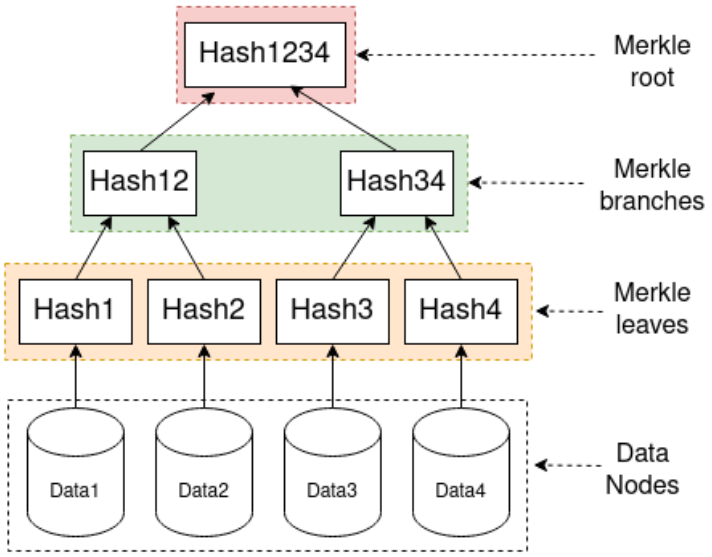

Figure 15. The forming of Merkle tree

Merkle tree structure ensures a tamper proof nature of transaction of the block. As each transaction on the block is hashed, then each two hashes on the same block are hashed together, till all pears are hashed creating Merkle leaves, and branches till we create the hash of the final two hashed values creating the root **Error! Reference source not found.**. The Merkle root value is then put as part of the validations provided on the block header as shown in **Error! Reference source not found.**. These strategies that are enforced through the application ensure no malicious or unethical behavior can be done. For example, unauthorized access by an attacker to prescribe certain drugs or

edit the dosage of a prescription cannot happen. As the application in hand provides a robust data encryption as explained; due to having an access control, and authentication mechanism to protect sensitive medical from unauthorized access.

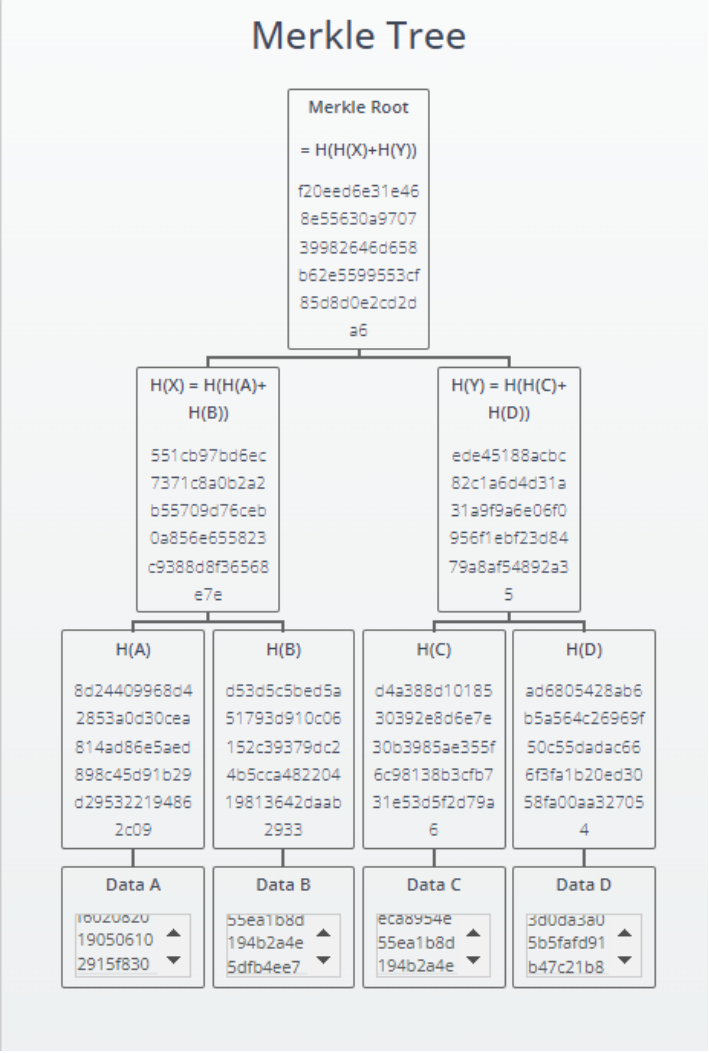

Figure 16. Merkle tree of our developed application

Immutability: Each block has the hash of the previous block recorded on its header, thus no block can be added or removed. The prescription history of the patient cannot be edited nor deleted as blockchain provides a tamperproof database. This is provided due to each transaction having its information hashed and signed digitally. As

provided in **Error! Reference source not found.** as each block has the hash value of the block as well as the previous block to achieve high transparency, traceability, immutability, and security.

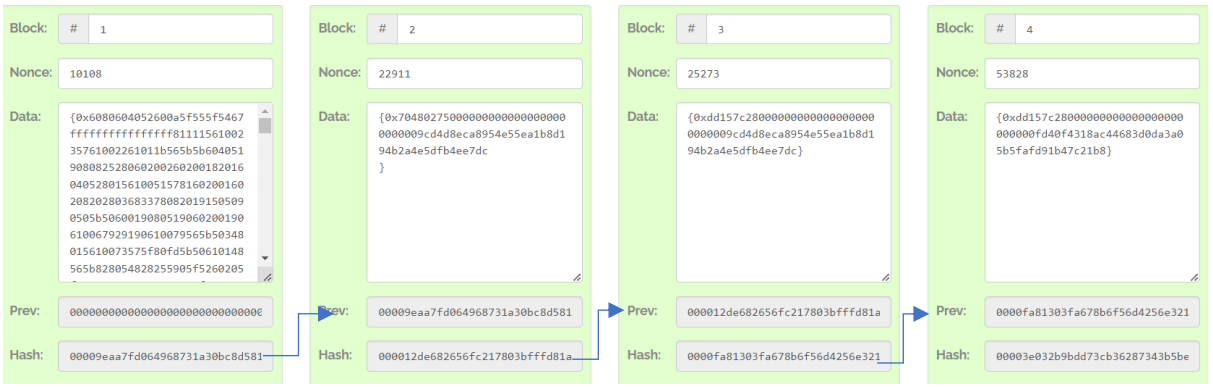

Figure 17. Hash value in the Blockchain achieving transparency, and immutability due to the hashing mechanism

The transaction has a cryptographic hash with 18 leading zeros making it a unique identifier for each transaction. The leading zeros in the hash increase the complicity of the hash, increasing the security functions of the application. This ensures the integrity and immutability of the record. The hash algorithms are a kind of a mathematical algorithm that creates a fixed length output for all length inputs, providing a compact numerical representation below in **Error! Reference source not found.** we can see the transactions with their hashes. It is computationally impossible to find two distinct inputs providing the same hash, as there are different used hash functions that provide 128bits (Rabah, 2005).

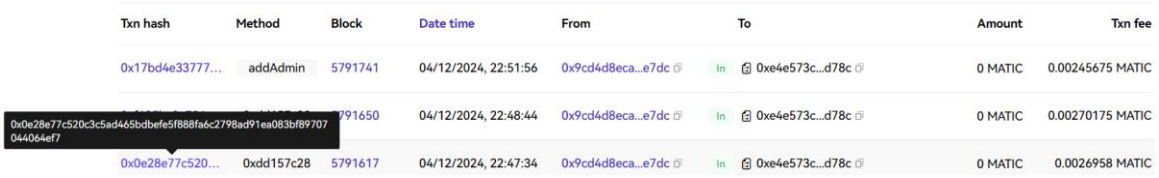

Figure 18. Transactions record showing the hash numbers created from prescription information

RQ2: Can smart contracts provide anti-incentive applications to eliminate the influence of pharmaceutical companies on physicians?

By deploying a smart contract, we are ensuring that agreements between the doctors and the patients are being transparently managed. Due to the function included in the smart contract that forces prescribers to give an additional generic prescription with each branded prescription. Mitigating the influence of only prescribing branded medications that are being widely used due to incentives received by doctors from pharmaceutical companies.

Below in **Error! Reference source not found.** the smart contract stresses that each prescription requires general medication [normalMedication], while the branded medication is optional.

```
function addPrescription(
        address patientAddress,
        string memory normalMedication,
        string memory normalDosage,
        string memory brandedMedication,
        string memory brandedDosage,
        string memory age,
        string memory diagnoses) public onlyDoctor {
        patients.push(patientAddress);
        require(bytes(normalMedication).length > 0 && bytes(normalDosage).length > 0, "Normal prescription is required");

        if (bytes(brandedMedication).length > 0) {
            require(bytes(brandedDosage).length > 0, "Branded dosage is required with branded medication");
        }
```

Figure 19. Add prescription function written as a solidity code in the smart contract

RQ3: Can the evaluation phase validate the efficacy of blockchain technology in mitigating incentive-based prescription practices within healthcare?

BCT can mitigate incentive based prescription if applied as the medication prescription program. We recommend it being enforced by the association of doctors to ensure all doctors apply it as it can be a condition when renewing or issuing the membership. As no doctor can practice medicine if they are not within an association. The consensus mechanism of blockchain ensures the intended objective of this research paper due to the features enforced in the application that cannot be applied in any other technology. Also, smart contracts facilitate a transparent, and automated the process of issuing prescriptions, validating them, and recording them in an immutable architecture. It is believed that this practice can limit the influence of the marketing efforts of pharmaceutical companies, as they can no longer be the dominant brand in the market. The patient can choose between medications.

It has been proven that BC can provide better outcomes in data management, as it increase the reliability of the data and improve the behavior of users. This is due to the high measurements of security. This has been reflected in the clinical trial that have been applied by (Harino et al, 2020) where they used BC to record the data and outcomes of a clinical trial conducted for cancer patients.

In connection to the previously mentioned features that we are capable of injecting the healthcare field with using BCT and the use case; there are many other reasons that motivated this research, as BC can be the solution to many encountered problems in the healthcare field as mentioned in the literature. A comparison between the traditional framework and the proposed one will be formed below, to showcase the

importance and relevance of our solution.

4.2. Hypothesis testing

To test the hypothesis of this research a comparative analysis has been done between the ongoing health care prescription behavior by reading, analyzing, and extracting valuable information through the literature review. Different cases have been studied covering different sides of the problem, motives behind incentivized prescriptions, environment, and consequences. Each situation was thoroughly investigated. This was the motive to provide the solution.

Incentivized prescriptions are a common practice in the healthcare field. That was continuing even after the measurements taken to limit from the practice itself, or even the consequences. Part of the measurements taken was PDMP, imposing regulations, regularity oversight, etc. BC achieve**s** a greater effect than laws and regulations as legal law is ambiguous and flexible; BCT is able to convert the code of law to a law of code, achieving stronger role that regulates and manage the behavior of users (Fillipe et al., 2018).

As provided in the literature the ongoing regulations were unable to detect crisis at an early stage, limit the branded prescriptions, manage the relationships between doctors and pharmaceutical companies and other behaviors that are rooting from incentives provided by marketing representatives for prescribers, resulting in many problems such as complications, addiction, medication misuse, crisis, delay in receiving medication, financial burden and more.

As a first step toward the solution transparency, traceability and immutability are needed, from this point BC was promoted as the best step to be taken. Further validation

can be provided when implementing the application in real life. As it is not possible to enforce it during the research. As it will provide us with data to be compared with the now available data to get a measurable difference rate between traditional method and BC method in limiting unethical behavior in prescription.

- **Null Hypothesis (H0): Blockchain was not able to prove its ability in mitigating incentive-based prescriptions. The results obtained using BC were the same as the ones studied in the traditional healthcare system.**
- **Alternative Hypothesis (H1): Blockchain was able to prove its ability in mitigating incentive-based prescriptions. The results obtained using blockchain were significantly better than the ones studied in the traditional healthcare system.**

A comparative study has been done to provide validation and reasoning how and why BCT is better than the ongoing technologies in the field of data recording. The comparison of the features have been done according to the key concepts that the literature have highlighted as important features to be available in the proposed solution for the ongoing crisis in the healthcare field.

Transparency: transparency is provided in BC due to its cryptography that is maintained during storage as well as in transit. Providing highly secure data that is reliable, transparent, and traceable. Due to the encryption of the block, transaction, and its content. Also, the nodes(computers) have full access to the data which does not limit the data only for authorized entities.

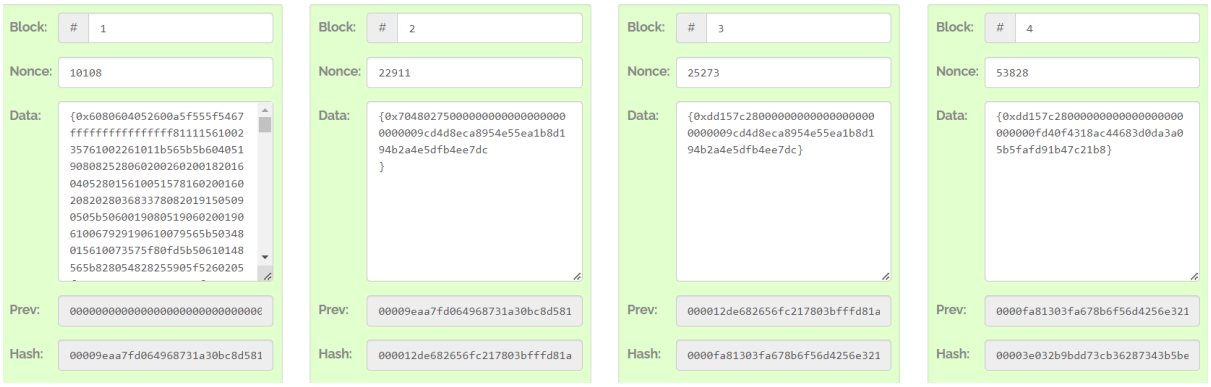

Figure 20. Transparency reflected by the hash values available on the blocks

Decentralization: anyone can get access to the data recorded to view it. This increases trust due to data being transparent and accessible to everyone. Also, the data is recorded on different nodes, ensuring that if one of the nodes goes down the other nodes stay connected, and all the data will be retrieved.

provides a comparative analysis of different technologies used to record data on them. Highlighting the vulnerabilities and downsides of the being used data bases for data recording in general and medical data in specific.

Table 2. Comparison between different data bases for recording data.

Features	BCT	SQL	Traditional DB
transparency	Accountability & transparency as all transactions are recorded and accessible by all authorized participants.	Limited transparency as data is provided only to certain people with a difference in the level of transparency based on access control mechanism.	Access is limited to authorized people only, with different access limitations specified according to a specific mechanism to limit transparency.
Scalability	Using Polygon, the issue of limited scalability due to its architecture and design was solved. As it provides a level 2 scaling solution for Ethereum.	High scalability and robustness. As it was designed to foster this feature, as it is capable of handling large volumes. Scalability can be achieved horizontal and vertical.	Scalable depending on if it is centralized(vertical), decentralized(horizontal). Can handle large amounts of data at a concurrent efficiency.

Immutability	Immutable data traits across the chain due to its consensus mechanism used for validating, which it ensures no revoking, deletion or editing any transaction. This ensures data integrity and immutability.	Data can be deleted or edited by authorized people with no trace. It does not provide data immutability or audit trails and controls. They can be added by implemented, but the data in the DB (data base) can be edited, or deleted by authorized people.	Authorized people can delete or edit without trace. Audit trails and functions can be implemented. However, authorized users can delete the data that is available on the DB.
Decentralization	Decentralized data among different nodes. If a node goes down the other nodes will still be connected to one another, and the data can be retrieved as they do not depend on one central authority. This enhances resilience and trust.	Centralized data stored and managed by authorized entity. This thing makes it risky as if the DB gets attacked it can be ruined. The DB can have back ups, but they are not as functional as BC.	Can be centralized or decentralized.
Data security	High security due to the Merkle tree & encryption and cryptographic algorithms, this ensures that no tampering or data breaches can happen.	Vulnerable to malicious attacks, which can change leak delete etc. Can add encryption protocols to protect the data. However, it is only possible while data is at rest and not in action.	Uses traditional access control making it vulnerable for attacks. Can implement extra security measures to protect its data at rest. However, it remains vulnerable for attacks.
Auditability	High level of auditability as data is verifiable. As it offers comprehensive auditability functions as it records all transactions in an immutable ledger with timestamps and encryption mechanism.	Limited audit. Can be enhanced by auditability features to achieve a higher level of auditability by providing insights about all DB activities.	Limited audit. However, it can be enhanced by adding features to enhance its capability of keeping trace of all activities.

References	Chowdhury, M. J. M., Colman, A., Kabir, M. A., Han, J., & Sarda, P. (2018, August). Blockchain versus database: A critical analysis. In *2018 17th IEEE International conference on trust, security and privacy in computing and communications/12th IEEE international conference on big data science and engineering (TrustCom/BigDataSE)* (pp. 1348-1353). IEEE.	Shahriar, H., & Haddad, H. M. (2017). Security vulnerabilities of nosql and sql databases for mooc applications. International Journal of Digital Society (IJDS), 8(1), 1244-1250. Thiyab, R. M., Ali, M., & Basil, F. (2017, April). The impact of SQL injection attacks on the security of databases. In Proceedings of the 6th International Conference of Computing & Informatics (pp. 323-331). School of Computing. Chowdhury, M. J. M., Colman, A., Kabir, M. A., Han, J., & Sarda, P. (2018, August). Blockchain versus database: A critical analysis. In *2018 17th IEEE International conference on trust, security and privacy in computing and communications/12th IEEE international conference on big data science and engineering (TrustCom/BigDataSE)* (pp. 1348-1353). IEEE.	Chowdhury, M. J. M., Colman, A., Kabir, M. A., Han, J., & Sarda, P. (2018, August). Blockchain versus database: A critical analysis. In *2018 17th IEEE International conference on trust, security and privacy in computing and communications/12th IEEE international conference on big data science and engineering (TrustCom/BigDataSE)* (pp. 1348-1353). IEEE. Zhang, Y., Katz, J., & Papamanthou, C. (2015, October). IntegriDB: Verifiable SQL for outsourced databases. In Proceedings of the 22nd ACM SIGSAC Conference on Computer and Communications Security (pp. 1480-1491).

Immutability: BC provides a technology where transactions are not immutable nor reversable at any stage. As seen in **Error! Reference source not found.** this is forced and insured by the hash provided with the information available at each node as it features the hash of previous node, the existing node, timestamp, difficulty, the number of transactions as well as other transactions. This creates a secure environment, with reliable data, transparent relationships as well as trust between parties.

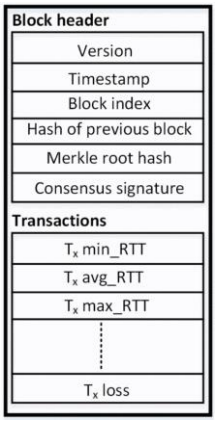

Figure 21. The block is split into two sections: block header and transaction

Auditability: is ensured due to the data being public as everyone can access to view it, transparent there is no restrictions to what data can be accessed by being authorized.

The analyses provided have validated and confirmed H1. As BC application has the capability of mitigating incentive-based prescription which is provided for doctors from pharmaceutical companies to increase the prescriptions of certain medication, or by making prescribers bias for branded medications. On the contrary H0 was not validated as there are no insights supporting it. Therefore, based on our research we support H1.

CHAPTER 5

CONCLUSION

The healthcare ecosystem has interoperated relationships between different layers of stakeholders, physicians, patients, medical suppliers, and many more who consistently interact simultaneously with each other resulting in many unethical dilemmas. This paper has drawn a conceptual framework of the influences affecting the decision-making journey of prescribing. It has also pinpointed the motive deriving each influence. Not to mention it also mentioned the pain points accompanied with each factor. From there we have drew the business solution that is being proposed by this paper, which is transformational version from the ongoing journey to limit the effect of unethical influences that are affecting the healthcare system in general and the patient in specific. This solution is not a digitalization solution. However, it works on digitalizing the mindset of the users of the technology. As they know all the transactions will be monitored, all prescriptions need to go through the application, and none of the transactions can be reversed, deleted, removed nor hidden.

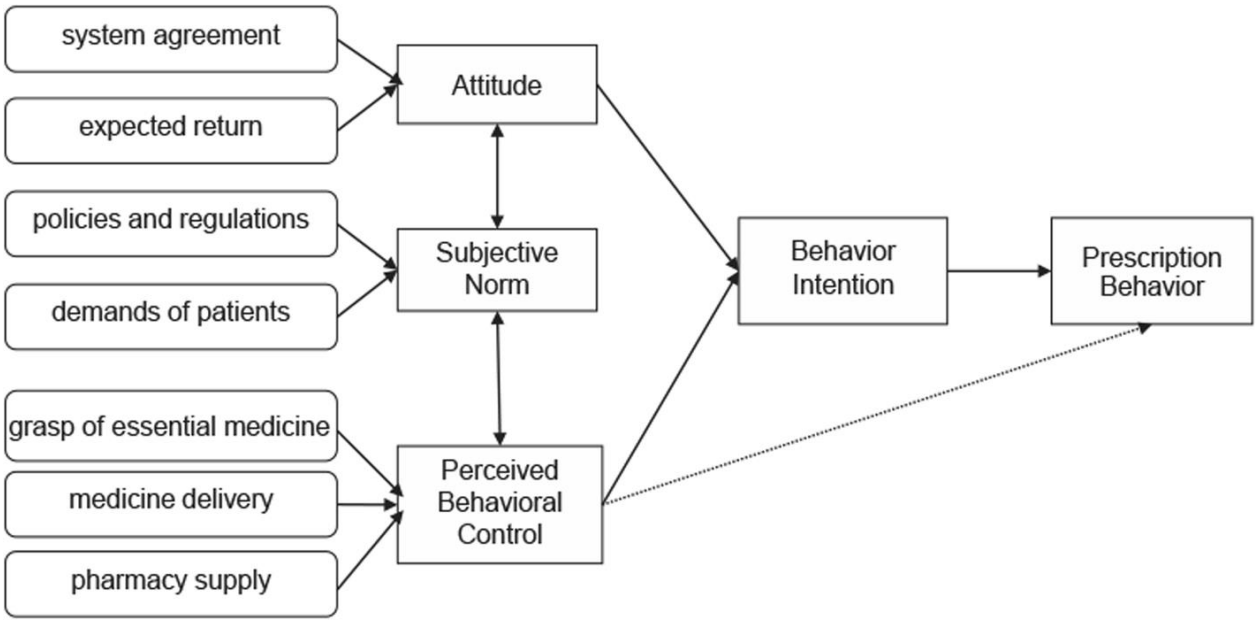

Figure 22. External factors influencing prescription behavior

Research model of the key factors influencing the priority usage of essential medication (Zhou et al., 2019)

These influences affect the healthcare industry in general by putting financial pressure on the insurance industry, government spendings, hospital resource allocation etc. And it directly impacts the pockets of patients, trust in the system, and delivery time of the solution as mentioned in the literature. These influences play a major role in deciding the kind of medication prescribed; whether it is branded or generic. Where branded medications are more expensive resulting in financial burden on the three parties mentioned before. First insurance companies who are covering the costs of patients. Second, governments who have insurance plans for locals. Third, it affects the time taken by patients in buying the medication as it may not be affordable. Surely the behaviors leading to the act of branded medication prescription vary and so do the effects, but in this paper, we decided to focus on this specific issue due to its complexity.

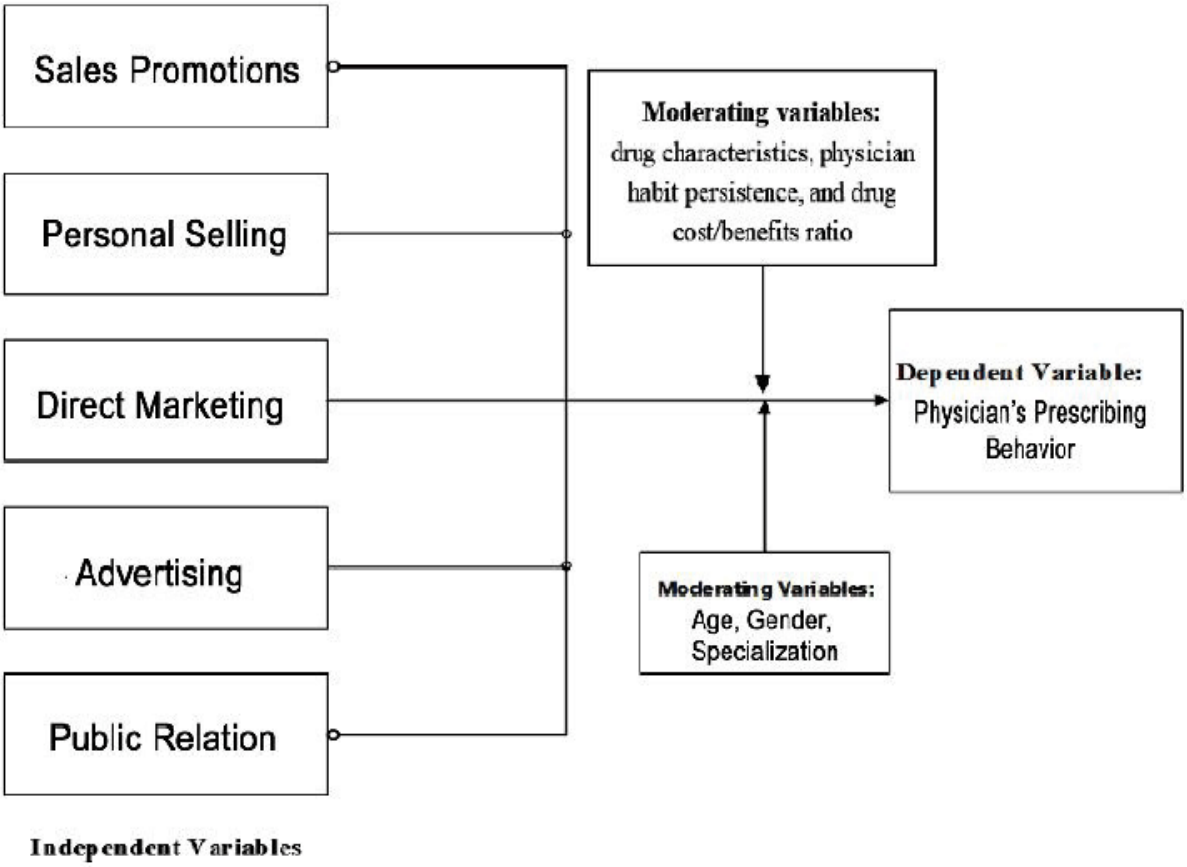

Figure 23. A conceptual model of physician's prescribing decision under the Influence of promotional tools. (Kani et al., 2018)

This solution will revolutionize the method followed in prescribing. As we have provided a robust framework that enhances the relationship between prescribers and receivers. It does not limit the physicians by regulations or restricting them to certain kinds of drugs. It allows doctors to prescribe the right medication to patients while providing substitution that is equally effective and functional.

There have been different technologies proposed and implemented to limit the act of overprescribing\ incentivized prescriptions. However, the previously provided programs have not achieved the needed reduction in these kinds of prescriptions (Rhodes et al., 2019). Here we are presenting a prescription system using smart contracts which provides a decentralized and fault-tolerant architecture. This will provide us with better

management of prescriptions, as well as limiting the doctors from only prescribing branded and expensive drugs, which have been proven in the literature that are leading patients to delay their treatment.

CHAPTER 7

RECOMMENDATIONS AND LIMITATION

We recommend this application to be fostered by the association of doctors, as it can be beneficial in different ways and on many levels. First it would provide reliable and creditable data about what prescriptions are being prescribed and for what reason. Second, traceable data that can not be edited, removed, or hidden. This will provide accountability, which can be beneficial for the problems mentioned as well as other problems in the medical field. Moreover, it enhances trust in the system as all the data can be accessed, and it is being monitored.

Nonetheless, it would be beneficial after implementation to integrate AI tools to enhance the detection of trends or even to predict crisis. As Machine Learning (ML) can be fed the data to provide real time analyses on what kinds of medication are being prescribed regularly, if any medication is being prescribed more often in an abnormal increase, if there is any pattern that looks suspicious. As well as many other implications that can be only done if reliable and accessible data is provided which is only possible to achieve at high standard by implementing BC.

BCT is relatively knew, this has imposed limitation in our study, as it is still emerging, the resources have been limited for example the applications of BC in the healthcare field have not been implemented yet. By that the systemic comparison provided is limited to the resources available at the time of study. Nonetheless, we were not able to run our application in real life to validate our input, and to give exact measurements of the difference BC is able to influence the field of healthcare in by limiting unethical behavior of basing their prescription on incentives.

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