DE-40 (DC&SE)

NUST COLLEGE OF

ELECTRICAL AND MECHANICAL ENGINEERING

PhamaB

A PROJECT REPORT

DE-40 (DC&SE)

Submitted by

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BACHELORS

IN

COMPUTER ENGINEERING

YEAR

2022

PROJECT SUPERVISOR

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COLLEGE OF

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PESHAWAR ROAD, RAWALPINDI

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DECLARATION

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We would like to thank our project supervisors Dr. Shoab Khan and Asst. Prof. Sajid Gul Khawaja for their wise counsel and guidance at every step of our project. Their help in both technical and managerial issues was of great value and without their support such an achievement was not possible.

We would like to acknowledge dedications and support of our technical advisor Sir Taha Firoz. His technical expertise has been of paramount importance in helping us achieve a full workable pharmaceutical supply chain management system.

At last, we are thankful to our parents as their patience, support and prayers have a big part in what we have achieved.

ABSTRACT

The scope and complexity of the 21st-century medication distribution chain has increased dramatically, while the digital technology and management systems required to simplify and protect the process have lagged. Pharmaceutical fraud, counterfeit medications, a lack of product registration, and supply chain visibility are only a few of the greatest difficulties faced by pharma supply management due to less secure technologies. Demand forecasting, data provenance, fraud protection, and transactional efficiency will all benefit from blockchain technology. The objective is to create a web application solution that uses blockchain technology to develop a supply chain management system that records all transactions that occur between any members of the supply chain. All of the information is stored in a smart contract's digital ledger. Medicine is gathered in a warehouse for future distribution once mass manufacture and packing has been completed. The blockchain stores information such as time, lot number, bar code, and expiration date. By entering the medicine information on the web application and viewing the entire supply chain procedure kept in blockchain, consumers can determine the validity of the medicine they're taking.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The pharmaceutical supply chain is the means through which prescription medicines are manufactured and delivered to patients. A well-functioning supply chain is essential to ensure that drug distribution is safe, reliable, traceable and that errors are minimized.

The scope and complexity of the 21st-century medication distribution chain has increased dramatically, while the digital technology and management systems required to simplify and protect the process have lagged. Because it involves the life-saving interests of humans, pharmaceutical supply chain management has become more complex, requiring the participation of various stakeholders such as pharmaceutical suppliers, manufacturers, wholesalers, distributors, customers, information service providers, and regulatory agencies. The pharmaceutical supply chain faces a number of challenges as a result of less secure systems, including drug counterfeiting as a result of manufacturers mixing no active pharmaceutical ingredients (API), an inferior-quality API, the wrong API, contamination from manufacturing multiple drugs in the same facility, production in substandard conditions or repackaged expired products, pharmaceutical fraud as a result of manufacturers mixing no active pharmaceutical ingredients (API), an inferior-quality API, the wrong API, contamination from manufacturing multiple drugs in the same facility, production in substandard conditions or repackaged expired products, pharmaceutical fraud which occurs when manufacturers provide false data or withhold negative data and a significant lack of supply chain visibility.

Visibility is the ability of the supply chain to see clearly from one end to another whilst sharing information that is key or useful to the stakeholders in the chain. Visibility in supply chain can play a key role in attaining sustainability as it will compel the stakeholders to minimize risk, work on working circumstances, and backing social causes, while at the same time working on friendly, moral, and execution of the chain.

This project proposes a blockchain technology-based solution to provide a single, universal system which is a public source of truth to be used as a reference to see a product’s journey throughout its life span. Blockchain could offer solid start to finish following and observing medications all through the inventory network. Blockchain can offer dependable start to finish following and observing of medications all through the inventory network. It can oversee stock as well as diminish falsifying and robbery issues which could prompt a medication supply framework that is safer, more effective, and more affordable to work in. Blockchain could offer solid start to finish tracking and observing medications all through the supply chain. It can oversee stock as well as

diminish forging and robbery issues which could prompt a medication supply system that is safer, more effective and more affordable to work in.

A web application arrangement executed utilizing blockchain will record every one of the exchanges that happen between any individual from the inventory network. Every one of the information kept in record inside a brilliant agreement. At the point when the huge scope producing close by the packaging of medicine is finished, drug is gathered in a stockroom for future spread. Information including time, bundle number, normalized ID, expiry date is associated with the blockchain. Clients can conclude the legitimacy of the medicine they're consuming by entering the prescription information on the web application and view all previous data sections, contact centers, regions, and timestamps to follow quite far back to track down the start of the thing, the producer and, shockingly, the specific cluster that it came from. This application would consequently allow things in the creation organization to be speedily followed and checked and could enable more straightforward identification and revision of issues. This hence would allow faster and more powerful disclosure and removal of phony, inadequate or lapsed things from dissemination.

The project's primary objective is to digitize the pharmaceutical supply chain management system and to develop a traceable, transparent, and immutable supply chain.

1.2 Motivation

With dispersed requesting settings of clinical supplies, drugs and basic assets, the issue of fake medicines has become progressively squeezing, both concerning the financial expense of this worldwide underground market and the endanger to human existence that comes from ingesting fake medications.

Fake drugs are currently viewed as the world's biggest fraud market. The medical care fraud analyticd market is projected to arrive at 4.6 billion US dollars by 2025 from 1.2 billion US dollars in 2020, at a build yearly development pace of 29.8%.

As per a concentrate by the World Health Organization (WHO), in excess of 100,000 individuals bite the dust because of ill-advised dosing from duplicated drugs requested from not known or confided in sellers. The Organization for Economic Co-activity and Development has found fake products represent 3.3 percent of the worldwide drug exchange. Specialists have assessed that the offer of fake medications is two times the lawful drug exchange rate, which is an extreme issue. Utilizing blockchain in the supply chain can lessen the gamble of deceitful medications penetrating the supply chain.

Despite thing and medicine copying, lacking thing library and blunders in bundling in a medical care office is another issue which can disturb the entire production network. Blockchain will be a

vital noticing development for exploiting the whole course of prescriptions and clinical things improvement. Since all trades are recorded onto the record, and every center point in the blockchain tracks the trade, it will end up being quite easy to check the start of the medicine, the dealer and the distributer right away.

With better comprehension into the inventory network through genuine and ideal affirmation cycle, pharmacies and clinical benefits providers will really need to ensure that the flow of legitimate prescriptions continues to show up at those patients who need it the most. In such way, blockchain development holds an uncommon responsibility for spreading out a trusted association of dealers that grants medical services chairman to watch patients from famous suppliers.

Past item trustworthiness and hostile to falsifying endeavors, blockchain could likewise assume a part in conquering the monetary difficulties looked by more modest administrators along the supply chain. This can be a specific issue in emerging nations; where medication supply chains are in many cases substantially more divided, with many organizations each taking a little portion of the market. In such settings, pharma retailers - which frequently need to stand by a few months to get installment for delivered medicines - experience issues getting to supporting without legitimate credit records and guarantee, which the transparency of blockchain could give.

1.3 Scope

The objective of this project is to permit items in the supply chain to be promptly followed and checked and empower simpler recognition and correction of issues. This would permit quicker and more effective identification and evacuation of fake, broken or terminated items from distribution.

The scope of the project can be defined in terms of the following objectives:

- To digitize the pharmaceutical supply chain management system.
- To develop a traceable, transparent, and immutable supply chain management system.

1.4 Structure

Following is the structure of the report ahead:

- Chapter 2, it mainly deals with the challenges faced by pharmaceutical supply chain in detail.
- Chapter 3, it deals with the innovative side of the project, exploring related solutions and explaining how the project is different from existing solutions
- Chapter 4, it deals with the design and development of the web application along with explaining the underlying theory of operation and system integration
- Chapter 5, it consists of concluding the report and exploring future possibilities and directions in which the project can be taken

CHAPTER 2

CHALLENGES FACED BY PHARMACEUTICAL SUPPLY CHAIN

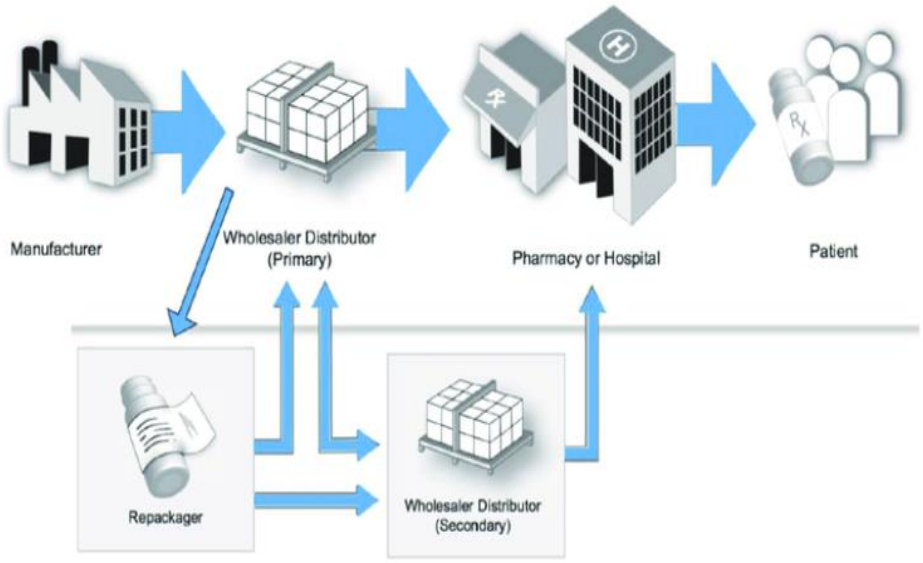


Figure 1Multiple steps in pharmaceutical supply chain image taken from ResearchGate

2.1 Overstocking and potential ripple effect:

Figure 1 shows the pharmaceutical supply chain and the process it includes all steps from primary to secondary. The major issue raised in this process is Overstocking. Overstocking, additionally called "surplus stock," happens when stores buy more item than they sell. Over-ordering stock leaves retailers with a lot of stock, and that abundance stock is left sitting on store racks or in warehouse, which can hurt benefit.

This problem has a name called “The bullwhip effect”, it is experienced due to inadequate sharing of information and results in overstocking upstream in response to initial shortages. When orders are sent to manufacturers and suppliers, they are greater as compared to the actual sales to the end customers, this underestimation or overestimation product demand negatively impacts the supply chain as a lot of product goes to waste or is expired. This results in material wastage along with the problem to discard these products.

Pharmaceutical is among the hardest-hit areas from this impact, because of the great shipment values included, perishability of the item, and frequently the earnestness in getting antibodies and different meds where they're required direly. Residual effects from the pandemic haven't lessened.

A portion of the causes are persistent, similar to infrastructure congestion or work deficiencies; infections and outrageous environment occasions will probably be repeating. Flexibility will depend on start to finish supply chain transparency and sharing of solid, real time information from a focal, believed source by production network accomplices.

2.2 Inability to easily identify the cause of disruption in supply chain:

COVID-19 pandemic highlighted one important issue when about 20% of total COVID vaccine was lost due to cold chain issues, this was reported by SDCExecutive.

Drugs and medicines need to store at precise temperature ranges in transit and storage, even the slight deviation from these ranges or shipment could be unusable because of moisture which can lead to losses of million and trillions of dollars.

Maintaining these conditions is hard as there's a lot that can go wrong in transit examples include the malfunction of refrigerated container containing the drugs, breakdown of the truck carrying the shipment, production delays and most of all human error in handling the goods. pharmaceutical industry loses $34 billion per year as per IQVIA due to supply chain temperature failures.

Recently a common practice among the pharmaceutical shippers have been to use active devices which analyze the situation and monitor it then send the data back from real time. This has been very helpful, but these active trackers come with their own set of issues e.g. they're quite expensive and their monitoring power is limited. As they have limited storage the data need to be stored in cloud but installing the entire setup to run cloud and modules that translate, and process data is another complicated task.

This issue is serious as the absence of real-time visibility slows response time to detect issues and go to remedial lengths. Absence of logical ability obstructs endeavors to get at underlying drivers of interruptions and drive upgrades.

2.3 Optimizing inventory levels:

Production of medicines is expensive they cannot be stored for long periods of time due to their perishable nature and loss of efficacy with time tracking down the right equilibrium to streamline stock in view of the item portfolio and on noteworthy interest and shipment designs is a continuing challenge for supply chains.

In order to cater this issue we have a developed an auto order system in our supply chain in which there's a reorder point for manufacturers and suppliers inventory. This reorder point is selected based on the previous data that we have collected; reorder point is recalculated for every order.

2.4 Quality Management:

Effective drugs guideline is a difficult errand in view of limited resources in the developing nations and the trouble to keep up with the right circumstances. In the drug business, quality principles are exceptionally rigid, as good manufacturers rehearses centers principally around the assembling of protected and quality items. Restricted accentuation on the enforcement of distribution of medicines might actually prompt expanded admittance to unsatisfactory and fake medications so it's important to have a system that keeps a check the quality of drugs that are produced. Fact based decision making is critical to maintaining the quality of the goods.

2.5 Digitization:

The digitization of documentation and normalization of the whole inventory network and barring the human mediation, advanced marks for administrative archives, smart contracts, blockchain, and mechanization. The primary test for drug businesses is the method for conveying changes safely, improving information security to assist with making the framework more productive and decrease the drug misrepresentation. Furthermore, how to follow transformation and rehash of store network apparatuses and procedures for ceaseless improvement inside the advanced world.

The supply we carried out in our project is totally digitized so every cycle runs all alone. This helps enormously in anticipation of human blunders and drug extortion.

2.6 Communications:

Successful connections and correspondence are vital to getting your workers, cycles, and innovation adjusted appropriately. Frameworks for correspondence ought to help continuous, useful discourse between authority, quality, workers, and outsider associations in the supply chain. Ongoing changes in administrative obligation have made it more basic than any other time in recent memory for drug associations to discuss really with individuals from the labor force and providers situated all over the planet.

Gaps in supply chain perceivability are addressed because of the transperency, which is given by blockchain, drug organizations deal with their supply chain and can relieve issues before they cause huge misfortune. By having perceivability across the supply chain, pharma organizations

can improve their stock levels, increment adaptability in light of transient interest variances, stay away from item overages/deficiencies and promptly impart the disparities.

2.7 Pharmaceutical fraud:

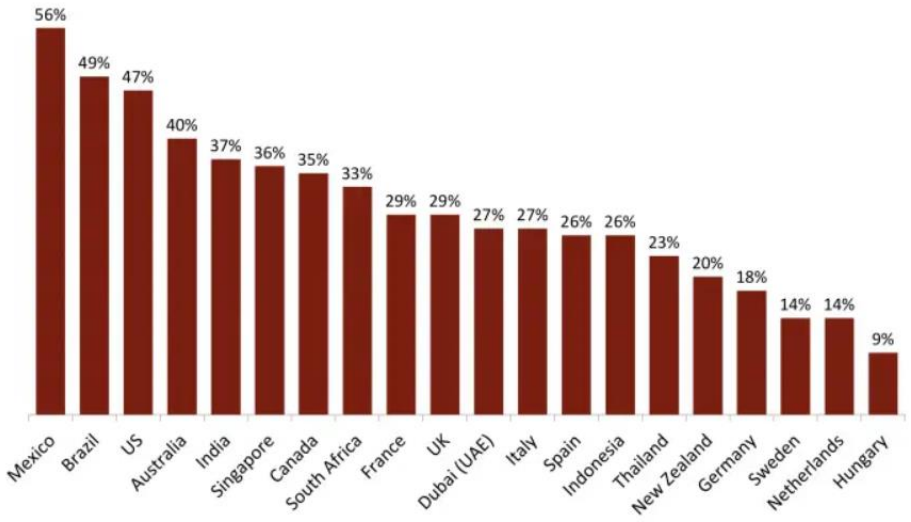


Figure 2 Percentage of pharmaceutical fraud experienced by consumers

Figure 2 shows the percentage of pharmaceutical fraud experienced by users in different countries. As per a Profit review, more than 40% of drugs provided in Pakistani business sectors are either fake or lapsed. Also, the nation has 4,000 drug ventures enrolled, yet in excess of 100,000 organizations make and sell drugs without authorization. Since the overseeing classes and government officials have no faith in the framework and know about Pakistan's low-class pharmaceutics, there is certainly not a solitary government common or military emergency clinic in the whole nation where they like to get treatment.

Thus, drug extortion keeps on being an enormous worry for the business, and as we saw during COVID-19, it has deteriorated. Wrongdoing during the pandemic, as per industry eyewitnesses, may result in higher-than-normal medical services extortion recuperations this year.

CHAPTER 3

RELATED PRODUCTS AND THERAPIES

3.1 Contribution of Blockchain in Supply Chain Management system

Blockchain might potentially drive cost-saving efficiencies and to further develop the customer experience through recognizability, transparency and tradability. The Global Brand Counterfeiting Report, 2018 evaluations that the hardships experienced due to web-based duplication all over the planet have amounted to 323 Billion USD in the year 2017. Counterfeit customer items address right around 188 billion bucks of lost pay with respect to expertly endorsed sedates alone. Blockchain engages an individual to make sure that a thing was gotten exactly and ethically.

Documentation producing and distortion are in like manner typical among acknowledgments, endorsements, and official distinctive confirmation. Blockchain records can transparently affirm licenses, official definitive reports, and bearing record-keeping immutably, which prevents manufacturing or coercion.

Production network detectability is one of the top use cases for blockchain advancement. Displacing the standard cycles with conveyed record advancement could expand anytime trade volume by 15% and U.S GDP by up to 5%. Blockchain gives the capacity to follow any undeniable level or authentic thing all through its lifecycle. Conveyed record advancement could maybe foster the sensible and moral creation and use of any thing on a general scale.

Basically every industry utilizes pariah makers or different things from various merchants prior to making and naming the last completed stock. Now and again, white imprint things are offered going before being repackaged and relabeled under another brand. Straightforwardness in process following gives makers a 10,000-foot perspective into their worth chain, permitting them to ensure the real handoff of untouchable item and result naming.

Blockchain can follow the development of assets, record the information, and show past asset records. Clever arrangements are used to maintain the asset following cycles on the Ethereum blockchain. Anyone can see the provenance and outing of an asset persistently, whether the asset is physical or modernized.

3.2 Major Advancements in Supply Chain Management developed on blockchain

Blockchain has made major impact on global supply chains and here below is listed few of the examples:

- Project Proton, a blockchain pilot carried out by PepsiCo, computerized components of the organization's automatic promotions inventory network through smart contracts. The undertaking utilized these agreements to accommodate promotion impressions from various information sources, working with installments through computerized tokens continuously and bringing about a 28 percent expansion in productivity
- Australian vehicle producer Tomcar utilizes Bitcoin to pay a portion of its providers and acknowledges the digital currency for installments from three clients in Israel and Taiwan. This interaction wipes out the requirement for global installment expenses
- In the food business, having strong records to follow items to their sources is becoming non-debatable. For instance, Walmart utilizes IBM's blockchain-based Food Trust to monitor their items along each progression of the chain. Nestlé, Tyson Foods, Carrefour, and Raw Seafoods, among others, likewise use Food Trust for this reason.
- Mining giant BHP is digitalizing its activities through blockchain, utilizing the innovation to check its providers and guaranteeing natural, social, and administration necessities are met along the production network. Last year, the organization finished its first blockchain iron metal exchange, worth around $14 million, with China Baowu Steel. The exchange was worked with by means of the MineHub stage
- South African paper organization Sappi and Indian texture maker Birla Cellulose collaborated to make GreenTrack, which tracks texture items from practical woods through to creation. The stage has been embraced by more than 250 supply chain accomplices, including Walmart and Marks and Spencer
- Walmart Canada utilized the DL Freight supply chain receipt and installment stage to mechanize exchanges and relevant pieces of information for in excess of 500,000 yearly shipments, following these through GPS and IoT-empowered gadgets. This brought about delivery disparities being diminished by 97%
- Jewel giant De Beers utilizes blockchain innovation to follow stones from where they're mined, straight up to when they're offered to clients. The innovation guarantees the organization maintains a strategic distance from 'conflict' or 'blood' precious stones and consoles their clients that they purchase the genuine article

3.3 Related Products of Pharmaceutical supply chain Management system on blockchain:

3.3.1 Infosys

Infosys Pharma Supply Chain Distributed Application is intended to give a seamless organization to manufacturers, suppliers, controllers, QA lab and logistics administrators on a common record to lay out provenance for specialty drugs at bundle level and diminish income spillage to drugs. Infosys Pharma Supply Chain Distributed Application gives a pre-designed blockchain fueled

network on further developing stock observing to improve quality control of medication, give information to more designated stock and review the executives and save lives. It plans to follow an unchanging record of pharma store network conditional information and facilitate the accreditation of unrefined substances and medications. The organization consolidates a look-into catalog got to through a blockchain with a permissioned informing network which empowers organizations to safely ask for and answer item ID confirmation demands. Just approved organizations can place their items in the registry.

3.3.2 Medi Ledger

There has likewise as of now been craving for using blockchain even more for the most part in the pharma supply chain. The Medi Ledger Network3 model was sent off in 2017. Medi Ledger's working, which involves medication creators and wholesalers, examines blockchain ability to meet the Drug Supply Chain Security Act requirements to trace and follow structure for US drugs by 2023. Medi Ledger counts a piece of the business' greatest medication associations as its people, and it has cultivated a blockchain-based system to follow specialist endorsed drugs across the stock organization to promptly deal with the improvement of phony prescriptions more. The middle limit of the Medi Ledger Network is to endorse the validity of medicine identifiers generally through the supply chain, which can be in every way made do with no prohibitive data being shared directly on the blockchain and without it genuinely leaving an association's control.

3.3.3 Novartis

Novartis, one of the world's biggest drug organizations, figured it could have an answer: blockchain, the innovation previously promoted by bitcoin, which allows gatherings to move esteem without the requirement for go between. As blockchain requires networks moving worth, Switzerland-based association wasn't all set at it alone.

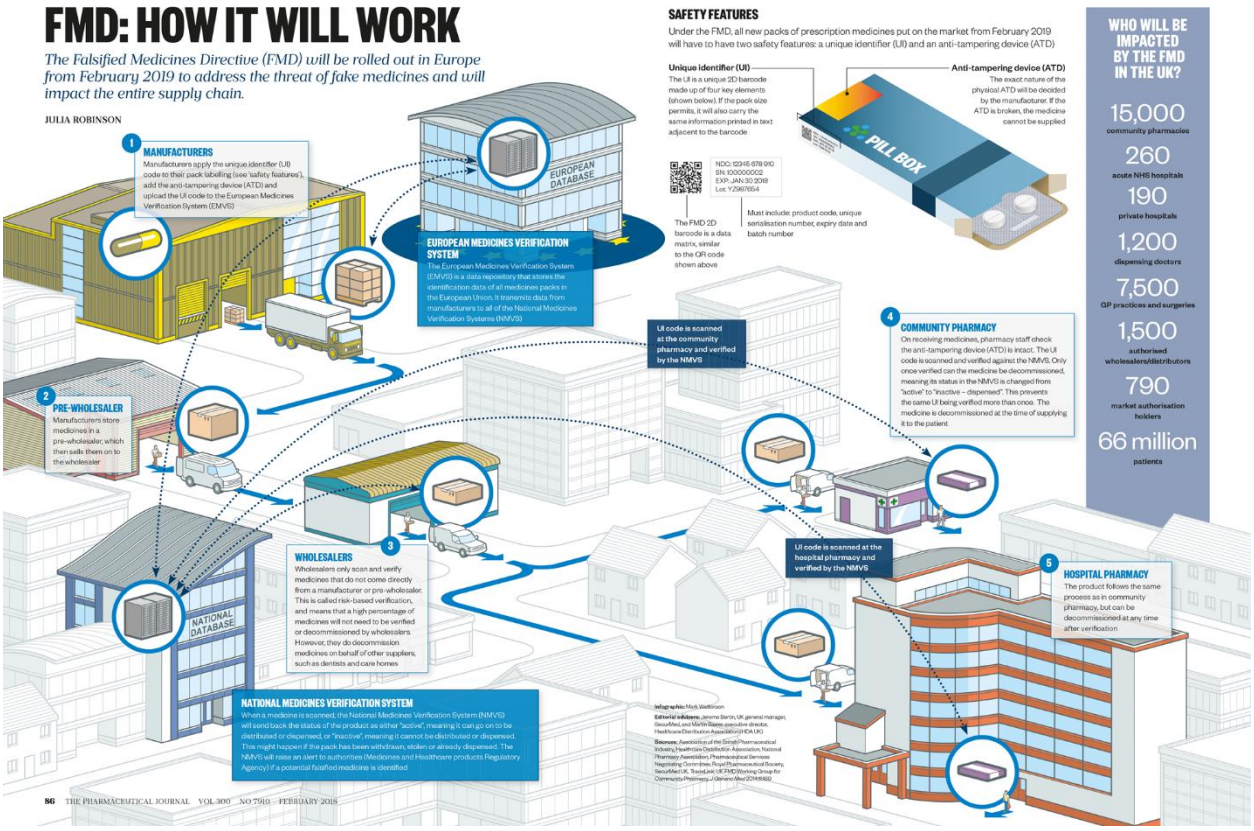


Figure 3 Novartis supply chain design

"Blockchain is a gathering action," says Daniel Fritz, an inventory network development designer at Novartis. His get-together dealt with a suggestion for a public-private relationship with the European Union, known as the Innovative Medicines Initiative, to investigate utilizing blockchain in clinical thought. The motivation driving the program, says Fritz, is to back projects that are "irrationally hazardous" or "excessively costly" for any one relationship to pursue detached.

The application for the Pharma Ledger project is to give patients electronic clinical flyers, which are varieties of the paper embeds genuinely expected by thriving specialists with colossal clinical data. It is hard to get fast changes to patients in view of the intricacy of the store organization, yet the supposition that is blockchain could ultimately give secure updates in near future.

3.3.4 TraceRx

It was developed by LeewayHertz , a platform of distributed ledger to provides traceability for delivering drugs and helps to solve the thefts, supports transparency for the shipment of the medicines. It allows third party traces for example it helps UNO to trace the distribution of free drugs its inefficiency and losses. Figure 4 shows the problems solved by TraceRx which is mainly recalling, theft and stock management in pharmaceutical supply chain management and the whole process of chain and how its handles from step 1 to step 5.

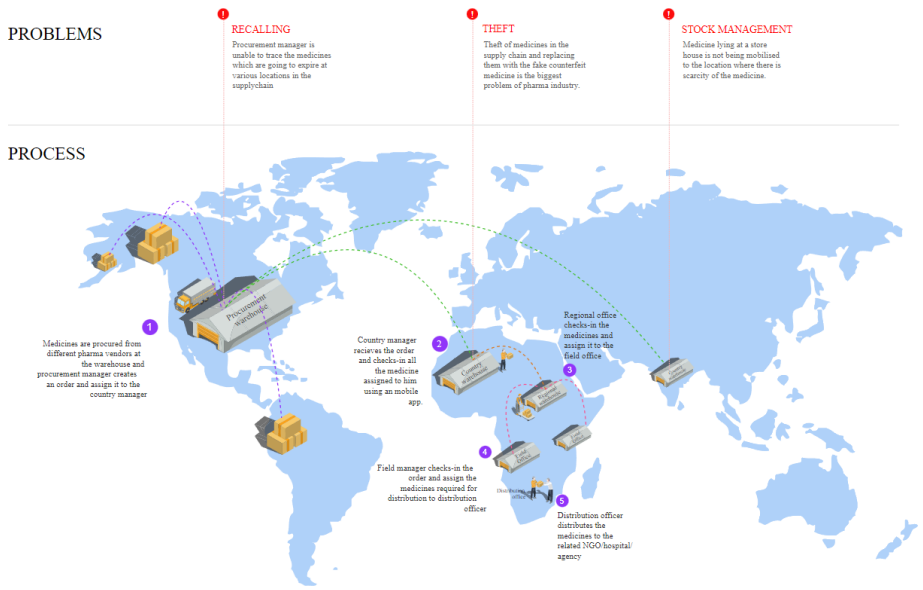


Figure 4 Problem and its provided Solution by TraceRx

3.3.5 SAP Pharma Blockchain POC App

Merck is the world's most seasoned working drug organization. It has cultivated the SAP Pharma Blockchain POC application in relationship with SAP.

SAP's ongoing game plan wasn't blockchain-based. It was called Advanced Track and Trace for Pharmaceuticals (ATTP).

A maker registers on the SAP Pharma Blockchain POC App resulting to dispatching a pile of medications as shown in Figure 5. It produces:

- Item number
- Serial Number
- Batch ID
- Expiration Date

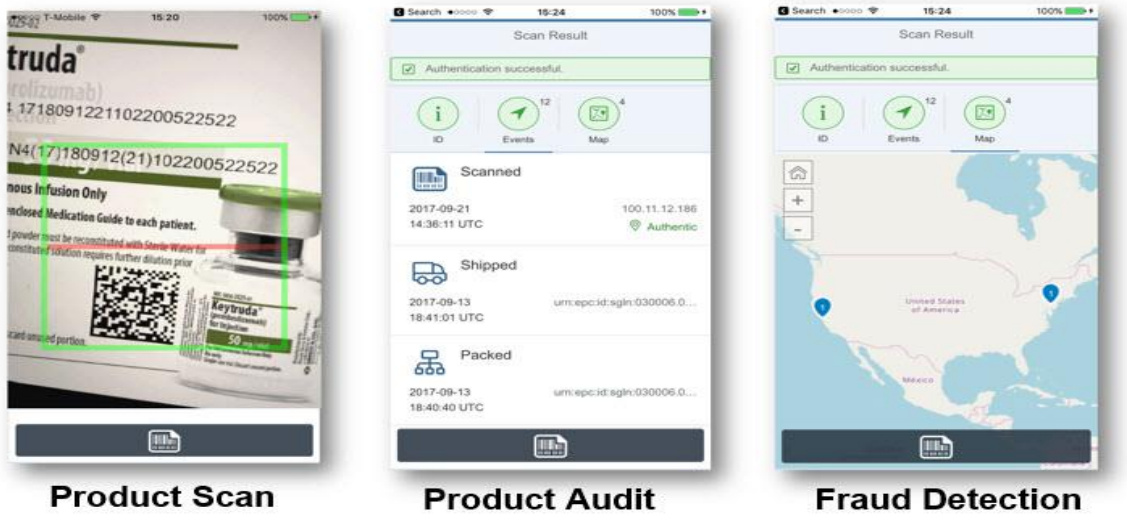


Figure 5 SAP Application Screenshots

The distributor can acquire this data from the bundle's standardized tag.

Fake scanner tags are stayed away from because of the following component. Likewise, the application permits the partners to guarantee that the conveyances are occurring with no peculiarities.

3.4 Potential of Pharmaceutical in Pakistan

In 2020, the worth of the drug area of Pakistan was assessed to be around USD 3.2 billion, copying from USD 1.64 billion of each 2011 Counting institutional game plans, industry places that this locale effectively transforms into a retail market worth USD 4 billion. Through and through things in 2019 remained at USD 218 million, from USD 44.4 million out of 2003. Anyway, trades from the area essentially addressed 0.9 percent of Pakistan's done things to the world in 2019, forgetting to look at Pakistan's consequences of different items in the success district like careful instruments and clinical hardware. Industry insiders guarantee that items from the area could appear at USD 0.5-1 billion in around 3 to 5 years — in the wake of showing up at this base sum, convey advancement could become wonderful.

This target depends on normal partner assumptions which consider delicate nature of item, high lead times to advertise, meeting progressively severe commodity prerequisites per item market, and current administrative shortcomings in the country. The progressions expected to accomplish this commodity target will put the business on the way to a lot higher portion of worldwide exchange the medium term. Essentially, because of ongoing development of public medical services in the fifth biggest worldwide market by size, the worth of drugs produced in Pakistan could ascend to USD 5 billion by 2024-25. Pakistan, with a local market of 215 million buyers and more than 700 medication associations is prepared well to procure from astounding entryways gave under these reworking overall instances of supply and request. In spite of being such a touchy and basic area that decides the wellbeing results of its whole populace, the area has never been upheld as a monetary undertaking. It has every so often been featured for misleading/fake medications or duplicate medicines, or inaccessibility of meds on the EDL, or lease looking for conduct, yet, seldom as a business undertaking. On this issue DR Ghazanfar issue a statement that to check counterfeit medicines drug testing labs are created [Figure 6] but this doesn't completely eliminates the risk of counterfeit medicines. Interestingly, focusing on the area has been the first fruitful strategy mediation of the relative multitude of driving drug areas of the world. When legislatures perceive the drug area as a driver of financial development and occupation creation, they strived to make an empowering financial climate. Making medicines that are authentic and provide transparency of the supply chain could help Pakistan to improve its production and export of medicine and revive the pharmaceutical industry of Pakistan making a bigger impact on the economy.

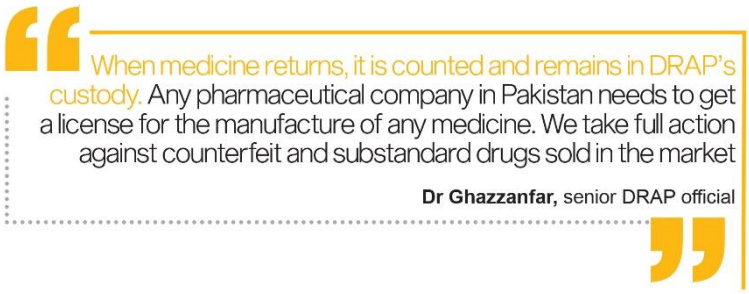


Figure 6 Dr Ghazzanfar A senior of Drug Regulatory Authority of Pakistan

3.5 Impact of Pharm-B and its Targeted Industry

As per an overview led by Profit, in overabundance of 40% of drugs sold in Pakistani business areas are unsuitable. Additionally, 4,000 medication associations are enrolled in the country, while more than 100,000 associations are making and selling drugs without anyone asking. There is unquestionably not a single government normal or military clinical facility in the whole country where the choice classes or government employees like to look for their treatment. Bad quality medications and clinical stock lacks were recognized as critical challenges in appropriating and getting to key meds during the supportive crisis following the 2005 shake, floods (2010), and inside removed people (2011). In Pakistan, the issue has obtained public as well as overall thought after two huge paces of bad quality prescriptions killed many individuals in 2011 and 2012.In Pakistan, medication permitting, producing, enlistment, estimating, imports, and commodities are managed

by the national government, while conveyance and deals are controlled by the particular common place legislatures. Worldwide specialists think about this decentralized administrative control as a primary shortcoming of the framework. Our Solution provide a solution of digitizing pharmaceutical supply chain in Pakistan without compromising the authenticity of medicines.

CHAPTER 4

THE DESIGN, DEVELOPMENT OF THE WEB APPLICATION AND UNDERLYING THEORY OF OPERATION AND SYSTEM INTEGRATION

4.1 Use Cases

1. Login
2. Sign Up
3. Check inventory
4. Search Items
5. Place order
6. Confirm order
7. Cancel Order
8. Ship order
9. Choose desired Supplier
10. Feedback

4.1.1 Use - Case Diagram

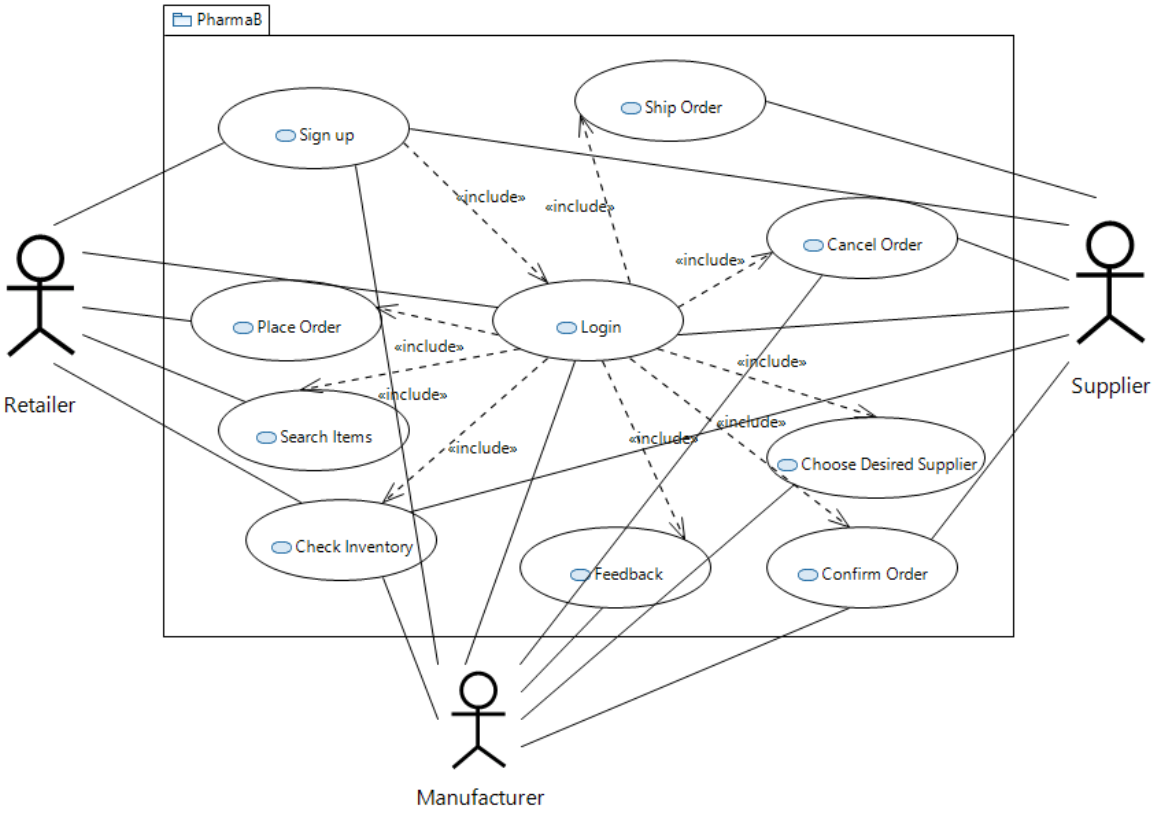


Figure 7 Uses Cases as stated in 4.1

4.1.2 Use – Case Description

4.1 2.1 Use Case: Login

Goal in Context: Actor requests to login to his/her account.

Scope: PharmaB application

Preconditions: Actor must be a registered user.

Failed End Condition: Login failed.

Primary Actor: Supplier, Manufacturer, Retailer

Trigger: This use case starts when the actor requests to Login to the system.

Main Success Scenario

1. Actor requests to Login to the system.
2. The system requests that the actor enter his/her name and password

3. The actor enters his/her name and password.
4. The system validates the entered name and password and logs the actor into the system

Extensions

4a. the actor enters an invalid name and/or password.

Special Requirements

None

4.1.2.2 Use Case: Sign up

Goal in Context: Actor wants to register himself on system.

Scope: PharmaB application

Preconditions: None

Success End Condition: The account is created successfully, and the actor is now a registered user of the system.

Failed End Condition: Account creation was unsuccessful.

Primary Actor: Supplier, Manufacturer, Retailer

Trigger: This use case starts when the actor requests to register himself on system.

Main Success Scenario

1. Actor requests to register himself on the system.
2. The system requests that the actor enter his/her details.
3. The actor enters his/her details.
4. The system creates the actor's account and saves his/her information.

Extensions

3a. The actor enters an email id which is already associated with an account the actor is said to log in to the system or use a different email id.

Special Requirements

None

4.1.2.3 Use Case: Search Item

Goal in Context: Actor wants to detail of specific medicine.

Scope: PharmaB application

Preconditions: Actor should be logged in to the system.

Success End Condition: Medicine name entered by actor is found

Failed End Condition: Medicine with the name entered by actor is not found

Primary Actor: Manufacturer, Retailer

Trigger: This use case starts when the actor searches for specific medicine.

Main Success Scenario

1. The actor browses the system for medicine he wants.
2. The system requests the actor to enter the name of medicine.
3. The actor enters the name.
4. The system searches for medicine matching the entered name.
5. The system displays the detail of medicine.

Extensions

4a. If no medicine with that name is found, “no items found” message will be displayed.

Special Requirements

None

4.1.2.4 Use Case: Place Order

Goal in Context: Actor wants to buy item.

Scope: PharmaB application

Preconditions: Actor must be logged in to the system.

Success End Condition: Order is successfully placed.

Failed End Condition: Actor us unable to place the order

Primary Actor: Manufacturer, Retailer

Trigger: This use case starts when the actor requests to order item.

Main Success Scenario

1. The system requests the user to enter the item name and quantity he wants.
2. The user enters the name of the item and amount.
3. The system checks for the availability of the item.
4. If the item is available, then the order is successfully placed.

Extensions

3a. The item name entered by the actor is not available or out of stock

Special Requirements

None

4.1.2.5 Use Case: Confirm Order

Goal in Context: Actor has received request for some item.

Scope: PharmaB application

Preconditions: Actor must be logged in to the system.

Success End Condition: Order is confirmed.

Failed End Condition: Order is cancelled.

Primary Actor: Supplier**,** Manufacturer

Trigger: This use case starts when the actor has received request for some item.

Main Success Scenario

1. The actor requests the system to show orders he has received.
2. The actor checks for the availability of the requested items.
3. If the ordered amount is less than available stock, he confirms the order

Extensions

3a. The ordered amount is greater than available stock, he cancels the order or messages user about delay in his order.

Special Requirements

None

4.1.2.6 Use Case: Cancel Order

Goal in Context: Actor has received request for some item.

Scope: PharmaB application

Preconditions: Actor must be logged in to the system.

Success End Condition: Order is Cancelled.

Failed End Condition: None

Primary Actor: Supplier**,** Manufacturer

Trigger: This use case starts when the actor has received request for some item.

Main Success Scenario

1. The actor requests the system to show orders he has received.
2. The actor checks for the availability of the requested items.
3. If the ordered amount is greater than available stock, he cancels the order

Extensions

None

Special Requirements

None

4.1.2.7 Use Case: Ships Order

Goal in Context: Order is ready to be shipped.

Scope: PharmaB application

Preconditions: Actor must be a registered user and must be logged in to the system.

Success End Condition: Order is shipped.

Failed End Condition: Oder is delayed.

Primary Actor: Supplier**,** Manufacturer

Trigger: This use case starts when the order received by actor is ready.

Main Success Scenario

1. The actor checks for the availability of the requested items.
2. If the item in available, item is packaged and shipped.

Extensions

2a. Item is not available right now delayed message is send

Special Requirements

None

4.1.2.8 Use Case: Choose desired supplier

Goal in Context: Manufacturer wants to order raw material.

Scope: PharmaB application

Preconditions: Actor must be a registered and logged in to the system

Success End Condition: Order is sent to desired supplier.

Failed End Condition: Desired supplier is not available.

Primary Actor: Manufacturer

Trigger: This use case starts when the manufacturer wants to order raw material

Main Success Scenario

1. Manufacturer wants to order raw material.
2. System shows a list of suppliers along with their rating and availability.
3. Manufacturer can select the desired suppliers and place order

Extensions

3a. Desired supplier is not available

Special Requirements

None

4.1.2.9 Use Case: Feedback

Goal in Context: Manufacturer rates the suppliers based on quality of raw material

Scope: PharmaB application

Preconditions: Actor must be logged in to the system

Success End Condition: Supplier rating is updated.

Failed End Condition: None

Primary Actor: Manufacturer

Trigger: This use case starts when the manufacturer receives the requested raw material.

Main Success Scenario

1. Manufacturer receives the requested raw material.
2. QA team checks the quality of raw material.
3. System requests manufacturer to rate the supplier.
4. Manufacturer gives rating and supplier rating is updated.

Extensions

None

Special Requirements

None

4.1.3 Functionalities

a) Supplier
- Checks inventory
- Receive order from manufacturer
- Confirms the order
- Cancels the order
- Ships the order

b) Manufacturer
- Checks inventory
- Search raw material
- Receive order from Retailer
- Confirms the order
- Cancels the order
- Ships the order
- Order raw material from suppliers
- Rate suppliers

c) Retailer
- Checks inventory
- Order medicines from Manufacturer
- Search medicines

4.2 Supply chain design:

Our supply chain has 3 main participants namely, manufacturer, retailer, and supplier

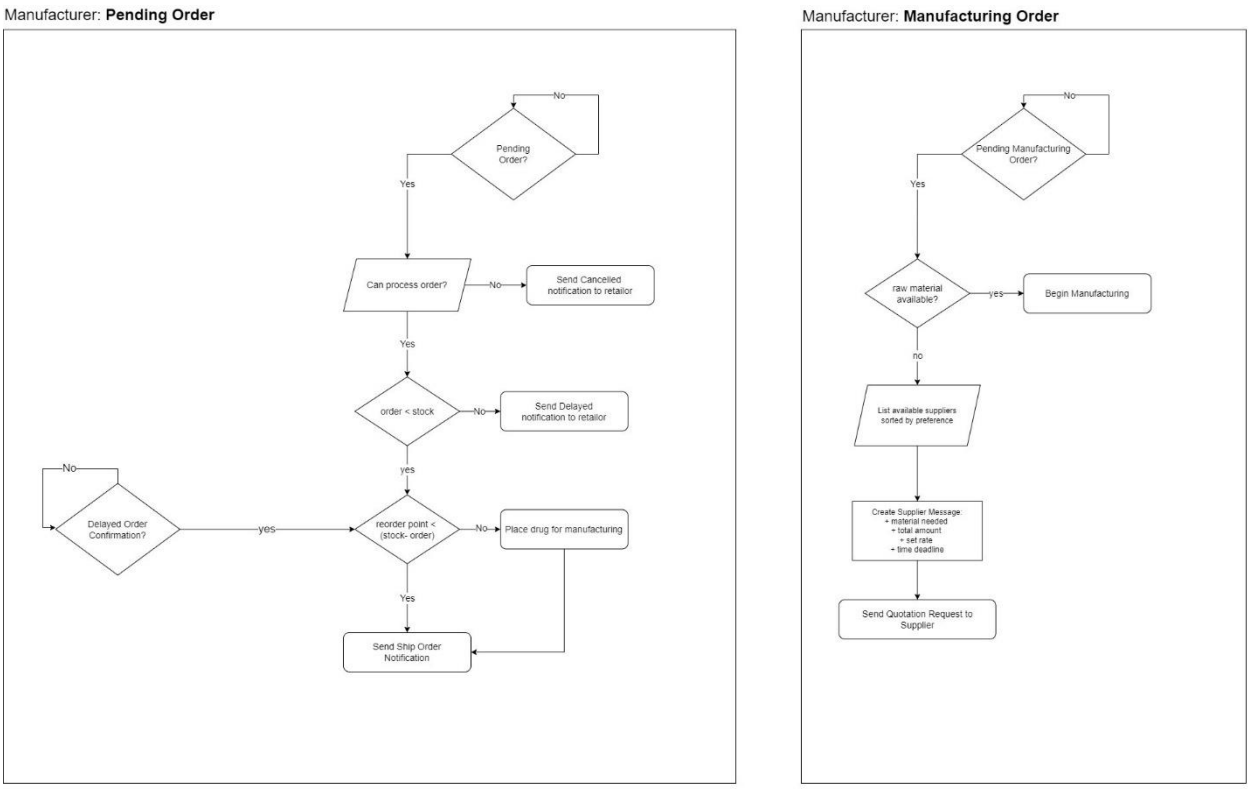


Figure 8 Manufacturers flow of work

In the Figure 8 above we see that manufacturer keeps checking for any pending orders in a continuous loop, once it gets the order, manufacturer has the option to manually cancel the order or to proceed with it, if it chooses the latter option then it checks if its stock point is still above the reorder stock point if yes then the medicine is manufactured and sent to the supplier.

In case the stock point is below the reorder stock point or equal to it, then manufacturer sends a delay notification to retailer if retailer accepts the delay, then manufacturer makes an order to the supplier, supplier is chosen from the priority list of suppliers, this priority list is based on the time it takes for a supplier to deliver raw material, quality of raw material it delivers and response time. Block containing raw material names their amount and delivery deadline is stored in blockchain.

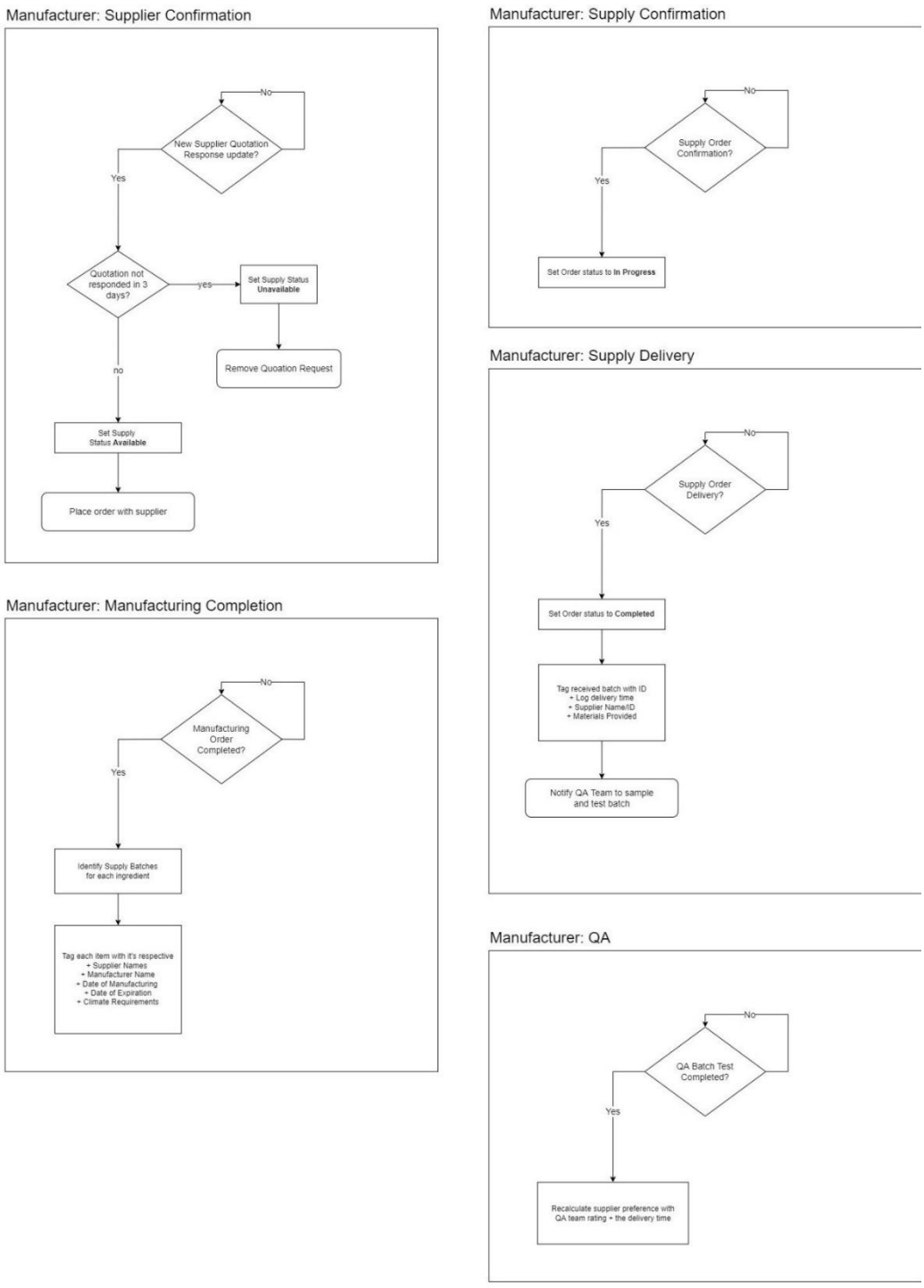


Figure 9 Manufacturer work flow

Incase the supplier does not respond to manufacturer within 3 days, manufacturer cancels the order with that supplier and contacts the supplier next on the priority list.

After the order is delivered by the supplier to manufacturer, it sends the entire batch to Q/A team which ensures the quality and timely delivery of products and update the rating of that supplier in priority list.

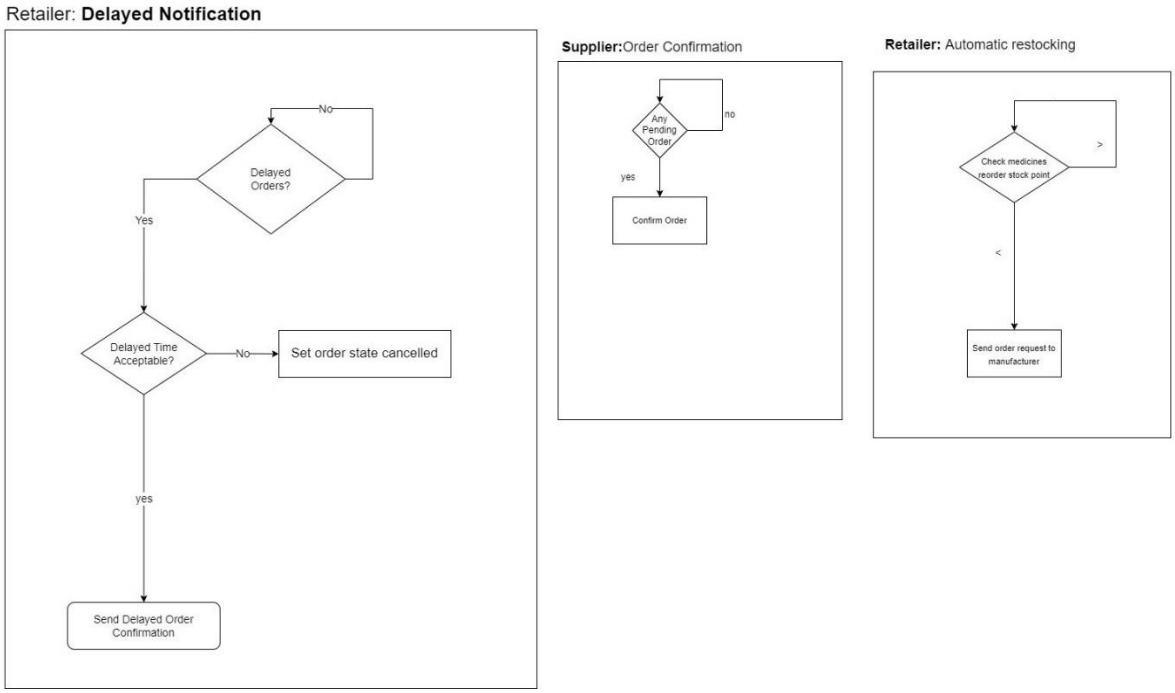


Figure 10 Retailer work flow

Here we can see that retailor keeps checking its stock, if its less than the reorder point then it makes an order to the manufacturer, this order can be made manually or automatically. Once the order is made, manufacturer can either accept the order, cancel it or send a delay notification in case of delay, retailer has to confirm if it wants to keep the order or cancel it. Once order to manufacturer is confirmed, information related to order is stored in a block which is then stored In blockchain.

4.3 Work Flow Diagram

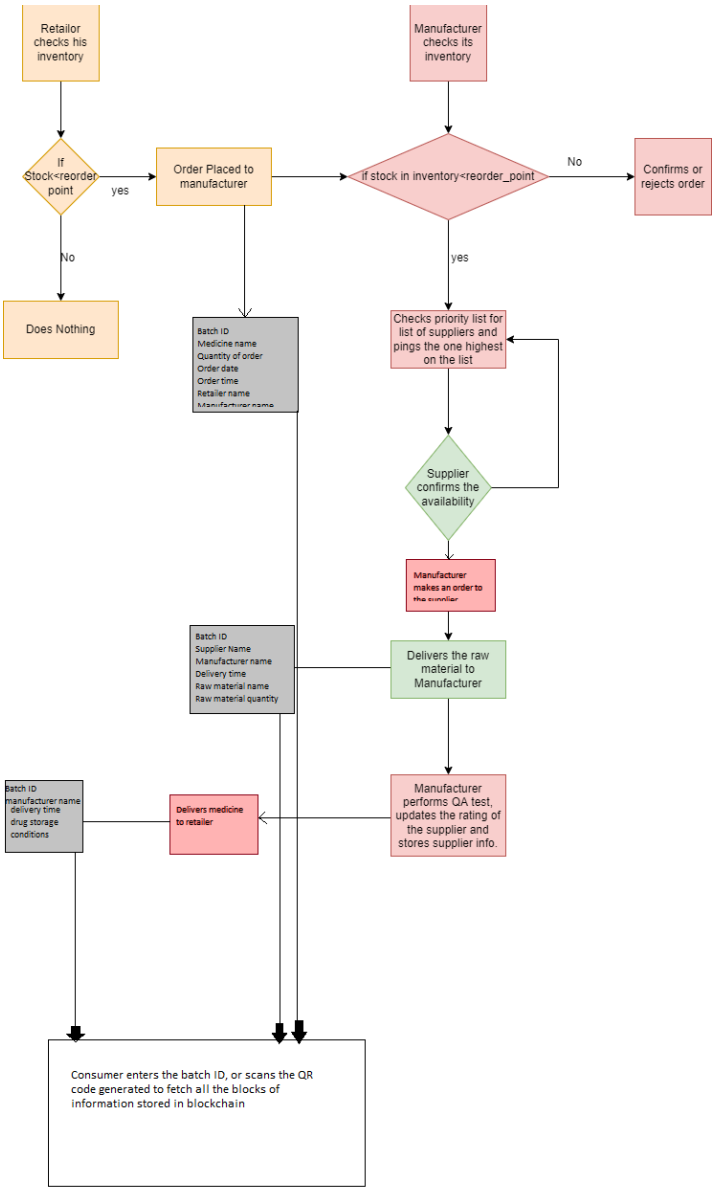


Figure 11 Workflow diagram of PharmaB

Figure 11 shows the flow of work of this project. It is explained in more detail in section 4.2.

4.4 E-R Diagram:

Figure 12 Shows the E-R diagram of the database required to store related data used in the web application for retailer, manufacturer and supplier. It contains all the information about the orders made by the participants in supply chain.

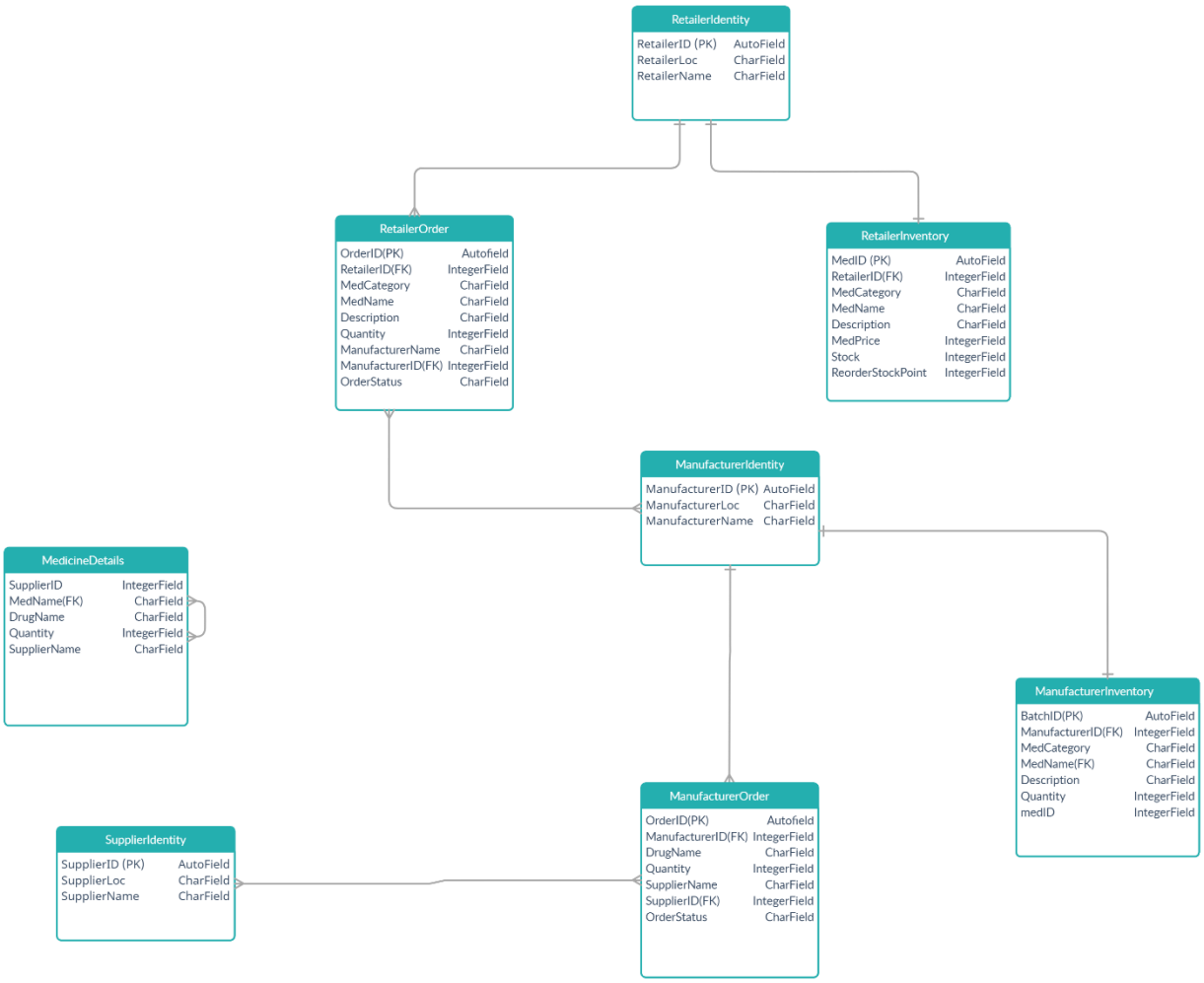


Figure 12 Database Model of entire website application

4.5 Backend Design Flow

The supply chain starts when the retailer places an order to the manufacturer. The application allows the retailer to place a manual order by entering the name of the medicine and order quantity. The application also provides the functionality of automatically placing an order whenever the stock of any medicine falls below the reorder stock point. Whenever the retailer sells a medicine, the system checks if the stock of the sold medicine is below the stock reorder point and if the stock is lower than the reorder stock point, an order with a predetermined order quantity is placed for that medicine.

To send and receive order messages, we have come up with a pub sub model. It works as a communication medium between all the roles of the supply chain. In this model, the senders of messages, called publishers publish their order messages on their respective channels. All the

receivers, also called subscribers, who are subscribed to the channel are able to listen to these messages on their servers.

The blockchain starts when an order is published on the retailer's channel. A successful transaction results in the formulation of a block in the chain and all the order information including medicine category, medicine name and order ID is saved on the blockchain using a smart contract.

The manufacturer also has the option to either place an order for raw material manually by entering the name of the required raw material and order quantity or an automatic order will be placed for the respective raw material whenever a new order message is received for a medicine and the stock is not sufficient to fulfill the order. Whenever a new order message is received, the system checks if the stock already present in the inventory is enough to complete the order, if enough stock is present then the manufacturer publishes an order confirmation message on its channel which is received by the retailer on its server. When the order is dispatched, a new block is created on the block chain. This block contains information like batch ID, expiry date of medicine, manufacture date of medicine and its storing conditions and its manufacturer's name. On the other hand, if the stock present in the inventory is not enough to complete the order, an order delay message is published on the manufacturer channel for the subscribed retailer. At the same time, an automatic order is generated for the required raw material for the manufacturing of the medicine whose order has been delayed. This order message is also published on the manufacturer's channel and it is received by the suppliers who are subscribed to the manufacturer's channel.

When this new order is placed, another block is created on the blockchain with information including order ID and the raw material ordered. Supplier receives this order on its server and confirms or delays the order. In both cases, a message is published on its channel which is received by the subscribed manufacturer. When the order for raw materials is dispatched, another block is created on the block chain containing the supplier information.

Whenever a new medicine is manufactured, a QR code is generated which includes all the information related to the medicine. In addition to the QR code generation, a new block is also created on the block chain and it includes information like batch id, expiry date of medicine, manufacture date of medicine and its storing conditions and its manufacturer's name. When the manufacturer is done manufacturing the medicine, it publishes an order confirmation message for the retailer on its channel. With the dispatch of the order to the retailer, the supply chain ends. All the information exchanged between the involved parties is stored on the block chain.

The application allows the consumers of the medicine to directly access the information stored on the chain by entering the batch ID of the medicine or one can also scan the QR code on the medicine to get the desired information.

4.6 Project Testing

We used Selenium which is an open source tool for functional testing across the modern web browsers, to test our project. We created multiple test cases most of them successful. Screenshots of these test cases are attached below.

Sign up test case:

Running 'Sign Up'

1. open on http://127.0.0.1:6379/ OK
2. setWindowSize on 1382x744 OK
3. click on linkText=Sign Up OK
4. click on id=name OK
5. click on id=name OK
6. type on id=name with value Dwatson OK
7. click on id=email OK
8. type on id=email with value dwatsonf10@pharmab.com OK
9. click on id=password OK
10. type on id=password with value rty OK
11. click on id=confirm OK
12. type on id=confirm with value rty OK
13. click on css=html OK
14. click on css=li:nth-child(3) > label OK

Figure 13 Testing the sign up process

Login test case:

Running 'Login'

1. open on http://127.0.0.1:6379/login OK
2. setWindowSize on 1382x744 OK
3. click on name=email OK
4. type on name=email with value dwatsonf10@pharmab.com OK
5. click on name=password OK
6. type on name=password with value rty OK
7. click on css=.btn OK

'Login' completed successfully

Figure 14 Testing the Log In system

Medicine history test case:

Running 'medicine history'

1. open on http://127.0.0.1:6379/ OK
2. setWindowSize on 1382x744 OK
3. click on linkText=MEDICINE HISTORY OK
4. click on id=order OK
5. type on id=order with value 548554 OK
6. click on css=.btn OK

'medicine history' completed successfully

Figure 15 Running the test case for medicine history

Order test case:

Running 'order'

1. open on http://127.0.0.1:6379/ OK
2. setWindowSize on 1382x744 OK
3. click on css=.fa-right-to-bracket OK
4. click on name=email OK
5. type on name=email with value retailer@gmail.com OK
6. click on name=password OK
7. type on name=password with value jkl OK
8. click on css=.btn OK
9. click on linkText=Inventory OK
10. click on linkText=Sell Medicine OK
11. click on id=name OK
12. type on id=name with value Panadol OK
13. click on id=quantity OK
14. type on id=quantity with value 500 OK
15. click on css=.btn OK
16. click on linkText=Order History OK

'order' completed successfully

Figure 16 Executing the test case for automatic ordering of medicine

4.7 Software Tools Used

The software tools used were primarily for developing the Web application and integrating the entire system.

Visual Studio Code

Visual Studio Code is a graphical programming environment. Microsoft's Visual Studio Code is a text editor and development tool for a variety of operating systems. It has a lot of features and can be set up to create a development environment for many kinds of apps and coding. It has debugging features, as well as Git compatibility, syntax highlighting, and Intellisense

SQLite

SQLite written in C programming is a database engine. Instead of being a standalone SQLite is a library that software developers embed in their apps. This is why it belongs to the embedded databases family. It is used with smaller programs.

Python

Python is a high-level, general-purpose programming language. Its plan rationale emphasises code readability while also emphasising the need of indentation. Python is a strong language, and we used it to construct the backend architecture for our project.

Flask

Flask is a Python-based microweb framework. It has been designated as a microframework since it does not need any particular devices or libraries. It lacks a database reflection layer, structure approval, and other features that prior outsider libraries provide. We used it to connect the backend to the database.

Solidity

Solidity is an object-oriented programming language used to create smart contracts on several blockchain platforms, the most popular of which being Ethereum. Christian Reitwiessner, Alex Beregszaszi, and a few prior Ethereum centre sponsors came up with the idea. It was used to create our smart contracts.

MetaMask

MetaMask is a digital money wallet that works in conjunction with the Ethereum network. It allows users to access their Ethereum wallet through a browser extension or mobile app, which can subsequently be used to interact with decentralised apps.

Ganache

Ganache is a tool that allows you to quickly create your own Ethereum blockchain, which you can use to perform tests, issue commands, and inspect the chain's status while maintaining control over it. It was used in our framework to operate the local Ethereum.

Selenium IDE

Selenium IDE is an open-source record and test robotization for the record that keeps track of different finders for each component it connects to. If one of the finders fails during playback, the others will be tried until one succeeds.

HTML

HyperText Markup Language is the standard markup language for texts that are intended to be viewed on a web browser. It may benefit from technologies like CSS and programming languages like JavaScript. It was utilised to build our frontend.

CSS

Cascading Style Sheets is a language for specifying the appearance of a document written in a markup language like HTML. Along with HTML and JavaScript, CSS is a key component of the World Wide Web. It was used to style the frontend of our website.

CHAPTER 5

CONCLUSION AND FUTURE PROSPECTS

5.1 Conclusion

Project developed a fully automated blockchain based pharmaceutical supply chain system that caters three participants of supply chain namely, Retailer, Manufacturer and Supplier. A fully responsive Web Application has been developed that has user friendly GUI to assist the participants of supply chain. A separate interface is made for the consumers of medicine where they can authenticate the medicine by scanning the bar code present on the medicine box. This barcode is generated from the batch ID against which the information related to that medicine is stored in three blocks of blockchain. Scanning the barcode which fetch information from these 3 blocks and display it to the customer. So the objectives of the project set at the start have thus been met and are stated below:

- Digitizing the pharmaceutical supply chain.
- Developing a traceable, transparent, and immutable supply chain management system.

5.2 Future Prospects

This project has many great prospects in the future. There are many new improvements and innovations that can be made to make this project even better, we were able to add all the features in our system that we originally planned but these are some additional features that we recommend. We hope that these recommendations will be taken with a positive outlook and will be worked on with great zeal.

We built our system on a public blockchain as it was more feasible for us, we had better resources available for this type of blockchain, but this project will be better deployed using a private blockchain e.g. Hyperledger fabric as shown in Figure 17.

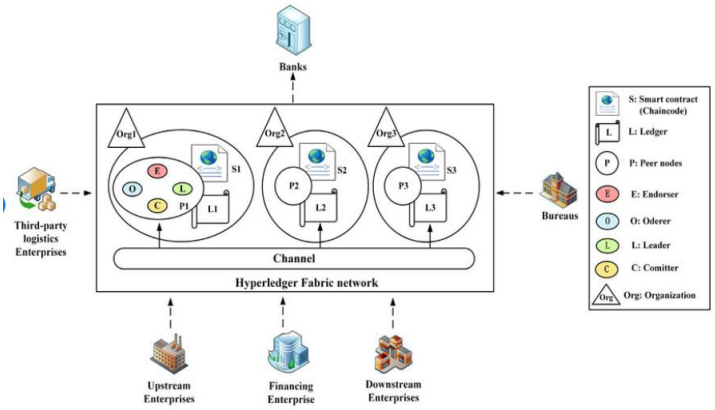


Figure 17Using Hyperledger Fabric in a supply chain

Another possible improvement that can be made is building this system in collaboration with a pharmaceutical supply chain and making this a real product.

Further improvement that can be made is making a proper cold chain sensor system. As drug drugs travel through the production network and require trust among all gatherings required, Due to the decentralized property of blockchain, it constructs trust in the computerized environment. The proposed system would utilize sensors and QR code scanner that empower checksum of all temperature observing sensor information and parcels QR code data as displayed in Figure 18. Assuming sensor temperature goes past the limit or on the other hand if QR code information are changed on the parcels, the framework won't acknowledge the bundles any longer.

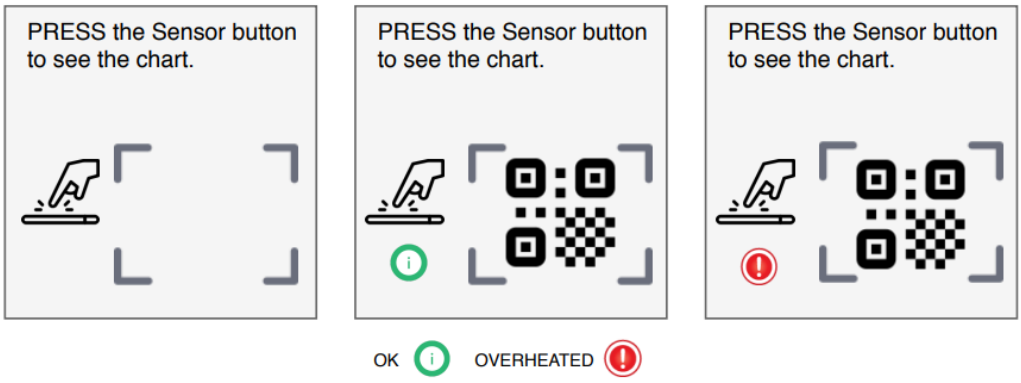


Figure 18Temperature sensor tracker

APPENDEX A

APPLICATION INTERFACE

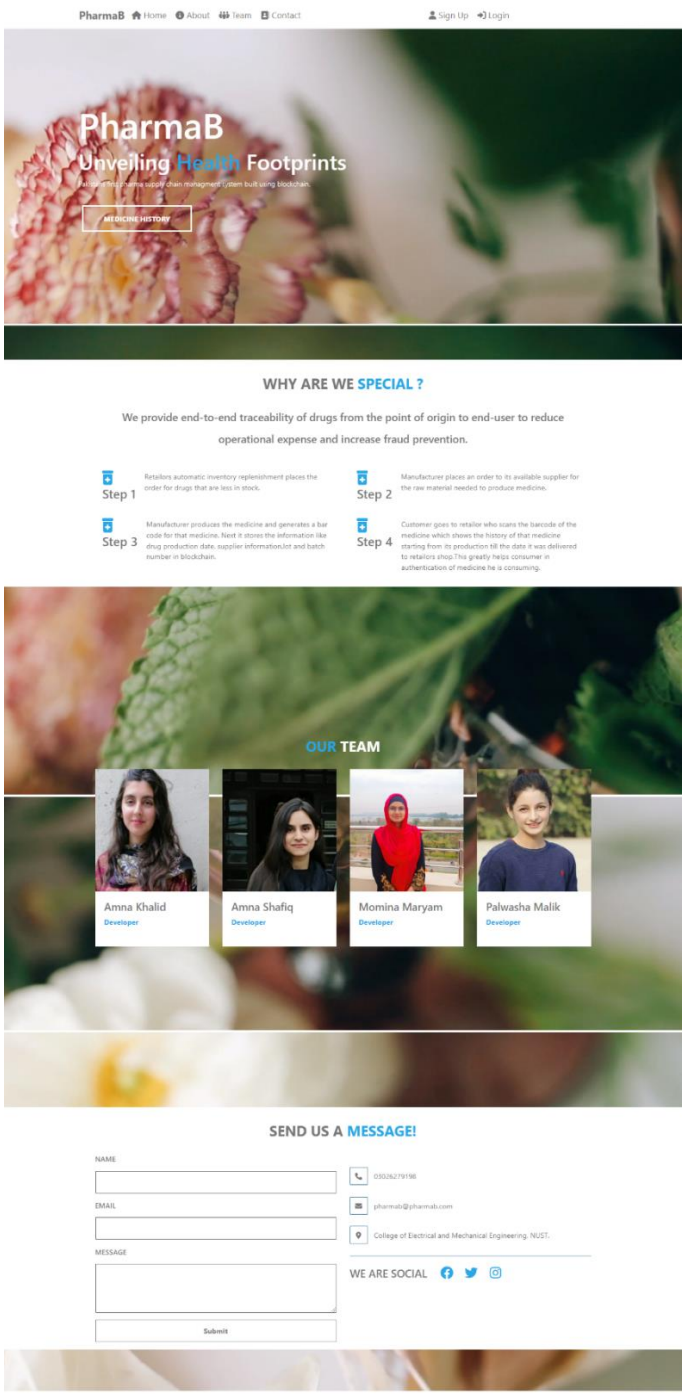


Figure 19 Desktop View

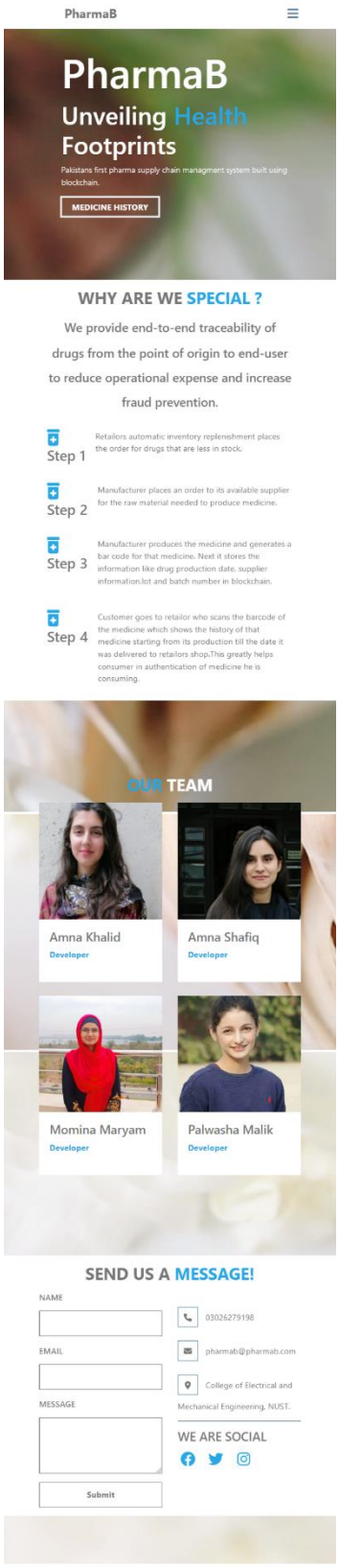


Figure 20 Mobile View

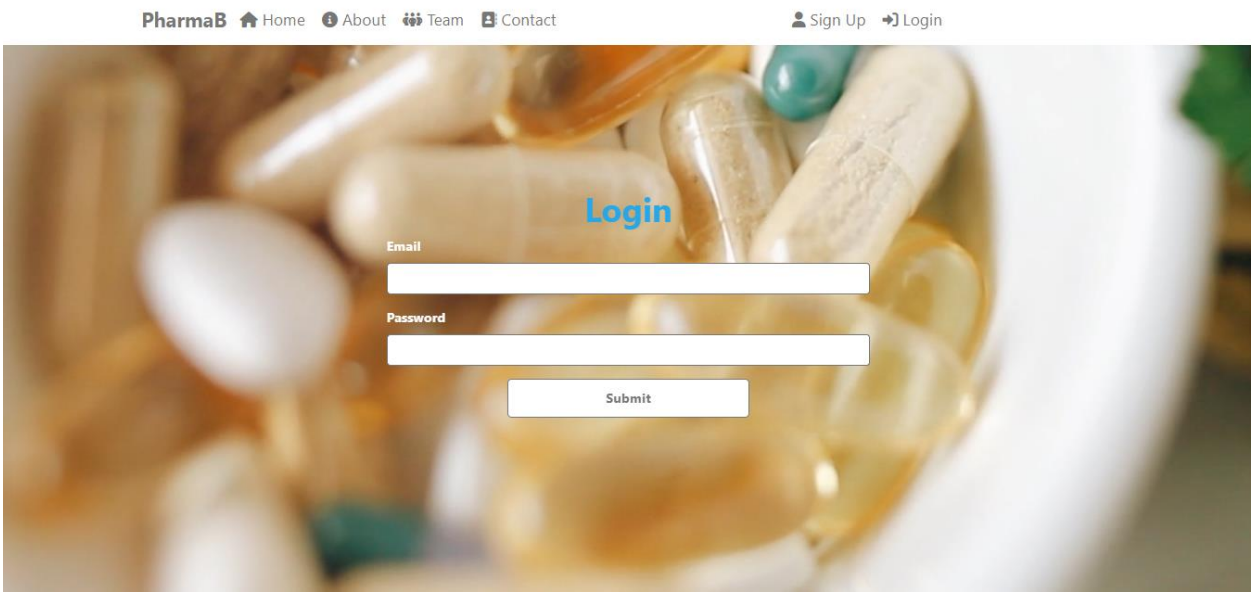


Figure 21 Login Page

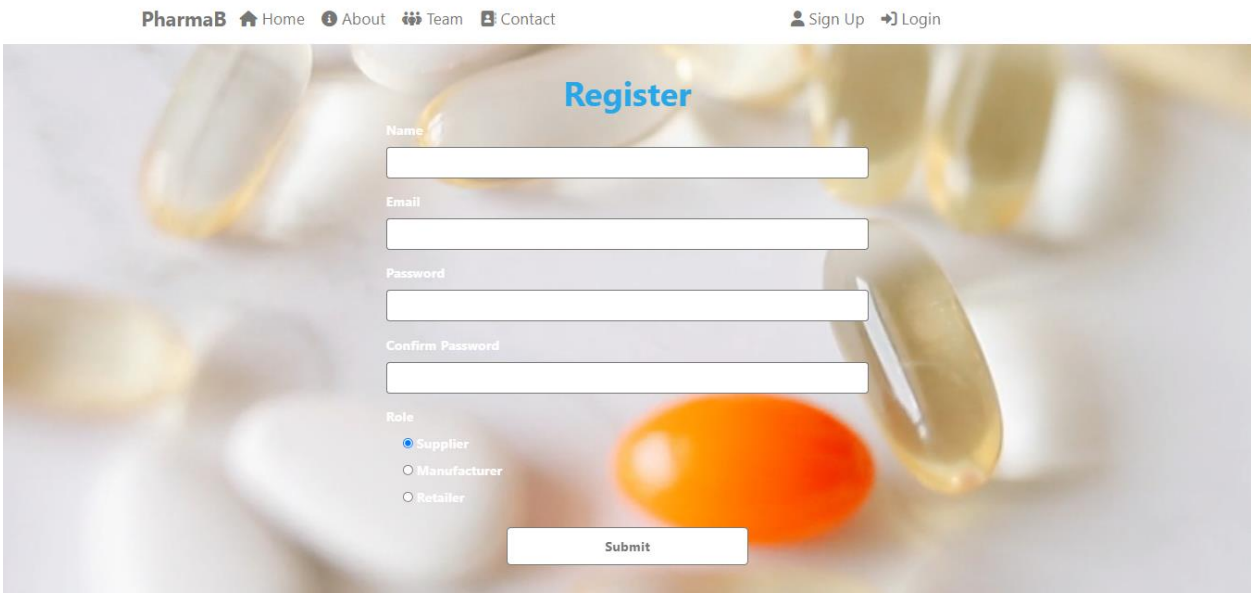


Figure 22 Sign up Page

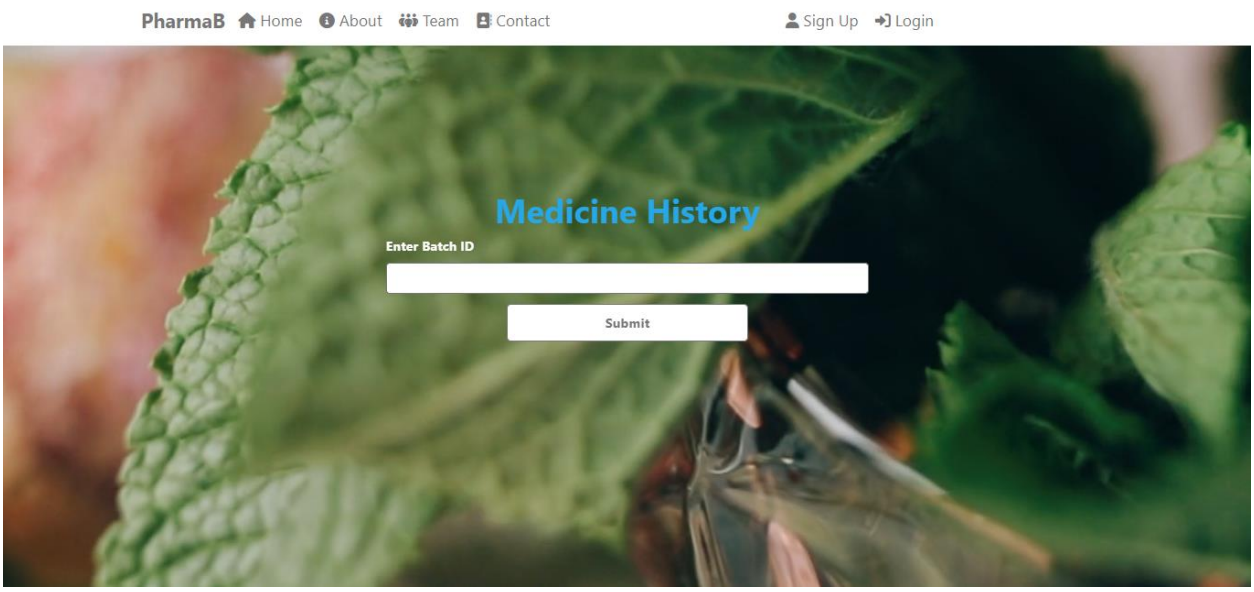


Figure 23 View Medicine History

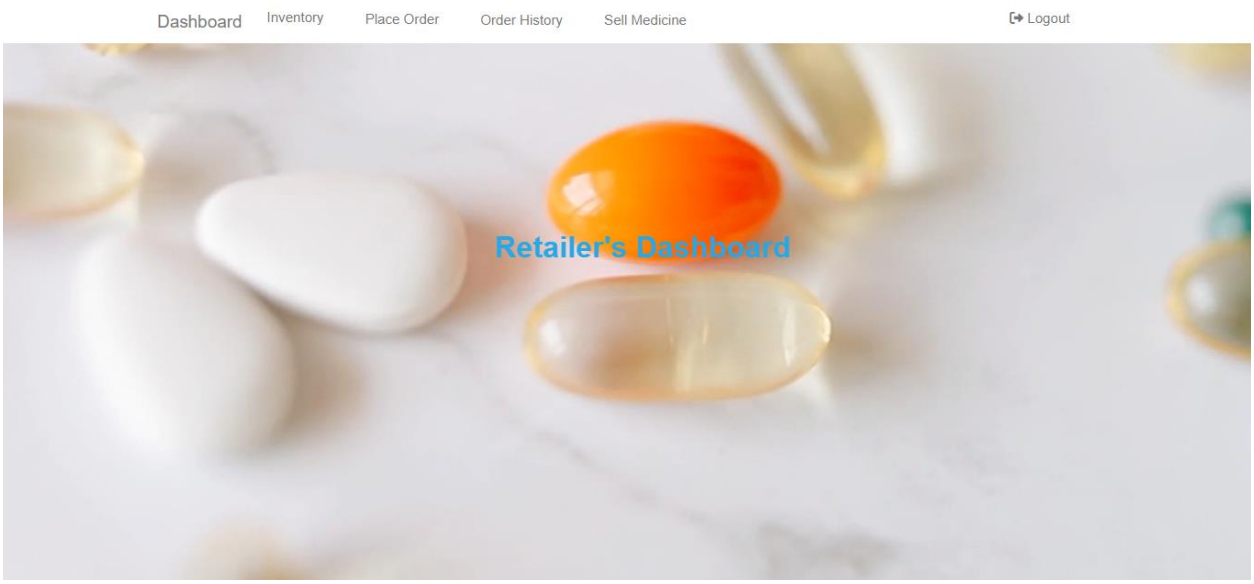


Figure 24 Retailer's Dashboard

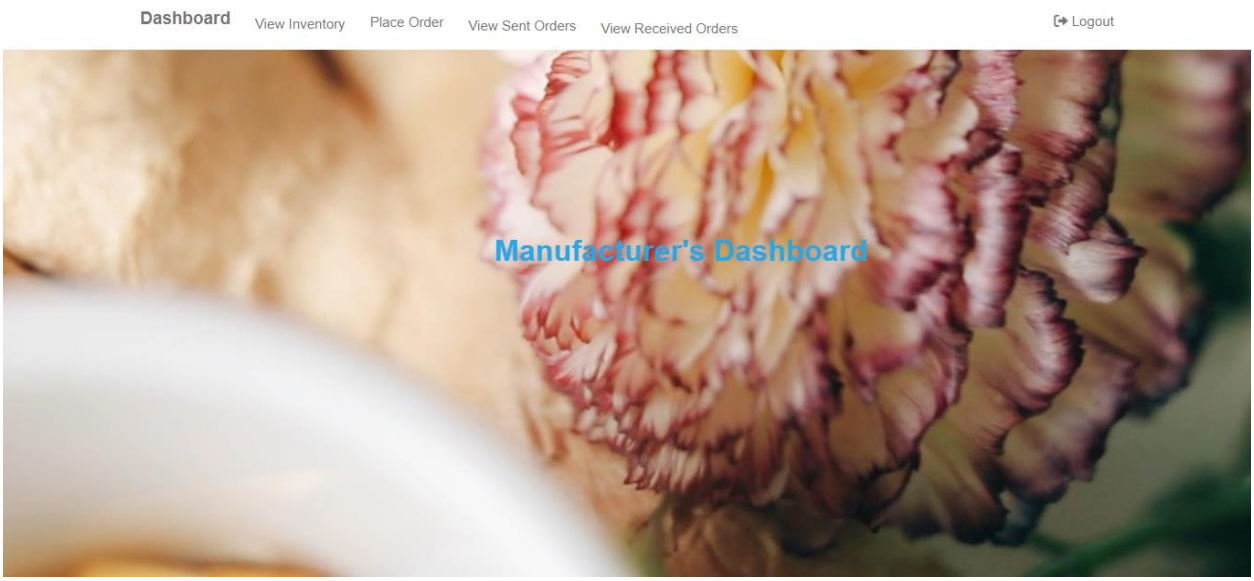


Figure 25 Manufacturer's Dashboard

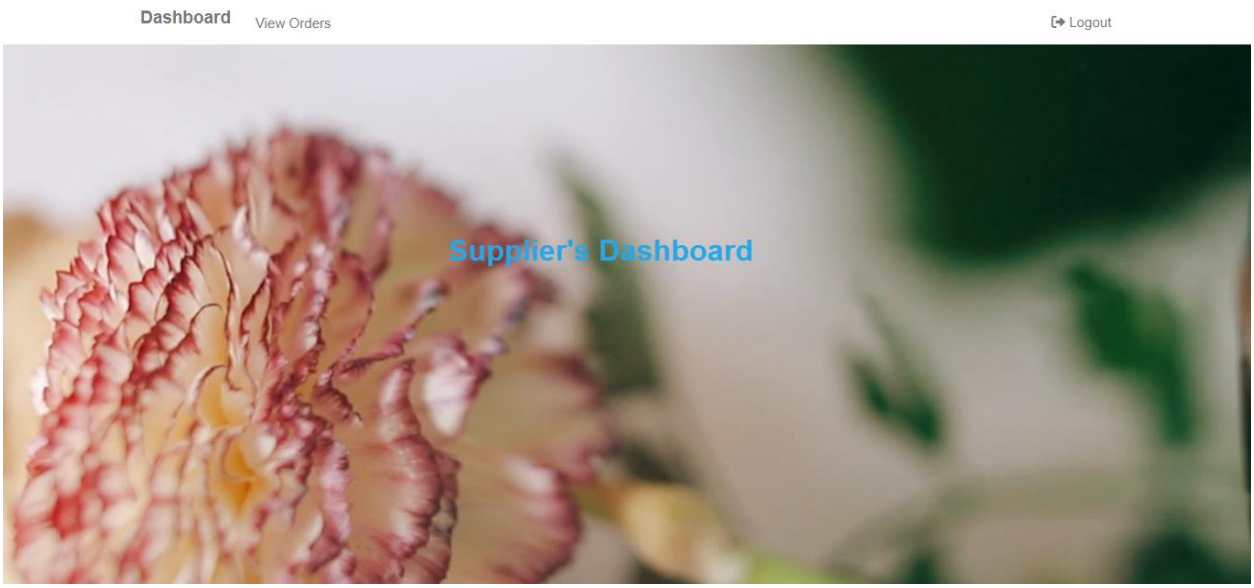


Figure 26 Supplier's Dashboard

WORKING

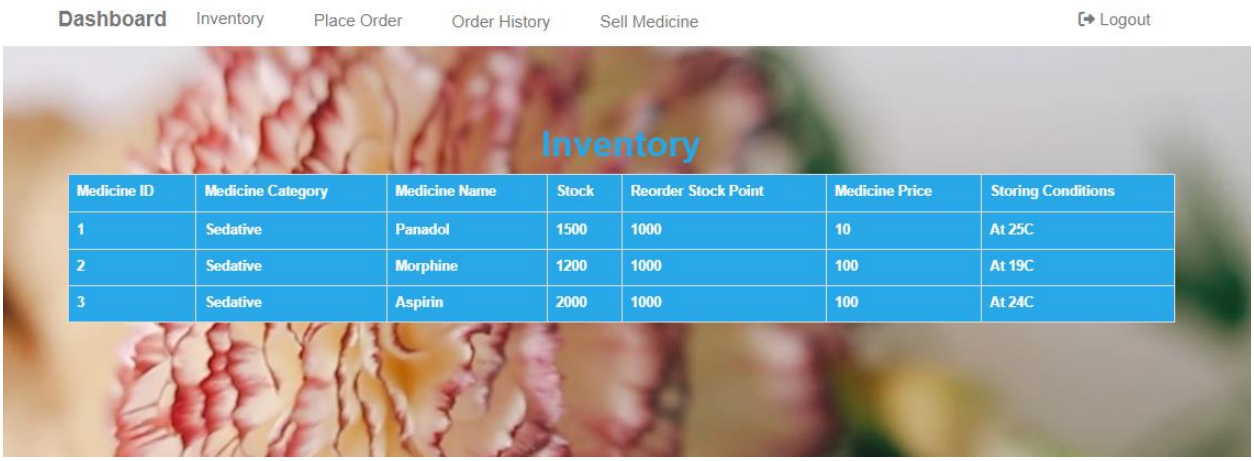


Figure 27 Retailer's Inventory

Figure 28 Manufacturer's Inventory

Step 1: Retailer sell 700 Panadols to customers. Now the stock of Panadol is less than reorder stock point so it will automatically place order for 500 Panadols to manufacturer.

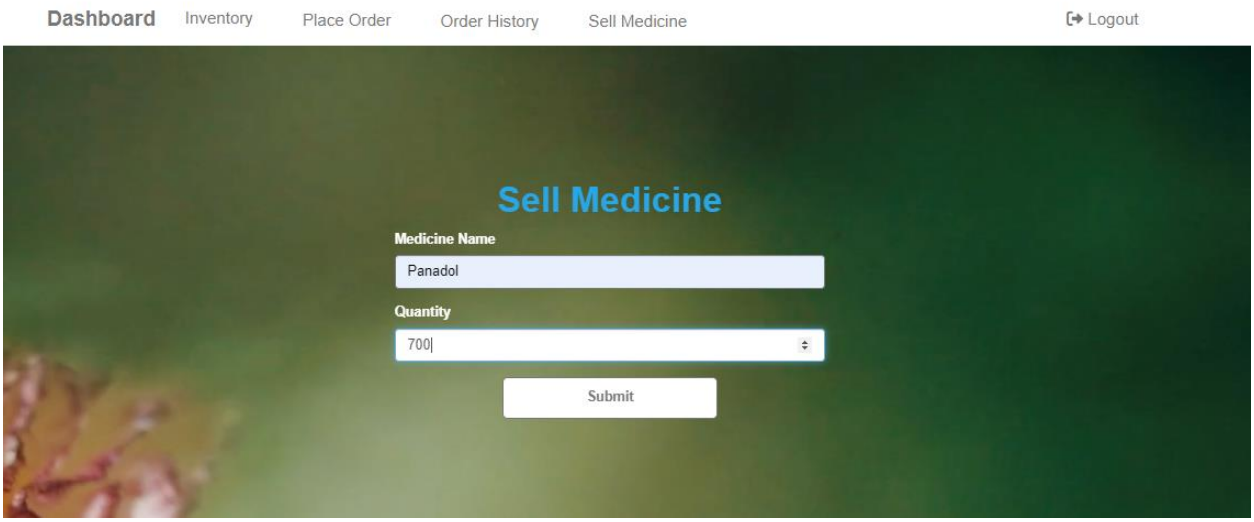


Figure 29 Sell Medicine

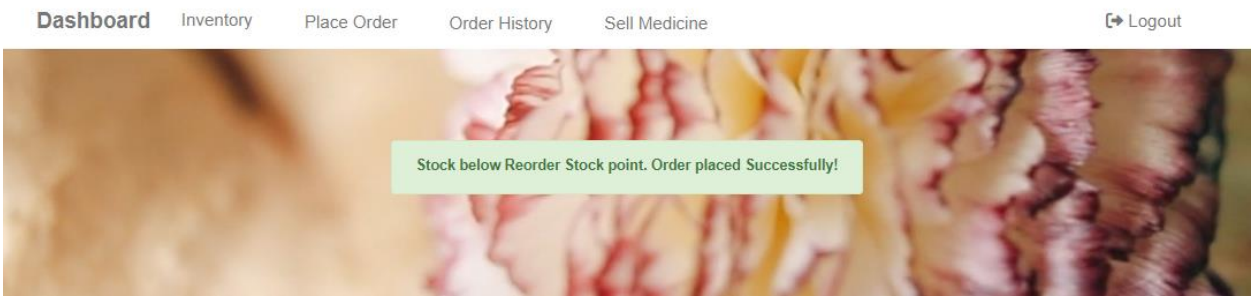
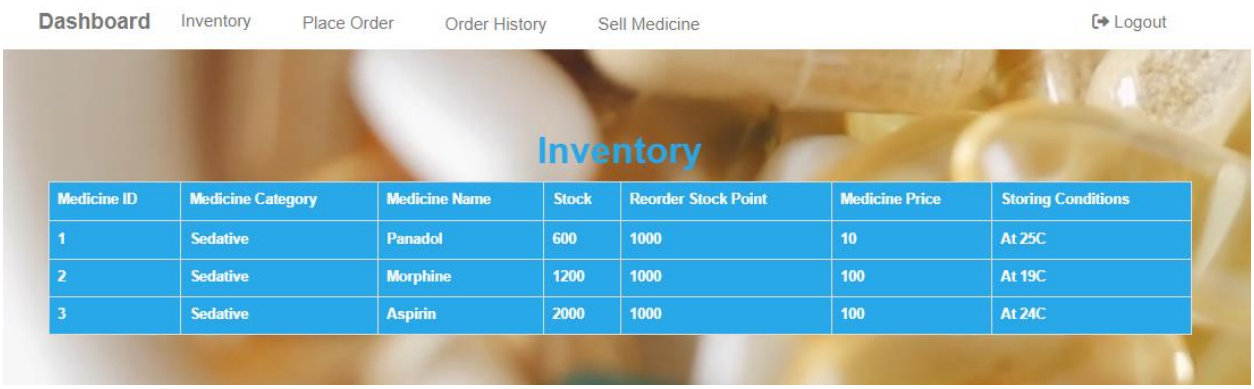


Figure 30 Auto Order Placed



Medicine ID	Medicine Category	Medicine Name	Stock	Reorder Stock Point	Medicine Price	Storing Conditions
1	Sedative	Panadol	600	1000	10	At 25C
2	Sedative	Morphine	1200	1000	100	At 19C
3	Sedative	Aspirin	2000	1000	100	At 24C

Figure 31 Retailer's Inventory After Selling 700 Panadols

Order ID	Delivery Time	Medicine Category	Medicine Name	Qunatity	Manufacturer Name	Expiry Date	Manufacture Date	Medicine ID	Batch ID	Storing Conditions	Order Status
493941	1 week	Seadtive	Panadol	500	Eli Lilly & Co	2023-05-11	2022-06-07	1	493941	At 25C	Confirmed

Figure 32 Retailer's Order History

Order ID	Medicine Name	Quantity	Order Status
493941	Panadol	500	Delayed
493941	Panadol	500	Confirmed

Figure 33 Order Received by Manufacturer

Step 2: Manufacturer’s the stock is not sufficient to fulfill the order. Automatic order will be placed for the respective raw material to Supplier

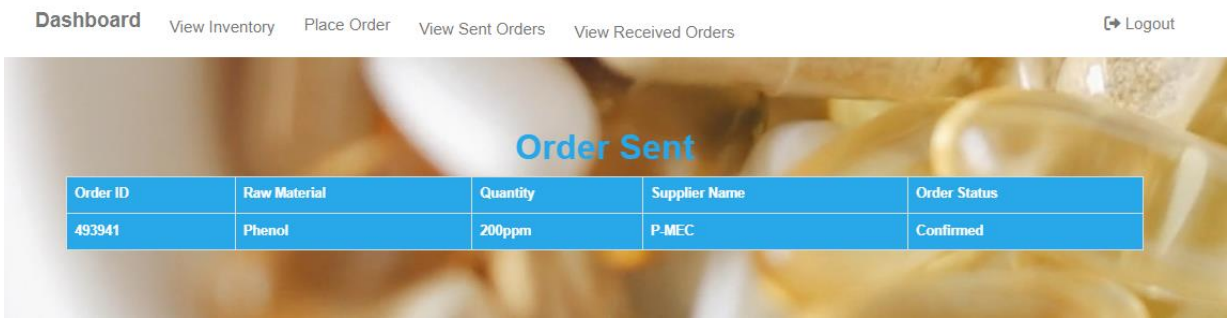


Figure 34 Manufacturer Place Order for Raw Material

Figure 35 Order Received By Supplier

Step 3: You can view medicine history by entering batch ID or by scanning QR Code.

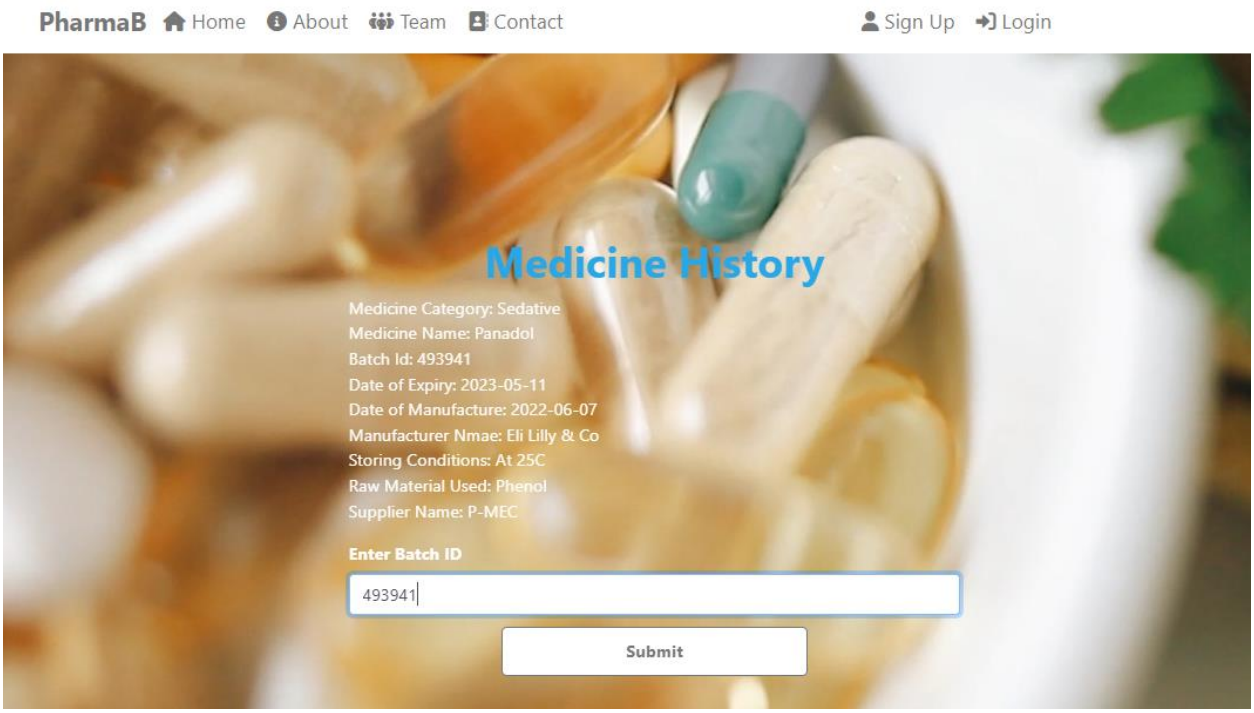


Figure 36 Medicine History Using Batch ID

Figure 37 QR code of Medicine

Step 4: All the data of order is stored on blockchain.

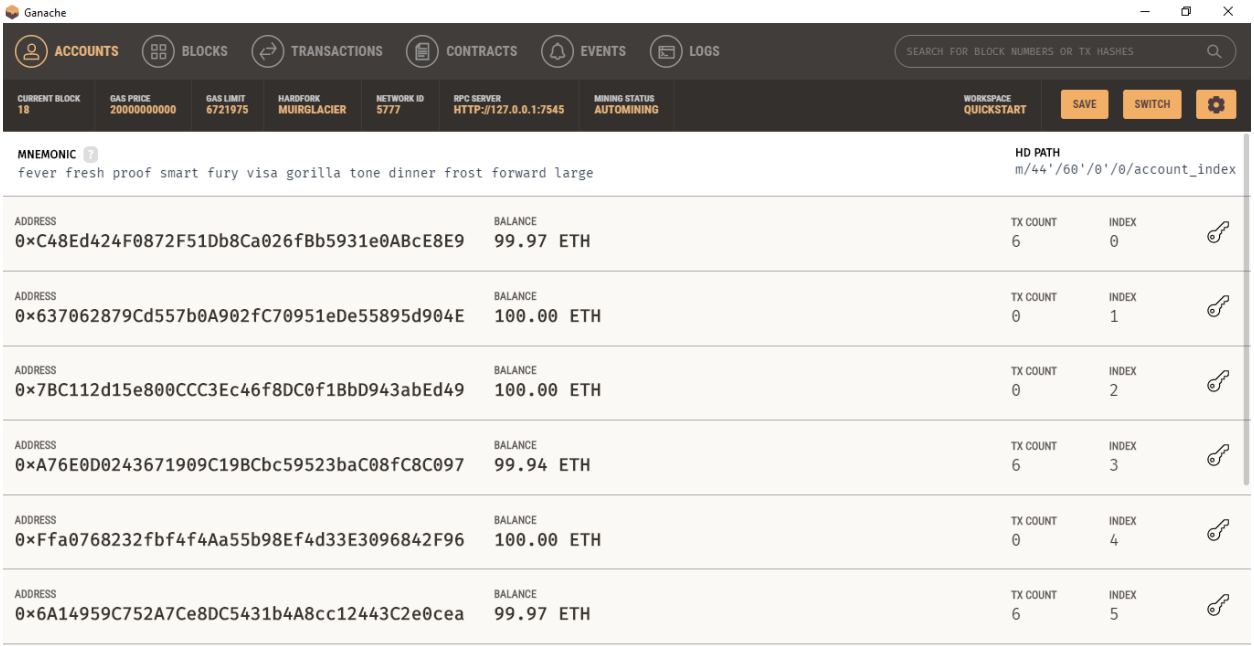


Figure 38 Ganache

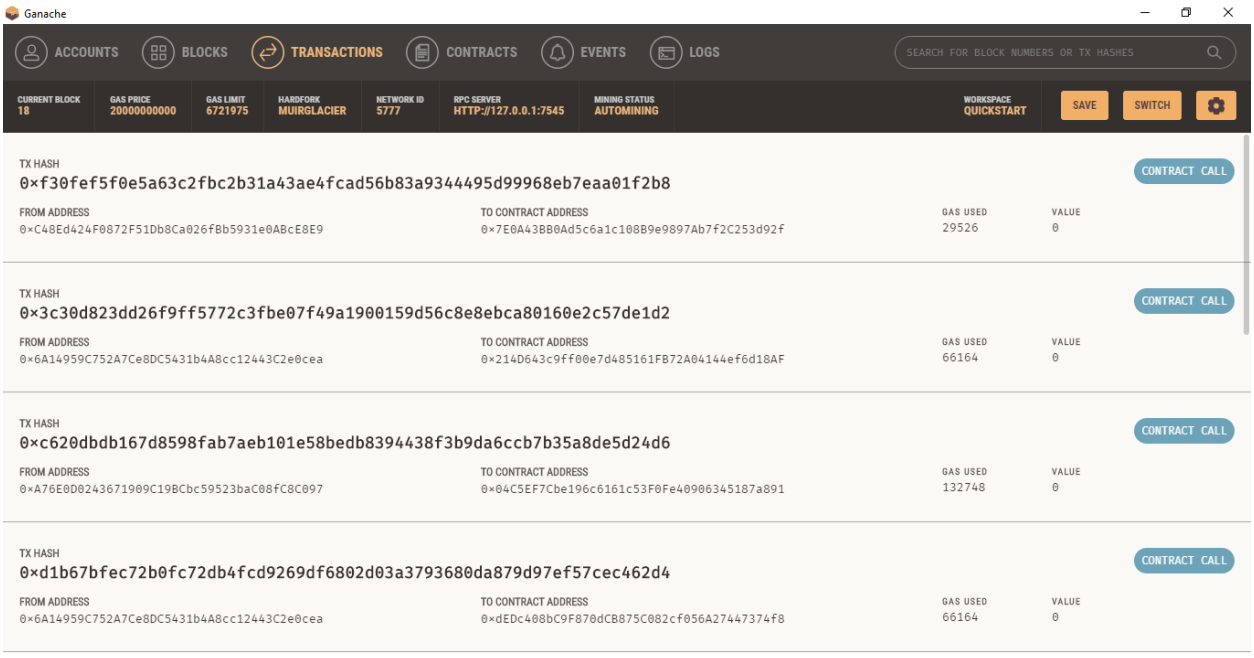


Figure 39 Transactions done during Order

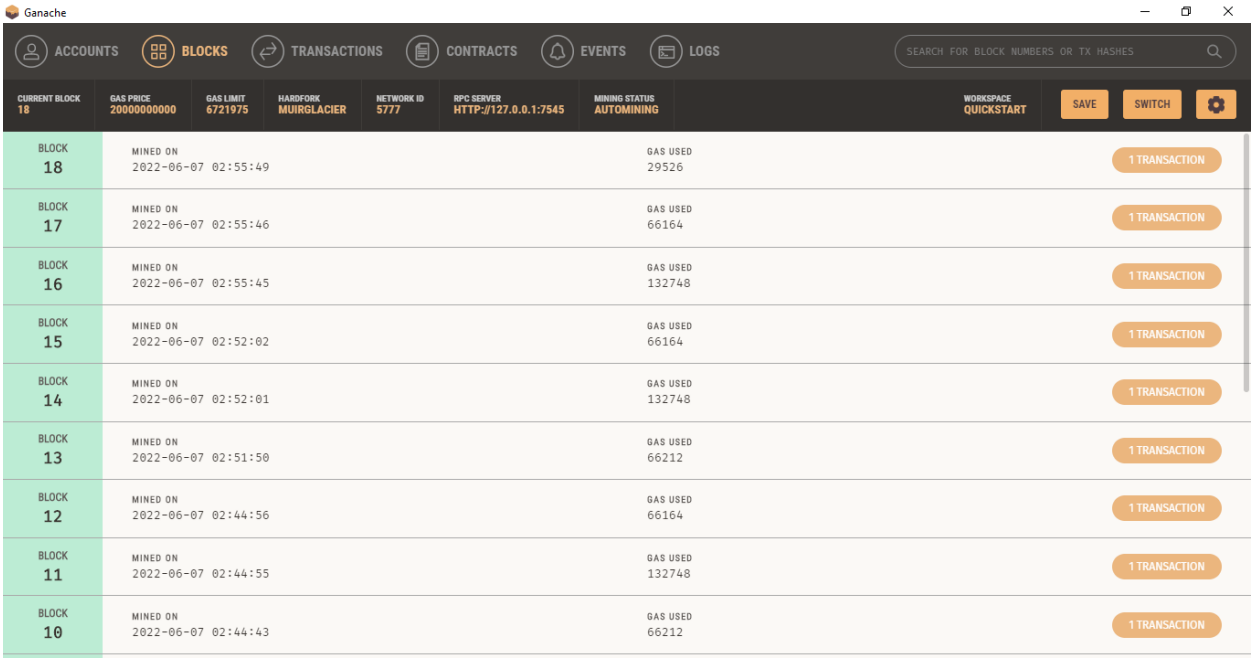


Figure 40 Blocks Created on Ganache

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