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# A framework for tracking the distribution of increasingly abused pharmaceutical medications

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***Abstract***
*The purpose of this study is to identify a system for tracking the distribution of increasingly abused prescription drugs. The problems identified in the study was the increase of prescribed drugs falling into the category of drugs that are frequently abused and this was as a result of improper systems in place designed to track such drugs alongside normal drug distribution networks. The theories of drug abuse highlight the propensity for the increased rate of drug abuse amongst individuals and why it has become imperative that a system that will track such drugs be developed and must be dynamic to readily update new discoveries falling into the abuse category. The study used the object-oriented design methodology to formulate designs for the system through eliciting information on the subject matter with documents and literature of previous works, empirical investigations and personal interviews. The obtained knowledge was then used in designing the proposed system requirements. Manual tests were carried out in units for each component's functionality before the system was tested as a single integrated unit. The study concludes with the development of a system that can meet the dynamic requirements for tracking the distribution of drugs that are subject to drug abuse along with the distribution framework.*
***Keywords:*** *drug abuse, drug prescription, drug tracking system, drug delivery system.*

## INTRODUCTION

Various governments, through their relevant agencies, have been trying to develop solutions to minimize or check drug distribution channels with the intent of curbing the number of prescription drugs that are frequently abused. Handling this challenge is becoming increasingly difficult because of several sources of drug procurement and several routes for moving drugs from producers to consumers. Furthermore, in Nigeria, challenges of ineffective and poor drug administration and control, inadequate funding of drug supply, and drug control activities still exist (Trouiller *et. al* 2017). Additionally, high dependence on foreign sources for finished drug products, pharmaceutical raw materials, reagents and equipment, inadequate storage facilities, poor transportation, and distribution of drugs were inclusive (Ogbonna, 2016).

There is also the challenge of illicit drug importation which the authorities responsible for these checks have little or no control over. To aid them in their task, therefore, it is important to develop systems that fundamentally help to keep track of the movement of drugs (Denise *et al* 2020). This will serve as a basis for better solutions in the future.

• Consequently, this study is aimed at using neural network models to depict and track the distribution of frequently abused prescription drugs based on the following objectives:

- Investigation of drug distribution systems.
- Investigation of the types of frequently abused prescription drugs.
- modeling of a conceptual solution to the problem using a hybrid combination of object-oriented and agile design methodologies.
- Simulation of a web-based application to see how the model will work using HTML5, CSS3, and JavaScript for the frontend and PHP together with MySQL for the backend.

## SCOPE OF THE STUDY

The study will focus on tracking the distribution of frequently abused prescription drugs as opposed to tracking all prescription drugs. The simulation will be done using GreenSock Animation Platform, a JavaScript animation framework.

## JUSTIFICATION FOR THE PROPOSED SYSTEM

### Theories of Drug Abuse

As more pharmaceutical (prescribed off the shelf) drugs fall into the category of drugs that are frequently being abused, it has become imperative to develop systems to track them alongside normal drug distribution networks. These categories of drugs are on the increase as those who are given to substance abuse device sundry combinations of conventional drugs to satisfy their urges. This implies that a system that will track such drugs must be a dynamic one which can be readily updated with such new discoveries falling into the abuse category.

The theories of drug abuse show that some individuals depend on particular drugs for their survival for a number of reasons. The main focus of the theories of drug abuse is that people have their own reasons for depending on a particular type of drug or the other. Such reasons, by (Eze and Omeje 1999) in Oluremi (2012), are explained by the following theories:

1. Socio-cultural Theory of Drug Abuse: This theory maintained that drug abuse is determined by the socio-cultural values of the people. For example, certain cultures permit the consumption of alcohol and marijuana, while other cultures do not. Among the tribes in Nigeria, for example, Edo, Ijaw, Igbo, Ibibio, Urhobo, Itesekiri, and Yoruba use alcohol in cultural activities. In the northern part of Nigeria, however, any form of the drug is not allowed.
2. Biological Theory of Drug Abuse: The theory maintains that drug abuse is determined by the individual's biological or genetic factors which make them vulnerable to drug addiction.
3. Learning Theory of Drug Abuse: The theory maintains that usage or dependence of drugs occurs as a result of learning of which there are three forms - instrumental learning, conditional learning, or social learning.

**Prevalence Rate of Drug Abuse in Nigeria**

From the record of drugs abuse in Nigeria, the Northwest has a statistic of 37.47 percent of the drug victims in the country, while the Southwest has been rated second with 17.32 percent, the south-East is been rated third with 13.5 percent, North-central has 11.71 percent, while the North-east zone has 8.54 percent of the drug users in the country (Akannam 2008). In Nigeria, the estimated lifetime consumption of cannabis among the population is 10.8 percent, followed by psychotropic substances like benzodiazepines and amphetamine-type stimulants at 10.6 percent, heroin at 1.6 percent, and cocaine at 1.4 percent, in both urban and rural areas. Drug abuse appears to be more common among males with 94.2 percent than females with 5.8 percent, and the age of first use is 10 to 29 years. The use of volatile organic solvents is 0.53 percent and is widely spread among street children in school, youths, and women. Multiple drug use happens nationwide with 7.88 percent to varying degrees. (UNODC World Drug Report 2012).

**Causes of Vulnerability to Drug Abuse in Youths**

Studies have revealed that most drug addicts started smoking from their youth. As they grow older, they seek new thrills and gradually go into hard drug abuse (Oshodi et al 2010, Igwe, *et al.,* 2009). A nationwide survey of high school students reported that 65 percent used drugs to have a good time with their friends 54 percent wanted to experiment to see what it is like, 20 to 40 percent used it to alter their moods, to feel good, to relax, to relieve tension and to overcome boredom and problems (Abudu 2008, Mamman *et al* 2014)

**Drug Trafficking**

Global drug-trafficking operations remain at the forefront of concerns for the international community, as "more than ever before, strong levels of cooperation exist between different [trafficking] groups transcending national, ethnic, and business differences" (Organized Crime Threat Assessment OCTA, 2011). These criminal networks quickly adapt to new social environments and fluctuating markets, illustrating their flexible and dynamic qualities. Drug-trafficking organizations face a shifting landscape dependent on a number of factors, including market demand, cultivation rates, access to established land trafficking routes, and law-enforcement activity (Boivin 2014, Caulkins, and Reuter 1998, UNODC World Drug Report 2012). Drug trafficking incidents also continue to prevail during forced migration with over 61.3% of a sample of respondents being exposed to drugs during their migration. (Ikenna *et al.*, 2021).

**Drug Poisoning**

Unintentional drug poisoning is now the leading cause of injury death for all age groups in the United States (Rosenblatt et al 2015, Unick et al 2013, Warner et al 2009). According to recent analyses of CDC mortality data, drug and alcohol poisoning are the primary drivers of the increased trend in mid-life mortality in the US. (Case and Deaton 2015). The trend in New York (NY) mirrored the national pattern of increasing drug and alcohol poisoning deaths; a 30 percent increase in opioid analgesic-related deaths was registered in NY between 2009 and 2014 (New York State Opioid Poisoning, Overdose and Prevention. 2015).

**Overdose**

Heroin overdose mortality is also increasing. According to the U.S National Survey on Drug Use and Health (2011, 2013), from 2002 to 2013, the rate of heroin-related overdose deaths nearly tripled

(Warner *et al* 2009). In NY, heroin was implicated in 55 percent of drug-related deaths in 2015 compared to 16 percent in 2009 (New York State Department of Health, 2016). It has been postulated that measures to reduce the supply of prescription opioids may have the unintended consequence of increasing heroin use (Unick et al 2013). However, studies thus far have been unable to demonstrate an elect of Prescription Drug Monitoring Programs (PDMP) on heroin overdose deaths (Dowell *et al* 2016), (Brown *et al* 2017). Subsisting systems focus strictly on tracking the distribution of a fixed set of drugs. This tends to enable the abusers of those drugs to procure such substances independently either from the same stores or different stores to avoid suspicion and evade detection. Furthermore, those who inspect drugs in higher institutions for example do not always know that these drugs when combined will generate the same psychotropic effects like the common ones they already know. This keeps the drug abuse incidence on the increase.

## RELATED LITERATURE
## LITERATURE ON EXISTING SYSTEMS

### Pharmaceutical Tracking System

Pharmaceutical Tracking System is a patent invented by Gerald E. Forth, David D. Swenson, and Patrick M. Steusloff (Forth *et al.*, 2004). The pharmaceutical tracking system and the method comprise a system server and a number of authentication code readers at the manufacturing facility and distribution destination, where the system server assigns a number of unique authentication codes to a manufacturer. An authentication code is applied to any level of product packaging and read by a code reader at the manufacturing facility for activation to serve as a mark of a certified product of the manufacturer. Code readers can be used at intermediate destinations in a distribution chain to verify the legitimacy of the product received and to track the location of the product along the distribution chain as illustrated in figure 1. (Forth *et al.,* 2004).

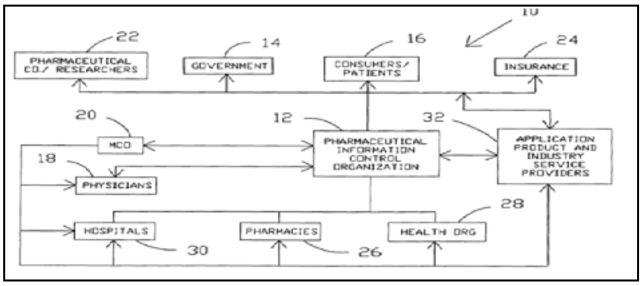


**Figure 1:** (Forth, G., Swenson, D., & Steusloff, P. (2004). Pharmaceutical Tracking System. American. Retrieved 25, December 2018)

### Controlled Substance Tracking System and Method

This system uses a very secure database to keep track of the medication history of patients which will help the pharmacists to prescribe drugs accordingly. The controlled drugs are tracked and are only administered to patients whose medical history allows for the consumption of said drug as deemed by a physician in a pharmacy residing in the secure network as illustrated in figure 2. The drawback to this system is it may be very expensive to increase the number of pharmacies connected to the network. Additionally, it focuses mainly on tracking drugs that are already in the pharmacies meaning drugs could be redistributed to pharmacies not registered in the network (Lily *et al.,* 2011).

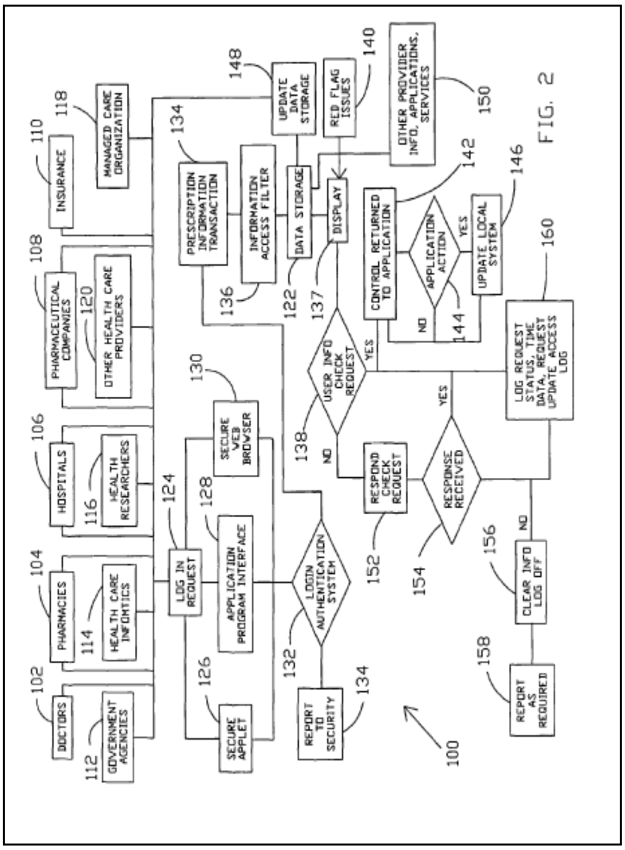


**Figure 2:** (Lily, R. B., Bornfreund, J. J., Anon, A. J. (2011). Controlled Substance Tracking System and Method. 705/2. Retrieved 25, December 2018)

### Drug Delivery Device

This system uses a tracking code associated with a syringe cradle label unit and/or a port cradle label and a device that houses the syringe or drug (fig 3). It is a very secure system but each pharmacy would have to have the device working at all times. Purchasing and maintaining the device proves to be a substantial drawback (Hanson et al 2012).

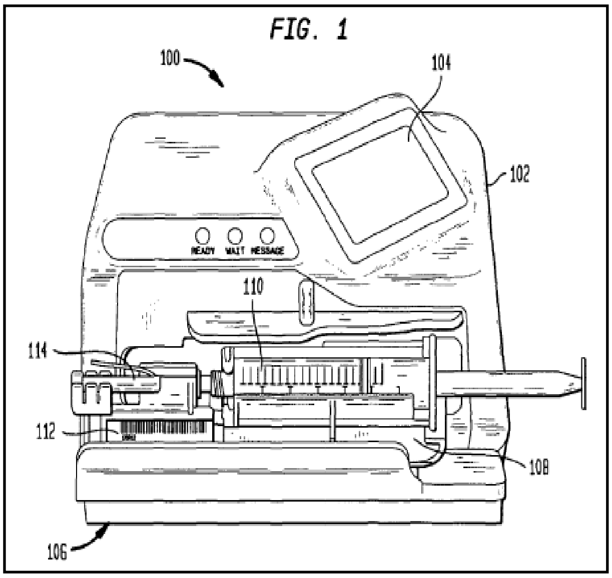


**Figure 3:** (Hanson, R., Sudduth, B., Detar, D. (2012). Drug Delivery Device Incorporating a Tracking Code. 700/14. American. Retrieved 25, December 2018)

## MATERIALS AND METHODS

## RESEARCH METHODOLOGIES

The following research methodologies were used in this study for information gathering:

- Documents and literature were downloaded and perused to find out more on the study.
- A personal interview was carried out to find out more about the drug distribution system in Nigeria.
- Empirical investigations were also carried out.

## EQUIREMENTS OF THE PROPOSED SYSTEM

The knowledge and insight gained from the analysis of literature and existing systems was used in the design of the proposed system. The design of the proposed system will commence with specifications that will cover all the requirements the proposed system is intended to have.

The requirements are as follows:

- The system should have a registration and login functionality. This would enable the system to differentiate between the various users (the admin, the various drug manufacturers and pharmacy admins) and provide relevant information and actions to them.
- The system should, therefore, have separate pages for its different users. In essence, the administrator should have a different view and possible actions when using the system, compared to when the manufacturer and various pharmacy administrators login.
- The manufacturer should be able to upload available prescription drugs.
- Pharmaceutical admins should be able to view available drugs in the lists shown to them.
- The system should have payment functionality. Hospital admins should be able to order for prescription drugs and manufacturers should be able to securely pay for the distribution of their products to designated pharmacies.
- Manufacturers, pharmacy admins and the system admin should be able to track the distribution of the order(s) live.
- The system should notify users when the distribution has been aborted or delayed.
- The system should be able to alert the user to report to relevant authorities and agencies when the distribution of the order takes a different unsolicited route.
- The system admin should be able to view and manage the list of controlled prescription drugs as maintained by drug law enforcement agencies.

## 3DESIGN METHODOLOGY

The study uses the object-oriented design methodology to formulate designs for the system. The different components of the modules of the proposed system, the functions executed within these components and the interrelationships between these components and modules are therefore depicted with a use case diagram, sequence diagrams, and a database diagram.

## DESIGN OF THE PROPOSED SYSTEM

Figure 4 depicts the actions of the various users of the system. The pharmacy admin logs in, views available prescription drugs and selects needed drugs based on the pharmacy's stock for order. The pharmacy admin can then track the distribution of the order live. The manufacturer logs in, uploads newly-produced drugs and can view the list of orders performed on drugs it produced.

The drug law enforcement agency logins, views the list of manufacturers and pharmacies that operate in its jurisdiction. The agency can add drugs to a controlled list so any distribution of such drugs will be monitored with extra care. Lastly, the agency can view reports made by pharmacies on the distribution of drugs and act on those reports.

The admin, once logged in, views analytic data available from various databases such as how many manufacturers and pharmacies are registered in the system. The admin can view details of these users and also track any distributions that may be ongoing.

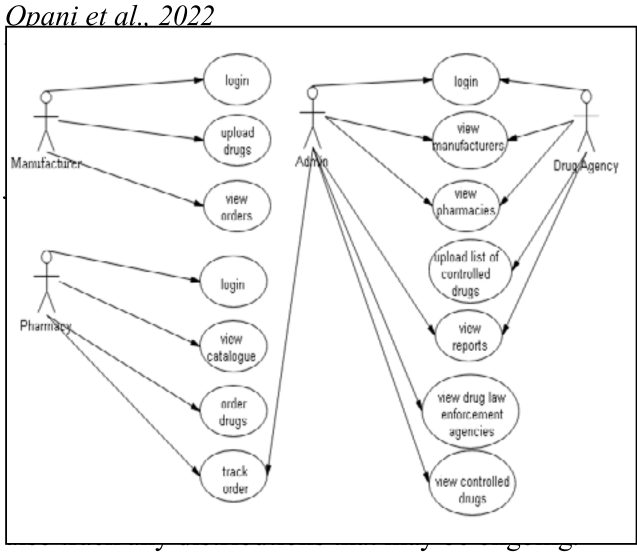


**Figure 4:** Use Case Diagram

Figure 5 depicts the sequence of activities for the pharmacy admin where he/she logins firstly, then, on authentication, proceeds to view available drugs and orders based on the needs of the pharmacy. A package ID is received for the order which will be used to track and check the progress of the delivery.

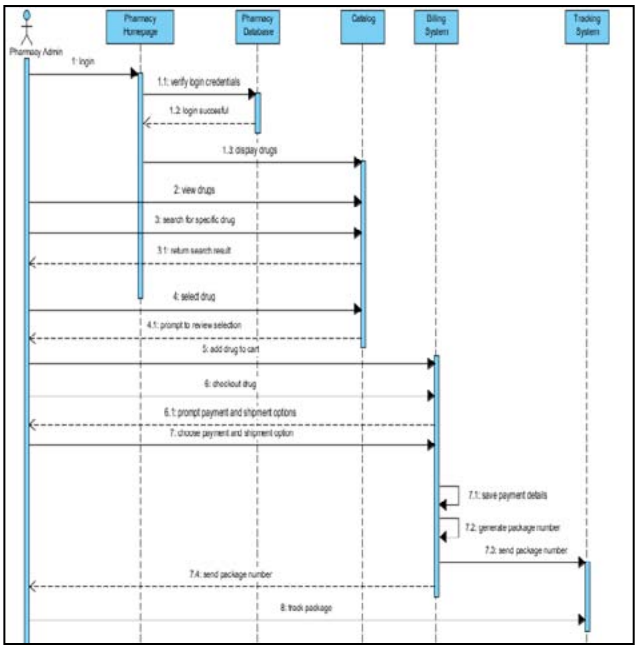


**Figure 5:** Sequence Diagram for the Pharmacy Admin

The manufacturer logs as shown in figure 6 then get verified. Next, the manufacturer uploads newly manufactured drugs and then tracks the delivery of any of his purchased products.

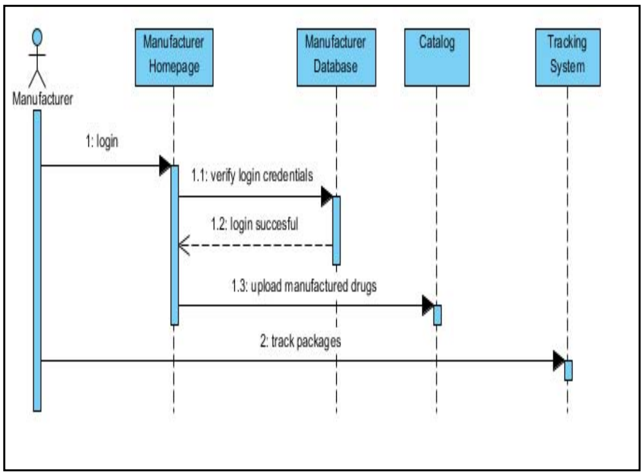


**Figure 6:** Sequence Diagram for the Manufacturer

The entity-relationship diagram in figure 7 depicts the relationship between the tables in the database as the manufacturer uploads many drugs and the pharmacy orders many drugs.

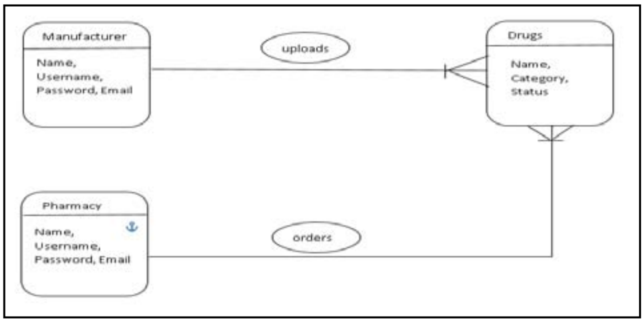


**Figure 7:** ER Diagram for Users of the System

## SYSTEM ARCHITECTURE

The architecture used in the system is a three-tier architecture. A three-tier architecture is a client-server architecture in which the functional process logic, data access, computer data storage, and user interface are developed and maintained as independent modules on separate platforms. Any one of the three tiers can be upgraded separately. The three tiers in this web application are:

**Presentation Tier (Client-Side):**

This is the tier that displays information related to services offered by the system. This is where the users and the medical personnel interact with the system. This interaction is achieved through the use of personal computer systems.

**Application Tier (Server Side):**

This is the tier that controls the web application's functionality by performing processing. This processing involves saving user information in a database table, verification of users, saving therapy questions, and saving user answers.

**Data-Tier (Database):**

This is the tier that houses all data and information sent to the system. It also allows the retrieval of data and information for system use.

The distribution chain using a neural network as shown in figure 8, ensures the drugs pass through a hierarchy of authorized pharmacies for instance the drug first gets to the national pharmacy from the manufacturer, through central and district pharmacies and then to regional pharmacies before finally getting to the local pharmacy. When the drugs are not tracked properly they can skip the authoritative pharmacies and easily end up with abusers. The proposed system will ensure drugs are tracked from the manufacturer (source) to the local pharmacies (leaf nodes in the neural network) and flag any contrary incident on which appropriate measures will be taken.

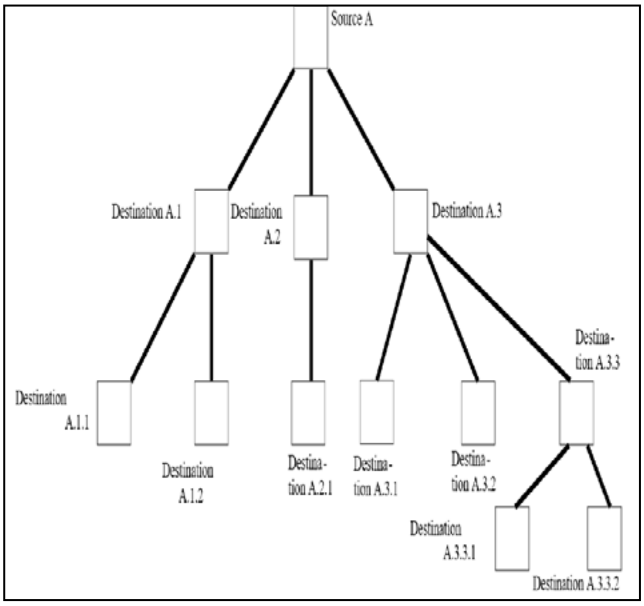


**Figure 8:** Distribution Chain Using a Neural Network

## SYSTEM TESTING AND RESULTS

## SOFTWARE TOOLS USED IN DEVELOPMENT

Visual Studio Code text editor was used for the development of the proposed system. Visual Studio Code was chosen because it was developed mainly to be used for the development of both the client and server-side of web applications. It is widely regarded as the best text editor for building websites due to its robust features. One which the development phase benefitted from is the emmet plugin package. Emmet is a plugin package available to most text editors to help type long html code in as little as a line using shorthand syntax. This saves a lot of time during development.

XAMPP was used to create a local webserver to help with testing and to host the database used for the proposed system. XAMPP stands for Cross-Platform (X), Apache A), MariaDB (M), PHP (P) and Perl (P). It is a simple, lightweight Apache distribution that makes it really easy for developers to have a local web server for testing and deployment.

## TESTING AND DEBUGGING

Google chrome's developer tools were used for testing and debugging of the proposed system. Manual tests were also carried out in units to make sure each component was functioning properly. Later the system was tested as a single integrated unit.

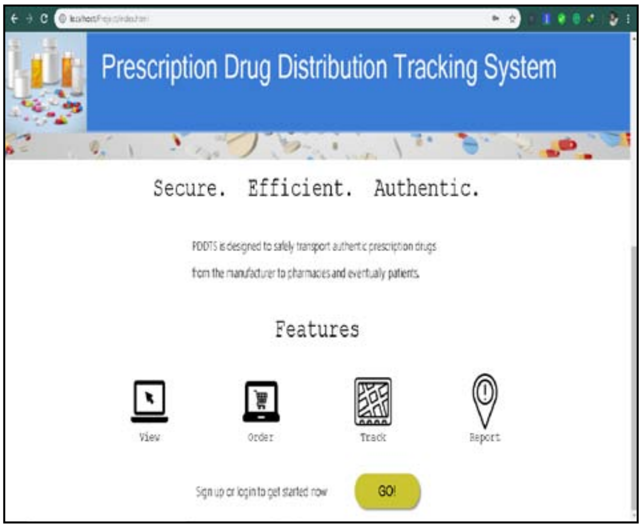


**Figure 9:** Landing Page

Figure 9 is the landing page of the app. The user clicks the 'GO!' button to go to the login/sign-up page shown below.

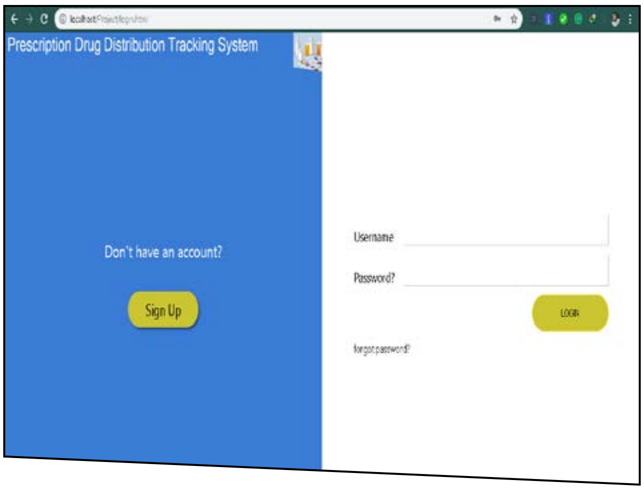


**Figure 10:** Login/Sign-up Page

The login page also has a sign-up part (figure 10). If the user is new to the system, he/she will click the sign-up button to create an account. An existing user will simply login. Assuming the user is a new one, the next figure will show the register page.

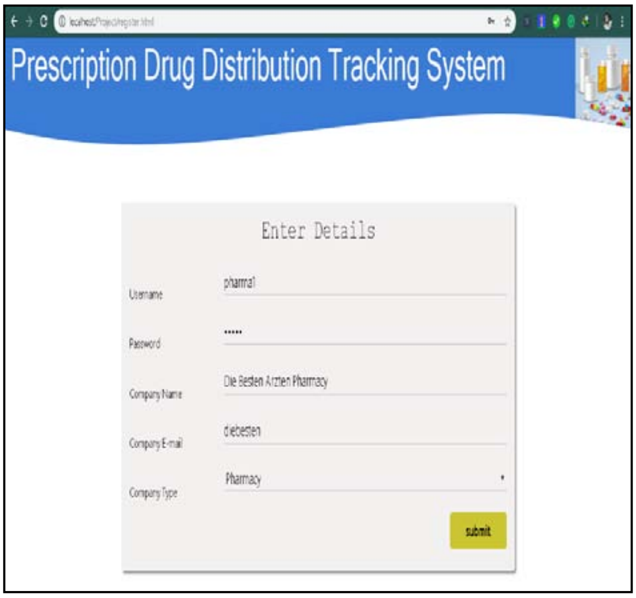


**Figure 11:** Register Page

The user signs up by filling out the register form and providing relevant information. The type of user is also chosen. Figure 11 shows a user registering as a pharmacy. After registration, the user is directed to the pharmacy homepage.

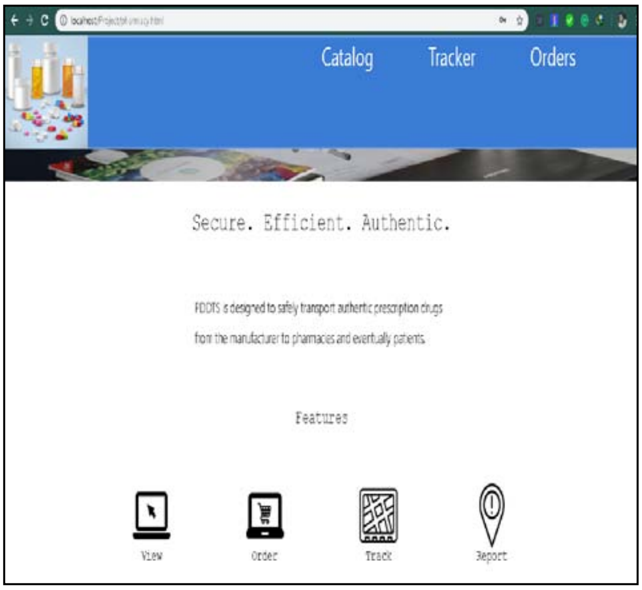


**Figure 12:** Pharmacy Home Page

The newly-registered pharmacist can then view the catalogue of available drugs by clicking the catalogue navigation link (figure 12).

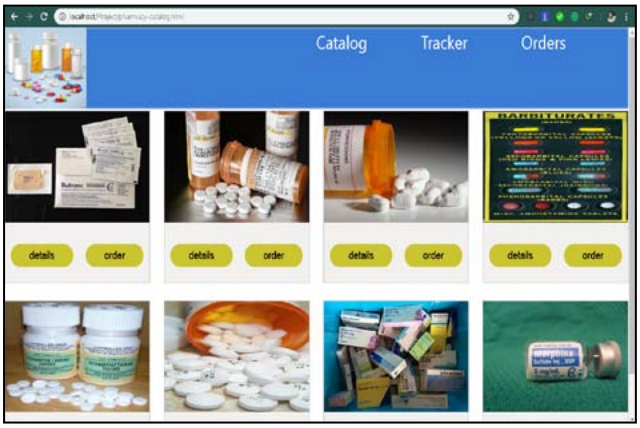


**Figure 13:** Pharmacy Catalogue Page

The pharmacy user views the available drugs and can view extra details of the drug before purchasing as shown in the figure below (figure 13).

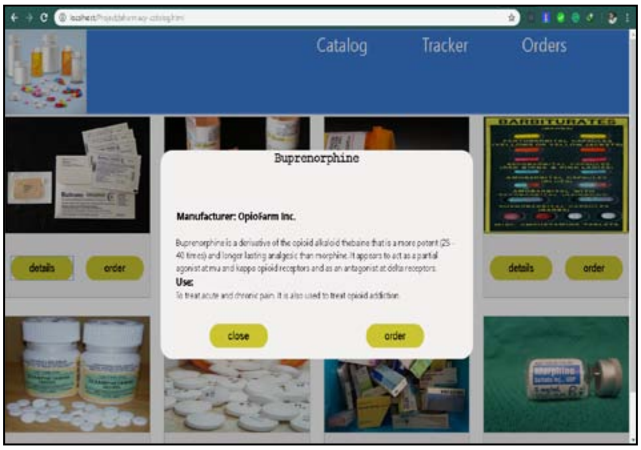


**Figure 14:** Drug Details Modal

A modal window comes up when the details button of the drug is clicked. It shows the manufacturer of the drug (who is registered with the proposed system), details about the drug and its use. After viewing the details, the pharmacy admin can order the drug, or close the modal and peruse other drugs.

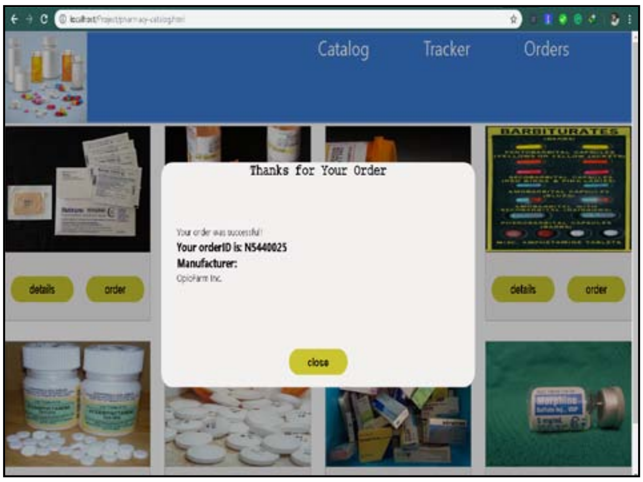


**Figure 15:** Successful Order Modal

After the pharmacy admin enters payment details a confirmation modal is shown and displays a generated alphanumeric order ID that can be used to track the package.

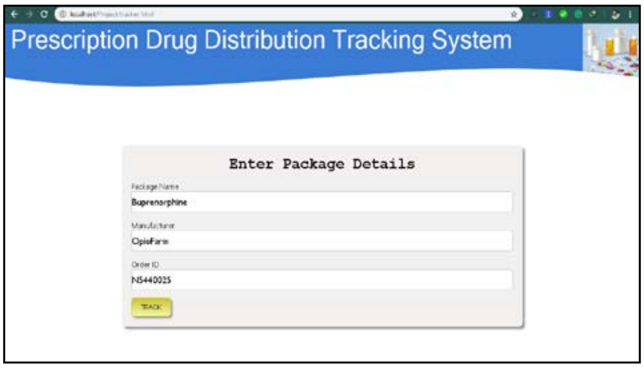


**Figure 16:** Tracker Page

The pharmacy admin enters the package details to track the distribution of the drug.

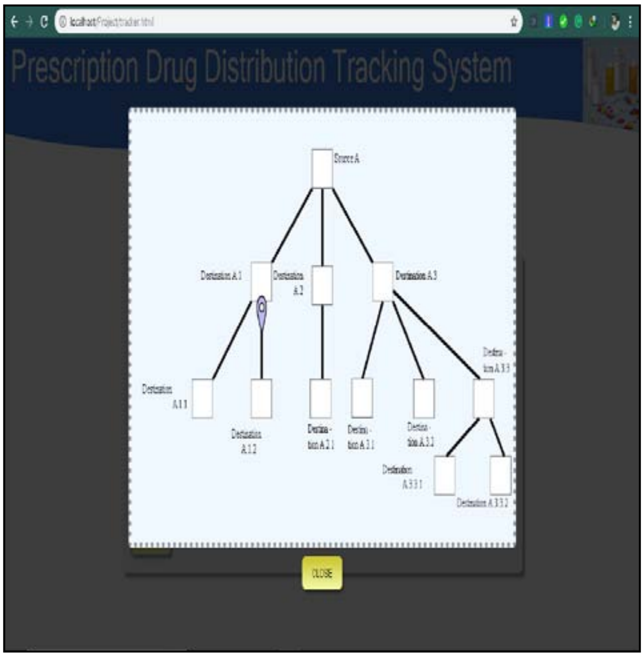


**Figure 17:** Tracking the Distribution of the Package

Figure 17 shows the package being tracked in transit. The routes to various destinations are modelled using neural networks as the package would have to pass through national, central and regional pharmacies before getting to the local pharmacy where it was ordered. The system tracks the package to make sure it passes through the main pharmacies first. The system uses a flashing blue icon to indicate a package that is still in transit and a red icon for a cancellation of the delivery or a diversion from the set-out route of which a report button appears so the user can flag the crime.

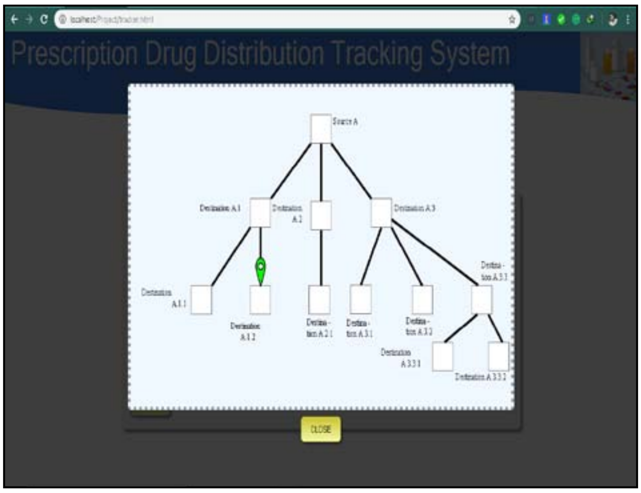


**Figure 18:** Package Arrived at Destination

The tracker icon turns green when it has reached its destination.(figure 18)

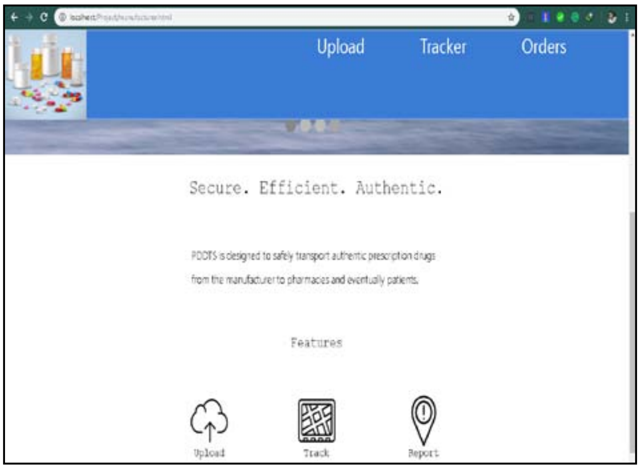


**Figure 19:** Manufacturer Homepage

Going back, if the user that logged in was a manufacturer then this would be the landing page visible to the user.(figure 19)

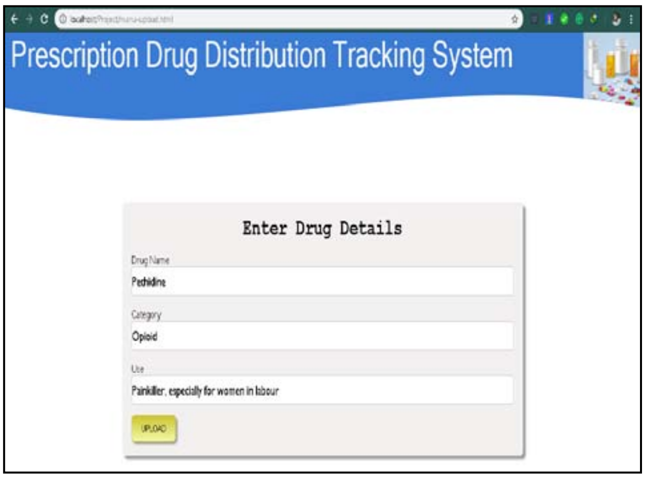


**Figure 20:** Manufacturer Upload Page

After logging in, the manufacturer would want to upload newly manufactured drugs or previously manufactured drugs that have run out of stock.(figure 20)

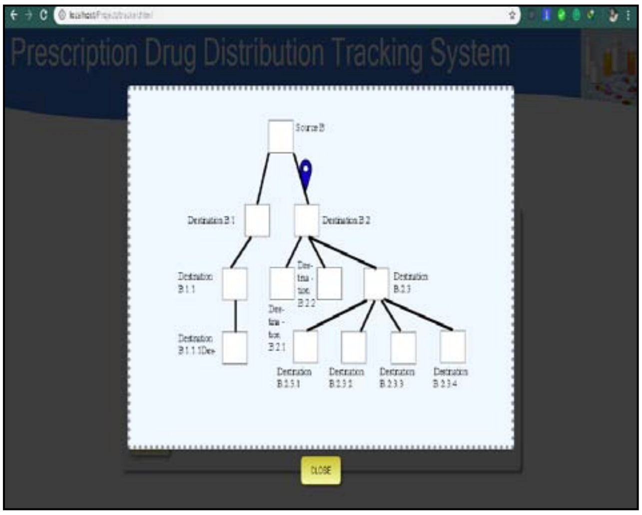


**Figure 21:** Tracking

After uploading drugs, the manufacturer may want to track the order made by a pharmacy admin.(figure 21)

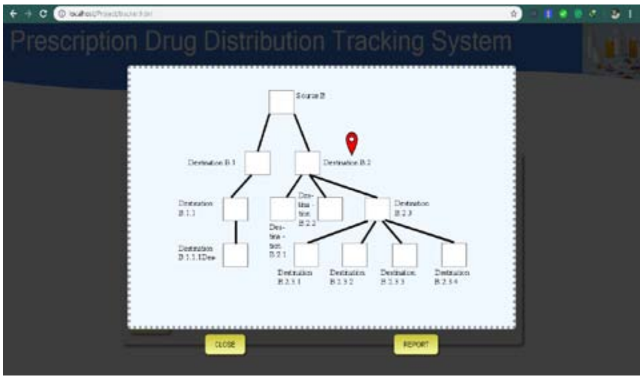


**Figure 22:** Package Going Off Track

As shown in figure 21, the manufacturer can report as soon as the package goes off-course. Because the tracker begins to flash red as a visual cue to the user.


**Figure 23:** Admin Homepage

The figure above shows the admin dashboard from which he/she has a number of capabilities including the tracker page available to other users.

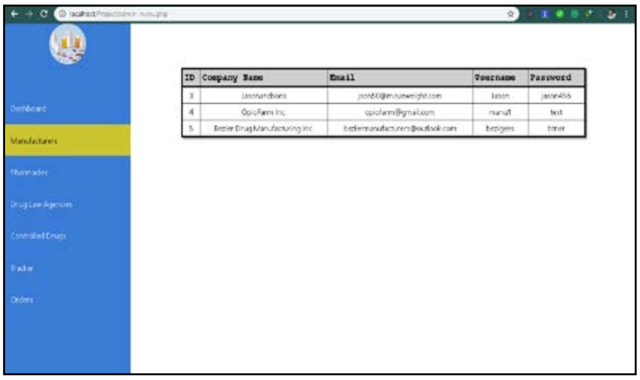

**Figure 24:** List of Manufacturers

The admin can view a list of all manufacturers registered on the system.

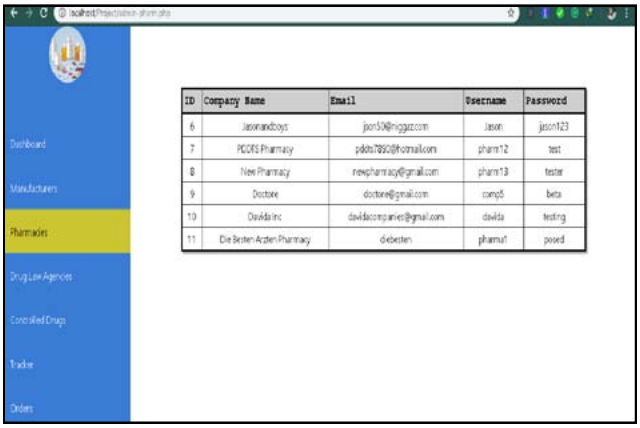

**Figure 25:** List of Pharmacies

The admin can also view the list of all the pharmacies registered on the system.

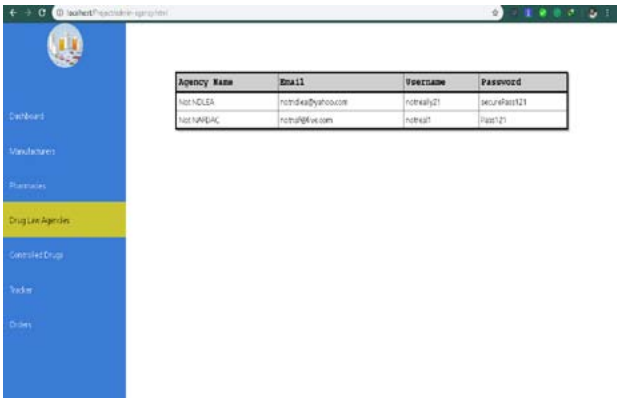

**Figure 26:** List of Drug Law Enforcement Agencies

The admin has a record of relevant drug law enforcement agencies that can be contacted for information on which prescription drugs have been added to the controlled list.

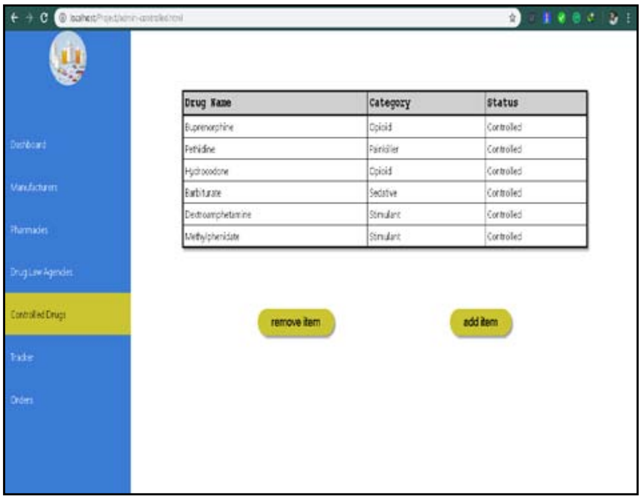


**Figure 27:** List of Controlled Drugs

After getting information from the law enforcement agencies, the admin can then maintain a list of controlled prescription drugs and put special care in tracking the delivery of those drugs.

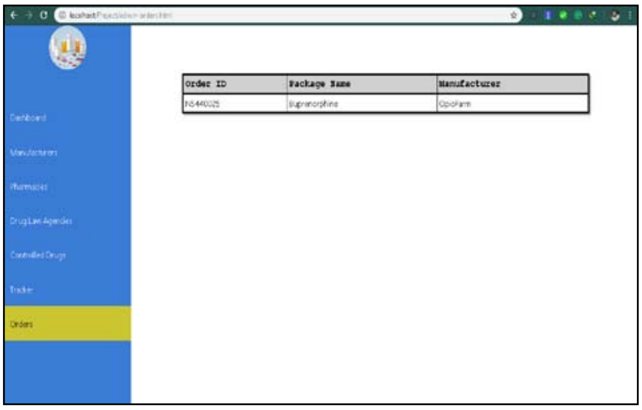


**Figure 28:** List of Orders Made by Pharmacies

The admin can view orders made by the pharmacies. The figure above shows the order made by the pharmacy created in figure 14.

## SUMMARY

The study investigated the distribution of prescription drugs, some reasons to track the distribution of these drugs, some reasons for drug abuse, the distribution chain in most developing countries and specifically Nigeria. The study then examined related systems and analysed their strengths and weaknesses using them as a basis to form its requirements and design. The design was then successfully implemented after going through testing and debugging.

## CONCLUSION

This study develops a system that can meet the dynamic requirements for tracking the distribution of drugs that are subject to drug abuse along the distribution network.

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