

E-Procurement System With Three Factor Authentication For Public Sector Projects In Nigeria

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Abstract— Many procurement systems are centralized hence giving authority to an individual third party to implement important processes within the system without adequate transparency. The lack of transparency raises issues concerning security, traceability, and fairness of the process as the bidders have to just trust the awarding authority to be honest. Public and industrial development can be greatly accelerated by a system that guarantees transparency, efficacy, cost effectiveness, ease of control, and monitoring. Due to the problems encountered in Single Sign on (SSO) e-procurement system, this study aims at using three factor authentication technology to mitigate fraud in the system. Multifactor authentication will ensure that more than one employee of the awarding authority will be involved in whenever the bid needs human interaction to reduce the risk of corruption. The Design Science Research Methodology (DSRM) is used in the study and HTML, React.js, PHP and MySQL software languages are used for the development. The result of the system shows that e-procurement system will be more efficient to manage, it will reduce corruption among trading partners.

Keywords— *E-Procurement, Security, Multifactor authentication, DSRM, Bids*

1. INTRODUCTION

In traditional Procurement, the bidders' details are kept manually on the shelves, and the evaluation process of tenders was erroneous, laborious and lengthy. Again, bidders were having difficulties to access the results of their bids. To improve their working environment, people around the world are becoming more and more reliant on technology, likewise technology is also developing. Since more businesses are leveraging the Internet and streamlining their procedures, e-business is being used by more organizations. As Electronic

Procurement (e-Procurement) systems are being utilized, procurement officers can work more productively and successfully by using online resources. Procurement involves obtaining goods and services by scrutinizing them closely and procuring them at the most reasonable price to meet the purchaser's needs in terms of quality, quantity, time, and location. The procurement departments are regularly looking for better ways to improve how the procurement process works. The use of such a system is of great importance, because it is very efficient in terms of easy storage of bids, tenders and easy access of responses from bidders. E-business solutions are continually being used in several business sectors [1] [2].

The merits of e-procurement include cost and time savings, better relationships between procurement agencies & vendors; real-time control of organizational spending; and the ability to manage data and information in a centralized manner. Despite all the advantages of e-procurement solutions, there are still some fraudulent activities that are still perpetrated by some staff of government and business organizations. These fraudulent activities include frauds perpetrated by employees, vendors or by a collusion between employees and vendors [3].

Web-based procurement software applications have made way for more complex and innovative solutions, like the smart contract procurement systems being used in Estonia, whereas developing countries, including Nigeria, continue to face challenges such as low levels of trust and transparency among procurement key players, the way procurement transactions is being handled is complex, there are insufficient systems for documenting transactions and even institutions that facilitate procurement are also prone to corruption. Olowu [4], asserts that institutions involved in public procurement have evolved into being not just excessively centralized and unaccountable but also opaque, dishonest, self-serving, and indifferent to the country's economic challenges. The problem with public procurement in Nigeria stems from deep-seated cultural and racial divisions, a tense political climate,

the way the procurement is structured to run within Ministries, Departments and Agencies, and the skill of personnel who have been trained in these tasks [5].

E-procurement systems typically involve a large number of transactions between multiple parties, including suppliers, vendors, and buyers. However, these transactions can be vulnerable to fraud and other types of financial misconduct. The fraudulent activities include collusion between employees and vendors to rip-off the organization financially, vendors defrauding the company, collusion among vendors within an industry to defraud the industry, employees defrauding their employers, vendors bribing employees to approve higher prices for products or services, bid-rigging, embezzlement, and submission of false claims and more [6]. With regard to the challenges mentioned above, an alternative approach for monitoring and carrying out all facets of public procurement that will enhance trust, transparency, and simplicity in the operations of the system is necessary.

2. LITERATURE REVIEW AND RELATED WORKS

2.1. Procurement Process

Procurement is an “overall process of acquiring goods, civil works and services which includes all functions from the identification of needs, selection and solicitation of sources, preparation and award of contract, and all phases of contract administration through to the end of the contract or the useful life of an asset” [7]. The Nigerian Procurement act of 2007 in part IV section 16 implies that all procurements should be “by open competitive bidding, in a manner which is

transparent, timely, equitable for ensuring accountability and conformity with this Act and regulations deriving therefrom, with the aim of achieving value for money and fitness for purpose, in a manner which promotes competition, economy and efficiency, and based on the law. [8]. The traditional paper-based method of procurement has been regular within the public sector; nevertheless, the traditional method needs a substantial amount of administrative activity and is susceptible to abuse due to insufficient security and transparency protocols. Therefore, the risk of tampering with procurement information and planned fraudulent practices existed with the traditional procurement process. [9]

The processes involved in public procurement in Nigeria begins by the owner organization that wants to give out the contract preparing the necessary contract documents based on the need to be satisfied before the contract that will be advertised to bidders. Each bidder is expected to submit a closed envelope as regulated by the public procurement act. The envelopes are then received and opened by a committee one by one in a public meeting. This process is seen in Fig. 1. The call for tenders’ team after examining and evaluating the technical documents of the bidders in private will examine the financial documents of the qualified bidders in an open meeting, this is shown in Fig 2. Finally, the successful bids are ranked, then the most advantageous bid (the lowest bid), make the review results available to the public and award the contract to the successful bid

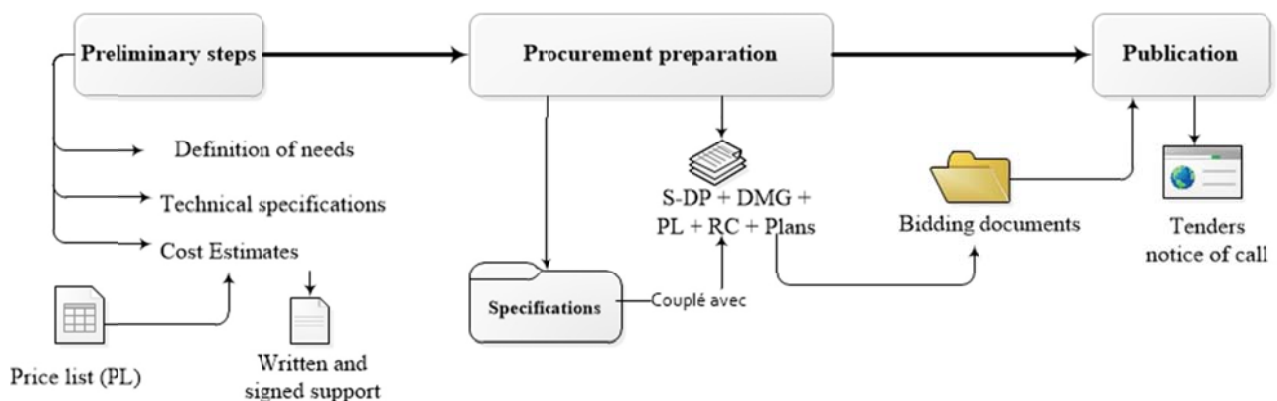


Figure 1. Process of preparation and publication of a call for tenders [10]

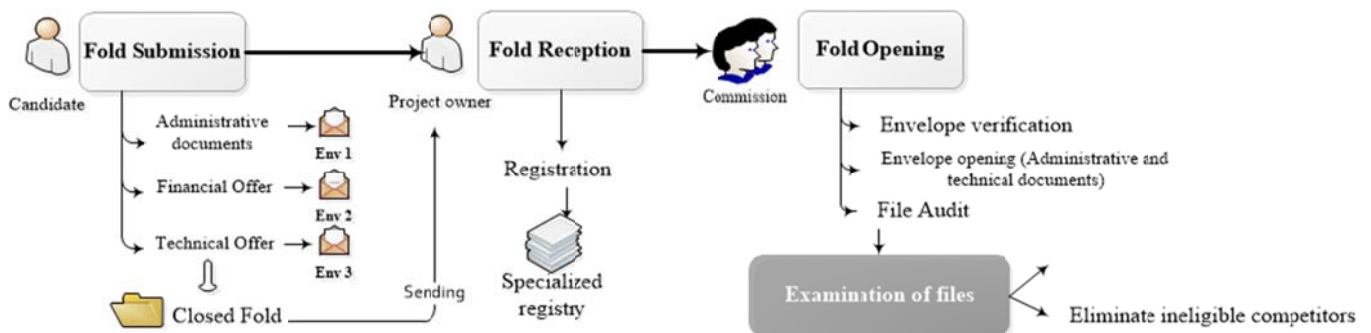


Figure 2. Processes of submissions, receptions and opening

2.2. E-procurement

According to Kishor et al [11], electronic procurement is defined as the use of Internet-based Information and Communication Technologies (ICT) to carry out one or more transactional or strategic procurement activities. We can describe these procurement activities as entailing the activities involved in the exchange of products or services between suppliers and buyers through the application of a digitalized system comprising the internet or any specialized software. E-procurement is taking a steady rise in providing an alternative to the current traditional procurement process by bringing advantages such as effectiveness in the sourcing of inputs and the reduction in cost. This has been done with adherence to the laid down requirements guiding the overall process. [12]

Different researchers on the topic have highlighted the benefits accruing from the implementation of an effective e-procurement system. Davila, listed the core benefits of an e-procurement system as cost reduction, meeting purchasing order at the stipulated time, and achieving the cycle time for purchasing the product [13], while Leipold opined those benefits from this system consists of openness and transparency, compliance and simplification of the overall process [14]. According to Thai, practicing e-procurement will provide quality bidding, efficient timeliness, cost saving, minimizing effort in doing business, reduce financial risks and technical risks, and finally increase supplier competition, which would lead to saving the cost of buying goods or services at high prices [15]. The bidding process presents the surest opportunity to explore e-procurement best practices due to the possibility of having bidding data that is open [16]. Additionally, it must be noted that the application of an e-procurement system ultimately creates an opportunity for the effective and proper handling of the entire procurement process.

With these benefits in view, it is also important to note that the e-procurement system also has its fair share of challenges. According to Nawi et al. [17], e-procurement systems are a relatively recent development in the business application area, and the lack of benchmark has enabled reference models to be developed, especially in new firms that are just beginning to learn of these systems' functionalities and their uses in their organizations. Like other technological solutions, these challenges, especially from the technology, legal, infrastructural, organizational and management aspects, are expected; hence practitioners and researchers are always on their toes to proffer continuous system improvements primarily through innovative research and planning.

In Nigeria, though there has been some attempt at adopting a fully operational e-procurement system, the system is still fraught in a lot of manual processes and procedures. In this procurement procedure, purchase orders are not usually processed in a timely fashion, and delivery dates are not met [6]. The procurement process is a very important aspect of Nigeria's

economic stability, since procurement accounts for approximately 80% of government spending at all levels [18], hence the need to get it right at all levels. According to Adebisi, The manual procurement methods used in government Ministries, Departments, and Agencies (MDAs) have long been plagued by a number of issues, the process of tender/order processing is characterized by excessive delays (around 4 to 6 months), extensive paperwork, delay due to multi-level inspection, physical threats to adequate bidders, contractors who create cartels to suppress competition and human interaction at every stage without complaint or due process, insufficient transparency, partiality throughout the bidding process, etc.

Different methods have been proposed by researchers to secure and make the procurement process more transparent. They include techniques like Blockchain, Public Key Infrastructure encryption, other MFAs are used [10] [19] [20] [21] [22] [23]

3. METHODOLOGY

3.1. Software development model and tools

The Design Science Research Methodology (DSRM) is used for this study, the approach mainly contains five stages which are; identification of the problem and motivation, definition of objectives for the solution, design and development, demonstration and evaluation. Software process models encompass the generic framework activities which include planning, designing, implementation, testing and deployment but each applies a different weight to these activities and defines a process flow that involves each framework activity [24] [25]. The process flow adopted for this project is incremental-iterative model because it is a simple progressive and repetitive method used in software project development.

The front-end is implemented using Hypertext Markup Language (HTML), Cascading Style Sheets (CSS) and JavaScript while the back-end is implemented using Hypertext Preprocessor (PHP), the database management system (MySQL) and Apache server.

3.2. System architecture

The architecture of the system as shown in figure 3 shows how the user interacts with the internet browser. The browser will send request to the webserver using PHP scripting protocols to get or store data in the database. The system is designed to provide the administrator with a platform to carryout users' registration, approve contracts, place offers and contract adverts, generate contract documents and send reminders. It also allows users to send and save contract documents, place bids and check available contract bids.

Figure 4 is the 3FA process; during the awarding authority's login phase, three employees of the awarding agency will need to sign in to access the

system using 3 different methods of authentication called 3-factor authentication (3FA), before they can enter data of for the contract for procurement that will be advertised into the system, view and evaluate the

bids submitted by vendors and finally select and upload the winner of the bid.

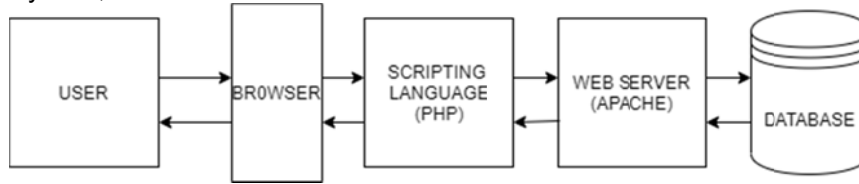


Figure 3. E-Procurement (BLOCKPRO) System Architecture

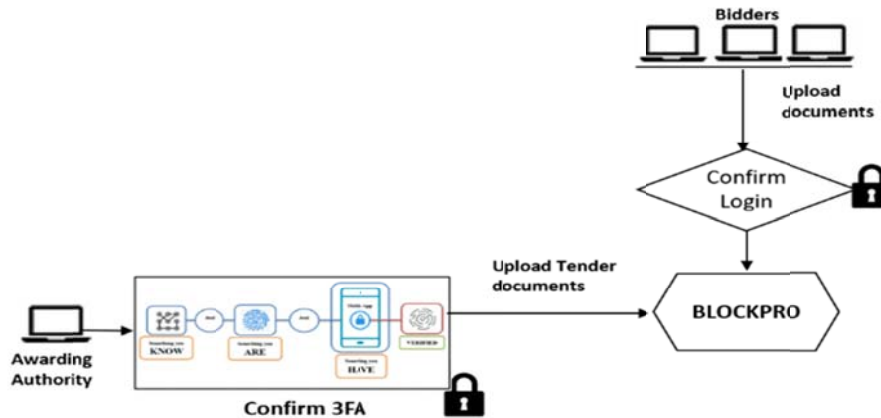


Figure 4. Three Factor Authentication (3FA) process

3.3. Database Design

The system requires a robust database in order to enable the search, sorting and retrieval of data which suits the system architecture. To achieve this, a relational database management system called MYSQL is used. XAMP server is used to host the database locally and helps in accessing data to ensure that multiple users can use it concurrently. The MySQL database stores all the data in this application. The reason for choosing MYSQL server is because it is very fast, easy, can store very large records and can easily be configured. In figure 5, Unified Modelling Language (UML) is used to show the Entity-Relationship (E-R) models between some entities in the database.

3.4. Design of modules and user interfaces

The system components are developed as modular units and tested to meet the desired system requirements and objectives. The modules are:

1. Registration and authentication
2. User's Management
3. E-bidding
4. Notifications

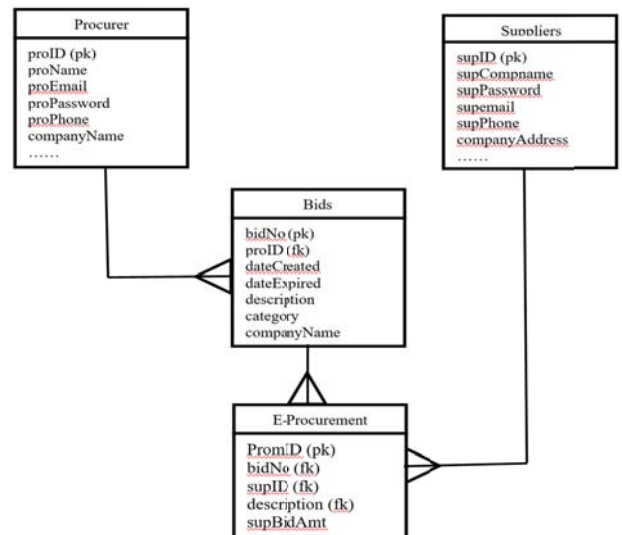


Figure 5. Database E-R Model

3.4.1. Registration and authentication system

On registration, users will register a unique username. Figure 6 is an authentication module that receives the unique username from users via the login system and compares it with the record on the database. If the username is found in the database, then the user is logged into the system, else an error message is displayed requesting correct login details.

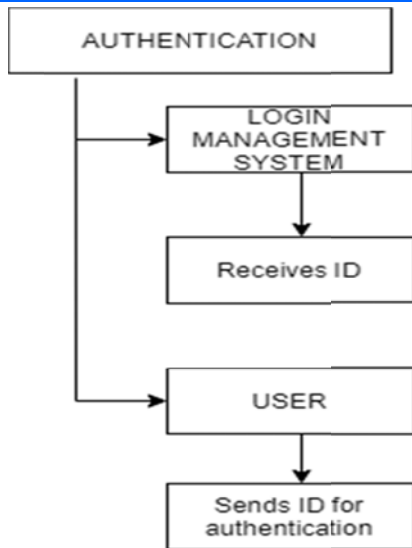


Figure 6. Registration and authentication module

The user registration enables users to register their information and login details before they can use of the system. Figure 7 is a design of the user registration interface.

Figure 7. User Registration Interface design

The bidder's login page allows only registered users to be able to access granted features of the system. Once they enter the correct email and password, the user is granted access based on privileges. Figure 8 shows the login interface design.

Figure 8. Bidder login Interface Design

The awarding authority's login interface is a 3-step process that allows 3 users to enter their authentication information at different levels of access. An algorithm for a multi-level authentication system that involves three levels of users is displayed in Figure 9. The security measures are the Sign-on authentication, biometric authentication and One time Password (OTP). In order to gain access, the first staff will enter his username and password and if correct, another layer will open requesting the second staff to place his thumbprint for capture and If that is also successful then an OTP will be sent to the third staff that will enter it into the interface that will be open for him. If the information is not correct, they will be given another chance to a maximum of five chances before the system locks up for 24 hours.

3.4.2. User management

The user's management module enables the user to save, modify, update information to the database as depicted in figure 10.

3.4.3. E-Bidding

The e-bidding module is shown in figure 11 below, in this module, the procurer creates the contract and advertises for bidders. The bidders place bids once they register and log into the system within the period that the contract is available. Once the period for collection of bid ends, the bids are opened, then the qualified bidder is offered the contract.

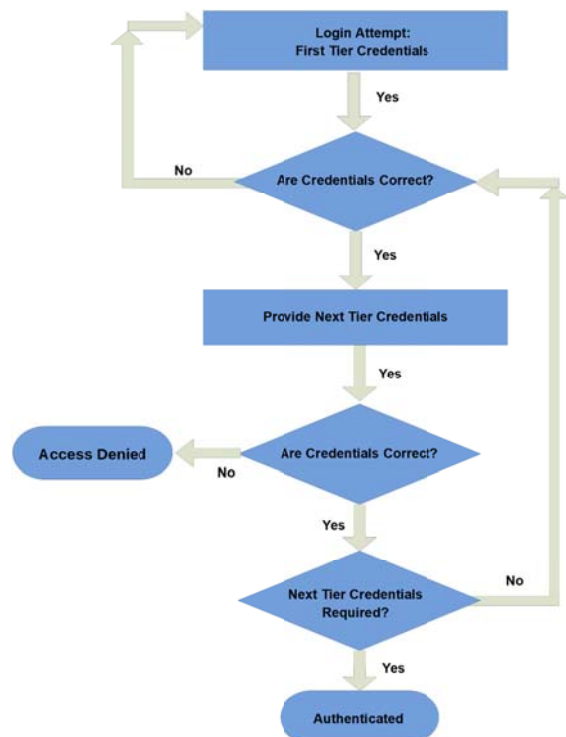


Figure 9. Workflow of Multifactor authentication

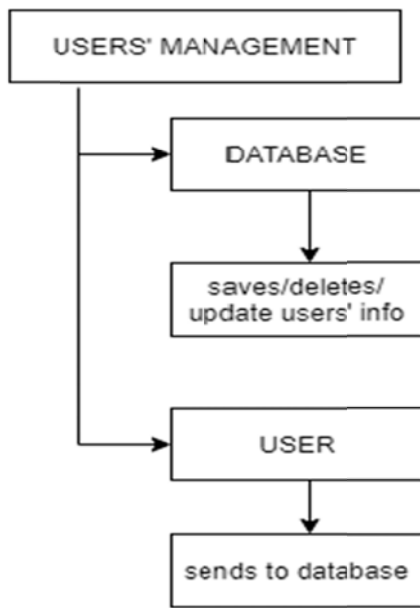


Figure 10. User management module

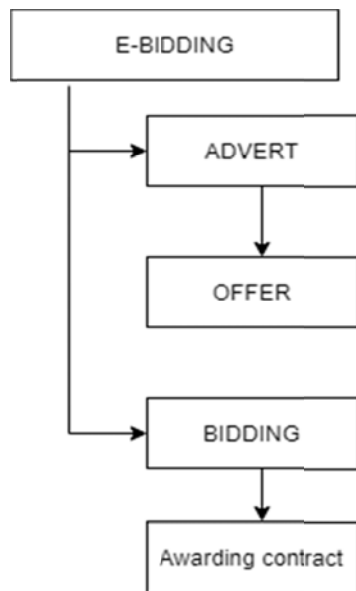


Figure 11. E-bidding module

3.5. Use-Case Design

A use-case is a collection of potential interactions between people and systems in a certain setting that are all aimed at achieving a specific objective. Here different use-cases are depicted for the administrator and supplier.

3.5.1.E-Bidding

The administrator has access to all the modules and other related activities of the system. The admin can update, delete or modify data in the system. The figure 12, shows the roles of an administrator.

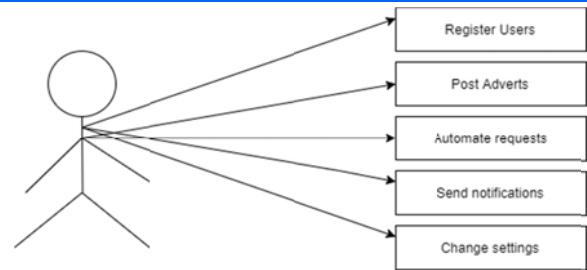


Figure 12. Use-case model for Admin

3.5.1.User-Supplier

The user who is a supplier can register and login into the system to view and place bids. Figure 13 shows the use-case diagram for the users.

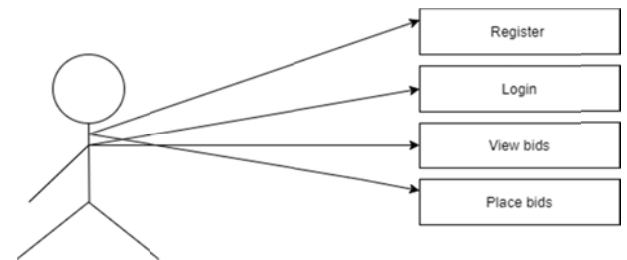


Figure 13. Use-case model for vendors

4. RESULTS

After implementation of the system, several graphical user interfaces (GUI) are created that will allow users access into the system and also to gather required information. A GUI displays objects that convey information, and represent actions that can be taken by the user. Some of front-end interfaces include the administrator, User registration, Login and Dashboard user interfaces.

The administrator page is where the admin controls the various activities of the website. It is linked to the admin module. Figure 14 shows the admin page.

In the user registration page as shown in figure 15, users can register and submit their information into the database of the system. It is the registered information that will be verified and used to allow access into the e-procurement system.

The login page is the module in which registered users can login into the system as shown in figure 16.

After logging in, the users' dashboard page comes up. It shows various activities that can be carried out at a glance. Figure 17 shows the dashboard page.

The database implementation involves installation of database software, configuration and customization, running, testing, integrating with applications, and training the users. The database was implemented as shown in the images below. Figure 18 shows the schema of the database in MySQL.

The test plan was designed to test for functionality, security and usability of the application.

A snippet of the Test plan is shown in table 1 below;

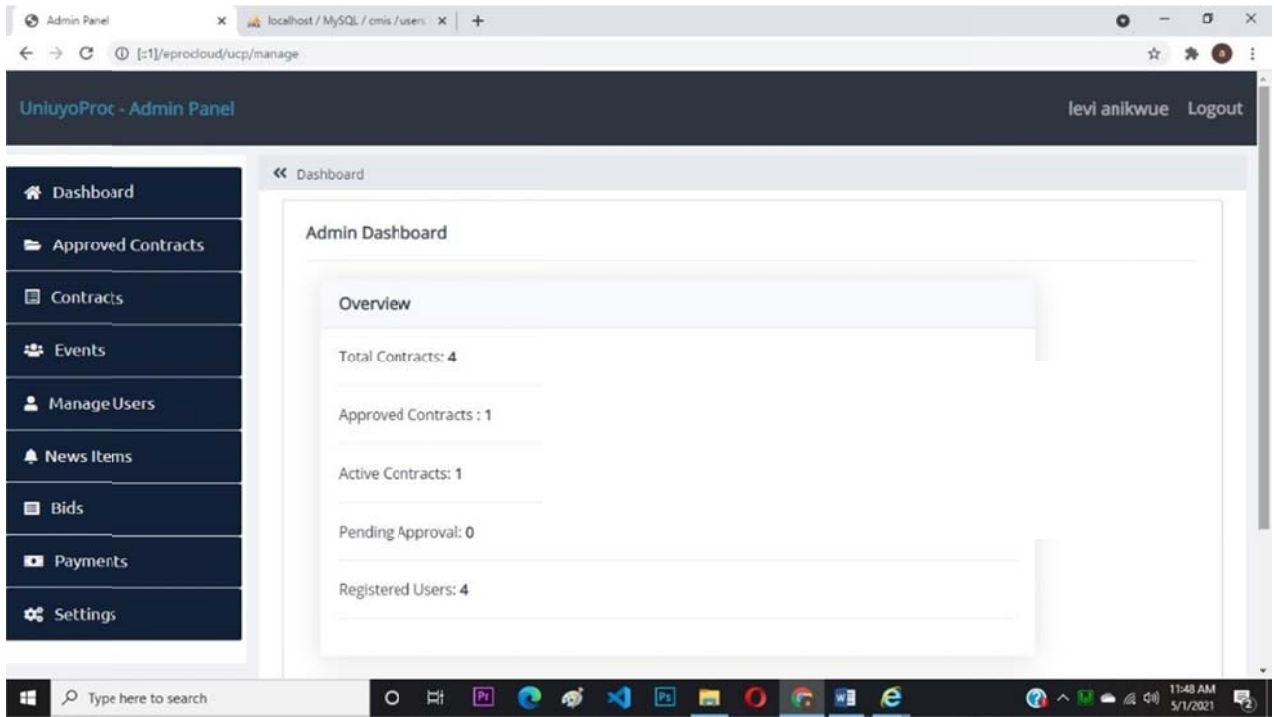


Figure 14. Admin Page

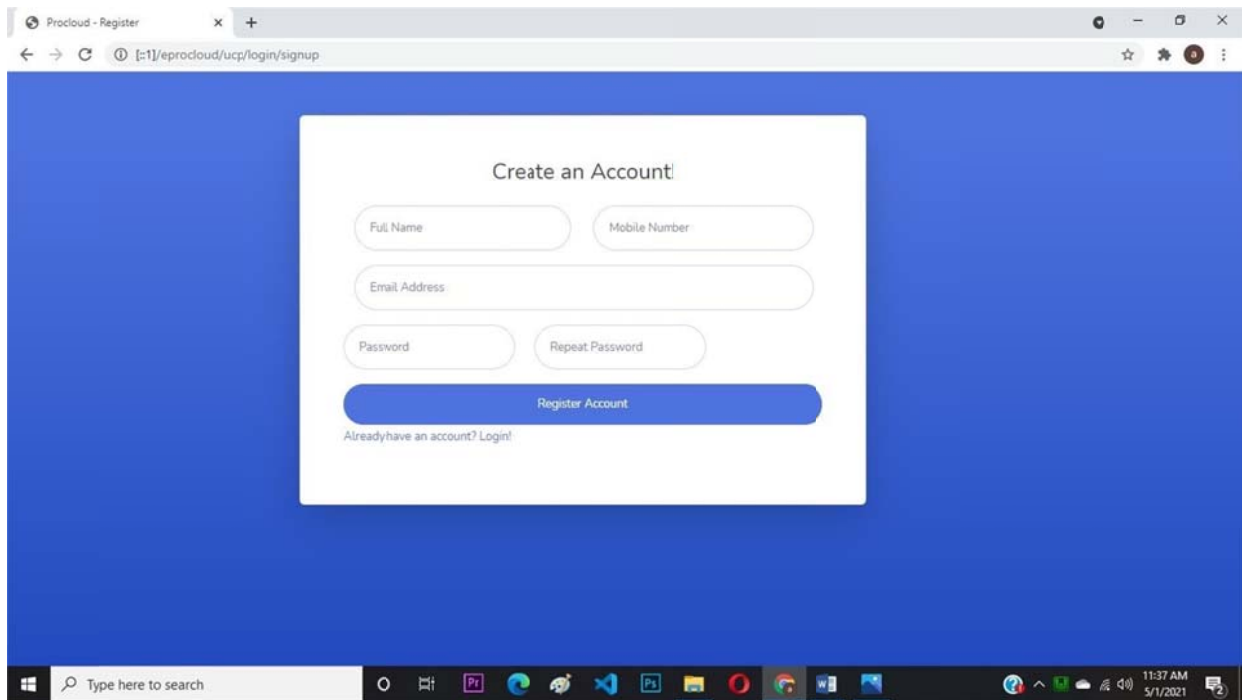


Figure 15. Registration page

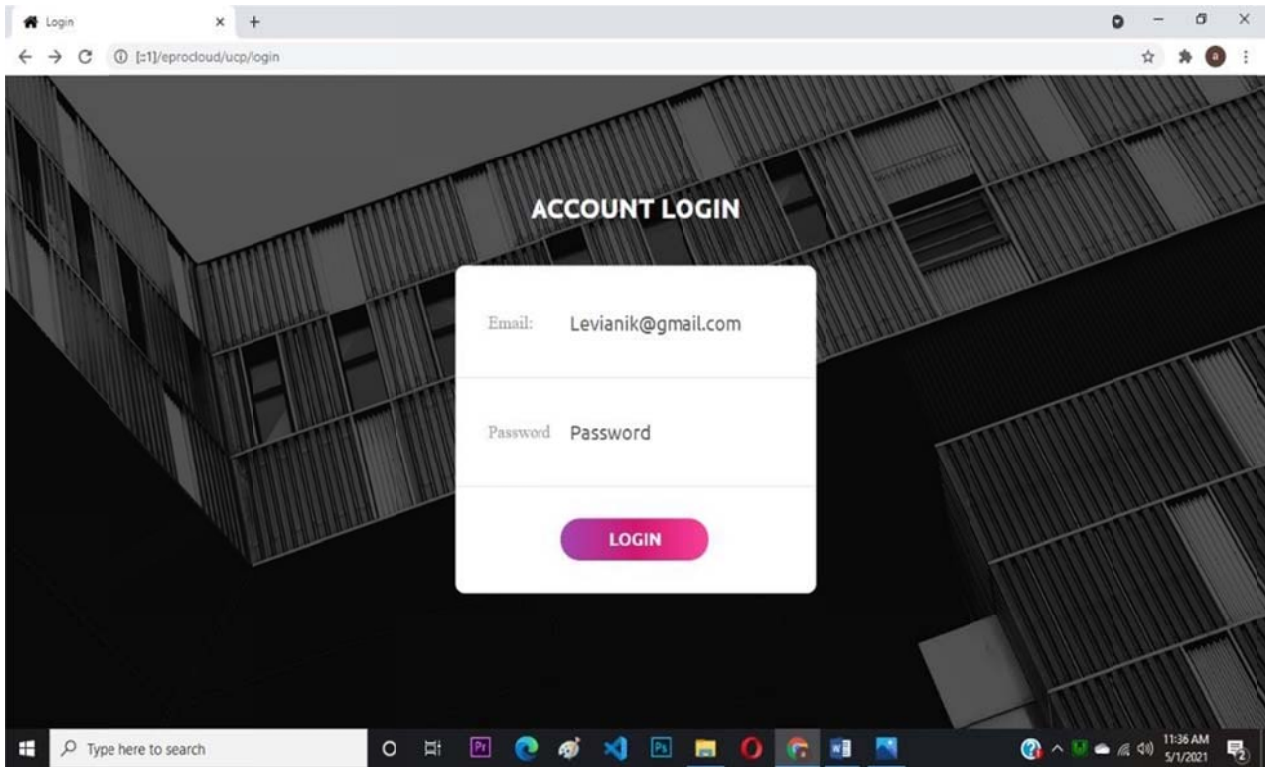


Figure 16. User login page

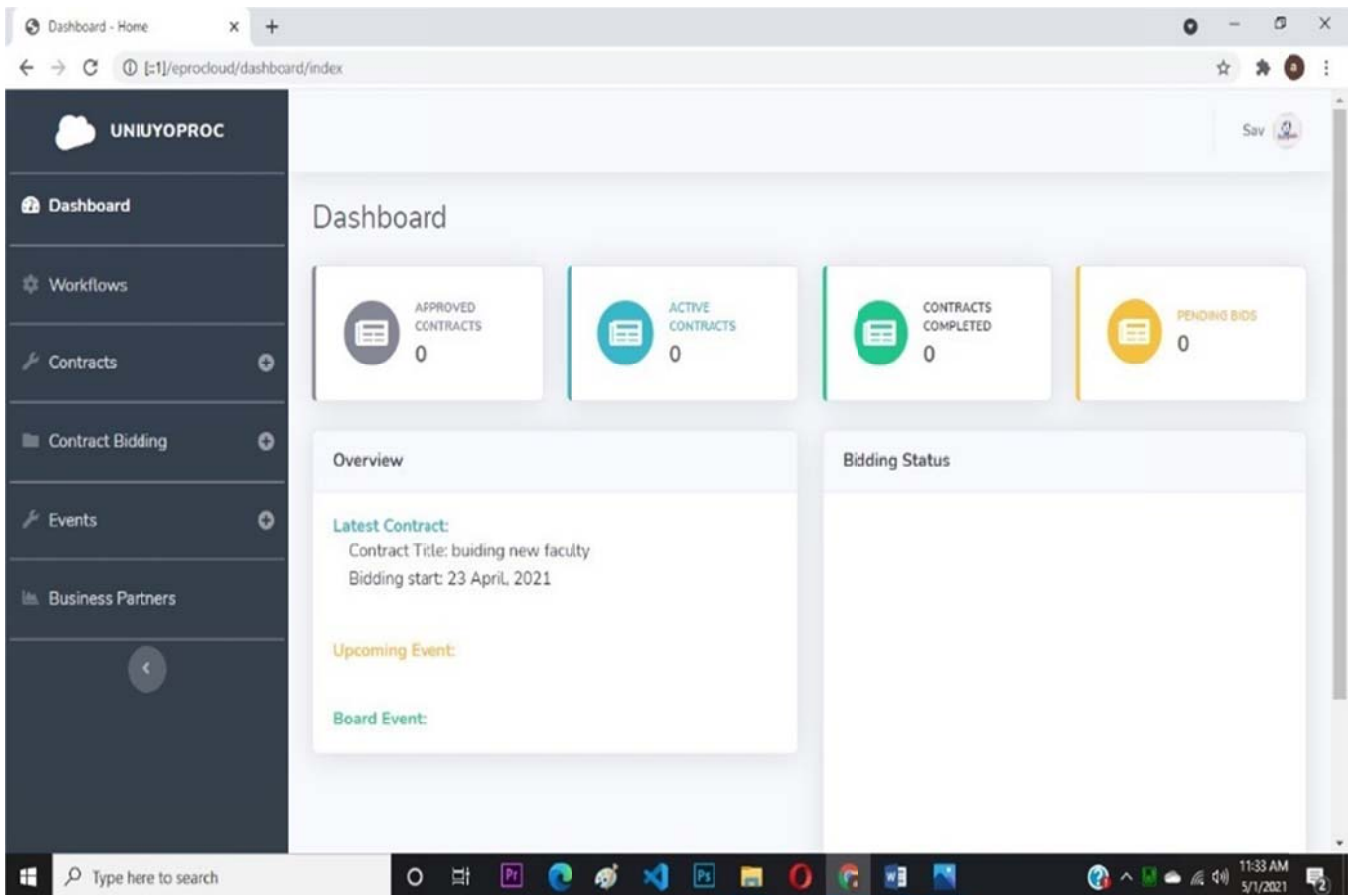


Figure 17. Dashboard Page

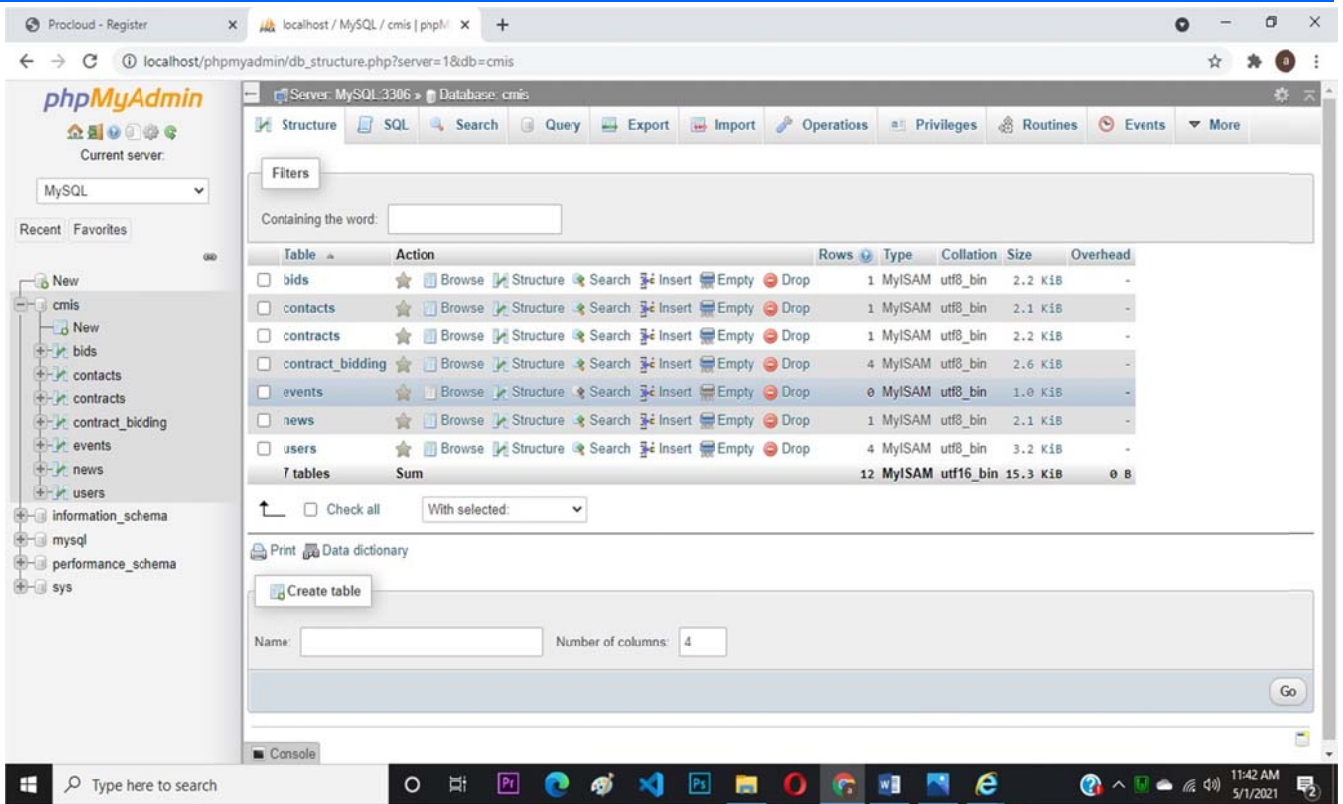


Figure 18. Schema of Database

Table 1: Test Plan

Test Case Type	Description	Test Step	Expected Result
Functionality	First Name should accommodate up to 30 characters	Input up to 30 characters	All 30 characters in the request should be appropriate
Security	Verify password rules are working	Create a new password in accordance with rules	The user's password will be accepted if it adheres to the rules
	Verify password rules are working	Create a new password that is not in accordance with rules	The user's password should not be accepted and an error message displayed
Usability	Ensure all links are working properly	Have users click on various links on the page	Links will take users to another page according to the on-page URL

5. DISCUSSIONS

To evaluate the functionalities of BLOCKPRO, four conceptual tendering scenarios for similar fixed-price construction projects were designed and tested. Four general contractors were assumed to be prequalified to perform the work. In each scenario, the general contractors participated through a competitive

tendering process. The results are discussed in terms of how the proposed framework addresses transparency, security, and legal challenges. For multi-level authentication system to be successful, one has to know the username and password, have the device to know the OTP and the fingerprint staff should be physically present to gain entry. The analysis below

depicts a higher security level with 3FA hence we conclude that by using multi-level authentication technique, we can improve the security measure.

5.1. Execution Time for Multi-Factor Authentication Layer

The execution time for MFA was also analyzed. Software testers are used to test the system's MFA for 20 trials. The goal of this step is to measure the overall execution time for verifying users based on the 3 major

layers: password entry, fingerprint capture and OTP delivery and entry. The execution time is measured per millisecond for a different number of users per each experiment. After the trials, the execution time for the password entry and verification has an average execution time of 4.62 s. The fingerprint detection time is averagely 5.065 s while it takes averagely 5.47 s to enter the OTP. This added averagely to a total of 15.16 s to gain access into the system.

Let us take three levels such as organization level, team level and user level and two outcomes such as success and failure to determine probability of breaking.

Let A be the sample space:

*Two outcomes of event are success S and failure F. To break this, one has to succeed in three times repeatedly. Hence, Sample Space $A = \{SSS, SSF, SFS, SFF, FSS, FFS, FFF, FSF\}$
 $\rightarrow n(S) = 8$ where $n(S)$ is the cardinality of set S*

Assuming:

- i. Success and Failure probability at each level is independent and*
- ii. The Probability of Success at each level is 'p'*

Therefore, the success of breaking a Three factor authentication (3FA) given by the probability of the event SSS is defined as $P(E)$. Note that $P(E) = p^3$.

Hence Failure in breaking the 3FA system is $1-P(E) = 1-p^3$.

For example, if probability of success at any level $p=0.1$

Then, the probability of breaking the 3FA (three level) authentication (S) = 0.001 and the probability of not breaking MLA (F) is $1-0.001 = 0.999$

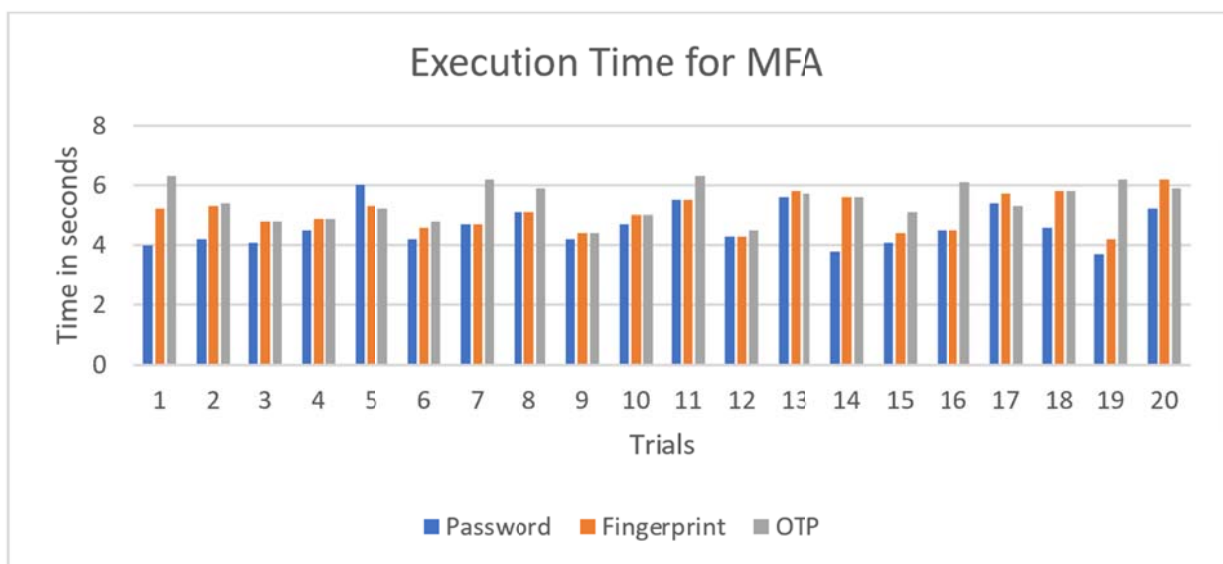


Figure 4. Execution time for MFA

5.2. Detection Performance for biometric verification

For most security applications and methodologies that apply different methods of protection and authentication, the measurement of detection performance is considered a major reference and guide for the efficiency of the proposed algorithms. In this section, the false-positive (FP) and false-negative (FN) rates are measured, where the false-positive rate reflects the percentage of detecting normal users as intruders, while the false-negative rate reflects the percentage of intrusions that succeed in penetrating the biometric security layer of the system (fingerprint). There was 3% FP for 20 different users. The false-negative (FN) percentage refers to the successful attack percentage that succeeds in gaining access to information from the platform, the FN rate was 0% with the fingerprint authentication for 20 users. In general, the proposed methodology and algorithm using MFA methods achieved high performance in detecting suspicious users and intruders to prevent any intentional attacks on the cloud server or cloud services. The performance evaluation of the proposed MFA framework and algorithm are conducted based on quantitative and qualitative measures to assess the success rate of attack prevention. Regarding quantitative measures, false-positive (FP) and false-negative (FN) rates are measured to identify the overall performance of the proposed MFA framework and algorithm. In addition to these quantitative metrics, the following qualitative factors were considered.

- Usability testing: Usability testing can be conducted to observe users as they interact with the MFA system. This can help to identify any areas where the system is confusing or difficult to use.
- Scalability: The system should be able to scale to meet the needs of a growing organization.
- Flexibility: The system should be flexible enough to accommodate different security requirements.
- Affordability: The system should be affordable for the organization

6. CONCLUSION

The use of 3FA to implement an e-procurement system has increased the transparency and security involved in the tendering process. This use of this system will boost trust among contractors as they are aware that multiple staff of the awarding authority will be involved in the opening of bids hence creating a more balanced system.

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