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Towards a Secure Multifactor Authentication Database Model for e-Procurement in Production Environments

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ABSTRACT

Procurement is one of the pillars, in fact, at the heart of goods production. However, traditional procurement is manual and beset with manipulations, forgery, missing documents, tattered documentation or outright fraudulence and so, most procurement in this digital age is electronic (e-Procurement), which still needs to be secure. To the best knowledge of this study, there is sparse information on secure multifactor authenticated e-Procurement database model for production database. Hence, this study is aimed at modeling a secure multifactor authentication database for production environments. Procurement requirement gathering for the study was gotten from literatures. Case study was built around the procurement data gathered, entities were determined using four test for entity validity. Entity-Relationship (E-R) diagram was drawn with MySQL Workbench from which Relational Model (R-M) was generated through five rules for converting an E-R to R-M model. Problematic many-to-many (m:n) relationships were resolved and the transformations of primary keys to foreign keys from one entity to the other were determined with many-to-one (m:1) relationships. The derived Relational Model became the third normal form for the modeled e-Procurement database. The e-Procurement Relational Model is the database schema.

Keywords: e-Procurement database authentication, Multifactor authenticated, digital, E-R e-Procurement model, Problematic relationships,

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INTRODUCTION

Integrating **e-procurement** into a **production environment** digitizes and automates the sourcing, ordering, and management of direct materials. This connection eliminates production bottlenecks, reduces inventory carrying costs, and links real-time manufacturing demands with supplier networks through centralized **B2B platforms**. The relationship between e-procurement and a production environment transforms supply chain operations.

2. RELATED WORKS

Kühne (2004) reiterated the fact that, anytime a new research area gains momentum the task of defining its central notions needs to be addressed, which takes communities surprisingly long time spans to agree on what the notions should be encompass in order to facilitate communication among community members. In Kuhne's review, in respect of model driven development, he quoted a model in term of three features: mapping (based on an original), reduction (only reflects a relevant selection of the original's properties) and pragmatic features (needs to be usable in place of the original with respect to some purpose). In another review, he also quoted a model as information on something, created by someone, for somebody and for some purpose. Moreover, a model was defined to be a small but exact copy of something; a description or analogy used to help visualize something that cannot be directly observed, a pattern or figure of something to be made or a theoretical projection of a possible or imaginary system Ergo, the "original" of which does not have to exist.

The two kinds of models when talking about basic notions such as "metamodel", are token (a map using UML where each individual model in a chain of models always directly characterizes the original) and type models (uses object properties to classify objects, mostly used in model-driven development and capture the universal aspects of an original's elements). A model containing types still may be used as token model for an original. A metamodel is truly a model with a reduction feature with respect to the language it models as a token model and it is sufficient to recognise that it universally captures all models that may be instances of it.

According to Starting Point (2006), a model can come in many shapes, sizes, and styles. It is important to emphasize that a model is not the real world but merely a human construct to help us better understand real world systems. In general all models have an information input, an information processor, and an output of expected results. In its review, three key features in development of any model were identified, vis-a-vis, simplifying assumptions must be made, boundary conditions or initial conditions must be identified and the range of applicability of the model should be understood. Starting Point reiterated that a well developed model of a real-world system will likely contain aspects of conceptual models (highlighting important connections in real world systems and processes, used as a first step in the development of more complex models), interactive lecture demonstrations (physical, easily observed and manipulated models of systems having characteristics similar to key features of more complex systems in the real world), mathematical and statistical models (used in solving relevant equation(s) of a system or characterizing a system based upon its statistical parameters), and visualization model (anything that can help one visualize how a system works).

A model is a representation of structure in a physical system and/or its properties, which is divided into four types, each with internal and external components: systemic structure, geometric structure, temporal structure and interaction structure. Furthermore, Quay and Frangos (2009) generalised that since models approximate natural phenomena, they could be inherently inexact, the mathematical description can be imperfect and/or its understanding may be incomplete, the mathematical parameters used in models are often uncertain and the initial or starting conditions and/or the boundary conditions in a model may not be well known yet, they are the only means to extrapolate to large spatial scales or predict the future. Model accuracy is assessed by **calibrating** and **validating** models, **sensitivity** of the model parameters output quantify the uncertainty of the model output.

Moreover, Hestenes (1997) corroborated that, scientific practice involves the construction, validation and application of scientific models, so science instruction should be designed to engage students in making and using models. Models provide an environment for interactive student engagement, enhance systems thinking abilities, allows the conduct of performance sensitivity studies to assess how changes in key system variables alter the system's dynamic behavior, allows the conduct of experiments related to the Earth System without altering and potentially harming the actual earth, knowledge gained while using models and the understanding of model development and implementation are transferable to other disciplines related to the Earth system.

Azumuta (2020) confirms that customers rely on the efficiency of a business, so it makes sense to invest in production planning. Manufacturing companies can save a lot of time and money by planning and organizing well. Several effective production planning tips include prediction of demand: Procurement of many materials requires a longer lead time than the typical customer order, most manufacturing companies rely on past demand to estimate their procurement needs in advance. Management of production inventory is another production planning issue: lean manufacturing is a way of production mode that focuses on minimizing waste while maximizing productivity, which fosters shorter lead times, lower operating costs and improved product quality. Furthermore, ideal production planning involves monitor and control: monitoring can detect and correct problems using IoT software platforms with connected sensors in production chain enabling real-time monitoring of production processes. Employee Training makes production much more efficient when workers know what is expected of them, which ensures easier quality control monitoring when processes are predictable and repeatable. Communication company's determined production schedule to the operators using the appropriate visual display software which speeds up the process.

Studysmarter (2022) defined **production** as the process in which diverse companies combined land, labor and capital to produce products or render services using a particular production strategy to maximise profits. The most logical step to take for cost minimization if the company is purchasing raw materials at a high cost is to switch suppliers. Firms might either use labor-intensive factories or capital-intensive factories, depending on which one helps them maximize their profit. Production maximises the use of resources, generates employment opportunities and attain economic efficiency if the products and services created are delivered to the right customers. In addition, choose a supplier who supplies raw materials at low prices. Primary, secondary, and tertiary are the types of production. A firm's efficiency is measured by looking at how the firm utilizes its factors of production, which are tangible and intangible resources that are used by the firm to produce goods and services.

Land, labor, capital and entrepreneurship are the factors of production, the proper utilization of which is significant to a company's continued growth. An entrepreneur combines all of the resources to produce a product or service through wise decisions. If the capital of a firm is fixed but labor keeps increasing, growth happens initially but at a point, growth remains constant and then decrease. If a firm decides to increase its fixed capital with an increase in labor, the output will likely grow along because the workers will have more capital available to them for the production process. When labor and capital are can change, firms can choose different combinations of them to generate output, whether more labor and less capital or more capital and less labor, depending upon what helps them to yield maximum profit.

According to Maiti (2020), **Production is a process of value addition, which is developed to transform a set of input elements, such as labor, raw materials, capital, energy, and information, into finished products and services of proper quality and quantity. Efficient production processes** can lead to cost savings, increased competitiveness, and higher profits for businesses. Production is a fundamental aspect of the economy that drives innovation, development, and progress. Maiti categorized factors of production into four: nature (land, water, and other resources), capital (capital goods like machines, equipment, raw materials), labor (Human effort) and enterprise (activity that combines all the other factors of production into a product or service for the consumer market), which determine the cost of production and how wealth is distributed in an economy. Unit or job type production, batch production, mass production, and continuous production or process production are the types of production.

Suitability of these types of production for deployment in any scenario is decided by the nature of the product being produced, demand for the product on the market and supply of raw materials. The production function is the expression of how variables like raw materials, its quantity, number of machinery, the number of finished products are combined to produce a certain level of output. Production planning and control cater for the determination and regulation of the Production processes and functions like routing, scheduling, dispatching, which are crucial activities for ensuring that production runs smoothly and efficiently, meeting quality standards and deadlines. Effective production, planning, and control are essential for optimizing resources, reducing costs, and maximizing productivity. The general framework for the production process often includes design and planning, sourcing and procurement, manufacturing/operations, quality control, packaging and labeling, delivery and distribution. An efficient production process is crucial for businesses to succeed because it ensures cost management, quality control, productivity and meeting customer needs.

Simfoni (2026) defined e-Procurement as a digital B2B business process that utilizes internet technology to centralize purchasing workflows and streamlines business transactions like procuring goods and services to reduce costs and improve purchasing processes. e-Procurement software integrates spend analysis, eSourcing, e-auctions, procure-to-pay (P2P), marketplaces, and contract management. It varies from e-commerce in that it utilizes a supplier's closed system, which is usually only accessible to registered users so, it creates a direct relationship between a company and a supplier, making interactions like bids, purchase orders, and emails easier. The components of e-procurement are management of indent, creating an RFP, submission of a bid, opening and judging of bids, e-Auction, selection and finalization of vendors and contract and vendor management. Benefits of eProcurement include savings, shorter purchasing cycles, enhanced inventory management and transparency.

The steps in traditional procurement process are requirement definition, sourcing, solicitation, evaluation, contracting, and contract administration while e-procurement's process are e-informing, e-sourcing, e-tendering, e-auctioning, and e-ordering. Functions of e-Procurement are reduction of mistakes and freeing up resources by automating operations; simplifying the procurement cycle by improving communication between stakeholders and partners; provisions of a consolidated platform for monitoring and auditing all procurement activities, offering stakeholders and management a single point of contact; provides suppliers, managers, stakeholders, and partners with real-time updates as well as the ability to organize and preserve procurement data; and facilitates collaboration amongst numerous partners and stakeholders.

Procurement personnel can also automate a variety of tasks, processes, and procedures, such as policies, contracts, and vendor relationships. e-procurement managers can identify which users will have access to which things, limit who has access to the budget data, control who has the authority to approve purchase requisitions, as well as who has the authority to examine and pay bills. There are four compelling reasons to build an e-procurement platform vis-à-vis time savings, cost savings, process optimization, and improved control. The procedures of vendor selection, payment conditions, contract discussions, and items purchase are all part of the e-procurement strategy. e-procurement is growing more popular, assisting firms in being more efficient.

1) *According to GEP(2024), Electronic procurement, also known as e-procurement, is a strategic and digitalized business-to-business (B2B) process involving the requisitioning, ordering and purchasing of goods and services online. It is a dynamic process with higher transparency. It utilizes a supplier's closed system that is typically available to registered users only where suppliers and customers interact through electronic bids, purchase orders and invoices, thereby eliminating traditional paper-based orders and invoices. It involves all core tasks including supplier evaluation and selection, contract management, electronic orders and payments. Stages of e-Procurement include e-sourcing, e-tendering, e-auctioning, and e-ordering. The key benefits of adopting e-procurement are improved efficiency, enhanced choice, increased transparency, boosted compliance, and improved reporting.*

Moreover, Manutan (2022) defined e-procurement as "the centralised management of a company's procurement and supply chain using an electronic platform". It is also sometimes known as supplier exchange, which is only suitable for business purchases, (Business to Business (B2B)) sector and not for the Business to Customer (B2C) sector, which concerns only personal purchases. It enables the purchases to become paperless for all or part of the Procure-to-Pay process (P2P), which has three main phases: selection of goods, sending the order and invoicing and payment. e-Sourcing is different from e-Procurement in that, it focuses on the Source to Contract (S2C) process, which involves using digital tools to digitise the Source to Contract process (the identification and selection of suppliers).

e-Procurement is mainly the domain of four different groups within companies: the procurement department which defines and optimises the procurement strategy, the end users who place the order, the person who approves orders and the financial and accounting departments, which reconcile orders and invoices and make payments. e-Procurement can be broken down into three main steps that are specific to the Procure-to-Pay process vis-à-vis selection of goods, sending the order and receipt of the invoice.

Selection of goods involves browsing online catalogues, a Punch-Out or a B2B vendor website for supplier's entire offers including contractual conditions which are eventually sent into approval process. Sending the order pertains to the approved purchase request becomes an order sent to the supplier electronically, which a supplier uses to instantly begin to prepare the products for delivery. Receipt of the invoice, paperless and trusted third party certified PDF file or any electronic document, which is automatically reconciled with the order and triggers the payment. The objectives of e-procurement include cost savings, elimination of low value-added processes, shortening the overall timeframe and controlled spending.

3.THE SECURE MULTIFACTOR DATABASE MODEL FOR E-PROCUREMENT IN A PRODUCTION ENVIRONMENT

3.1 Case Study for the e-Procurement Database Model in a Production Environment

The information on e-procurement, used for this study, was gathered from the literature. When a particular organization, A wants to procure goods and services from another organization, B, if she is a new buyer, there is the need to register. During registration, the form filled by the buying organization's admin would have made her supply username and password, fingerprint and face capture (passport photo), iris, and palmprint, which will have been persisted in the database. After registration, registration confirmation and login details would have been sent to the Organisation A's inbox. Organisation A logins with the details sent to her inbox and the two or more access control means. After being verified, authenticated and authorized, she selects a supplier, out of many choices, through e-tendering and negotiation to achieve the most attractive deal. Such buying organization A, selects goods and services by browsing the selling organisation's (B) online catalog or websites for entire products and contractual conditions. The selected goods and services (requisition) will then be submitted for approval on the purchasing Organisation's (organization A) procurement platform.

The submitted purchase request, when approved by the Administrative Officers, becomes an Order. The Order is then sent to the Supplier electronically or through an e-market place, which is then used by the supplier to pick requested goods and services for delivery. After the Order has gotten to the Supplier, the Supplier respond to the buyer with an electronic invoice. On receipt of the electronic invoice, which is a trusted third party certified PDF file or any electronic document, which is automatically reconciled with the order, triggers the payment process. The payment is made, receipted and then, goods and services are delivered. The paying organization checkmates the supplies made with the invoice content to confirm conformity between the two. If there is disparity, complaint is raised immediately else, delivery confirmation is done.

3.2 Determination of Entities for Modeling of the Production e-Procurement Database

The entities for this modeling must first be determined. There are four tests for determining the valid entities to consider for modeling in this scenario. First test, any object or thing that will be elected as an entity must be important to the procurement and the organization ordering. Second, such entity must be uniquely identifiable, must have an identifier that cannot be shared by two entities. Third, such must have more than one attributes and finally, it must have more than one members. When an entity passes these four tests then, it is a valid entity otherwise, it is dropped. In the case study in section 3.1, the valid entities for the modeling of the e-procurement database are ACCESS_CTRL (Access control), BUYER, SUPPLIER, PRODUCT, PURCHASE, ADMIN, APPROVAL, REQUISITION, ORDER, TRANSMISSION, DELIVERY, INVOICE, PAYMENT and RECEIPT.

Each of these entities has its own attributes, one of which is the unique identifier, the primary key. The ACCESS_CTRL has acc_ctrl_id, acc_ctrl_desc, acc_ctrl_type. The BUYER has buyer_id, buyer_name, buyer_address and buyer_email, buyer_phon_contact and buyer_whatsapp_no as attributes. The SUPPLIER has attributes: supplia_id, supplia_name, supplia_address, supplia_email, supplia_phon_contact, and supplia_whatsapp_no. prod_id, prod_category, prod_srn, prod_qty, prod_item_rate, prod_mfd_date and prod_exp_date are PRODUCT attributes. PURCAHSE entity has attributes: purch_id, purch_date, purch_desc, and purch_amt. DELIVERY has as attributes, delvry_id, delvry_date, delvry_time, delvry_officer, and delvry_receiver, delvry_status, delvry_source and delvry_dest. ADMIN has admin_id, admin_fname, admin_mname, admin_lname, and admin_sign as attributes. APPROVAL entity has apprva_id, apprva_date, apprva_time, apprva_officer, apprva_status and apprva_sign. req_id, req_date, req_officer, req_status and req_amt are attributes for REQUISITION. ORDER has order_id, order_desc, order_date, order_amt and order_officer_sign. The entity, INVOICE has attributes: invce_id, invce_desc, invce_date, invce_amt. TRANSMISSION entity features trans_id, trans_date, trans_stat_time, trans_end_time while PAYMENT has pay_id, pay_date, pay_bal and pay_amt. RECEIPT entity has recipt_id, recipt_name, recipt_desc, recipt_date, and recipt_amt.

3.3 Requirements for the Secure Multimodal e-Procurement Database

Secure design principles requires that security features are factored in at designs time of a system, be it software or otherwise. This helps to proactively identify certain upcoming threats and the risks they might impose on a system as well as the needed implementation of security controls to counter, remove and manage the risks involved. The concerns here should include possibly prevention (secure the computer from being attacked and damaged), detection (discover when, how, and by whom an attack occurred), and recovery (stop the attack, assess the damage done, and then repair the damage) from a security attack. The database related threats in e-Procurement system are insider threat, internal fraud, vendor fraud, rogue spending, data breaches and theft, ransomeware and malware, DDOS attack, SQL injection and System hacking. Insider threat could come from employees who unintentionally expose data causing breaches and internal fraud are employees exploiting reduced oversight for unauthorised transactions.

Vendor fraud could involve forging invoices or colluding with suppliers. Rogue spending is purchasing outside of established contract procedures, bypassing approval workflows. Data breaches and theft exposes sensitive supplier information, bank details and financial data. Ransomeware and malware are attacks that encrypt or damage data, interrupting procurement operations. DDOS attack can bring down procurement portals. SQL injection and system hacking could be attackers manipulating database. These systems are high-value target for Cyber criminals due to the sensitive financial data and bid information stored, requiring robust security measures.

4.1 Entity-Relationship (E-R) Diagram for secure Multifactor authentication e-Procurement Database in Production Environments

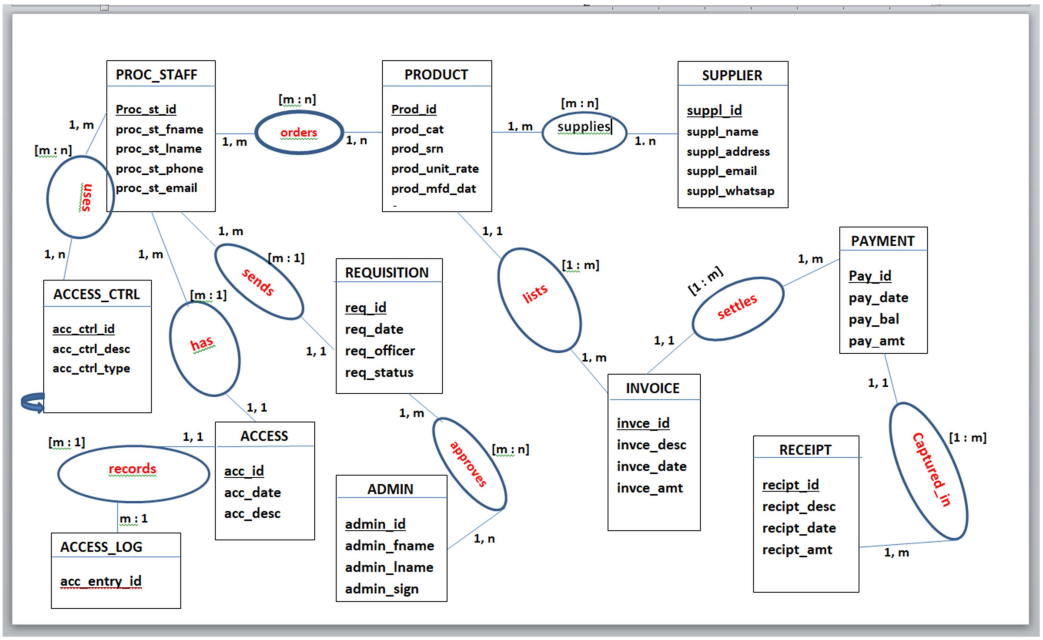

Figure 1: Entity-Relationship (E-R) Diagram for secure Multifactor authentication e- Procurement Database

Figure 1 depicts how the entities relate one to the other. A PROC_STAFF (Procurement staff) can order a minimum of 1 product and maximum of many (1, m) while a PRODUCT can be ordered by a minimum of 1 PROC_SATFF and a maximum of many (1, n) at a particular time giving a maximum cardinality of [m:n]. Cardinality many-to-many [m:n] relationship between two entities is a problem that needed be solved when converting an E-R to a Relational Model (R-M). In between PROC_STAFF and REQUISITION entities: a PROC_STAFF can make a minimum of 1 requisition and a maximum of m (1, m) while a REQUISITION can be made by a minimum of 1 PROC_STAFF and a maximum of 1 (1, 1), maximum cardinality of which is [m:1].

A relationship of [m:1] is a normal relationship. Three other maximum cardinality [m:n] exist also in between PRODUCT and SUPPLIER, PROC_STAFF and ACCESS_CTRL (Access control) and between REQUISITION and APPROVAL entities. Other maximum cardinality of [m:1] occurred between PRODUCT and INVOICE, INVOICE and PAYMENT as well as in between PAYMENT and RECEIPT. One other different relationship aside of many-to-many and many-to-one in between two entities is the one-to many from ACCESS_CTRL to itself and this is where the multifactor authentication if factor-ed in. This means that, a PROC_STAFF can be subjected to different types of access control two or more times under verification, identification and then authenticated to access resources on the e-Procurement database tables.

4.2 Relational Model Diagram for the Secure e-Procurement Database Model

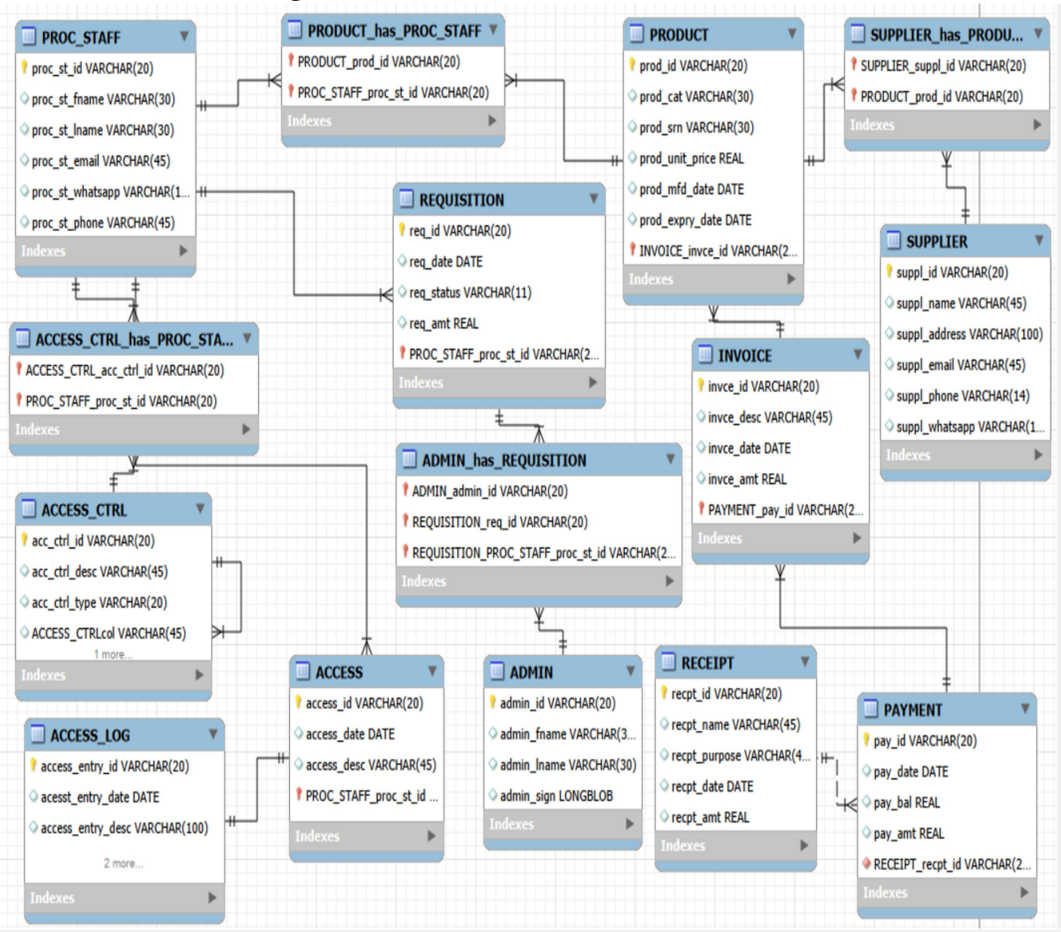

Figure 2: Relational Model Diagram for the Secure Multimodal e-Procurement Database Model

When converting from E-R to R-M, entities in E-R becomes relations in R-M as in Figure 2. This transformation of E-R to R-M was deployed using 5 rules. First, entity names transforms to relation names; second, primary keys in entities becomes relations' primary keys; third, the attributes in the entities are also attributes in the relations; four, for maximum cardinality, many-to-one (m:1), the primary keys (pry_keys) on the m-sides transform to foreign keys on the 1-sides in the relations; and finally, for maximum cardinality, many-to-many (m:n), a new relation will be born, the two involved entities donates their primary keys as composite key in the relation plus additional attributes the relation might have. In the Entity-Relationship (E-R) diagram in Figure 1, PROC_STAFF (Procurement Staff) and PRODUCT entities had may-to-many (m:n) relationship, which is a problem and must be resolved. In the resolution of the problem, a new relation emerged, PRODUCT_has_PROC_STAFF, renamed, ORDER. PROC_STAFF and PRODUCT contribute proc_st_id and prod_id as attributes and composite key for ORDER plus additional attributes: order_id, order_date, order_amt and order_expt_date_of_delvry (Oder expected date of delivery).

Moreover, the entity relation (E-R) had m:n relationship between the entities PRODUCT and SUPPLIER, a problem that needs resolution. So, a new relation was born, which resolved the m:n relationship into two many-to-one (m:1) relationships. The new relation, SUPPLIER_has_PRODUCT, which has been renamed DELIVERY had the pry_keys of PRODUCT (prod_id) and SUPPLIER (suppl_id) as composite key for delivery in addition to delvry_id, delvry_date, delvry_report as attributes. Furthermore, there is another problematic m:n relationship between REQUISITION and ADMIN entities (in the E_R diagram). Resolving the problem, a new relation was born, ADMIN_has_REQUISITION, otherwise named, APPROVAL. APPROVAL attributes constitute the req_id and admin_id plus apprva_id, apprva_date. PROC_STAFF and ACCESS_CTRL (Access control) entities had another m:n relationship otherwise called, AUTHETICATION in the R-M (Figure 1). The relationship is a problem and was resolved into two m:1 relationships.

The AUTHETICATION relation had proc_st_id and acc_ctrl_id contributed from the PROC_STAFF and ACCESS_CTRL, respectively, as composites key plus additional attributes: auth_id, auth_date, auth_time and auth_status. The other relationships between INVOICE and PAYMENT; PAYMENT and RECEIPT; PRODUCT and INVOICE; PROC_STAFF and REQUISITION; PROC_STAFF and ACCESS; ACCESS and ACCESS_LOG, even in the ACCESS_CTRL and itself are many-to-one (m:1), which are normal relationships. In all the m:1 relationships on the E-R diagram of the Relational Model in Figure 1, the pry_keys (primary keys) of the m-sides become foreign keys in the 1-sides. The m:1 relationship on the ACCESS_CTRL and itself indicated that a PROC_STAFF can be authenticated with two or more different authentication types, which is the basis for multifactor authentication in this study.

5. CONCLUSION

The Secure Multimodal e-Procurement Database Model for Production Environment had been achieved and could be deployed in manufacturing companies, organisations and enterprises e-procurement applications.

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