Hospital Pharmaceutical Vendor Managed Inventory Supported by Internet of Things

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Abstract

The pharmaceutical inventory management process adopted by the hospitals are facing challenges in data communication, which implied to excess inventory problems as the leading cause of bad forecast of their lack. This study aims to redesign the information flow and business process in the pharmaceutical inventory management by increasing its efficiency by implementing Vendor Managed Inventory (VMI) supported by the Internet of Things (IoT). Business Process Re-engineering (BPR) and Structured System Development (SSD) as a method used in this study. Four stages of SSD consist of structuring Entity Relationship Diagram (ERD), relational table, use case diagram, and Data Flow Diagram (DFD) for process improvement. This study proposed five improvement scenarios simulated using iGrafx. The best scenario for the hospital to consider in conducting improvement is VMI intervention, IoT technology in the form of QR Code or RFID Tag, and Hospital Management Information System (HMIS) development. The proposed model resulted in pharmaceutical inventory management's time efficiency to 95.64%, which previously took 22.11 days to 7.72 hours.

Keywords

Business Process Reengineering, Hospital Information System, Vendor Managed Inventory, Inventory Management, Internet of Things

1. Introduction

Indonesian State Hospitals generally allocate 23% of its annual expenses to pharmaceutical spending and the numbers are expected to rise in the coming years (DBS Vickers Securities Group Research, 2015). A high pharmaceutical allocation must be used carefully in order to maximize performance. The fact in practice suggest contradictory to this concept as cases of suboptimal budget are frequently discovered with a large number of expired drug stocks. Findings by financial government auditor in 2019 claims two problems in pharmaceutical services, which implied in the discovery of expired drugs scattered in various hospitals and other health services that inflict financial loss equivalent to IDR24,058,151,347.00 for the Indonesian Government. Followed by potential IDR96,171,940,620.00 loss in case if the medicine supply that is expiring in six months is not appropriately utilized (Badan Pusat Keuangan, 2019)(Sunardi & Angelia, 2019). Inventory shortages due to poor data communication and supply lead to bad forecasts, which implied excess inventory problems (Al Juffali et al., 2019)(Vila-Parrish et al., 2012).

This study aims to redesign the information flow and business process in the pharmaceutical inventory management by increasing its efficiency through the implementation of Vendor Managed Inventory (VMI) supported by Internet of Things (IoT). This study was conducted at one of the state-owned hospitals in Jakarta, involving four interviewees from procurement, pharmacy, and recipient goods units. The study began with the data collection process by document review and in-depth interviews to map the current pharmaceutical inventory management process (as-is model) using iGrafx software. Statistical reports generated from the simulation used to identify processes in need of improvement. Statistical reports supported by Voice of Customer (VOC) analysis generate the design improvements that suit the user needs. Analysis related to pharmaceutical inventory management design is reviewed based on a comparison between the results from the current process statistical simulation (model as-is) and the proposed process (model to-

be) to determine the ideal scenario for the improvement. The research resulted in a proposed design of the pharmaceutical inventory management process and information system using Entity Relationship Diagram (ERD) and Data Flow Diagrams (DFD).

The novelty of this research is to redesign the business process and information flow in implementing IoT-based VMI on pharmaceutical inventory management typically to be emergency and life-saving using Business Process Reengineering (BPR) and Management Information System (MIS) methods. Furthermore, VMI implementation in Indonesian hospitals has never been discussed in previous studies.

2. Literature Review

2.1 Business Process Reengineering (BPR)

Business Process Re-engineering (BPR) was first introduced by Hammer in 1990 as a new approach involved the radical redesign and fundamental rethink of all existing processes. BPR is used to achieve better overall performance in terms of quality, cost, service, and speed (Hammer & Champy, 1993). The 6 stages commonly used in implementing BPR consist of identifying the process to re-engineer, analyze the current situation, process redesign (come up with alternatives), laboratory testing, redesign process implementation, and change management (Sudhakar, 2010).

In a pharmaceutical company's logistics system, the design of re-engineering resulted in improved efficiency and effectiveness of the logistics process through a significant time reduction (Dachyar & Novita, 2016).

2.2 Management Information System (MIS)

Analyzing and designing systems related to information flow to be traversed successfully used through Management Information System (MIS). Conceptual design and logical design as the two stages in conducting MIS. MIS is supported by Entity Relationship Diagram (ERD) and Data Flow Diagram (DFD) mapping to help in designing databases and information flow for the upcoming systems (Sajja, 2017).

2.3 Vendor Managed Inventory (VMI)

Vendor Managed Inventory (VMI) was first initiated by a collaboration between Procter & Gamble and Walmart as an integrated inventory management approach to enhance continuous replenishment in the supply chain (Al-Ameri et al., 2008). VMI is the term for inventory management systems where the buyer's inventory is managed and monitored primarily by the vendor based on real-time demand information sharing. VMI approach allows buyers to allocate their work to the main process business, while the day to day inventory activities are managed by the vendor to achieve more optimal inventory with minimal cost considerations (Vigtil, 2007). VMI is widely known as an inventory management system with a balance supply chain efficiency and effectiveness potency (Yu et al., 2015).

Based on several studies, the implementation of VMI in hospitals states that VMI is able to increase process efficiency which reduces annual savings up to 10% every year, reduces holding costs by 40%, increases the order filling rate by 98%, and ultimately increases service level for patients (Matopoulos & Michailidou, 2013; Putri et al., 2019; Sharma & Singhi, 2016; Yu et al., 2015; Zhou et al., 2019).

3. Methodology

This study is composed four major stages; the initial stage, the design stage of the as-is model, the analysis of the as-is model, the design and formulation of the to-be model, and the final stage shown in Figure 1.

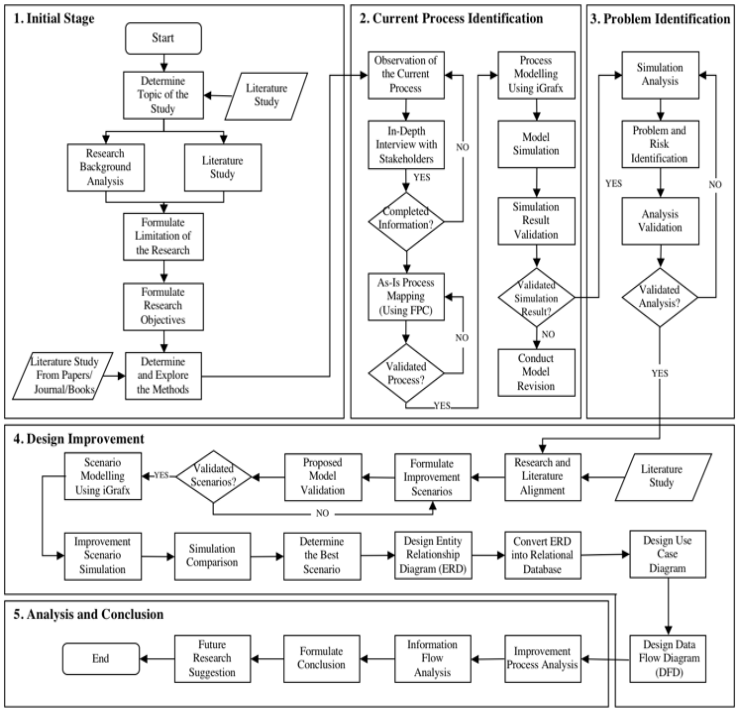

Figure 1: Methodology Process Flow

In the initial stage, the literature study, formulation of topics, formulation of background, research objectives and limitations, and determination of the study methods are carried out. Literature study conducted using papers, research journals, and books to support the research. In the second stage, observation and in-depth interviews with stakeholders are conducted to identify the pharmaceutical inventory management's current process, which is then simulated and validated. In the third stage, the problems and risks identification are carried out to help formulate design improvement for the next stage. In the third stage, the problems and risks identification are carried out to help formulate design improvement for the next stage. In the fourth stage, the existing problems are combined with VOC from the stakeholders are synchronized with literature to produce some alternative solutions for the improvement. The final result of this stage is determined the best improvement scenario for the hospital. In the last stage, the to-be process simulation results are compared with the as-is process simulation results. The study ended with the conclusion and suggestion for future research.

4. Results and Discussion

Pharmaceutical products considered in this study are emergency and life-saving medicines. Table I shows the comparison of studies related to VMI Implementation.

Table I: Comparison of Studies Related to VMI Implementation

Research Focus	***Purpose***
Pharmaceutical Supply (Krichanchai & MacCarthy, 2017; Tsui et al., 2008; Weraikat et al., 2019)	Identify factors affected in VMI Adoption.
	Investigate the robustness of the VMI model under demand uncertainty.
	Reduce the number of staffs required to provide imprest services, reduce stock holding, and improve customer service.
Blood Supply Chain (Stanger, 2013)	Develop a generic framework to discuss the feasibility of VMI in the German blood supply chain.
Eye Care Supply (Sharma & Singhi, 2016)	Generate the relation of VMI with the revenue earning and smoothening of operational efficiency.

Based on in-depth interviews, the implementation of the pharmaceutical inventory management process consists of six main stages; Planning, Procurement, Receipt, Storage, Distribution, and Control. The procurement stage said to be completed if the payment has been made from the hospital to the vendor.

This study designed a simulation model of the current pharmaceutical inventory management process starting with the daily planning process and has two process endings consists of distributing products to users and the payment process by financial units to vendors. Interview results in the form of time range and stages of each process validated by the speakers produce an as-is model, as shown in Figure 2. The model is then simulated using to identify problems from the current process.

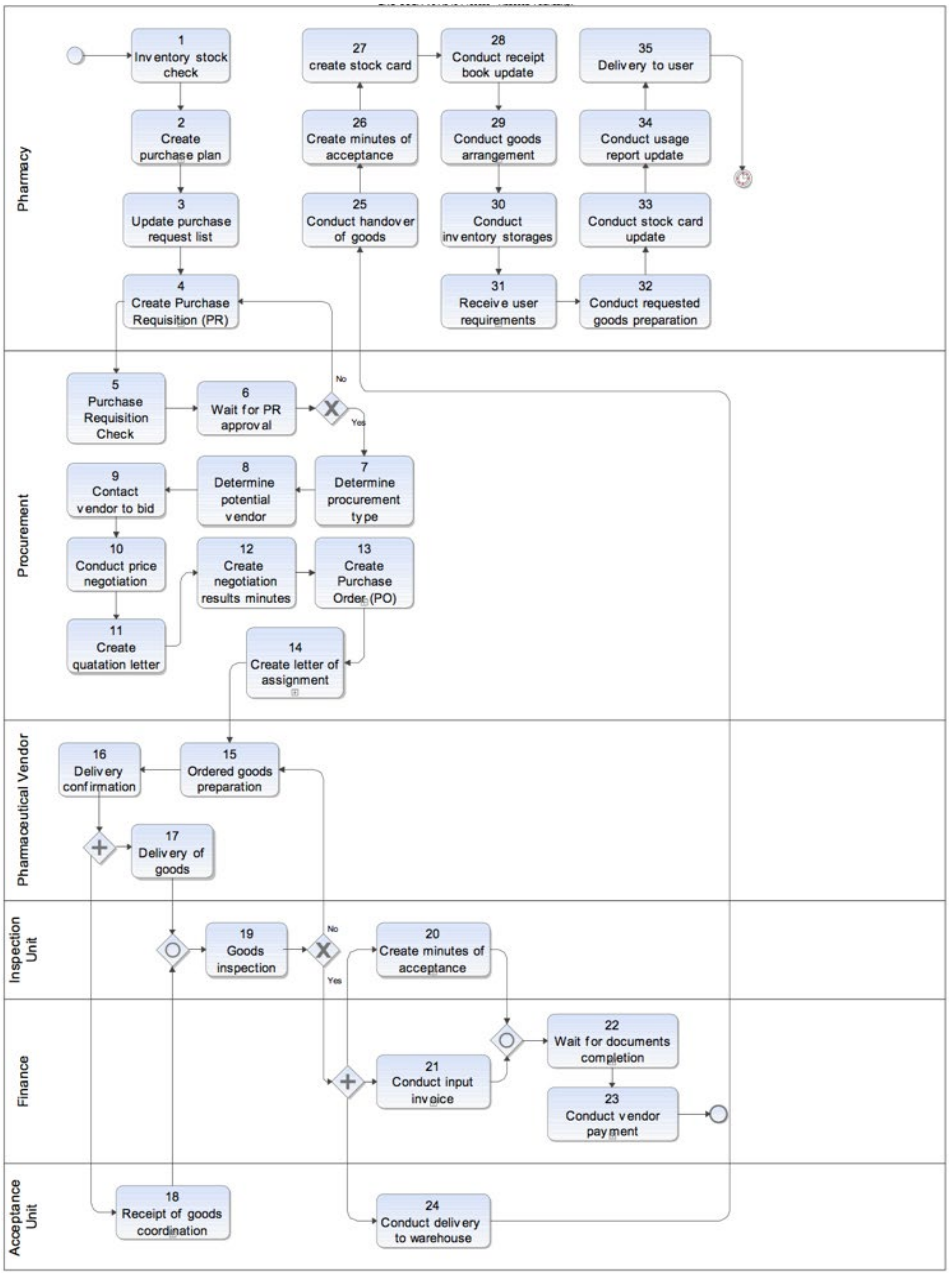

Figure 2: As-Is Process for Pharmaceutical Inventory Management

Inventory management of pharmaceutical products consists of 35 main processes involving six hospital units and one external hospital party that acts as a pharmaceutical product vendor. The pharmacy's planning stage aims to estimate and design purchasing pharmaceutical goods according to the hospital's level of inventory. This stage's final results are in the form of Purchase Requisition (PR) documents and purchase plan documents. The procurement process is carried out between the procurement unit and the pharmaceutical vendor with the final result in the form of a Purchase Order (PO) document. They were followed by acceptance stage to ensure the suitability between the goods ordered and received. The official report stating the suitability of the goods received is a document that marks the next stage, namely vendor payment and storage of goods in the warehouse which was conducted simultaneously. The storage of goods is carried out by the pharmacy unit which is then followed by the distribution process to the users. The control stages in this study were not simulated because the procurement evaluation is conducted once a month.

Simulation results from iGrafx software shown in Table II indicate an average of 22.11 days for the normal condition until the payment process is completed. The average time until the pharmaceutical products' distribution process requires 1.35 days. 95.41% of the total time is dedicated to paper-work, including procurement preparation, receipt of goods, and the collection of documents for the payment process. The simulation states the pharmaceutical and finance units require the most cycle time in performing one procurement transaction. On the other hand, procurement units require the least cycle time with the average work at 0.32 hours due to performance imbalances between units.

Table II: Transaction Statistics in The As-Is Process

Lane Transaction Statistics (Hours)	***Avg Cycle***	***Avg Wait***	***Avg Work***
Goods Inspection	5.44	0.16	5.20
Goods Recipient	56.88	14.08	42.72
Pharmaceutical	169.76	60.72	109.04
Finance	168.40	26.40	142.00
Procurement	1.28	0.96	0.32
Pharmaceutical Vendor	5.60	0.64	5.04
Pharmaceutical Inventory Management (Days)	**22.11**	**7.79**	**14.32**

4.1 Proposed Solutions and Alternative Improvement

The improvement was designed based on identifying problems from the current conditions and identifying user needs in the pharmaceutical inventory management using the VOC method. Table III is the goal-problem-solution obtained from the VOC analysis results, which is then processed to generate the improvement of process and management system of emergency and life-saving pharmaceutical products inventory. The design of the proposed solution aims to create integrated, efficient, and accurate inventory management.

The Goal-Problem-Solution is used to formulate three alternative improvements consists of the development of Hospital Management Information System (HMIS), Application of IoT technology in the form of QR Code/RFID Tag, and the implementation of Vendor Managed Inventory (VMI). The alternative improvements are combined to design five possible scenarios in improving the pharmaceutical inventory management shown in Table IV. Scenario 1 is defined as the basic improvement regarding to the current condition through the integrated HMIS. Scenario 2 and 3 aims to demonstrate whether the VMI able to be implemented independently or must be supported by integrated HMIS. Scenario 4 is considered to optimize the HMIS performance using IoT devices in the form of QR Code/RFID Tag. Eventually, scenario 5 is designed to demonstrate whether the combination of the three alternative improvements have a significant effect.

Table III: Goal-Problem-Solution for Designing Improvement

Goal	***Problem***	***Solution***
Data Integration (Fu et al., 2019; Hastie et al., 2017; Meehan et al., 2017)	Inventory quantity identification is carried out manually	Inventory early warning system
	Technical documents are carried out manually	Documents digitization and registered vendor database
Collaboration (Ahsan & Rahman, 2017; Harding & Epstein, 2019)	Shortages and excess inventory are often experienced	Vendor Managed Inventory
Process Efficiency (Meehan et al., 2017; Pauliina Haukipuro et al., 2017; Smith & Flanegin, 2004)	Inventory quantity identification is carried out manually	Automatic inventory movement identification

Table IV: Alternative Improvement Scenarios

Alternative Improvement	***Integrated HMIS***	***Integrated QR Code / RFID Tag***	***Vendor Managed Inventory (VMI) implementation***
1st Scenario	✓		
2nd Scenario			✓
3rd Scenario	✓		✓
4th Scenario	✓	✓	
5th Scenario	✓	✓	✓

Organised database recorded entirely in the system can be confirmed as the most suitable solution to improve service level performance (Dachyar et al., 2014). The integrated HMIS application is believed to reduce the processing time, especially in manual paper-work, through digitizing documents connected to the system database and applying warning systems. Technology that can accurately identify the flow of goods movement in hospitals is needed to eliminate the time of manual stock calculation. Through QR Code/RFID tag scanning that integrates with the instrument, the Pharmacy Unit and the user can access information about each item, such as usage history, the amount available in the warehouse, the amount used, and the position of the item in real-time. The implementation of integrated VMI by HMIS improved the planning and procurement process's efficiency due to the handing over of hospital responsibilities to vendors. Forecasting and determining replenishment by pharmaceutical vendors aim to reduce shortages/excess stocks often experienced by hospitals.

Through the development of HMIS in scenario 1, a registered vendor database and an early warning stock system applied to reduce waiting times, especially in the initial payment process and stock calculation process manually. Scenario 2 proposed the application of VMI in order to achieve an optimal inventory level since the vendor determines when to replenish. The combination of HMIS development and VMI implementation in scenario 3 aims to optimize inventory levels by digitizing the vendors' integrated processes. IoT technology in the form of RFID tag/QR code applied to scenario 4 with HMIS development. Through the application of IoT, the identification of pharmaceutical products able to access in real-time. Scenario 5 combines the application of HMIS development, VMI, and IoT technology, which aims to maximize pharmaceutical inventory management's performance with the concept of smart-hospital.

4.2 BPR Scenario Analysis

Each predefined scenario modeled and simulated. Scenario simulation model 5, which combines three alternatives improvement shown in Figure 3 – Figure 4. The highlighted yellow process is a process that has changed to support the application of the VMI concept and the development of HMIS integrated with QR Code or RFID Tag.

The implementation of VMI contributed to eliminating a large part of the procurement process and purchasing planning process by the hospital procurement and pharmacy unit. The development of HMIS contributes to eliminating the need for paper and activities involving the input of documents such as official reports, work order sheets, vendor administration documents, and other technical documents.

The elimination of the process helps workers allocate their time to concentrate on examining pharmaceutical inventory management's sustainability. The application of QR Code / RFID Tag technology can also eliminate the manual data collection process. It allows users to access various data in real-time such as usage history data, inventory data in pharmaceutical warehouses, data on the number of usages in a certain period, etc.

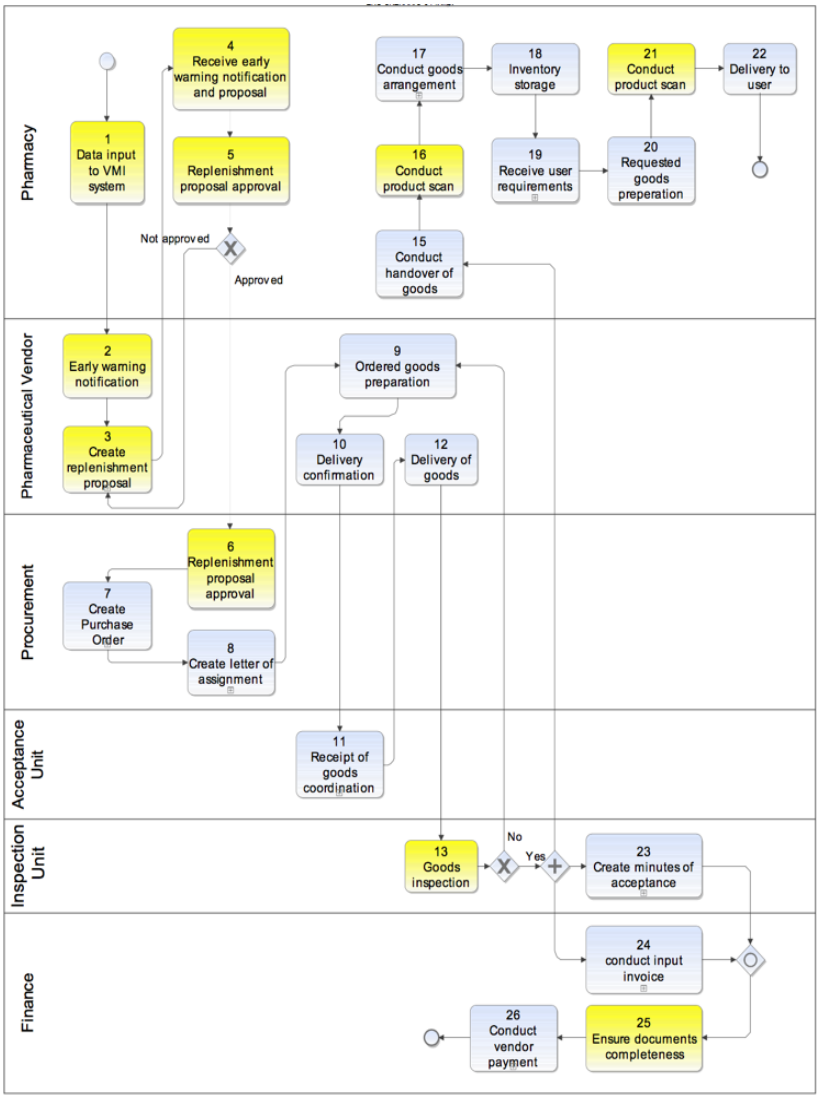

Figure 3: To-Be Process for Pharmaceutical Inventory Management

Figure 4 is a subprocess of the replenishment proposal document work that marks the start of the procurement process through VMI implementation. Replenishment proposals submitted by vendors to hospitals contribute to eliminating a series of procurement preparations such as manual supply checking, purchase requests input, PR documents commission, and negotiation with vendors.

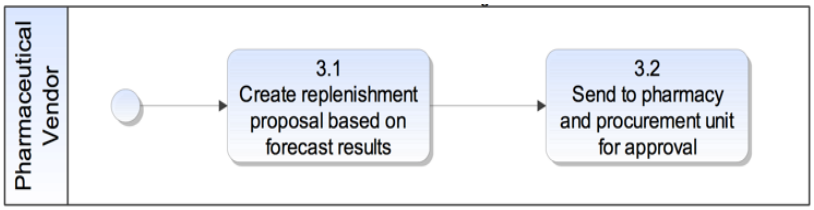

Figure 4: Sub-process of Procurement Preparation for Replenishment Proposal

A results comparison summary of the statistical simulation between the current inventory management process and the proposed process shown in Table V.

Table V: Comparison of Transaction Statistics for Each Simulation

Scenarios	***Time***		***Time***		***Time***	
	Avg Cycle	***%***	***Avg Work***	***%***	***Avg Wait***	***%***
As-Is Model	176.9	-	62.32	-	114.6	-
1st Scenario	8.66	95.10	2.77	95.56	5.89	94.86
2nd Scenario	77.18	56.37	5.67	90.90	71.51	97.58
3rd Scenario	8.24	95.34	7.24	83.38	1.00	99.13
4th Scenario	8.31	95.30	2.59	95.84	5.72	95.01
5th Scenario	7.72	95.64	3.93	93.69	3.79	96.69

Scenario 1 shows the average cycle of pharmaceutical inventory management processes through the development of HMIS. From the simulation results, it can be concluded that the involvement of the HMIS development contributes to significant time reduction, especially in processes related to the completeness of documents that were previously manual. Scenario 2 is an improvement scenario with the lowest level of time efficiency through the application of the VMI concept with a note that the HMIS used by the hospital has not yet improved. Scenario 1 and 4 generate the highest efficiency of average working time up to 95%. However, the scenarios do not provide a balance between the working and waiting time.

Scenario 5 shows the average cycle time of pharmaceutical inventory management processes through a combination of the development of HMIS, VMI, and QR Code / RFID Tags with the highest level of time efficiency that is able to change the processing time from 22.11 days to 7.72 hours. The development of HMIS has a significant influence on reducing cycle times, besides the VMI and QR Code / RFID Tags on reducing some of the processes carried out by the procurement and pharmaceutical units. It can be concluded that the involvement of the three improvement classifications can create a more efficient inventory management process, so scenario 5 is set as an ideal improvement.

4.3 Database Design of Proposed System

The database system's conceptual design for the proposed improvement is explained using the Entity Relationship Diagram (ERD). ERD describes the database structure used in the system through the application of scenario five as an improvement scenario. Figure 5 explained ERD's design for scenario five consists of 6 key entities and 13 weak entities. 6 weak entities that support the VMI concept's sustainability consist of a database containing product stock

data, product usage lists, product information data, delivery schedules, performance evaluation lists, and vendor databases.

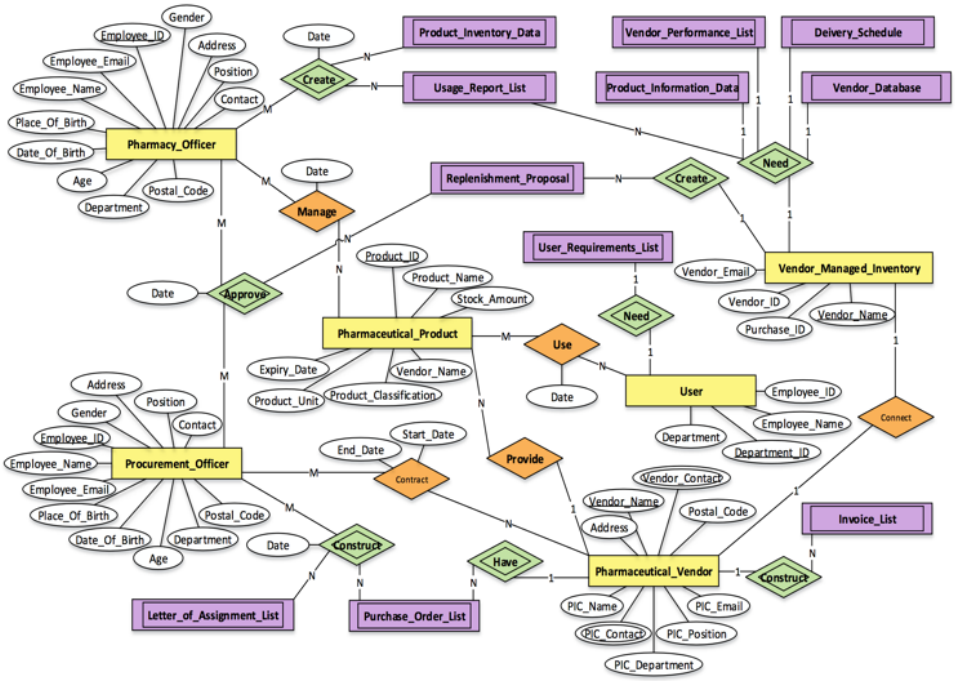

Figure 5: ERD of the Proposed System

4.4 Data Flow Diagram (DFD) of Proposed System

Figure 6 shows the context diagram in the Hospital Management Information System (HMIS). The context diagram illustrates the flow of data or information between the system and external entities involved in general. The context diagram of the proposed system consists of 9 external entities that will directly relate with hospital management information systems consisting of pharmaceuticals, procurement, user units, system administrators, finance, pharmaceutical vendors, QR / RFID readers, goods inspectors, and recipients of goods.

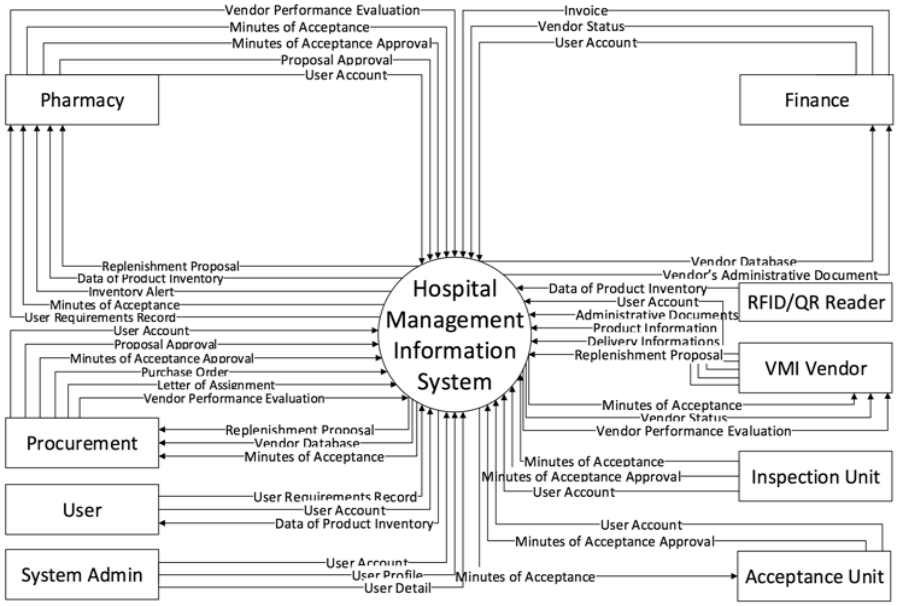

Figure 6: DFD Context Diagram of the Proposed System

DFD level 0 describes the flow of information comprehensively to the proposed system by showing the relationship between main functions/processes, data flow, external entities, and data storage (see Figure 7). HMIS consists of 6 main processes starting from the registration of user accounts (process 1.0), notification of inventory stock in the system (process 2.0), preparation of procurement (process 3.0), procurement process (process 4.0), payment and storage (process 5.0), and vendor performance evaluation (process 6.0). HMIS also consists of 14 types of data storage to support system performance integrated with the database.

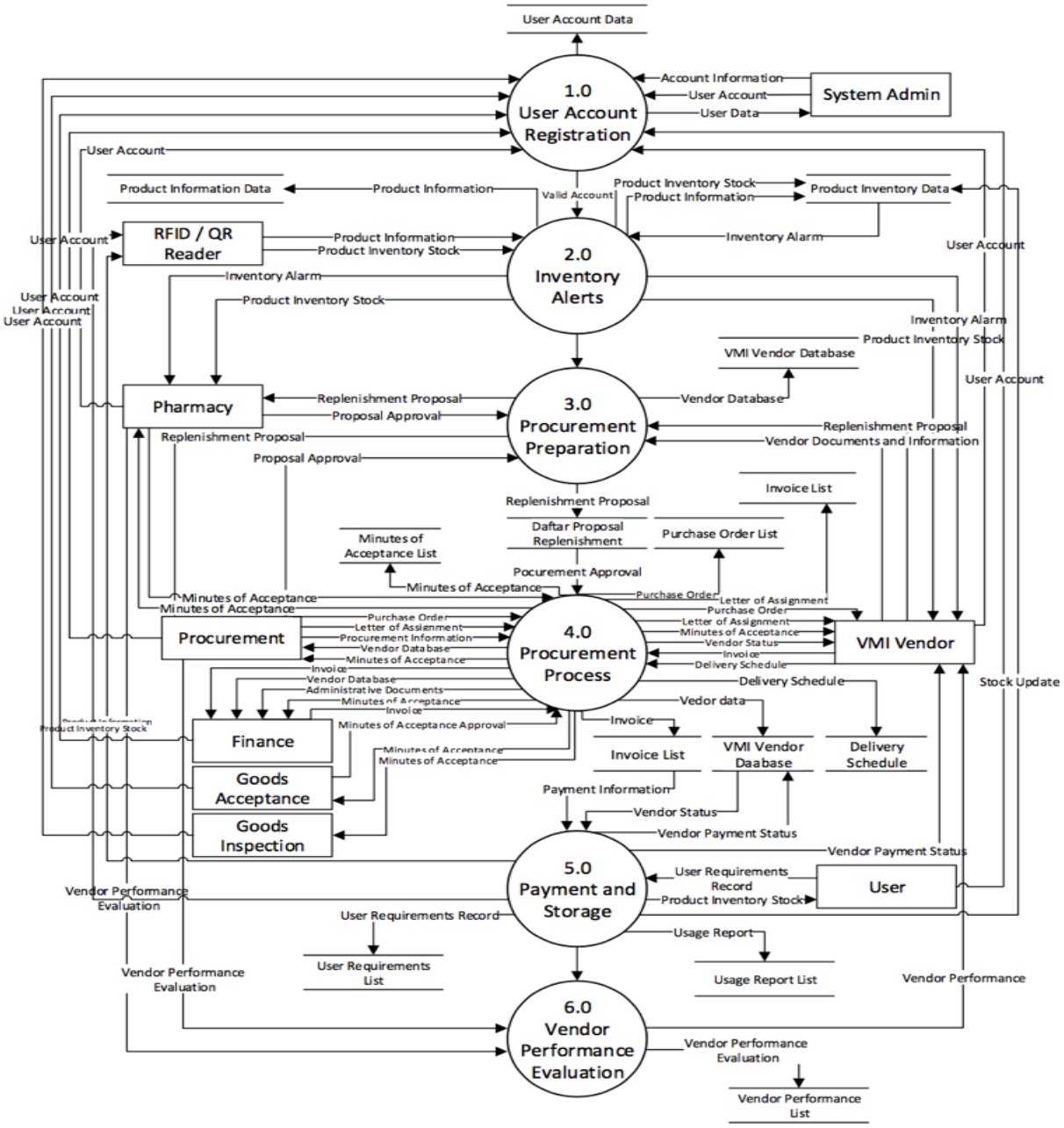

Figure 7: DFD Level 0 of the Proposed System

5. Conclusion

This research has successfully redesigned the pharmaceutical inventory information system and business processes previously dominated by manual and offline processes into a system that applies IoT-based Vendor Managed Inventory (VMI) in the form of QR Code / RFID Tag. The proposed new business process design in scenario 5 succeeded in creating a leaner process. The implementation of IoT-based VMI improves data accuracy for pharmaceutical inventory and results in optimation of inventory level.

For future research, it is necessary to analyze the readiness for VMI implementation since the VMI itself has never been applied in Indonesian hospitals.

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