A DESIGN PATTERN FOR MODELLING AND SIMULATION IN HOSPITAL PHARMACY MANAGEMENT

Wirachchaya Chanpuypetch and Duangpun Kritchanchai
Department of Industrial Engineering, Faculty of Engineering
Mahidol University
Phutthamonthon 4Rd., Nakhonpathom, 73170, Thailand
E-mail: wirachchaya@gmail.com, duangpun.skr@mahidol.ac.th

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Design pattern, conceptual modelling, process redesign, modelling, simulation, hospital pharmacy management.

ABSTRACT

Nowadays, several Thai hospitals are still suffering from inefficient processes. Redesigning business processes is an effective way for improvement. However, business process mapping and analysis in healthcare environment has become a complex task. Besides, most healthcare professionals often resist change. To deal with these obstacles, a design pattern useful for modelling and simulation is suggested in this paper. For deriving patterns in this study, current problems focusing on hospital pharmacy management are initially identified through empirical investigation. Then the suitable solutions can be determined based on the literature review. The design pattern is represented through various attributes including pattern name, purpose, description, modelling structure using a modelling language. In addition, more attributes related to simulation modelling are also combined such as control variables and performance measures. Process modellers can rapidly understand the context of problems through design patterns. The proposed patterns can be reused to create a new model and conduct a successful simulation study. This approach can be a valuable tool to redesign healthcare systems.

INTRODUCTION

In Thailand, hospital pharmacy management is still suffering from inefficient processes. Many Thai hospitals urgently need to improve their business processes. However, redesign projects in healthcare systems have often been unsuccessful (Patwardhan and Patwardhan 2008). Business process analysis and improvement in this environment is a complex task and challenge (MacPhee 2007). They need a high degree of collaboration and coordination among individuals and functions. Besides, resistance to change often exists (Patwardhan and Patwardhan, 2008; Khodambashi 2013). To support these issues, simulation modelling is an effective approach to achieve success in healthcare redesign (Williams and Vanessa (2003). Changes in healthcare systems can be tested prior to real-life implementation (AbuKhousa et al. 2014). It can also lead all healthcare stakeholders to participate in a redesign project.

Nevertheless, in simulation modelling, a process modeller spends the most time for understanding the context of the problems and structuring the conceptual model (Robinson 2015). It is one of the most challenging tasks in a simulation study. To accelerate these tasks, a design pattern has been suggested as an effective way. This approach represents business process flows and offers some best practices for applying them to the specific context (Barchetti et al. 2011). Typically, a design pattern depicts the description of solution through various attributes such as pattern name, description, purpose, as well as process workflow using modelling notation (Barchetti et al. 2011). Likewise, a non-software specific description of the computer simulation may be included into the pattern such as inputs (experimental factors), outputs (responses), content (scope and level of detail), assumptions, and simplifications of the model (Robinson 2015; Tolk et al. 2013). These elements can facilitate a specification of a simulation project.

A design pattern allows users to adopt in practical context. Reusing process patterns can reduce error-prone task and time in modelling. It has the potential to offer a well-defined practice to healthcare professionals in healthcare management. Besides, this way enables all stakeholders to communicate more effectively (Gschwind et al. 2008), which is one of requirements to achieving successful business process improvement in healthcare system. Therefore, in this paper, a design pattern for modelling and simulation is proposed focusing on crucial problems in hospital pharmacy management.

The paper is organised as follows. Next, current problems of hospital pharmacy management are investigated empirically. The crucial problems are described along with their solutions. Then the design pattern that integrates elements of modelling and simulation is proposed as an exemplification. Finally, the paper is concluded.

AN EMPIRICAL INVESTIGATION OF CURRENT PROBLEMS IN HOSPITAL PHARMACY MANAGEMENT

In this section, the methodology used to develop the design patterns is proposed. An empirical investigation was conducted to understand the context of hospital pharmacy management through case studies at the beginning stage. Then crucial problems and their suitable solutions can be identified. Eventually, the design patterns

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useful for modelling and simulation in hospital pharmacy management can be established. The methodology is structured in four main stages, as illustrated in Figure 1.

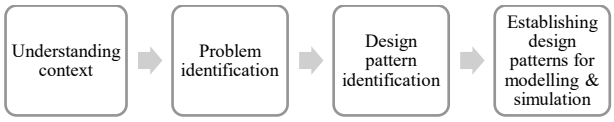

Figure 1: Stages for Developing a Design Pattern

According to the proposed methodology, fifteen hospitals in Thailand where convenience to access were visited to investigate the problem situation. The selected cases of hospital are listed in Table 1.

Table 1: The Selected Cases of Hospital in Thailand

Nature of owner	Type of hospital	Level of expertise	# Stocked drug SKU	Number of cases
Public Hospital	Community	Primary care	360 – 450	3
	General	Secondary care	1,122	1
		Tertiary care	N.A.	1
	Regional	Tertiary care	1,000 – 2,000	2
	Teaching hospital	Tertiary care	800 - > 2,000	4
Public Organisation Hospital	-	Secondary care	1,700	1
Private Hospital	-	Secondary care	1,732 – 2,000	3

In data collection process, we used the core open-ended questions as the guideline for semi-structured interview. The interview pursued to understand hospital business processes and recognise current problems in term of hospital pharmacy management. The managers at senior level who could provide relevant information were interviewed. They included the head of a hospital pharmacy department, a pharmacy purchasing manager, a pharmacy warehouse manager, and a pharmacy store manager. All interviewees were asked the same questions, and interview length ranged from 1 to 3 hours. Simultaneously, direct observation was also performed.

After crucial problems are addressed, we then reviewed and synthesised the applicable practices based on the related literature. The context of problems in hospital pharmacy management is described along with their solutions can be offered in the following section.

PROBLEMS IN HOSPITAL PHARMACY MANAGEMENT AND THEIR SOLUTIONS

According to empirical evidence, five crucial problems of pharmaceutical products management that Thai hospitals currently confront can be identified. The contexts of each problem are described along with literature-based solutions as follows.

Inefficient Management of Inventory and Warehousing

In Thailand, an inefficient warehousing and inventory management is often found in small size primary care hospitals. These hospitals manage and control their inventory without a computerised material management system. Stock cards are mostly used to provide a simple stock control system in the hospital. Important data of drugs are also neglected in recording such as drug expiration dates and a manufacturing lot information. Besides, drug items which are stored in the hospital warehouse may be placed on the shelf inappropriately. Expired drugs are frequently found.

This problem can be resolved through the warehouse planning and control structure with the use of a computerised information system (IS) in the entire materials management processes (Ferretti et al. 2014; Holm et al. 2015). Several advantages can be obtained such as better space organisation, stock reduction, no more expired drugs with saving cost, safety improvement with reduction in administration errors, no more transcription errors, and relationship improvement with the providers (Ferretti et al. 2014). This solution can provide real-time information of inventory status. Drug inventory management has been improved with reducing of waste and inventory shortage. Moreover, availability of medication at the point of care can be increased through this approach (Holm et al. 2015).

Unable to Track and Trace Drug Items

Traceability is becoming an essential in many industries to improve supply chain efficiency. It is increasing interests related to the problem of theft, counterfeited drugs, and recall. However, drugs traceability cannot be currently achieved in Thai pharmaceutical supply chain. After drug receiving and placing, various hospitals neglect to record important drug data such as a batch or lot number. Moreover, most IS in Thai hospitals cannot support an entering of these data. Thus, the past and present locations of the movement of prescription drugs cannot be determined exact data of where the drug is located and where, or to whom, each drug has been sold. Likewise, it is impracticable to recall a drug from the market. These recalled drugs may cause patient harm due to defect or failure of quality.

Currently, to protect consumers from contaminated medicine and counterfeit drugs, the United States Food and Drug Administration (FDA) defines a drug pedigree for pharmaceutical track and trace. An electronic form of this document includes the basic data elements from pharmaceutical supply chain companies such as lot, potency, expiration, National Drug Code and Electronic Product Code (EPC). Besides, track and trace technology, such as 2D barcode and RFID, is also required for interchanging through the whole supply chain (Hamid and Ramish 2014).

Inventory Inaccuracy

According to the empirical data, the delivered items from distributors are manually checked and recorded for receiving to store in the hospital warehouse. Likewise, the replenished items are mostly operated with the similar activities for storing the received drugs in each pharmacy repository. However, these placed items may not be checked and recorded in suddenly. This fragmented operation flow leads to various error types of inventory inaccuracy. It is a common problem of supply chains (Kök and Shang 2014; Sarac et al. 2015).

Typically, inventory inaccuracy can be divided into three main types including shrinkage error, transaction error, and misplacement (Dai and Tseng 2012). They can be caused by thefts, shipment errors, delivery errors, scanning errors and misplacements (Sarac et al. 2015). When this problem occurs, the actual inventory levels are higher or lower than the nominal inventory. Likewise, ineffective decision making for replenishment cannot be avoided. This can lead to high out-of-stocks, backlog, and/or excess inventory (Kang and Gershwin 2005). Inventory costs may increase resulting from inaccurate information significantly (Kök and Shang 2014).

However, inventory inaccuracy cannot be observed by IS until an inspection is performed (Kök and Shang 2014). Thus, the actual inventory levels are hardly maintained (Kang and Gershwin 2005). To remedy this problem, the optimised cycle-count policy should be proposed to correct inventory record errors (Kök and Shang 2014). Although, a cycle-count program is used, this approach cannot prevent misplacement errors and shrinkage errors. Particularly, shrinkage type errors lead to the biggest impact on supply chain performance (Fleisch and Tellkamp 2005). To facilitate this alignment, automatic identification (Auto-ID) technology, such as RFID, is frequently suggested to provide inventory visibility (Zhang et al. 2011). The proposed system with RFID implementation can enhance supply chain effectiveness by minimising the inventory inaccuracy problem.

Inefficient Inventory Management Policy

According to empirical evidence, most hospitals in Thailand allow each hospital pharmacy to control and manage their inventory independently. Decentralised decisions may create a strong bias for making a requisition with high inventory levels. The demand distortion can affect the supply chain partners with inaccurate forecasts, increased inventory levels, and increased overall cost of inventory management (Kamalapurkar 2011).

To deal with this problem, information sharing with considering inventory control policies and/or collaboration strategies between supply chain partners has been studied by many researches. For this approach, actual end-customer demand data access should be available to all stakeholders in order to forecast the demand, instead of on the requisition data from each stage. Mostly, the well-known collaboration strategies have also been suggested to integrate supply chain and improve inventory control, namely; Vendor Managed Inventory (VMI) and Collaborative Planning, Forecasting and Replenishment (CPFR). Groznik and Maslaric (2009) reengineered business processes of oil/retail petrol supply chain by providing the improved integration of whole parts of the supply chain and centralised distribution process management. The renewed business models with information sharing by considering VMI strategy can reduce inventory holding cost and the bullwhip effect. In healthcare sector, Kim (2005) implemented the VMI system for improving pharmaceutical products management in hospital. The study developed the online procurement system, which provides real time information sharing functionalities to achieve information integration. After the system deployment, it enables hospitals to eliminate errors, decrease administration tasks, and increase reliability of information flow. Average inventory amounts and total inventory costs of drugs has been decreased significantly.

Another such supply chain collaboration practice is known as CPFR. It is the latest strategy in the evolution of supply chain collaboration that extends the idea of VMI to include joint planning process (Kamalapur and Lyth 2014; Alftan et al. 2015). Most studies show that the benefits gained from CPFR are always higher than VMI (Kamalapurkar 2011). In healthcare industry, Li (2010) evaluated the inventory collaborations through a system dynamics study. As a result, the total average inventory reduces almost 20%, the amount of backlogs decreases over 60% by VMI and fully eliminates by CPFR. Recently, the benefits of CPFR in the healthcare sector were examined by Lin and Ho (2014). They concluded that this approach could enhance medical service quality and eliminate inefficient purchase and waste of valuable medical resources.

As described above, information sharing among supply chain members can significantly deal with inefficiency inventory management practice. Inventory control policies and collaboration strategies such as VMI, CPFR are frequently combined in the proposed information sharing models. However, these approaches must rely on communication mechanisms such as Electronic Data Interchange (EDI), XML, etc. (Liu and Kumar 2003). This approach helps to reduce the bullwhip effect and improve service level.

Prescribing Problems

Prescription medication is the most important aspect of patient treatment in a hospital. However, in drug prescribing, physicians have made a prescription using a prescription form until now. This handwritten prescription leads to various types of medication error such as prescribing error, transcribing error, pre-dispensing and dispensing error. These errors may be harmful to patients who encounter wrong medication. Besides, physicians may select the drug item that is not stored in the hospital for a prescription. This event brings about to create rework activities that are non-value added.

To cope with this problem, a CPOE system is offered to facilitate medication errors related to manual drug order writing with paper (Al-Rowibah et al. 2013). A deployment of a CPOE can decrease adverse drug events (ADEs) and medication errors related to handwritten prescriptions. Physician orders can be transferred to hospital pharmacy through a secure way. However, physicians often resist an electronic prescribing. Hence, the strategy to promote an adoption of CPOE is needful to overcome this top barrier (Charles et al. 2014).

As described above, five literature-based approaches for dealing with the crucial problems of hospital pharmacy management can be summarised in Table 2. Subsequently, these approaches are considered to create the design patterns for hospital pharmacy management.

Table 2: Summary of Problems in Hospital Pharmacy Management and Their Solutions

Problems	Solutions	Benefits
Inefficient management of inventory and warehousing	Warehousing and inventory management with implementing of a computerised material management system	• Reduce stock and waste with saving cost • Reduce inventory shortage • Improve safety with reduction in administration errors and medication errors
Unable to track and trace drug items	Traceability architecture and a deployment track and trace technology– 2D barcode, RFID	• Able to track and trace each movement of the drug • Increase correctness and timeliness
Inventory inaccuracy	Counting items in the pharmacy inventory and using auto-ID technology such as RFID	• Eliminate inventory inaccuracy errors such as misplaced type error and theft type error • Provide better replenishment decisions
Inefficient inventory management policy	Information sharing and providing a collaboration strategy such as VMI, CPFR	• Improve system efficiency and service level • Reduce inventory amounts and total inventory costs
Prescribing problems	A deployment of a CPOE system including the strategy to promote an adoption of an electronic prescribing	• Provide a secure way of transferring a prescription to hospital pharmacy • Prevent an occurrence of non-value added activities

DESIGN PATTERNS FOR MODELLING AND SIMULATION

As the suitable solutions presented in previous section, the details of the design patterns can be provided. Typically, the proposed pattern represents the description of solution through various attributes including pattern name, pattern description, purpose, as well as structure of the pattern using a modelling language technique (Barchetti et al. 2011). However, these attributes have not been exactly determined. To support a simulation study, which is a useful approach for a redesign project in healthcare context, necessary elements related to simulation modelling are also encompassed such as independent variables (control variables) and response variables (performance measures). Thus, the proposed design pattern consists of the following six attributes:

- *Pattern name* – A pattern identifier.
- *Purpose* – Description of the purpose or motivations needed to identify the patterns.
- *Pattern description* – Description of the pattern.
- *Modelling structure* – Representation of the pre-defined activities assigned to specific stakeholders using modelling language technique.
- *Independent variables (Control variables)* – Factors that affect the system.
- *Dependent variables (Response variables)* – Performance measures.

Here, the authors exemplify *the design pattern of information sharing and providing a collaborative strategy for hospital pharmacy inventory management*. The pattern supports a hospital that confronts with inefficient inventory management practice and policy. This problem has been mentioned for bias forecasting as the crucial problem from all hospital cases. Effective literature-based solutions related information sharing and providing a collaborative strategy have been suggested such as VMI and CPFR. Based on the process reference model for hospital pharmacy management developed by Chanpuypetch and Kritchanchai (2015), sequences of events under each strategies are represented using Business Process Modelling Notation (BPMN). The proposed pattern leads to improving system efficiency and service level. Likewise, inventory amounts and total inventory costs can be reduced. Important parameters that impact on supply chain performance are also included into the design pattern for investigating their impact for both the hospital warehouse and the hospital pharmacy in different collaboration strategies. An example of the design pattern is shown in Table 3.

CONCLUSION

Currently, redesigning business process is much needed to improve inefficient processes for hospital pharmacy management in several Thai hospitals. However, business process mapping and analysis in healthcare has become a complex task. To ease of deriving a process model and achieve success a redesign project in healthcare, a design pattern is suggested in this paper.

The design patterns proposed in this study are created based on the crucial problems focusing on hospital pharmacy management. They are inefficient management of inventory and warehouse, inefficiency management policy, unable to track and trace drug items, inventory inaccuracy, and prescribing problems. According to these problems, the suitable practices, technologies, or strategies can be then determined to overcome these problems. Each pattern is represented through various attributes useful for modelling and simulation including pattern name, purpose, description, modelling structure, control variables, and performance measures. Process modellers and business users can rapidly understand the context of problems through the patterns. A design pattern also allows users to reuse workflow patterns and conduct a successful simulation study. It can be a valuable modelling tool to redesign healthcare systems.

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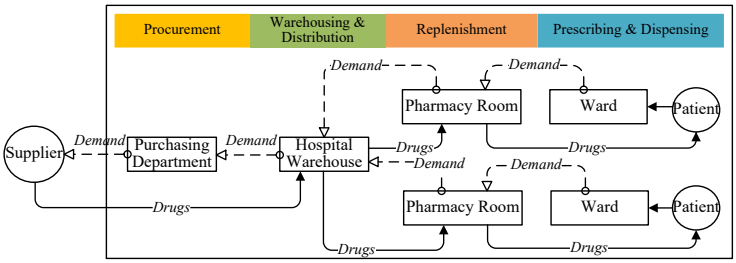
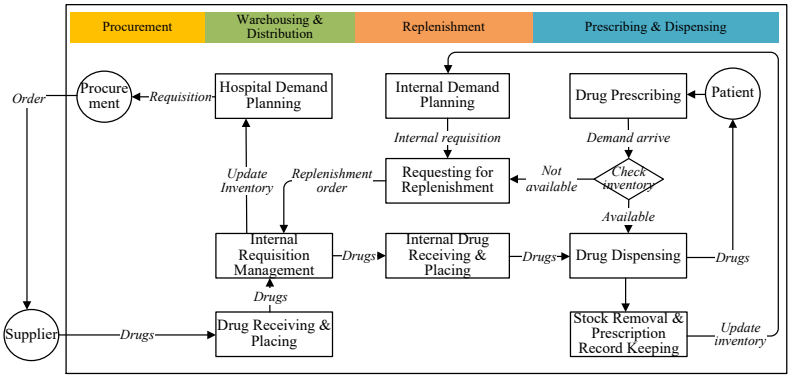
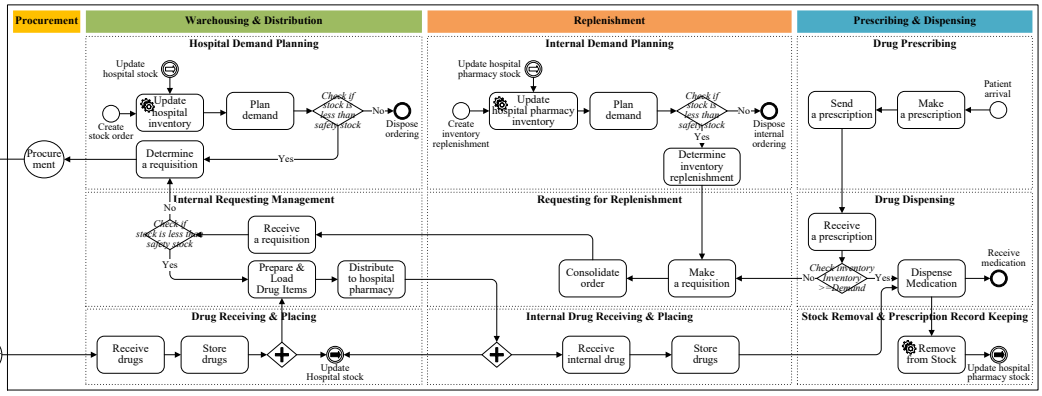
Table 3: Design Pattern – Information Sharing and Providing a Collaborative Strategy for Hospital Pharmacy Inventory Management: An Exemplification

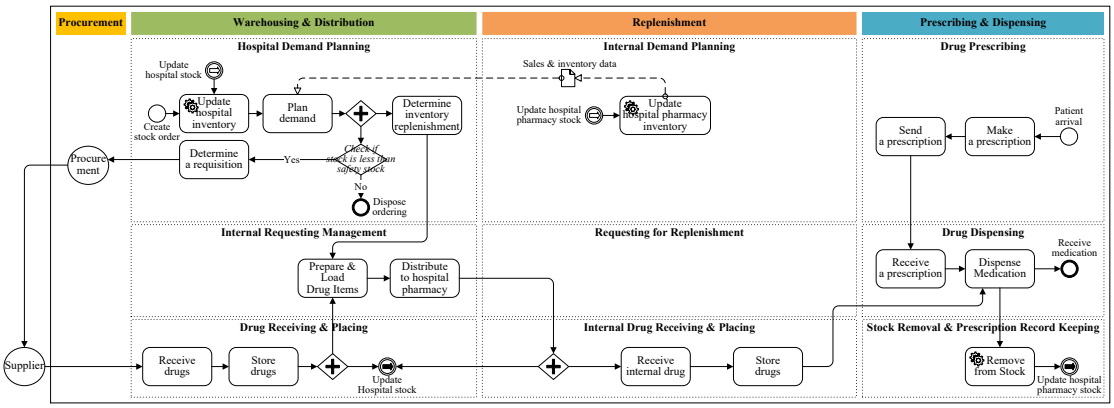
Attributes	**Description / Detail**
Name:	Information sharing and providing a collaborative strategy for hospital pharmacy inventory management
Purpose:	The design pattern represents modelling structures of hospital pharmacy inventory management process through information sharing and providing a collaborative strategy.
Description:	The pattern represents all activities related hospital pharmacy inventory management. It involves four main functions of hospital pharmacy management. They are procurement, warehousing and distribution, replenishment, and prescribing and dispensing. These functions are processed at four locations including hospital wards, hospital pharmacy, hospital warehouse, and purchasing department. A three-echelon inventory system is illustrated as the 1st hierarchical level of modelling. The current tasks and its activities are operated as follows. Tasks and activities of "Prescribing and dispensing" function: 1) *Drug prescribing* – Physicians make and send a prescription to hospital pharmacy. 2) *Drug dispensing* – Hospital pharmacy receives a prescription and dispenses medication. 3) *Stock removal and prescription record keeping* – After dispensing, the drug items are removed from stock for updating inventory level. Tasks and activities of "Replenishment" function: 1) *Internal demand planning* – If stock is less than safety stock, the internal order quantities are determined for replenishment. 2) *Requesting for replenishment* – Hospital pharmacy makes a requisition for replenishment. Internal order requisitions are then consolidated and sent to the hospital warehouse. 3) *Internal drug receiving and placing* – After receiving shipments from the hospital warehouse, hospital pharmacy inventory is available for dispensing. Tasks and activities of "Warehousing and distribution" function: 1) *Hospital demand planning* – The hospital warehouse plans their demand forecast independently and calculate their order-up-to inventory level. If stock of the hospital warehouse is less than safety stock, the order quantities are determined for purchasing. 2) *Internal requisition management* – The requirement that are requested from hospital pharmacies are prepared for replenishment. An internal delivery is operated for distributing the requested drug items to replenish pharmacy repositories. 3) *Drug receiving and placing* – The hospital warehouse receives shipments from suppliers. Hospital inventory is available for fulfilment hospital pharmacy repositories order. (see the 2nd hierarchical level of modelling and the 3rd hierarchical level of modelling: sequence of events in AS-IS) To cope with inefficient inventory management policy, two different collaboration strategies are often offered as follows. • *Vendor Managed Inventory (VMI)* – The hospital warehouse manages the inventory of hospital pharmacies. Hospital pharmacies share sales and inventory data with the hospital warehouse. The warehouse forecasts and determine inventory level of hospital pharmacies during each period (see 3rd hierarchical level of modelling – 3.2 Sequence of events under VMI). • *Collaborative Planning Forecasting and Replenishment (CPFR)* – Hospital pharmacies share historical usage, forecast and inventory level information with the hospital warehouse. The hospital warehouse does not forecast and uses this information to determine their inventory level during each period (see 3rd hierarchical level of modelling – 3.3 Sequence of events under CPRF). The pattern need inventory information sharing and/or exchanging between the hospital warehouse and hospital pharmacies via well-organised mechanisms to support their collaboration planning process. Finally, at the end of period, the hospital pharmacy cost and the hospital warehouse cost per period are calculated based on inventory level or backorder quantity.
Modelling Structure:	*1st hierarchical level of modelling* – A three-echelon inventory system  *2nd hierarchical level of modelling* 

3rd hierarchical level of modelling

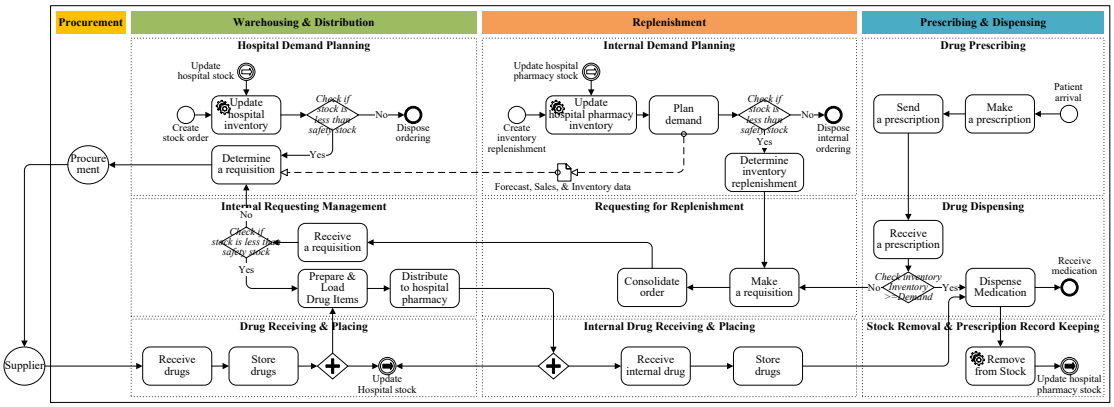
3.1) Sequence of events in AS-IS – No information is shared.



3.2) Sequence of events under VMI – Sales and inventory data are shared.



3.3) Sequence of events under CPFR – Forecast, sales, and inventory are shared



Control variables:

To investigate the impact of collaboration strategies to the hospital warehouse and hospital pharmacy in variable demand environment. Most variables are considered in the experimental design for simulation such as;

Control parameters	*1*	*2*	*3*
Supply chain strategy	TRP	VMI	CPFR
Demand variability level	Low	Medium	High
Random forecast error	Low	Medium	High
Bias forecast error	Negative	Neutral	Positive

Basic assumptions: Demand type; Demand forecast technique; Inventory replenishment policy; Review period; Information is exchanged real time without any delay in information sharing; Initial values of inventory; Capacity constrain; Delivery lead time.

Response variables:

Financial measurement	*Inventory control*	*Customer service*
⇩ Hospital pharmacy cost (inventory holding cost + Backorder cost) ($) ⇩ Hospital warehouse cost (inventory holding cost + Backorder cost) ($) ⇩ Total hospital cost (Hospital pharmacy cost + Hospital warehouse cost) ($)	⇩Inventory holding (units) ⇩Backorder quantity (units)	⇧ Fill rate (%)

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AUTHOR BIOGRAPHIES

WIRACHCHAYA CHANPUYPETCH is a PhD candidate in Logistics and Engineering Management, Department of Industrial Engineering, Faculty of Engineering, Mahidol University, Thailand. She holds a BSc in Food Science and MSc in Technology and Information System Management. Her research interests focus on logistics and supply chain management, information technology, business process and applications of operation management. Her e-mail address is wirachchaya@gmail.com.

DUANGPUN KRITCHANCHAI was engaged as the project leader for several large-scale projects for hospital logistics and supply chains. She received her PhD in Manufacturing and Operation Management from the University of Nottingham, UK. Her research interests are in healthcare logistics and supply chain management. She is currently serving at Mahidol University, in the capacity of Associate Professor in the Department of Industrial Engineering, Faculty of Engineering and Director in the Healthcare Supply Chain Excellence Centre and Centre of Logistics Management and her e-mail address is duangpun.skr@mahidol.ac.th.