THE STUDY OF SUPPORTIVE FACILITIES ALLOCATION IN NEW HOSPITAL BUILDING

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ABSTRACT

This study was conducted for two main reasons. Firstly, it aimed to investigate patient congestion in outpatient department under two circumstances: (1) facilities located in one building and (2) classification of the facilities in different allocated buildings. The facilities were classified according to outpatient flow value chain developed from the original value chain model. Throughout the past decades, there has been a great deal of interest in the application of discrete-event simulation for solving issues in hospital especially related to patient flow. Therefore, discrete-event simulation was used to model the outpatient flow value chain. The second objective was to plan capacity for the support facilities. Opt Quest was used to run the capacity optimization model under the constraints of less congestion and shorter cycle time at the pharmacy facilities.

The research found that the floors where their support facilities were separated from primary facilities were less congested which led to smoother patient flow. Therefore, patients circulated in the hospital under less congested environment. Moreover, the study also provided meaningful reasons on the selected support facilities, which was allocated differently from the primary facilities to do the capacity planning. Since it was the optimum capacity improvement, the utilization of the resource capacities remained high, hardly idle, but the congestion and total time of the facilities were reduced.

KEY WORDS: DISCRETE-EVENT SIMULATION / PATIENT FLOW / VALUE CHAIN / FACILITY ALLOCATION / CAPACITY PLANNING

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LIST OF ABBREVIATIONS

A&E	Accident & Emergency
Che	Chemical Treatment Clinic
Den	Dental Clinic
Der	Dermatology Clinic
ED	Emergency Department
ENT	Ear Nose Throat Clinic
ER	Emergency Room
Hem	Homology Clinic
Med	Medicine Clinic
Obs	Obstetrics Clinic
OnD	On Duty Clinic
OPD	Outpatient Department
Oph	Ophthalmology Clinic
Ort	Orthopedic Clinic
Pha	Pharmacists dispensing the medicine
PreM	Preventive Medicine Clinic
Psy	Psychology Clinic
Q	Number of patients waiting in the queue
Sur	Surgery Clinic
Ult	Utilization

CHAPTER I
INTRODUCTION

1.1 General background

Over the last 100 years, healthcare service has been improved significantly as new and useful technology and science have been discovered. As the result, people have benefited from such an improvement for modern and better quality healthcare service. However, they still face suffering because appropriate accessibility to the healthcare service is still limited. It might be caused by confusing or inefficient healthcare system (Hall, 2013).

There are many factors creating the inefficient healthcare system such as patient delay (Hall, 2013), size or capacity, a variety of services (Marshall et al., 2015 & Yip et al., 2016), etc. The patient delay is one of the most critical factors. To reduce the patient delay, interfaces which patients are transferred (sometimes, called patient flow) from an activity to another activity or a clinic to another clinic must be taken into account to make an improvement. The patient flow is a critical component of the healthcare system. It has a very significant impact on overall performance of hospital. Hence, it has been used wisely as a criterion investigating the performance of the hospital (Nikakhtar et al., 2015; Adeyemi, Demir, & Chaussalet, 2013; Bhattacharjee & Ray, 2014). Investigating the patient flow is very challenging due to the social network characteristics, high volume, various distance, and destination (clinics or departments) of the flow (Nikakhtar et al., 2015; Hall, 2013). Actually, patients move from one place to another because they just want to have treatment from their clinics. It is the main objective of the movement. As a matter of fact, the patient flow is always concerning to functions such as registration, cashier, laboratory, and so on. Although the main objective is to get the treatment at the concerning clinic, these functions cannot be eliminated because they create value to the flow.

According to Porter (1985), value chain refers to the value created along all links from input (raw material) to output (final product). There are two categories of the activities in value chain. The first concerns the primary activities, which are the core contributions to final products. The second is the support activities. Sometimes, they are not really important for contribution to the final products, but they cannot be eliminated. Studying value chain helps identify the value created along all involved activities or functions.

Moreover, the value generated by the activities depends on how the facilities are designed. The facilities design has significant impact on healthcare efficiency and outcomes. Good hospital facilities design can help the hospital archive big improvement such as reducing medical errors, better resource utilization (bed occupancy rate), shorter patient length of stay, higher patient satisfaction. More importantly, that good design also provides advantages to staff such as staff absenteeism, stress level, and verbal outbursts. All these improvements really matter patient safety.

Healthcare buildings are complex due to range of the activities and users. Therefore, architects play an important role to ensure adequate spaces for delivering care. Specially, the activities are in constant changes, with the development of medical technology and changes in the users profiles, and new configurations of delivering care and new spaces are required in order to support and contribute to the implementation of new activities.

1.2 Research questions

The problems mentioned above lead us to the following research questions:

What if primacy activities are separated from support activities?

To answer this research question, first, it is necessary to define the activities or facilities which are operated to serve the patients. By using the value chain conceptual model, the activities related to the patient flow can be identified as the primary and the support activities. The primary activities refer to facilities of the clinics of outpatient department (OPD). In this research, there are thirteen clinics namely On Duty, Orthopedic, Medicine, Obstetrics, Surgery, Preventive and Social Medicine, Dermatology, Ophthalmology, Ear Nose Throat (ENT), Dental, Psychiatry, Hematology, and Chemical treatment clinic. By merging the value chain conceptual model with the activities inside OPD derived from literature and case study, outpatient flow value chain model can be proposed.

What should be the capacity planning for such allocation?

The second research question can be answered by applying the outpatient flow value chain with optimization model. To get the optimization capacity, the number of resources required and the right location for the facilities can be obtained. Good capacity planning and facilities allocation result in less congestion of floors and shorter patient cycle time.

1.3 Research objectives

The objectives of this research are:

1. To investigate the congestion of the patients on every floor of OPD within two conditions: (1) when all types facilities are located in one building and (2) when facilities are classified as the primary facilities and the support facilities, based on value chain, and they are allocated in different building.

2. To plan the optimum capacity for the support facilities at new building so that the patients can be discharged faster.

1.4 Research framework

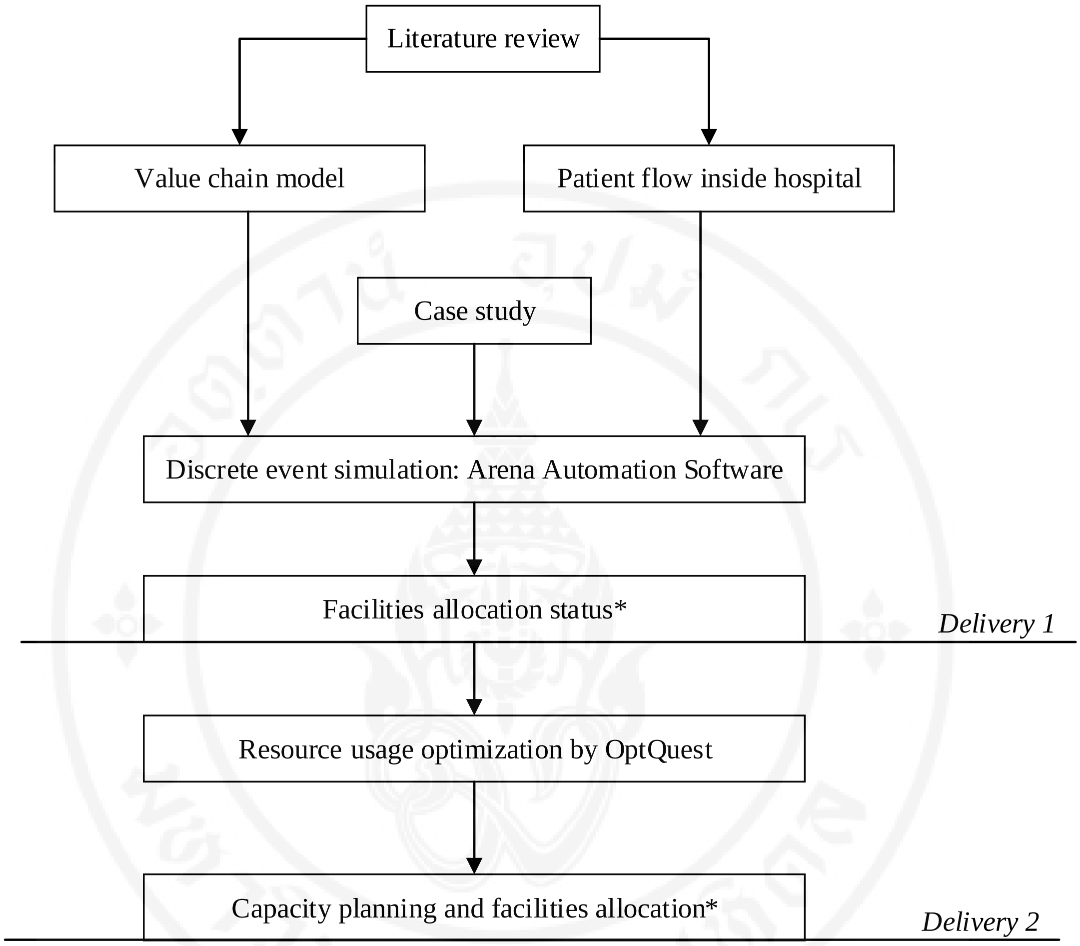


Figure 1.1 Research framework

1.5 Scopes of study

The ultimate customers of the hospital are the patients. Hence, every activity inside hospital is operated to serve the patient demand. Therefore, the patient flow is concerning every department and operation of the hospital. However, this research studies only the patient flow in outpatient department containing thirteen clinics namely On duty, Orthopedic, Medicine, Obstetrics, Surgery, Preventive and Social Medicine, Dermatology, Ophthalmology, Ear Nose Throat (ENT), and Dental \, Hematology, Psychiatry, and Chemical treatment clinic. Thus, the flows in other clinics or departments inside the hospital are out of the scope of the study.

Concerning input data in this research, mix of on-site observation and a reference state in qualitative is used (Kritchanchai and MacCarthy, 2002). The number of patient arrivals, average exam time of each clinic, and the facilities capacity are derived from the system. From the observation, then it is plotted as the arrival schedule according to the percentage of the arrival every hour. Moreover, on the top of the data derived from the system, rough observation was also made. However, the resource capacity is varied somehow to make sure that the utilization is acceptably high and all the patients get all services within services' working hours as shown in Appendix A, Appendix B, Appendix C, and Appendix D.

1.6 Contributions

After the research is completed successfully, the following results and benefits are expected

- By using value chain model, it shows that primary facilities and support facilities for outpatient treatment service can be identified and separated.
- It illustrates how the primary facilities and support facilities of outpatient department influence the patient flow.
- By using discrete event simulation, it demonstrates that it is possible to allocate resources to have better outpatient flow although the primacy and support facilities are separated.

CHAPTER II
LITERATURE REVIEW

Literature review is the essential preliminary task for research study. It basically establishes the theoretical root of the knowledge in the area of research, enhances and consolidates the knowledge, and helps to integrate the finding into the body of knowledge. In this thesis, the literature review firstly examines the patient flow of in hospital and value chain in various industries. Then, the patient flow is narrowed down to only Outpatient Department (OPD). Based on the conceptual model from value chain, primary activities and support activities related to patient flow in OPD can be identified. More importantly, reasons and content of primary and support activities or facilities are also addressed within this chapter.

2.1 Patient flows through healthcare system

Over the last century, the right, welfare, and quality of life of human has been paid attention so much. As the result, the human health has been improved to advanced level. Vaccinations, water quality, various disease preventions and treatments have been discovered, developed and applied. Nevertheless, the people, patients to be exact, are still suffering because healthcare assessment is not quite easy and appropriate yet. It means that healthcare delivery is still in confusing and inappropriate manner. The academic, science world and real practice still have so many variations.

One of the most common painful experiences the patients ever have is delay. The delay not only makes the patients feel unsatisfied with the services of the hospital, but also makes the hospital unable to do its operations efficiently. Many literatures suggest that effective management of healthcare delay can dramatically improve medical outcomes, patient ratification, and service accessibility. At the same time, it leads to healthcare cost reduction. In this thesis, the delay, therefore, will be studied along the interface which the patients are transferred from an facility to another facility or clinic to clinic through the healthcare system.

The patient flow through healthcare system always has common pattern scope which is from patient arrival until patient discharge, patient leaving the hospital. The arrival patients at the hospital can be either scheduled or unscheduled. Unscheduled patients may visit hospital by walking into the emergency department, ambulance delivery or walking into particular clinics. On the other hand, schedule patients only visit certain clinics or departments at the promising time (Hall et al., 2013; Jones et al., 2009).

The patient flow through the healthcare system is commonly from two main sources. The first is the patients who leave the Emergency Department (ED) and needs to go other departments of the hospital such as Operation Rooms (OR), Intensive Care Unit (ICU), Inpatient Nursing Units (NU). In some cases, after leaving the ED, the patients become outpatient patients which they might need to visit several clinics in Outpatient Department (OPD) such as Lab, Radiology (X-ray, CT Scan, MRI), particular OPD clinics (for example, Orthopedics), Pharmacy, etc. Therefore, the patients leaving ED might require additional processes and resources from the hospital. Poor resource planning which does not consider ED's output will create lengthy delays in the hospital (Hall et al., 2013). The second is the patients who visit the certain clinics regardless of patient type (scheduled or unscheduled) (Hall et al., 2013; Kolker, 2013). Lack of attention in patient arrival pattern can make the healthcare system congested more than it should be. Moreover, the hospital resources (both man and material) are poorly allocated which means that some period, the resources are busy with the long queue while some period, the resources are idle.

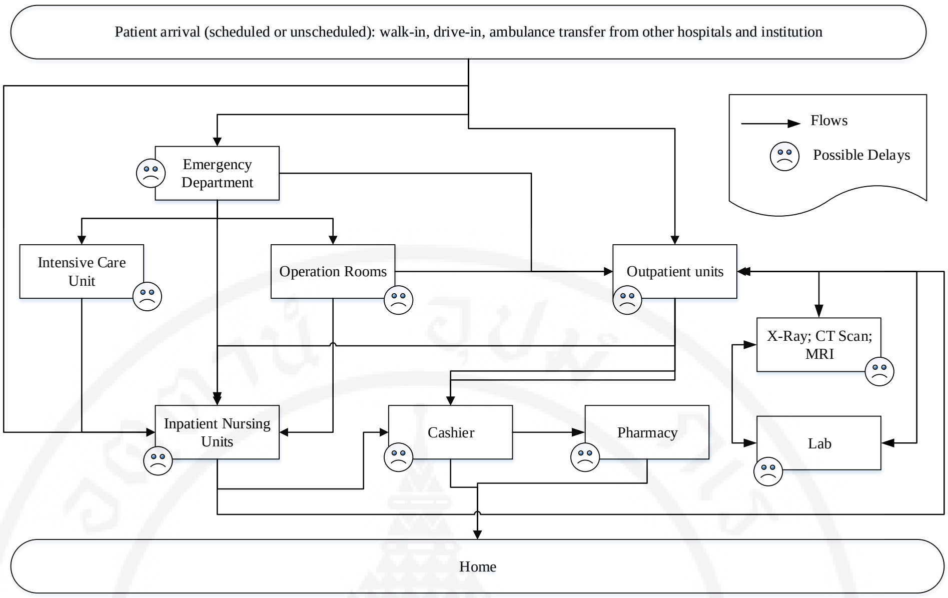


Figure 2.1 Patient flow and delay through healthcare system

2.2 Value Chain

2.2.1 Value system

Value chain concept, for gaining the competitive advantage, was firstly developed by Porter (1985). By study value chain, all activities performed in a firm can be systematically examined. When the value chain is studied in a larger scope (stream of activities in the whole supply chain), it can be termed value system (Figure 2.2).

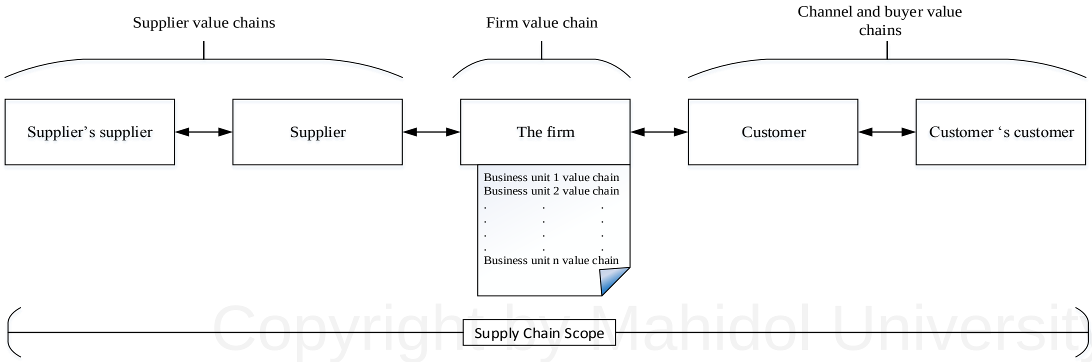


Figure 2.2 Value system

2.2.2 Big picture of value chain

In a firm, to have one finished product, there are activities performed such as production, marketing, delivery, and other support activities. There are two main classifications in value chain model (Figure 2.3) namely value activities and margin. The value activities are the activities related to technology or product physical producing which a form performs. Basically, the value activities include all primary activities and support activities. Some examples of these activities are inbound and out bout logistics, operation, services, human resource management, technology development, etc. The margin refers the value which the firm earns out of cost of the activities for the total production. Simply it is the difference between total value and the collective cost of performing the value activities. Actually, there are ways measuring the margin. Since there are many organizations involving in one supply chain system, the supplier, channel or buyer value chains are also included for the margin measurement. Therefore, it is very important to clearly understand about source of a firm's cost position.

2.2.3 Value activities

As mentioned previously, the value activities consist of primacy activities and support activities. In this section, these two types of the value activities are descripted in detail. Originally from Porter (1985), the value chain model can be explained via graph as shown in Figure 2.3.

2.2.3.1 Primary activities: in the primary activities, there are five generic categories which have distinct activities. However, those activities might vary from one industry type to another.

- Inbound logistics: it contains the activities mainly related to the suppliers of the firm .such as receiving, storing, and disseminating inputs to the product.
- Operations: it refers to the activities performed inside the firm. Specifically, it is related to the activities which are performed to transform raw material to finished product. They are machining, packaging, assembly, equipment maintenance, testing, printing, and facility operations.

- Outbound logistics: in contrast to inbound logistics, the activities in the outbound logistics category associate with the operations between the firm and the buyers (whole seller, retailer, or consumer). The activities are collecting, storing, and physically distributing the product to buyers.
- Marketing and sales: it concerns product orientation to the customers and pursing getaway which they can buy the product from the firm.
- Service: it refers to the activities associated with enhancing or maintaining the value of the product which could cover the whole supply chain.

2.2.3.2 Support activities: there are four categories of the support activities involved in competing any industry. Similar to primary activities, the support activities can be devised into distinct value activities. It could vary from one industry to another.

- Procurement: "it refers to the function of purchasing inputs used in firm's value chain, not to the purchased inputs themselves." Those include raw materials, supplies, and other consumable items as well as assets such as machinery, laboratory equipment, office equipment and buildings.
- Technology development: technology is quite commonly applied in any business of any industry. Concerning the production, the technology could be employed in every process of the firm ranging from document preparing and good transporting to the product itself. Hence, the technology consists a range of activities which can improve the product and process.
- Human resource management: technology is very important for the better and efficient production. However, at the end of day, it still requires human to operate. In any firm, there are always activities related to human resource management such as recruiting, hiring, training, development, and compensation of all types of personnel.
- Firm infrastructure: unlike other support activities, the firm infrastructure support the whole chain regardless individual activities. It includes general management, planning, finance, accounting, level, government affairs, and quality management. More importantly, it functions as a powerful source of the firm to compete with others.

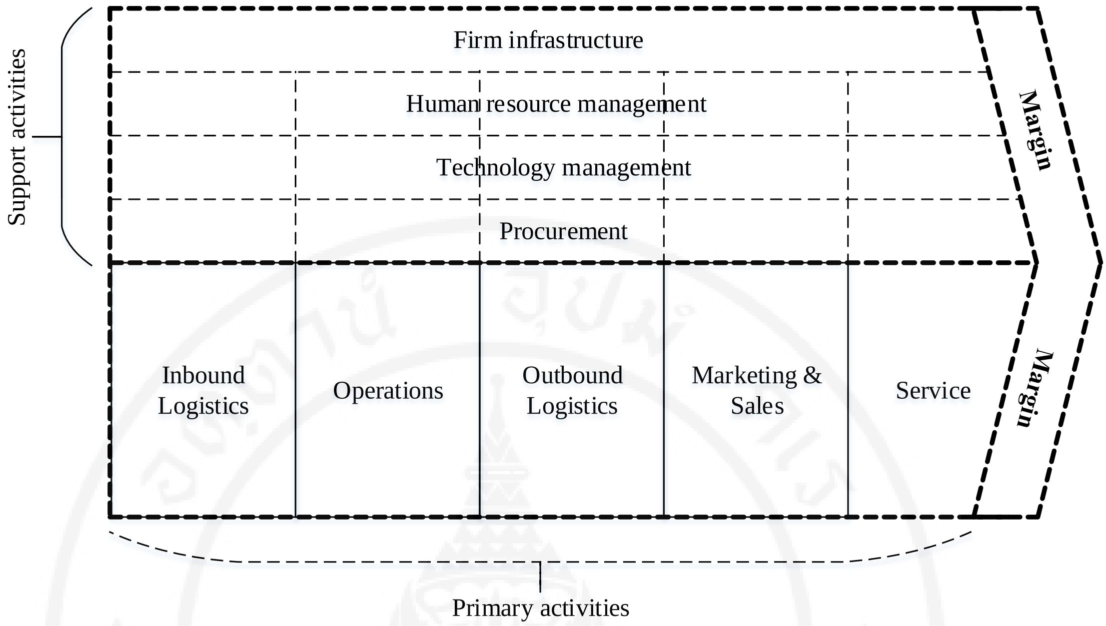


Figure 2.3 Value chain (adopted from Porter, 1985)

2.2.3.3 Defining the value chain: as different industries have different natures, operations and constrains, the value activities are identified differently according to the firms. To have more discrete value activities, broad functions such as manufacturing or marketing should be narrowed down by subdividing them into activities. For example, there are many machines in one factory. Surely, those machines perform different operations. Hence, it is appropriate to treat every machine as a separated activity. There are three principles that the activities are recommended to be isolated and separated:

1. The activities have different economics.
2. The activities have a high potential impact of differentiation
3. The activities represent a significant or growing proportion of cost.

One more important issue as well is the appropriate category for the activities. This stage has no clear-cut methodology. It may require judgment and can be illuminating in its own right. Take order processing as example; to some industrie, it might be classified as part of outbound logistics; to some industries, it could be classified as port of marketing. Moreover, there are cases which one firm resource is used in different facilities or categories. In such a case, the activities in those categories should be combined into one value activity and classified wherever the function yields the best outcome for the firm.

2.3 Outpatient Department facilities

In the hospital, there are departments which are operated separately although they sometimes require the same facility, for example Emergency Room (ER). In case the patients need no hospitalization, Outpatient Department (OPD) is the right place for such medical service (Orth-Gomer et al., 1979; Côté, 1999). The number of clinics in OPD varies from one hospital to another according to the ability to provide the medical services. However, the main task of OPD is to examine and treat patients who need specialized care and hospital resources by not staying in the department overnight, and who are referred from other hospitals both private and public. Therefore, the patients are sent for clinical examination, blood testing (Lab), X-ray, CT scan, etc., so that the right diagnose can be made.

Concerning OPD, there are several key departments which the patients might flow through, namely Emergency Department, Radiology, Laboratory, Pharmacy, Cashier, and outpatient clinics.

2.3.1 Emergency Department

An emergency department (ED), a medical facility of primary care center or the hospital, is also be known as an emergency room (ER), accident & emergency department (A&E), or casualty department. The main function of ED is emergency medicine. Commonly, the patients who have life threatening and require complex care and immediate attention, present at ED without prior appointment, either by their own means or by the ambulance. Moreover, the emergency department of most hospital normally operates 24/7 although its staffing level may be different from one shift to another (NHS, 2015; King et al., 2006).

Over the last decade, the problems within emergency department have grown getting so much attention from both academics and healthcare practitioners (King et al., 2006). The problems, mainly related to demand mismatching, are found in the ER such as overcrowding, resource utilization, ambulance diversion, and boarding of admitted patients. Mostly, the patients have to wait very lengthy time before receiving care which sometimes, lead to leaving without being seen (Saunders et al., 1989; Miro et al., 2003; Medeiros et al., 2008; Ahmed & Alkhamis, 2009; Lucas et al., 2009).

2.3.2 Radiology

Radiology department might have various facilities according to individual hospital's resources. However, the common facilities are diagnostic X-ray, nuclear medicine, diagnostic ultrasound, off-site MRT, CT scan, various interventions. Since the radiology department is for supporting the clinics of OPD, clinicians are the ones who generate the patient flow across the radiology department (Hall et al., 2013).

The radiology department is playing very important role in the hospital. There are clinics and departments, which require the diagnoses from the radiology department. Hence, the patient flow in the radiology department has been noticed, studied and improved to have more efficient resource utilization, less time spent in the department, and smoother patient flow (Klafehn, 1987; Ciaran O'Kane, 1981; Revesz et al., 1972). Moreover, "lean" was also adopted in the clinical radiology department, so that efficiency, performance, and safety can be achieved (Workman-Germann & Hagg, 200; Kruskal et al., 2012).

2.3.3 Lab

Lab is for service of testing such as blood. Like the radiology department, demand of lab is generated by clinicians. Lab could provide centralized services of variety of tests. However, the primary one is specimens (blood in tubes). Lately, the hospital, especially in developed countries, do not transport the blood tubes manually (hand-carry) anymore, but pneumatic tube. On the tubes, there are codes attached either barcode or QR codes which store various information. By using pneumatic tube system, the hospital can get the work done fast (shorter turnaround time in the lab), convenient, and efficient. It is also important to note that beside being so advantageous for blood-sample transportation, the pneumatic tube system also can be used for transporting mail, patient reports and accounts, medical records or even x-ray film (Pragay et al., 1974; Hall et al., 2013; Guss et al., 2008).

2.3.4 Pharmacy

Pharmacy is one of the hospital facilities which is mainly related to choosing, preparing, storing, compounding, and dispensing medicines and medical devices (Greef, 2013; Gerrard, 2016). Moreover, advising how to use the medicine effectively and efficiently is also from the pharmacy. The main important task of the pharmacy is to maintain (at least) and improve (if possible) medication management and pharmaceutical care of the patients, so that the better standards inside the hospital can be achieved. Typically, the hospital pharmacy is not retail establishment which does not provide prescription service to the public. However, retail pharmacy still can be found in some hospitals, which sells over the counter as well as prescription medications to the public (WHO, 1994).

2.3.5 Outpatient clinic

Outpatient clinic is one of the healthcare facilities providing the healthcare services for the patients who do not need to stay overnight. Most commonly, the patients are coming to OPD first. Therefore, the outpatient clinic is the demand driver for any healthcare services of the hospital serving the community. The quality level of the hospital is mainly determined by how well OPD can operate (Mohd & Chakravarty, 2014; Healthwise, 2014).

There are numbers of clinics in OPD. Those numbers vary from one hospital to anther according to the hospital capacity and ability. However, the most common clinics are general medicine, surgery, orthopedics, pediatrics, obstetrics-gynecology, psychiatry, dentistry, ophthalmology, allergy center, endocrinology & nutrition center, emergency center, and ENT (ear, nose, and throat) (Hing et al., 2010; (Bumrungrad International Hospital, 2016)

2.4 Facility allocation

According to Jun et al. (1999), the hospital has effective and efficient patient flow if:

- The hospital could discharge larger number of patients in one particular period.

- The patients spend fewer days or hours staying in hospital.
- The patients waiting time to get services from the hospital is shorter.
- And the clinic overtime is low.

To achieve such flow, beside good practice of patient scheduling and admission, and optimum resource allocation, the facilities of the primary activities and support activities should be integrated and stay as close as possible. However, in the real world, those facilities are allocated separately due to two main reasons: capacity limitation and economic condition.

Healthcare demand is increasing year to year which means that the hospital needs to expand its capacity along the way. Concerning facility (building) expansion, it is always nice to have new space expanded from the old facility's area. However, based on some condition of the space availability for construction, new building needs to be constructed away from the old facility location. This has created nonvalue added process, travelling time, when the patients need to get the services at both old facility area and new facility area.

Sometimes it is possible to expand the building to have larger capacity at the same location. However, it would be economic to move some facilities away from the old location, so that the capacity of the facilities can be expanded both at old and new location. By moving some facilities to another place, the organization might be able increase the profit since land and labor-intensive fee could be cheaper, and some geography advantage for demand creation (Rattanakhamfu et al., 2014).

Therefore, it is very acceptable to expand the capacity size when the service delivery or production is close to the maximum capacity (Julka et al., 2007). However, construction of new building for new facilities costs so much money. Hence, the building space needs to be allocated in the way that it will achieve the objectives of the business, normally profit maximizing, within the long term (Ghosh & Craig, 1984; Owen & Daskin, 1998).

Capacity expansion, either by moving some facilities to additional location or enlarging all facilities at current location, requires proper trade-off queueing number and travelling distance. When the facilities stay too close to each other, the place will be too crowded or congested. Such crowded situation can influence customers' subjective perceptions of waiting time. The customers, therefore, might feel unsatisfied with the services provided (Davis & Vollmann, 1990; Bitner, 1992; Baker & Cameron, 1996). If the facilities are moved to additional location, walking distance will be required. It can make the total cycle time longer.

2.5 Capacity planning

Capacity planning is very important in one organization of any industry especially when demand excesses the organization's resource capacity. In the hospital, especially the public one, it is very clear that the hospital never have enough resource capacity to server the patient's demand. Therefore, the resource allocation and sound capacity planning are required to obtain possible maximum efficiency (VanBerkel and Blake, 2007; Gross, 2004). In healthcare industry, there are two sides which could lead to insufficient hospital management, hospital supply side, and patient demand side. Therefore, to avoid wasting of main hospital resources and inefficient patient flow, the hospital needs to have a good plan for its capacities (bed, staff, operation room, etc.,) to serve the patient demand (random patient arrival, stochastic clinical time, etc.) (Ma and Demeulemeester, 2013). This implies that, to have sound hospital capacity planning, the hospital needs to take account of both patient volume and resource requirement for such amount of patients (Vissers et al., 2001).

Related to resource capacity planning, many tools or techniques, found from previous researches, have been used. Brandeau and Hopkins (1984) formulated a linear programming model to examine the monetary and resource effects of marginal changes. The resources taken into account were number of beds and operation rooms accounting for amount of service available in each department. Bretthauer and Cǒté (1998) developed an optimization/queuing network to identify the number of beds for the blood donor at the hospital. In their research, the number of beds needed to be enough, so that the donors did not wait for too much long time. Kokangul (2008) used nonlinear mathematical models (combination of deterministic and stochastic approaches) to determine the optimum size of the required bed capacity based on total bed demand. The total bed demand can be identified by the sum of the daily accepted, rejected or transferred arrivals. Nguyen et al. (2005) constructed a multiple criteria score aiming to determine the optimum number of beds for a hospital department. The number of beds needs to be capable enough to guarantee for security, accessibility and productivity. According to Jacobson et al. (2006) discrete event simulation technique can be used to solve my problems of various dimension in healthcare industry. One of them is asset allocation needed (staffing level or physical capacity) to service the patients. Similarly, Grootuis et al. (2001) demonstrated how discrete event simulation technique, a popular tool for capacity planning in several health care domains , could help optimize the use of resource capacity related to patient flow problem at the department of cardiology.

2.6 Simulation model

The term “simulation” is very general due to its applications in various industries such as manufacturer, bank, computer network, super market, theme park, hospital, and so on. According to Kelton et al. (2008), “Simulation refers to a broad collection of methods and applications to mimic the behavior of real systems, usually on a computer with appropriate software”. Due to the advanced computer system, simulation is becoming more powerful day to day.

Simulation can be classified in many ways, but commonly there are three dimensions of simulation model comparisons: deterministic vs. stochastic, static vs. dynamic, and continue vs. discrete time (Özgün and Barlas, 2009; Kelton et al., 2008).

- Deterministic vs. stochastic: the simulation model that has no random input is called the deterministic model, while the stochastics simulation model does have random input.

- Static vs. dynamic: the static simulation model does not change anything over time while the dynamic model changes. Therefore, it is not common to develop the static simulation model since things naturally always change over time.

- Discrete vs. continue: in the discrete even simulation, value of elements or variables in the system changes in discrete time and discrete procedures. In contrast, the element or variable of the continuous simulation system changes value continuously over time.

Recently, there have been great interests of researcheres applying the simulation model in healthcare industry due to its enormous field allowing many different ways of analyzing. The simulation has been used in various parts of hospital such as inpatient facilities, outpatient clinics, and the whole hospital. Vasilakis and Marshall (2004) studied on patient flow by developing as dynamic patient flow model aiming to estimate the number of patients in any of state and their length of stay. The patients in their research referred to the stroke-related patient, age 65 and over. Two models were used to descript their dynamic patient flow: compartmental model of patient flow and discrete event simulation (Queuing system). Harper and Shahani (2002) developed a detail simulation model to plan and manage hospital beds. The simulation model was about the patient flow in care units. The number of beds in the care units, therefore, was used as the model input. Wijewickrama and Takakuwa (2005) developed discrete event simulation of Outpatient Department to identify the best scheduling rules. Their research modeled the patient flow in Outpatient Department from 8:30 am to 5:30 pm during weekdays with basically four different types of patient visits: appointed patients, same day appointment patients (walk-ins) patients who come for a medical test (exam patients) and new patients. Takakuwa and Katagiri (2007) aimed to evaluate the performance of new built hospital ward by investigating patient waiting time and congestion. The evaluation was made via Arena simulation model of the planned outpatient ward. Cochran and Bharti (2006) developed discrete event simulation for 400-bed hospital. The main objective of this simulation was to define a step by step procedure for bed capacity planning.

2.7 Literature analysis

Based on the previous section, the Outpatient Department consists of many facilities both primary facilities and support facilities. In this research, the following facilities have been selected for the study of patient flow in OPD:

- **Outpatient Department clinics:** Orthopedic, Medicine, Obstetrics, Surgery, Preventive and Social Medicine, Dermatology, Ophthalmology, Ear Nose Throat (ENT), and Dental, Hematology, Psychiatry, and Chemical treatment clinic.
- **Others:** Triage, Register, Screening, Lab, X-Ray, Cashier, and Pharmacy.

Commonly, the patients will go through all these facilities or services. However, based on the value chain model, all the processes or activities of one system can be categorized as primary activities and support activities Porter (1985). According to Vissers and Beech (2005), there are two types of resources in hospitals or Outpatient Department: the leading and the following. The characteristic of these resources is that the leading resources generate other processes which require the other resources (the following resources) to complete those processes. Similarly, before the patients going to get services from particular clinics of OPD (for example Orthopedic), they can be required to get some diagnosis form other facilities (Lab or X-ray). Then, they need to pay the bill with the cashier and might get some medicine from the pharmacy. Hence, it is pretty clear that the resources of the OPD clinic (the leading resources) trigger other resources such as the resources of diagnostic department (Lab, X-ray), Cashier, and Pharmacy (the following resources) to complete the activities or processes. By merging this practice with value chain model, it can be assumed that the OPD clinics (Orthopedic, Medicine, Obstetrics, Surgery, Preventive and Social Medicine, Dermatology, Ophthalmology, Ear Nose Throat – ENT and Dental, Hematology, Psychiatry, and Chemical treatment clinic) are the primary facilities of OPD while the others (Triage, Register, Screening, Lab, X-Ray, Cashier, and Pharmacy) are the support facilities of OPD. Another evidence from Hall et al. (2013) also confirms that the Radiology, Pharmacy, Laboratory are the support facilities for the particular clinics because flow of the patients is generated by the clinician's orders. Therefore, the outpatient flow value chain can be developed as Figure 2.4.

Concerning the location of all facilities in the outpatient flow value chain, the hospital should increase its capacity size either expanding the building or moving some facilities to additional location when it reaches the maximum capacity. However, any options the hospital will choose, there should be a good trade-off between queueing number of patients in one particular place and their travelling time from one facility to another. More importantly, any hospital resources for providing services to the patients must be planned properly.

Concerning technique for patient flow and capacity planning, simulation is very common in many industries especially healthcare. To be precise, discrete event simulation is a very good technique for dealing with such issues.

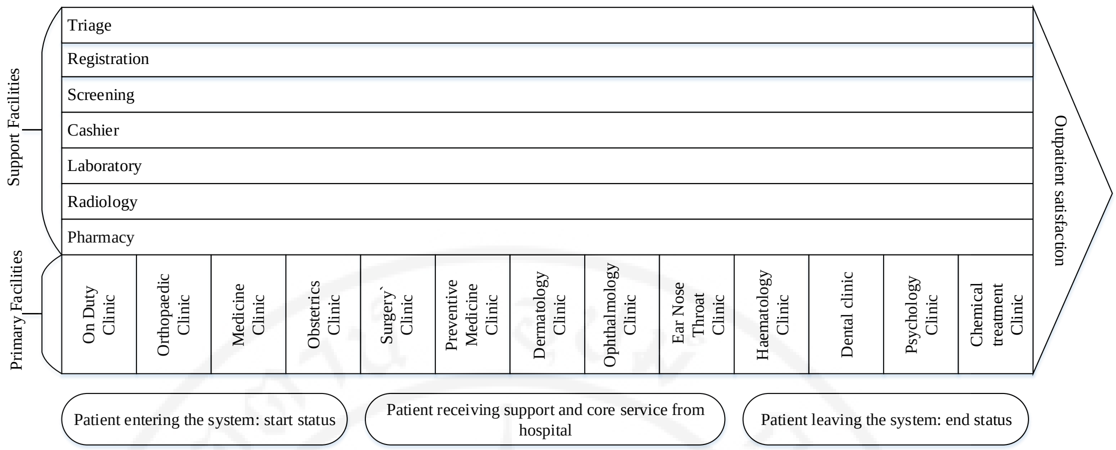


Figure 2.4 Outpatient flow value chain

CHAPTER III
RESEARCH METHODOLOGY

This chapter aims to describe the procedure of the research methodology. The methodology is focusing in detail on three key areas:

1. Research problem formulation: it explains about steps in reviewing overview of common practices in Outpatient Department (OPD), and value chain theory for the research model. The review is mainly based on literatures (textbooks and journal articles) and current practices of the hospitals in Thailand, which derived from their websites.
2. Conceptualizing research design and contracting an instrument for data collection: the OPD practices, then, are mapped with value chain model to study the OPD patient flow. By mapping OPD practice with value chain model, OPD value chain model can be developed by considering the primacy facilities of the clinics and the support facilities in OPD. Next, data collection technique is developed.
3. Sampling: Outpatient Department of the hospital is selected to study.

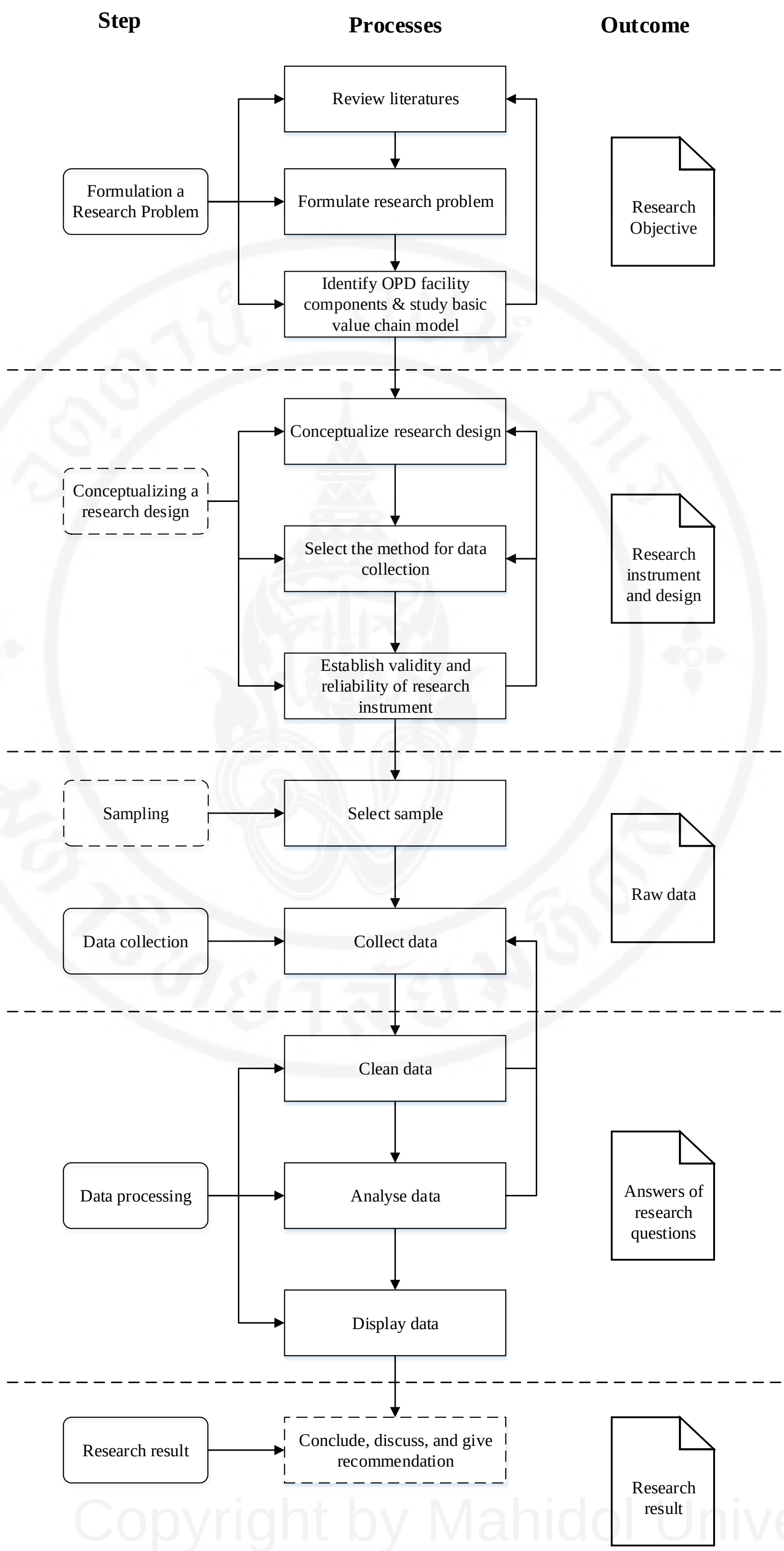


Figure 3.1 Research methodology

3.1 Step 1 Formulating a research problem

Formulating a research problem is the initial step in this thesis. It provides the destination where research should go. More importantly, how big or small the problem is definitely depends on financial resource, time available, and the knowledge and degree in the field (Kumar, 2010). Within this step, there are three processes. In this study, the research problem is mainly formulated by literature review.

3.1.1 Review literature

Literature review is the integral process of research in formulation of the problem. Even though it is sometimes a time consuming task, it provides valuable foundation to develop theoretical root for a study, and contributes to almost the other processes. Additionally, literature review enhances the knowledge of researchers and helps integrate the knowledge with existing research (Kumar, 2010). In this study, the sources used to prepare a bibliography are:

- Article: as the most important source for the research, articles could be found in many scholarly journals. Having been checked by academics and other experts, information of article is always reliable. Additionally to this importance, article shows the researcher topics or problems which were already studied and yet to be studied.
- Previous research report: similar to article, the research reports are normally written by the qualified researchers of research organizations. Since they belong to the research organization, the report is sometimes not published in any journal.
- Reference books or reports of related-industry (healthcare) organizations: in addition to research organization, other organizations, even the commercial one, also have research projects. New finding is normally published in articles, annual reports or reference books of the organization.
- Textbook: textbooks contain authoritative information such as comprehensive accounts of research or scholarship, historical data, overviews, experts' views on themes or topics. However, in research, the books are normally used when the topic or problem is already defined. They are for enhancing knowledge of background information and related research on a topic.

- The internet: beside the sources mentioned above, internet provides the power ability to search other material in the database of websites. Surely, there is some information which is not reliable, but some information is also reliable such as the information derived from government websites, and other recognized organizations.

In this thesis, the articles and previous research reports help identify research gaps and nature of concerning topic, patient flow. More importantly, they provide the ability to set the scope of study. The books and reference books help to enhance the understanding of the nature and research topic selected. For example, value chain theory and Arena simulation program are used in this thesis; articles about applications related to them might not be really sufficient enough. To understand them deeply, there is a need of their handbooks. Additionally, internet is also used for further explanation on a certain topic. However, the internet is not always reliable since there is no standard references, but there are sources which are very acceptable to be references such as the information on government's websites and other well-known organizations'.

3.1.2 Formulate a research problem

After the gaps of previous researches have been identified based on literature review, it is time to formulate research problem. In general, research problem refers to the questions needed to be answered, or any assumption or assertion requiring challenge investigation. Research problem is a foundation of research study. Hence, good and clear research problem leads to efficient resource (financial and time, etc.) utilization. In this thesis, research problem is in a form of questions. As the result, there are two research questions developed from the literature review as mentioned in chapter 1.

3.1.3 Identify the components of OPD facility and value chain

In research, the components of OPD facilities are identified, according on the literature reviews, current practices of the hospitals, and the flow of outpatients. Moreover, by study of the value chance model, the primary and support facilities in OPD can be derived. Therefore, outpatient flow value chain model can be developed as in the Figure 2.4 in Chapter 2.

3.2 Step 2 Conceptualizing a research design

3.2.1 Conceptualize a research design

After research problem and the model have been developed, it is time for research design coming to play. Research design refers to plans and procedure that narrow down the decisions from broad assumption to detailed methods of data collection and analysis to answer the research questions or problem (Creswell, 2009). There are three common types of design: qualitative, quantitative, and mixed methods. In this thesis, quantitative method is used because all properties attached with the patient flow are quantitative such as:

- Patient arrival: it is about the number of patients arriving the OPD at particular time, which all are numeric.
- OPD resources: it refers to the numbers of doctors in the clinics and nurses for example at X-ray rooms, and lab, cashier, pharmacy, and so on which are for serving the patients. All are also numerical.
- Finally, in this thesis, simulation, which is wisely recognized as the quantitative research technique, is used to simulate the outpatient flow based on value chain model concept (Eldabi et al., 2002).

3.2.2 Select the method for data collection

Data collection technique is a means of collecting information for the study. Examples of data collection technique are observation forms, interview schedules, questionnaires, and interview guides, secondary data inquiry. Constructing the data collection technique is the first practical step in carrying out the study.

Information of a situation, person, problem or phenomena could be derived from two major data categories: primary data and secondary data. Primary data refers to information originally collected for a particular purpose of research. On the other hand, secondary data refers to the data that someone else has already conducted, but its result is available for others to use. In this thesis, the data will be gathered from both sources: primary and secondary source. The secondary data is derived from the excel files and some other information from the document sof the hospital. On the other hand, the primary data is derived from observation. It mainly related to the logic flow of the patients circulating across the clinics and department, and the number of the exam rooms or doctors.

3.3.3 Establish validity and reliability of research instrument

Good validity and reliability of research instrument can establish the quality of research result. For the validity, there are three common types namely face and content validity, concurrent and predictive validity, and constructive validity. On the other hand, procedure of determining reliability of research instrument can be classified into two groups: external consistency procedure, and internal consistency procedure. Since this thesis uses the OPD of one hospital as the case study, two elements of Triangulation research method, namely direct observation, and analyses of written documents and natural sites occurring in case environments. These are the common valid and reliable method for data collection (Woodside, 2010) which content, constructive, and predictive validity can be guaranteed.

3.3 Step 3 Sampling

Commonly, the research arms to show the fact of particular situation or behavior as the whole (population). However, it is somewhat impossible to study the whole population due to time and finance constraint. Therefore, other procedures have been used in place of population. Those procedures are sampling and case study. The sampling refers to the process of selecting a sample from a population. The sample then will be used to represent the characteristics of the population to discover some unknown information. Sampling can be categorized into three strategies: random sampling design, non-random sampling design, and mixed sampling design (Kumar, 2010; Creswell, 2009). On the other hand, a case study, which is also acceptable and useful for the research, is a procedure used to investigate current situation or behavior of the study subject or topic. Researcher of case study gets involve directly in the real life context for some period of time which is long enough to understand the system of the subject clearly (Yin, 1994; Woodside, 2010). In this thesis, a case study of OPD of one hospital is used to study the outpatient flow. Since the patient flow is a complex phenomenon, plus simulation is used to simulate the flow, a case study procedure is the most suitable for this type of research.

3.4 Step 4 Collecting data

The data is collected via two means based on Triangulation research method. Actually, the Triangulation research method consists of three components: direct observation, probing, and analyses of written documents and natural sites. However, in this thesis, two of the three components are used for the data collection. There are direct observation, and analyses of written documents and natural sites.

- **Analyses of written documents and natural sites:** it is the secondary data source for the research. The outpatient flow related documents is gathered from the hospital. The data of such documents is mainly about time and the number of patient arrivals at the department, examination time of the clinics which the patients need to flow through, layout of the building, and the sequence of the flow.
- **Direct observation:** direct observation is conducted, firstly, to collect more data related to the number of exam rooms of all clinics and the number of counters of the support facilities such as Lab, and X-ray. Additionally, it also could help verified the patient flow documented in the hospital.

3.5 Step 5 Processing data

After the data have been collected, it is time to process the data to answer the research questions. There are three processes in the processing data: editing data collected, analyzing data and displaying data. Although most proportion of data are from secondary source, the data should be edited before analyzed because information obtained from the source is just raw data. It might not be completed or ready to be analyzed.

Editing data process aims to identify and minimize, as much as possible, error, misclassification, and missing information derived from both data sources. For the secondary data, there is nothing much of data to be cleaned or edited since this kind of data set is normally out there. It is just to be used and not to be used due to its relevance to the research objectives. It is why, in this study, direct observation is used to gather additional data which is not available in secondary data source.

For analysis in this research, discrete event simulation is use to model the outpatient flow, and Arena Rockwell Automation Software is used to simulate the flow. Of cause, there are tools, more than just Arena simulation is used to get the answer for the research question. Some tools of Rockwell Software are also used namely:

- Output Analyzer: it is used to exports the statics data collected by the express built in the Arena. Moreover, with this tool, the two samples t-test means comparison can also be performance. In addition, the Output Analyzer is also used to plot some basic graphs of the criteria required in this study.
- Opt Quest: it is used to search for optimal solution with the outpatient flow models. In this thesis, it is used to search for the optimum resource capacity in constraint of the specific number of patients on the floors and cycle time of the patients.

3.6 Step 6 Research results

As the result, three processes will be covered. Firstly, conclusion will provide the summary of the whole research processes. Next, discussion is made to provide deep understanding of research result. Finally, recommendation suggests methods and conditions in applying the research result. Moreover, the research limitation will be included as well.

CHAPTER IV
DISCRETE EVENT SIMULATION FOR OUTPATIENT FLOW

As mentioned in the previous chapters, Chapter 2 and 3, discrete event simulation will be used to model the outpatient flow. Therefore, this chapter aims to describe the outpatient discrete event simulation model in detail.

4.1 Patient flow at Outpatient Department

In the case hospital in this research, the following facilities of Outpatient Department are used to form the discrete event simulation model for the patient flow. They are On Duty clinic, Orthopedic clinic, Medicine, Obstetrics, Surgery, Preventive and Social Medicine, Dermatology, Ophthalmology, Ear Nose Throat (ENT), and Dental clinic, Hematology, Psychiatry, and Chemical treatment, Triage, Register, Screening, Lab, X–ray, Cashier, and Pharmacy. In the model, arrival patients are classified into six categories:

1. Non–appointment arrival: it is the walk–in patients, who have no appointment at all with the hospital. The patients come to see doctors first

2. Lab patient arrival: it refers to the patients who have Lab appointment meaning that before seeing the doctors, the patients need to have the Lab testing, and the result beforehand.

3. X–ray patient arrival: similarly, to Lab patients, X–ray patients refer to the patients who need to have X–ray testing and the result before seeing the doctors.

4. Walk–appointment patient arrival: it is a group of patients who have the appointment with the doctors, and they all can walk.

5. Not–walk appointment patient arrival: it is a group of patients who have the appointment with the doctors and they need transportation assistance like stretcher and wheelchair to move around the hospital’s facilities. This group of patients moves slower a cross the facilities and tend to come to the hospital a bit early.

6. On duty clinic patient arrival: it is also the group of patients who come to the hospital without any appointment. They arrive the hospital a bit late in the morning.

` The behavior of the patient flow across the facilities is described as the following. Firstly, the patients arrive at the hospital. Before going to particular clinics, they need to go through some OPD facilities. Regardless of any arrival types, all not-walk patients need to go to Triage first. The patients who had Lab and X–ray appointment before going to meet the doctors will go Lab and X–ray rooms separately. For Lab and X–ray processes, there are three sub-processes namely registration (Lab or X–ray, Cashier, and Lab or X–ray). After that, all patients go to register. The registration counters are classified into two categories: Appointment patients (Lab, X–ray, and appointment patients) registration, and new (walk-in) patient registration. After the registration, only walk–in and not–walk appointment patients will be screened in front of their clinics. After that, all patients, if they are done screening early, need to wait the doctors until opening clinic working hour starting at 9:00 until 13:00. Next, all patients go to submit their prescription to the pharmacist assistants who key in drug and calculate all the fees including medicine fee. After that the patients go to pay the fee at cashier counters. Finally, they pick up medicine from pharmacists and leave the hospital.

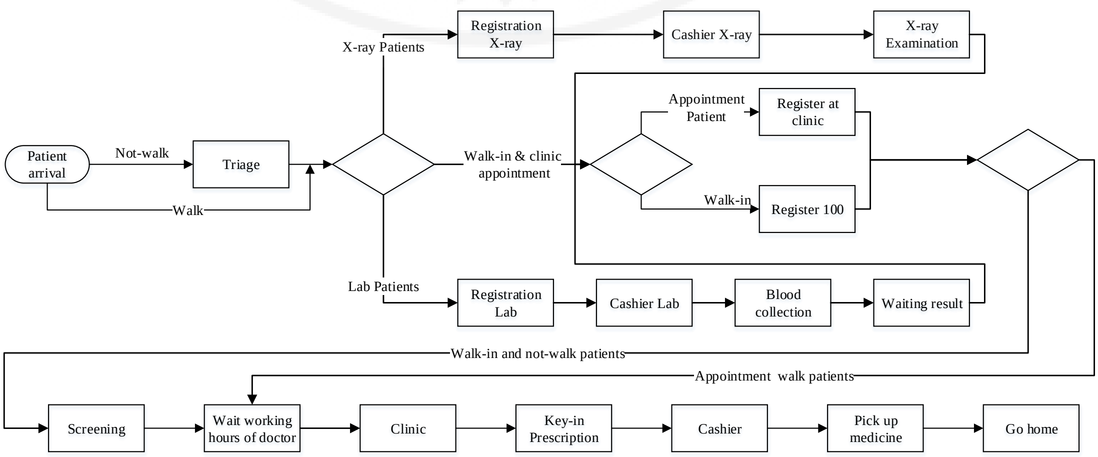


Figure 4.1 Flow overview of the patients in Outpatient Department

4.2 Patient flow simulation element

As mentioned in chapter 2 and chapter 3, discrete event simulation is used to model the patient flow, and Arena commercial software version 11 is used to develop such system (Kelton et al., 2008). In this research, the following discrete event simulation elements are identified.

- Entities: it refers to the players or objects which move around, change the status in the system. The output performance of the system depends on the changes of the entities. The beginning stage of the entity is arrival to the system, and the last is dispose from the system. The entities for the outpatient flow model are the patients. Since there are thirteen clinics, there are thirteen entity types representing the clinical patients.
- Process: it refers to the stations which service the entities. In this research, the stations of triage, registration, screening, all the clinics, laboratories, X–rays, cashiers and pharmacies (pharmacists' assistants who key in the prescription and the pharmacists who give the medicine to the patients) are the process.
- Resource: resource refers to the servers which provide the service to or process the entities. Simply, the resource is the manpower of the process. In one process, there might be the number of resources. They change their status (idle, busy, fail, and inactive) during the simulation running time. In this research, resource is counted based on the number of nurses at triage, registration, screening, laboratory, and X–ray, the number of doctors at all clinics, the number of cashiers, and number of pharmacists' assistants and pharmacists.
- Statistical counters: it is for collecting data from the simulation run. After that, the data will be analyzed. Since the ultimate objective of this study is capacity planning, the main data is related to number of the patients on the floors and time interval of the patients circulating from facilities to facilities in the system.
- Event: in simulation, normally, there are three events: arrival, departure, and end. The arrival is when the patients coming to the hospital. The departure is when the patients got all services they want. Normally, it happens when the patients get the medicine from the pharmacy. Finally, end is when the simulation run time reaches ten hours.

4.3 The outpatient flow description

There are two cases of the patient flow in Outpatient Department which are modeled by discrete event simulation. The first case is called "the basecase" and the other is called "the alternative".

4.3.1 Basecase model description

As mentioned above, there are two cases: "The basecase" and "The alternative". In the basecase, all facilities (all the clinics, Lab, X–ray, cashier and pharmacy) are located in the same building as shown in Figure 4.2. Moreover, the patient flow for the basecase model is shown in Figure 4.3.

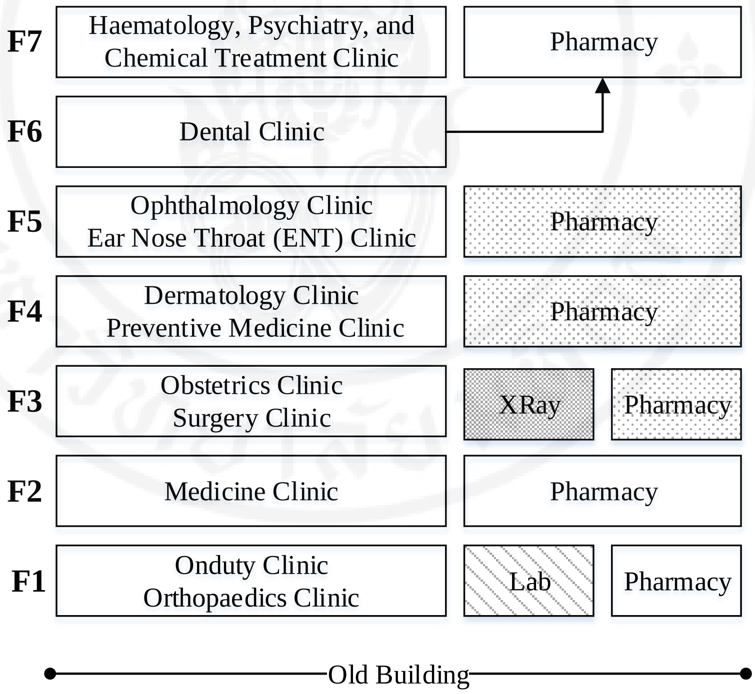


Figure 4.2 Facility locations in basecase model

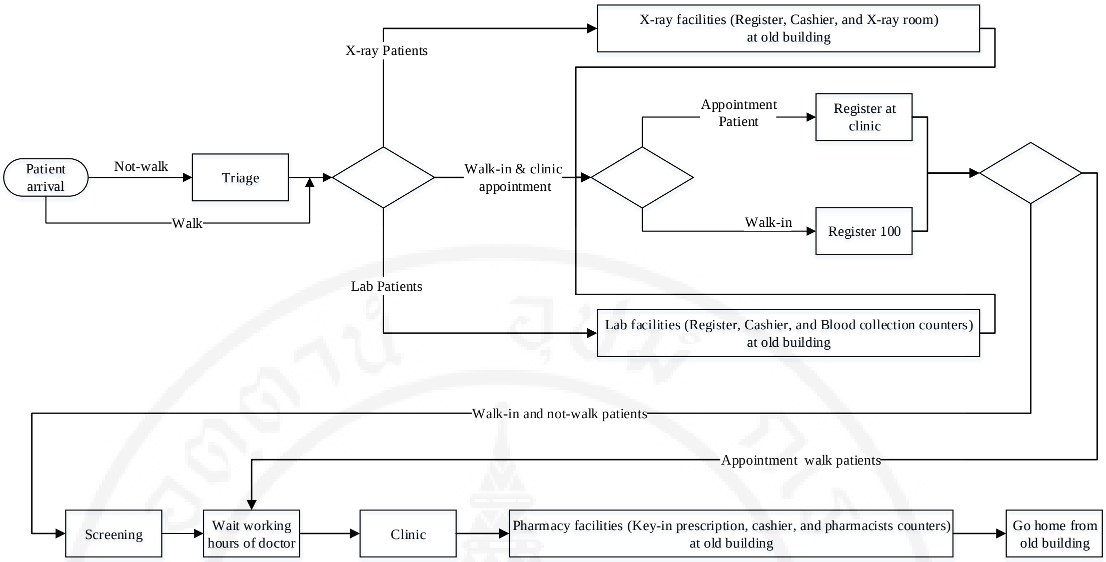


Figure 4.3 Conceptual flow of basecase model

4.3.2 Alternative model description

The other case (the alternative) is designed due to some facilities located separately. The demand is increasing year by year, and area of the old building is not big enough for the near future number of patients. Moreover, it is not feasible and economic to build some more floors at the old building. Therefore, new building is constructed and some support facilities of Outpatient Department will be moved to the new building (Figure 4.4). The support facilities moved to new building are:

1. Lab facilities: the lab facilities contain registration, cashier, and blood collection counters. Most of the amount of these facilities are moved to new building for serving the patients from twelve clinics namely: Orthopedic clinic (1st floor) Medicine clinic (2nd floor), Obstetrics (3rd floor), Surgery (3rd floor), Preventive medicine, and Dermatology clinic (4th floor), Ophthalmology and Ear Nose Throat clinic (5th floor), Dental clinic (6th floor), Hematology, Psychiatry, and Chemical treatment clinic (7th floor). Therefore, the other clinic, On duty clinic on 1st floor still uses the Lab facilities in old building.

2. X–ray facilities: most of the amount of X–ray facilities namely registration, cashier and X–ray rooms, are moved to new building. The same as Lab's

case, X–ray facilities are moved to new building to serve the patients from the twelve clinics. Hence, the remaining clinic uses the facilities at old building.

3. Pharmacy's facilities: pharmacy's facilities from 3rd floor to 5th floor are moved to new building, so that they will serve the patients from clinics located in 3rd floor, 4th floor, and 5th floor. The other pharmacy's facilities are kept to serve the clinics located on the same floors. Hence, they are 1st floor pharmacy facilities serving patients of all clinic on 1st floor. 2nd floor pharmacy facilities serve 2nd floor clinic. 7th floor pharmacy facilities serve the clinics located on both 6th and 7th floor.

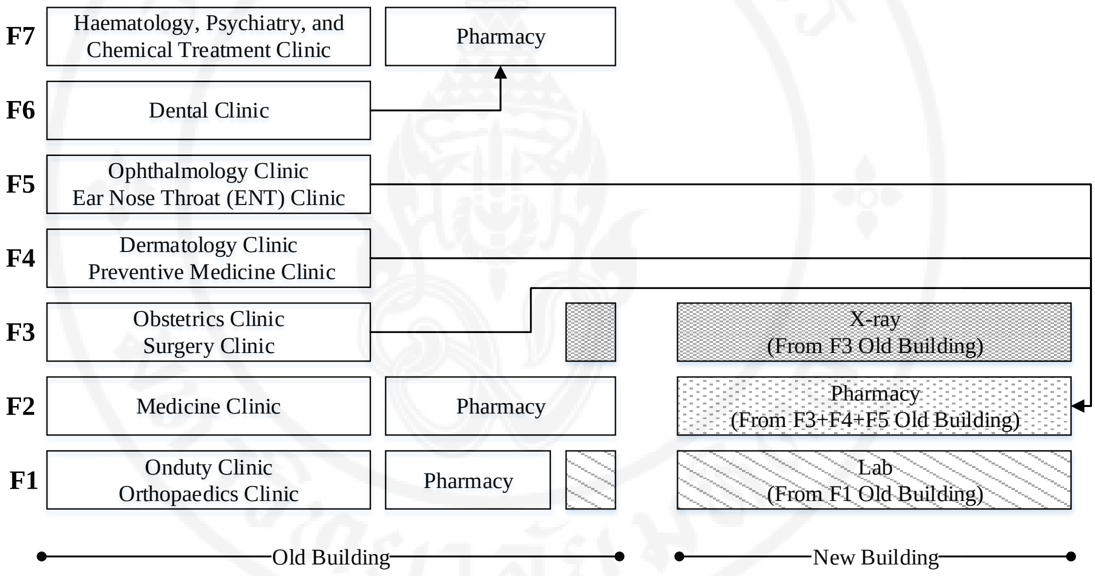


Figure 4.4 Facility locations in alternative model

The conceptual patient flow of this alternative model is shown in following Figure 4.5

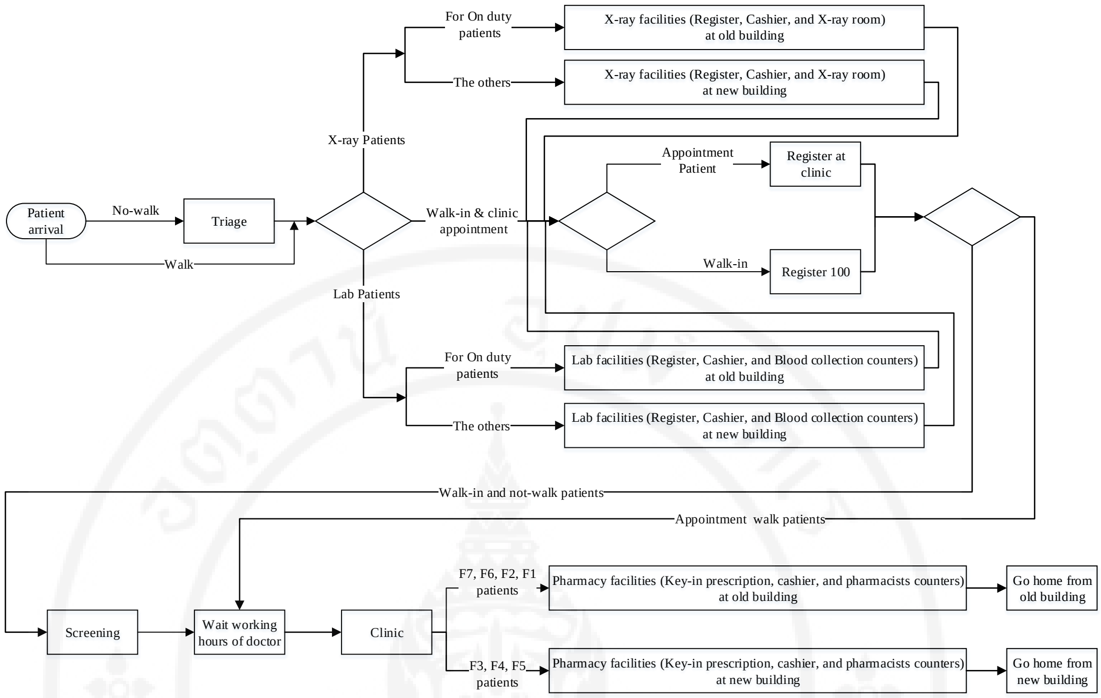


Figure 4.5 Conceptual flow of alternative model

4.3.3 Model objectives and KPIs

Simply speaking, the objectives of this thesis's outpatient model for both cases are, first, to investigate how congested the traffic of the patient flow is between the basecase and the alternative, and, second, to provide the optimum capacity planning for the facilities moved to the new building. As a matter of fact, the hospital gets congested because there many people waiting for the services for a long period of time. Therefore, the congestion in this thesis relates to two criteria: the number of patients at service points and cycle time of those service pointes. Capacity planning refers to resource allocation for the facilities. The allocations must be made in the way that there is balance for resource capacity at every facility. Therefore, three main key performance indicators (KPIs) are to be measured namely the number of patients, patient cycle time and resource utilization:

1. The number of patients: statistics of the number of patients is collected from the basecase and the alternative model. This statistics, next, is compared to see how different the congestion on each floor of both models is.

2. The number of patients, patient cycle time, and resource utilization: these three KPIs are measured for the capacity plaining for the facilities at the new building. If the resource utilization is low, there is a room for resource capacity reduction. If the resource utilization is very high and the number of patients and the cycle time is high, there is a need of resource capacity improvement.

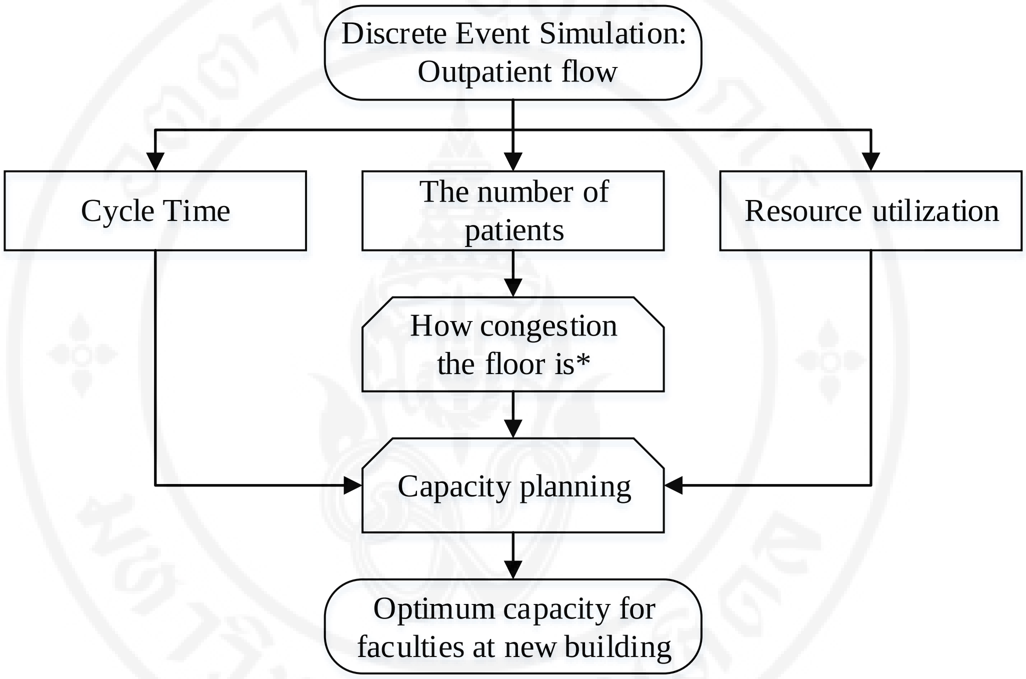


Figure 4.6 KPIs used to achieve the objectives

4.3.4 Conceptual model

The conceptual model is more detail and complex than conceptual flow due to complicities of the KPIs required to achieve the model objective, and program software used to build the model. The conceptual flow only illustrates the logical of the logic flow of the entities moving across all the process until it deposes. On the contrary, the conceptual model is more than just the logic flow of entity. It also illustrates the status of the entity moving across the processes. More importantly, it contains the logic which answers the model's questions or achieves model objectives. Figure 4.6 and 4.7 show the detail of outpatient flow.

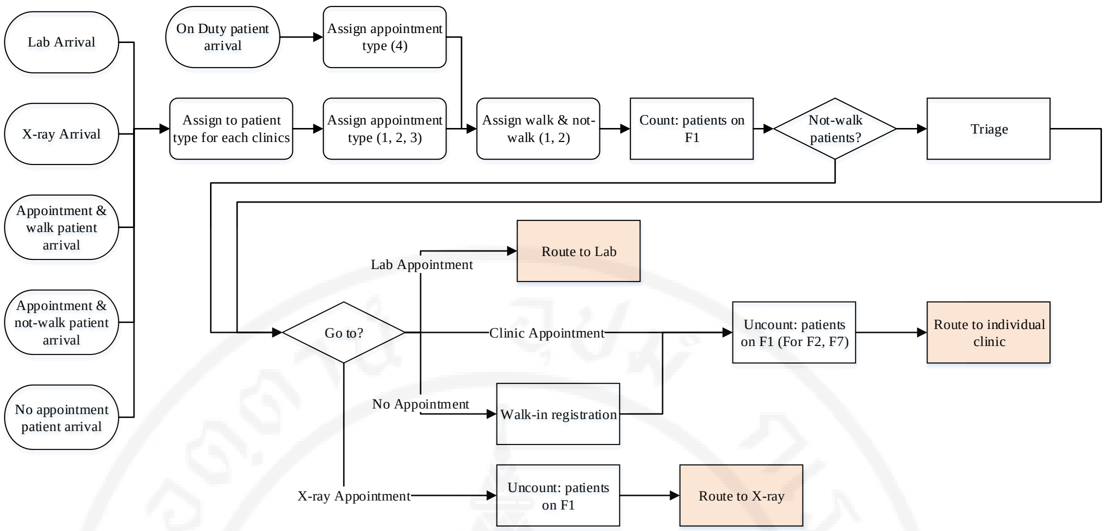


Figure 4.7 (a) Conceptual model of the basecase – Arrival, Lab and X-ray

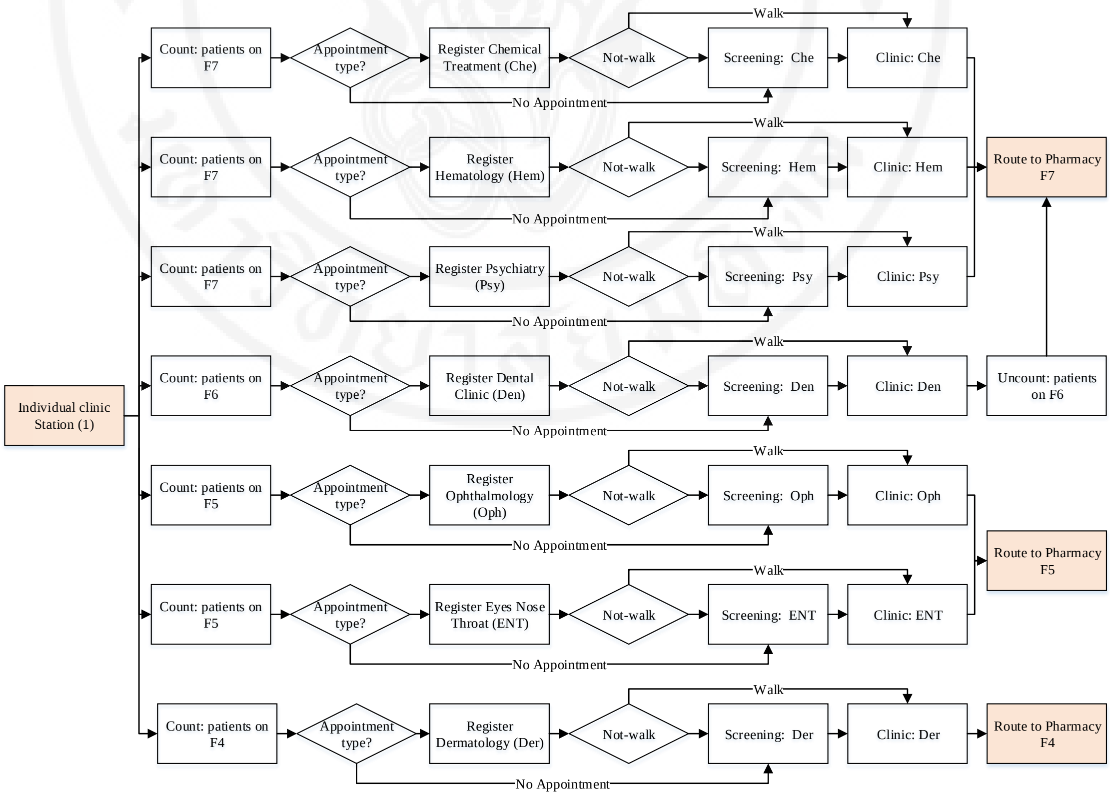


Figure 4.7 (b) Conceptual model of the basecase – Screening and Clinic 1

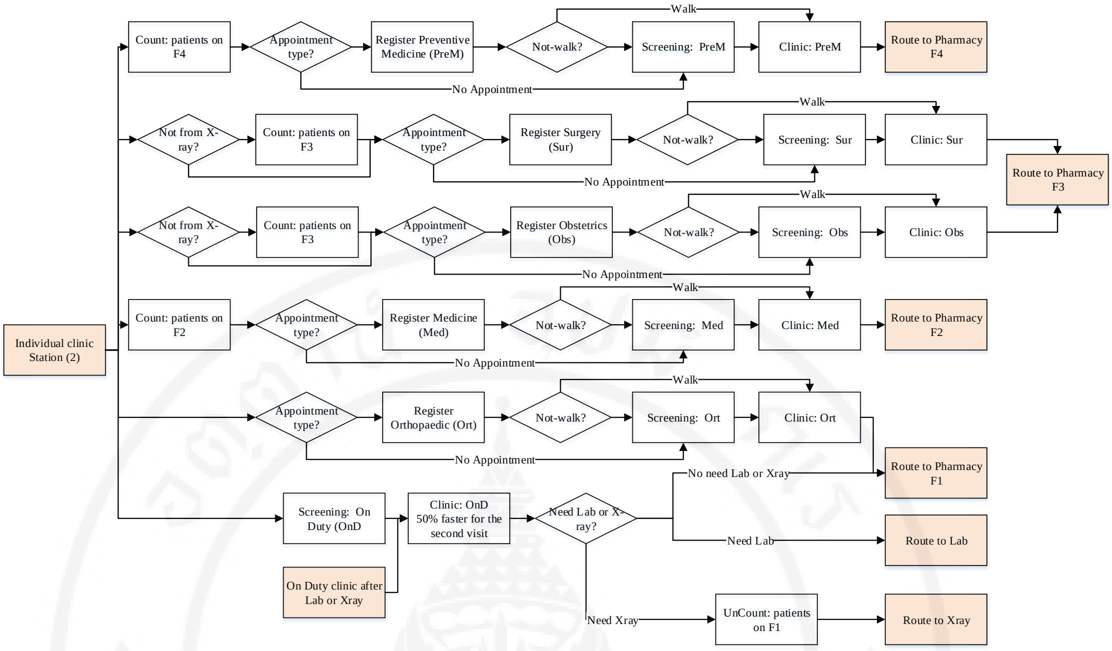


Figure 4.7 (c) Conceptual model of the basecase – Screening and Clinic 2

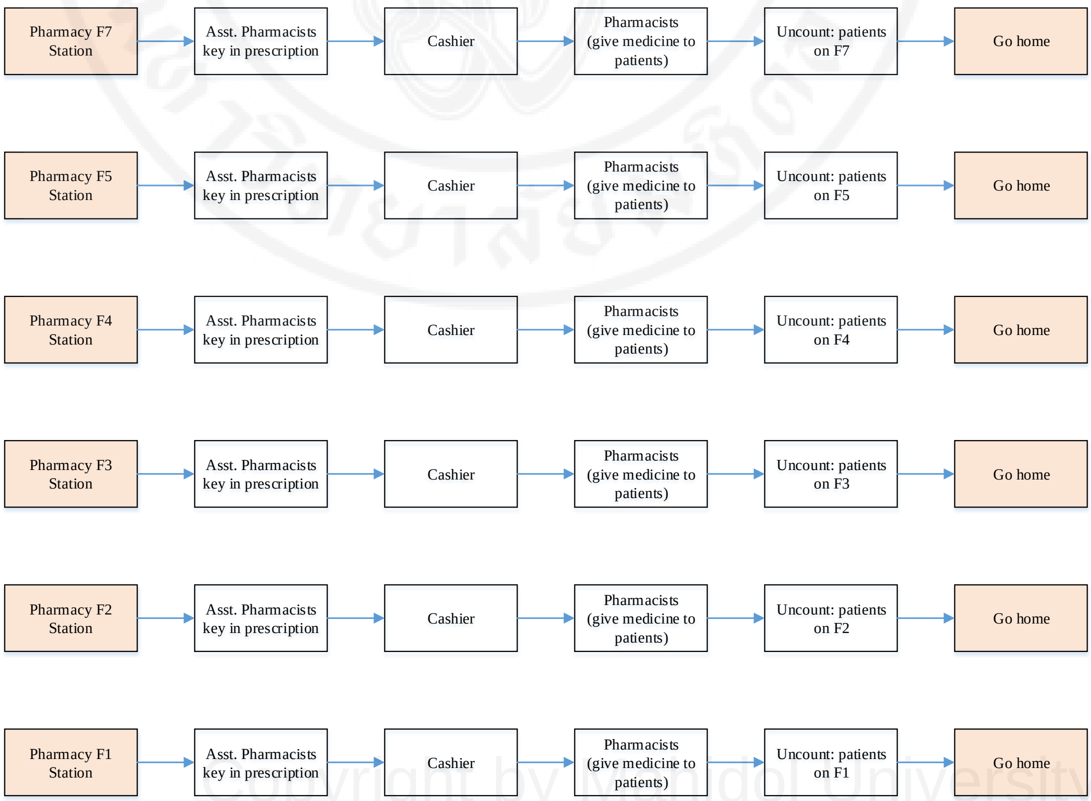


Figure 4.7 (d) Conceptual model of the basecase – Pharmacy

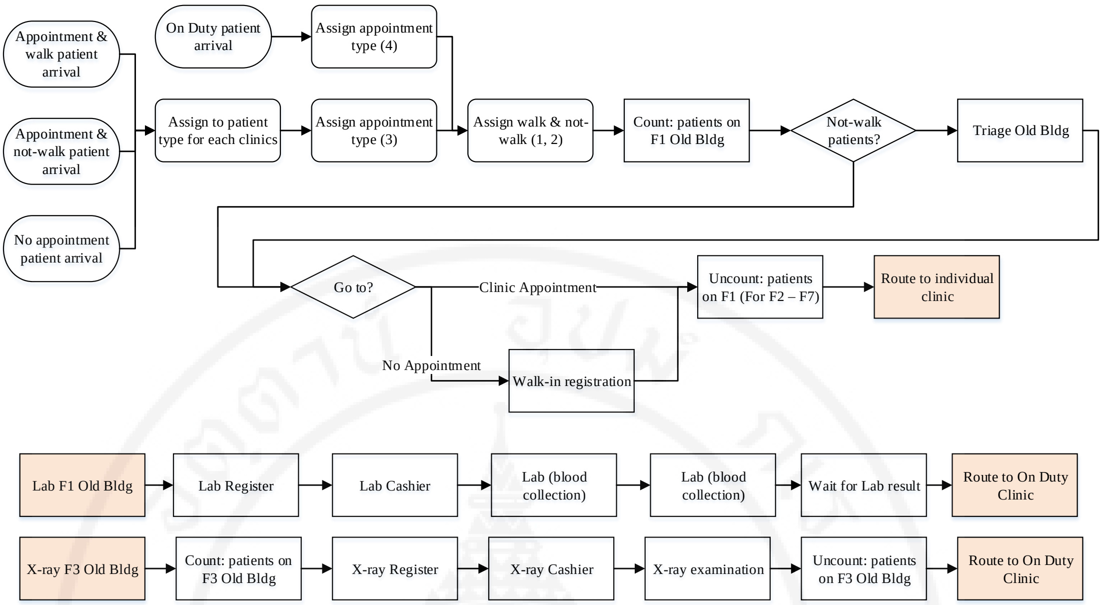


Figure 4.8 (a) Conceptual model of the alternative – old building

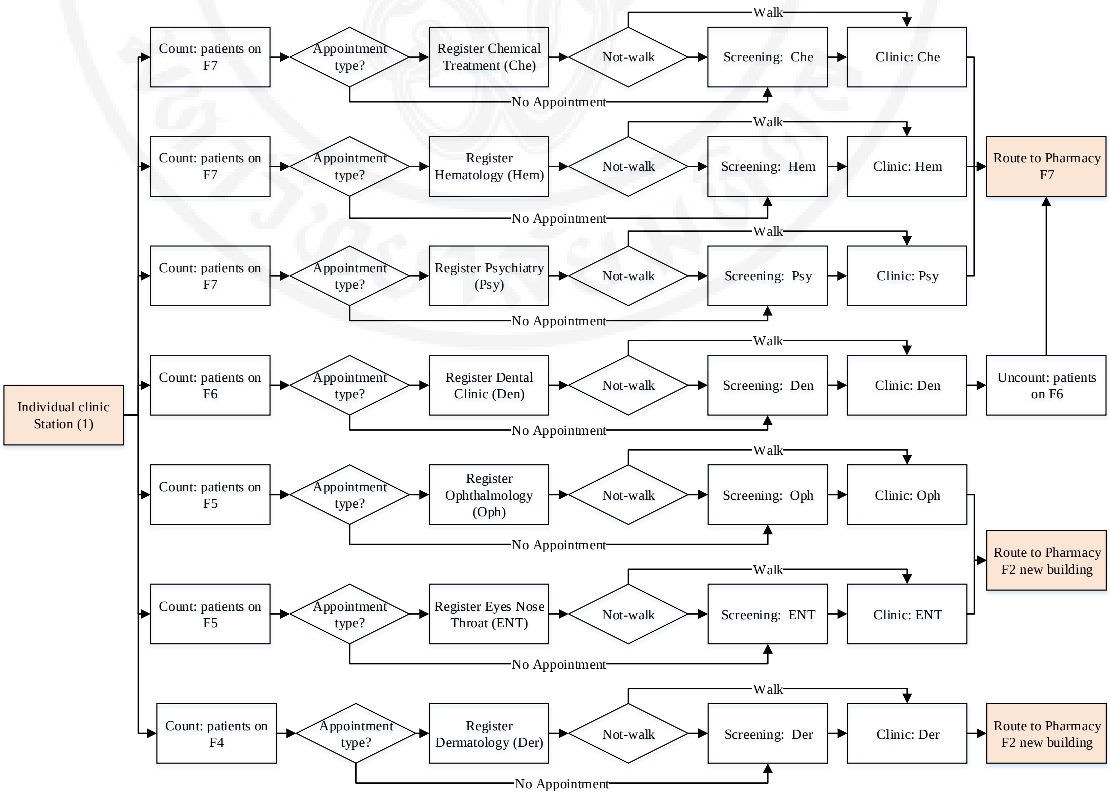


Figure 4.8 (b) Conceptual model of the alternative – Screening and Clinic 1 old building

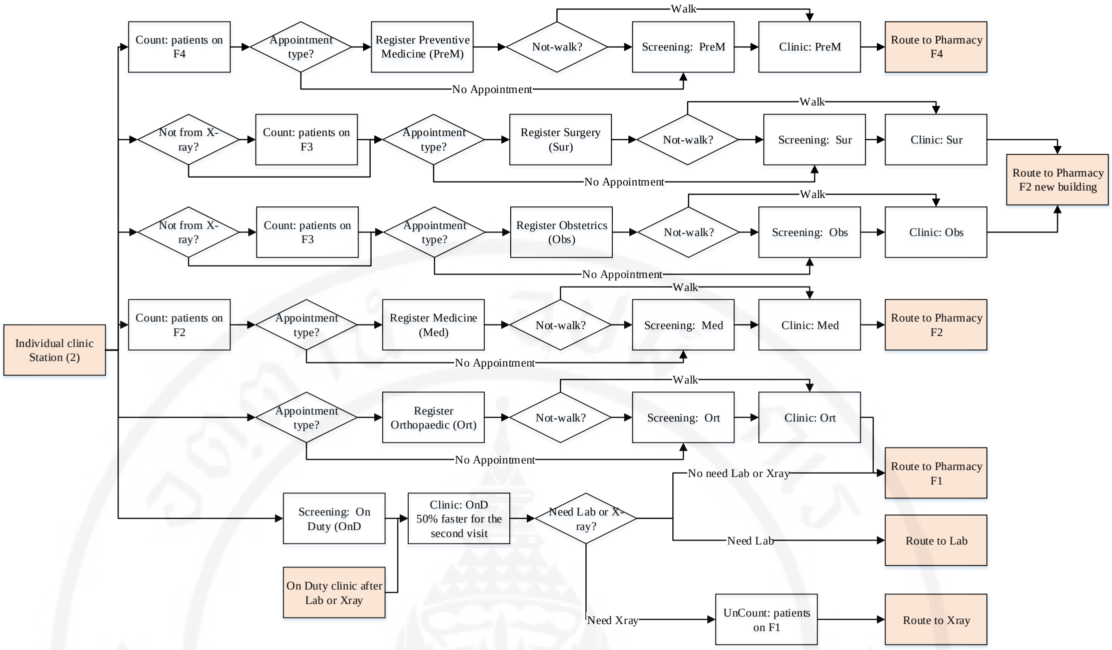


Figure 4.8 (c) Conceptual model of the alternative – Screening and Clinic 2 old building

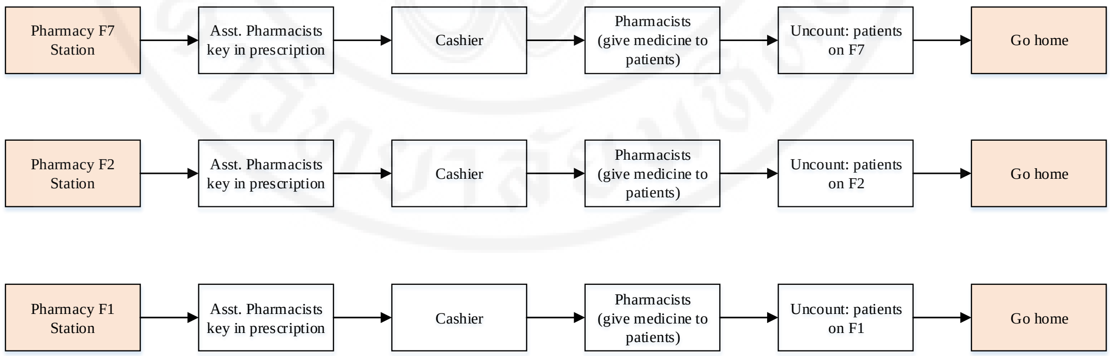


Figure 4.8 (d) Conceptual model of the alternative – Pharmacy old building

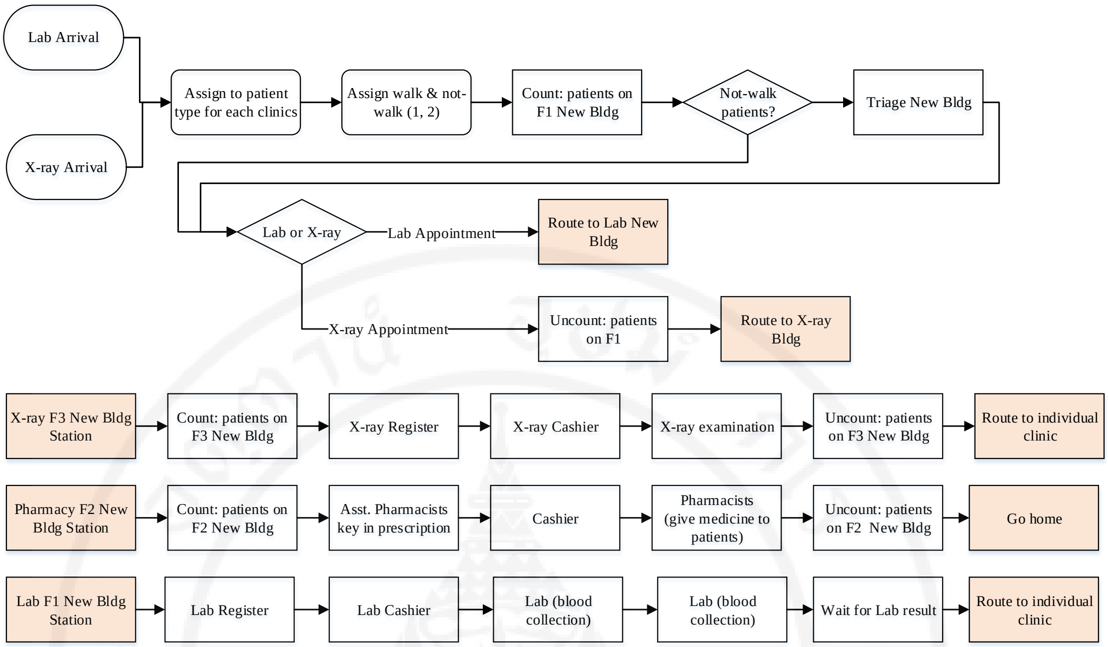


Figure 4.8 (e) Conceptual model of the alternative – new building

4.3.5 Input data for the basecase model

For the model in base case, there are main modules which require input data.

1. Create (patient arrival): the secondary data available from the hospital is that the number of patients arrives at the Outpatient Department per hour is provided. The patient arrivals are classified into six types. First, it is for Lab patients. Second, it is for X–ray patients. Third, it is for no–appointment patients. Fourth, it is for appointment patients who cannot walk. Fifth, it is for appointment patients who can walk, and last, it is for On Duty patients who tend to come very late morning. The number of arrival patients is shown in the following figure.

2. Process: process modules have been used to model the service points in the OPD. They are Triage process, Lab process, X–ray process, Registration process, Cashier process, Screening process, Clinical Process, Key in Prescription process, and Pharmacists process.

3. Delay: there is only one significant delay in this model, wait for blood testing result from the Lab.

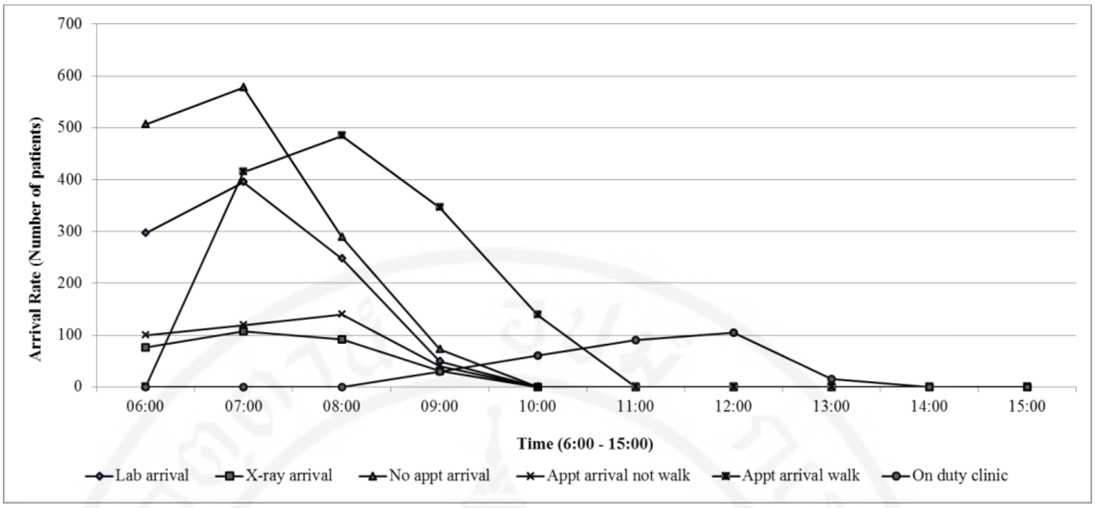


Figure 4.9 Patient arrival

4. Resource: resource is what doing jobs at the process to serve the entities (patients). All the resources for the processes are:

a. Triage resource: it is at Triage process

b. Registration resource: there are Lab Registration, X–ray, clinic registration, and no–appointment patient registration.

c. Lab: there is a Lab resource.

d. X–ray: there is an X–ray resource.

e. Screening resource: there are thirteen clinics, so there are thirteen different screening resources.

f. Clinic: there are thirteen clinics, which have thirteen resources individually.

g. Key–in Prescription resource: there are six pharmacy where the patients go to pick up medicine. Therefore, there are also six resources for Key–in Prescription Process.

h. Cashier resource: there are six cashier resources next to the six pharmacies plus one for Lab and the other for X–ray. Hence, there are eight resources for Cashier process.

i. Pharmacists resource: the same as Key–in Prescription resource, there are six resources for Pharmacist process.

5. **Route:** route is used to transfer entities from one place to another.

Table 4.1 Resource, resource capacity and processing time

Process	Service Time	Resource capacity
Triage	TRIA(0.5,1,1.5) Minutes	6:00 – 9:00: 6 | 9:00 – 11:00: 2 | 11:00 – 16:00: 1
Lab Registration	UNIF(15,30) Seconds	6:00 – 10:00:2 | 10:00 – 16:00:1
Lab Cashier	TRIA(30,50,70) Seconds	6:00 – 10:00:4 | 10:00 – 16:00:1
Lab	UNIF(1,3) Minutes	6:00 – 10:00:9 | 10:00 – 16:00:1
X–ray Registration	UNIF(15,30) Seconds	6:00 – 10:00:2 | 10:00 – 16:00:1
X–ray Cashier	TRIA(30,50,70) Seconds	6:00 – 10:00:2 | 10:00 – 16:00:1
X–ray	UNIF(3,5) Minutes	6:00 – 11:00:5 | 11:00 – 16:00:1
Registration No Appointment	TRIA(25,45,90) Seconds	6:00 – 7:00:4 | 7:00 – 9:00:8 9:00 – 16:00:2
Registration Orthopedic	UNIF(15,30) Seconds	7:00 – 12:00:1
Registration Medicine	UNIF(15,30) Seconds	7:00 – 12:00:1
Registration Obstetrics	UNIF(15,30) Seconds	7:00 – 12:00:1
Registration Surgery	UNIF(15,30) Seconds	7:00 – 12:00:1
Registration Preventive Medicine	UNIF(15,30) Seconds	7:00 – 12:00:1
Registration dermatology	UNIF(15,30) Seconds	7:00 – 12:00:1
Registration ENT	UNIF(15,30) Seconds	7:00 – 12:00:1
Registration Ophthalmology	UNIF(15,30) Seconds	7:00 – 12:00:1

Table 4.1 Resource, resource capacity and processing time (cont.)

Process	Service Time	Resource capacity
Registration Dental	UNIF(15,30) Seconds	7:00 – 12:00:1
Registration Psychiatry	UNIF(15,30) Seconds	7:00 – 12:00:1
Registration Hematology	UNIF(15,30) Seconds	7:00 – 12:00:1
Registration Chemical treatment	UNIF(15,30) Seconds	7:00 – 12:00:1
Screening On Duty clinic	TRIA(0.5,1.5,2) Minutes	9:00 – 10:00:1 | 10:00 – 14:00:3 | 14:00 – 16:00:1
Screening Orthopedic	TRIA(0.5,1.5,2) Minutes	7:00 – 11:00:2 | 11:00 – 12:00:1
Screening Medicine	TRIA(0.5,1.5,2) Minutes	7:00 – 9:30:4 | 9:30 – 12:00:2
Screening Obstetrics	TRIA(0.5,1.5,2) Minutes	7:00 – 12:00:1
Screening Surgery	TRIA(0.5,1.5,2) Minutes	7:00 – 10:00:2 | 10:00 – 12:00:1
Screening Preventive Medicine	TRIA(0.5,1.5,2) Minutes	7:00 – 10:00:3 | 10:00 – 12:00:2
Screening dermatology	TRIA(0.5,1.5,2) Minutes	7:00 – 12:00:1
Screening ENT	TRIA(0.5,1.5,2) Minutes	7:00 – 11:00:3 | 11:00 – 12:00:2
Screening Ophthalmology	TRIA(0.5,1.5,2) Minutes	7:00 – 8:00:2 | 8:00 – 12:00:1
Screening Dental	TRIA(0.5,1.5,2) Minutes	7:00 – 12:00:1
Screening Psychiatry	TRIA(0.5,1.5,2) Minutes	7:00 – 12:00:1
Screening Hematology	TRIA(0.5,1.5,2) Minutes	7:00 – 8:00:2 | 8:00 – 12:00:1
Clinic: On Duty clinic	POIS(10) Minutes	9:00 – 10:00:6 | 10:00 – 16:00:13

Table 4.1 Resource, resource capacity and processing time (cont.)

Process	Service Time	Resource capacity
Clinic: Orthopedic	POIS(10) Minutes	9:00 – 13:00:20
Clinic: Medicine	POIS(10) Minutes	9:00 – 13:00:65
Clinic: Obstetrics	POIS(10) Minutes	9:00 – 13:00:14
Clinic: Surgery	POIS(10) Minutes	9:00 – 13:00:11
Clinic: Preventive Medicine	POIS(5) Minutes	9:00 – 13:00:7
Clinic: Dermatology	POIS(7) Minutes	9:00 – 13:00:8
Clinic: ENT	POIS(17) Minutes	9:00 – 13:00:29
Clinic: Ophthalmology	POIS(9.5) Minutes	9:00 – 13:00:15
Clinic: Dental	POIS(15) Minutes	9:00 – 13:00:7
Clinic: Psychiatry	POIS(7) Minutes	9:00 – 13:00:7
Clinic: Hematology	POIS(10) Minutes	9:00 – 13:00:16
Clinic: Chemical treatment	POIS(15) Minutes	9:00 – 13:00:7
Key–in Prescription 1st Floor	TRIA(0.4,0.8,1) Minutes	9:00 – 10:00:1 | 10:00 – 16:00:2
Cashier 1st Floor	TRIA(30,50,70) Seconds	9:00 – 10:00:1 | 10:00 – 16:00:2
Pharmacist 1st Floor	TRIA(40,70,120) Seconds	9:00 – 10:00:1 | 10:00 – 16:00:3
Key–in Prescription 2nd Floor	TRIA(0.4,0.8,1) Minutes	9:00 – 16:00:3
Cashier 2nd Floor	TRIA(30,50,70) Seconds	9:00 – 12:00:3 | 12:00 – 16:00:4
Pharmacist 2nd Floor	TRIA(40,70,120) Seconds	9:00 – 16:00:3
Key–in Prescription 3rd Floor	TRIA(0.4,0.8,1) Minutes	9:00 – 13:00:1 | 13:00 – 16:00:2
Cashier 3rd Floor	TRIA(30,50,70) Seconds	9:00 – 13:00:1 | 13:00 – 16:00:2
Pharmacist 3rd Floor	TRIA(40,70,120) Seconds	9:00 – 10:00:1 | 10:00 – 16:00:2

Table 4.1 Resource, resource capacity and processing time (cont.)

Process	Service Time	Resource capacity
Key-in Prescription 4th Floor	TRIA(0.4,0.8,1) Minutes	9:00 – 16:00:1
Cashier 4th Floor	TRIA(30,50,70) Seconds	9:00 – 13:00:1 | 13:00 – 16:00:2
Pharmacist 4th Floor	TRIA(40,70,120) Seconds	9:00 – 11:00:1 | 11:00 – 16:00:2
Key-in Prescription 5th Floor	TRIA(0.4,0.8,1) Minutes	9:00 – 11:00:1 | 11:00 – 16:00:2
Cashier 5th Floor	TRIA(30,50,70) Seconds	9:00 – 11:00:1 | 11:00 – 16:00:2
Pharmacist 5th Floor	TRIA(40,70,120) Seconds	9:00 – 11:00:1 | 11:00 – 16:00:3
Key–in Prescription 7th Floor	TRIA(0.4,0.8,1) Minutes	9:00 – 16:00:2
Cashier 7th Floor	TRIA(30,50,70) Seconds	9:00 – 16:00:2
Pharmacist 7th Floor	TRIA(40,70,120) Seconds	9:00 – 16:00:2

Beside, there are also modules used for logic and statics collection of the models.

1. Hold: hold is used to keep the entities (patients) before the clinical working hours, which are from 9:00 to 13:00. Since there are thirteen clinics, thirteen Hold modules have been used.

2. Assign: it is used to create the variable and attribute in the model

a. Variable: there are two main variables in the base case model. First, varID is the variable storing the number of patients coming to the hospital. The other variable is varWIP, which stores the current number of patients in the hospital.

b. Attribute: there are attributes used in the base case model. First, attribute "att_apptID" is used to classify the types of appointments of the patients. There four values of att_apptID attribute.

i. att_apptID=1: the patients have Lab appointment.

ii. att_apptID=2: the patients have X–ray appointment

iii. att_apptID=3: the patients have clinical appointment

iv. att_apptID=4: the patients have no any appointment.

Second, “att_WalkID” attribute is used to classify walk and not–walk patients.

i. att_walkID=1: the patients who can walk.

ii. Att_walkID=2: the patients who cannot walk.

Third, “att_walkSpeed” attribute is used to set the walking speed for the walk and not–walk patients

i. att_walkSpeed =1: the walk patients will have normal moving time (transfer time).

ii. att_walkSpeed =1.5: the not–walk patients will have 50% longer moving time compared to walk patients.

Last, “att_ScrFactor” attribute is used to set the screening speed.

iii. att_ScrFactor =1: it is for the appointment patients. Hence, they will be screened with normal service time.

iv. att_ScrFactor =2: It is for the new patients (walk–in patients) who will be screened two times longer than the appointment patients will be.

3. Sore and Unstore: they are used to record the current number of patients on each floor. Therefore, they are seven StoreNames have been used in the base model.

4.3.6 Input data for the alternative model

The alternative model is the “as if” model of the basecase meaning that it is the future patient flow of the Outpatient Department. In the alternative model, the new building is built. Therefore, some facilities are moved to the new building and the other facilities are still at the old building. Based on the outpatient flow value chain, the support facilities could be separated from the primary facilities. Therefore, the facilities moved to new building are Pharmacy, Lab and X–ray; surely along with their co–facilities namely the registration, and the cashier as in Figure 4.3: the alternative conceptual patient flow in Outpatient Department.

In this model, all most the data inputs remain the same. Since most of the Lab and X–ray facilities are moved to new building, Lab and X–ray patients will arrive new building at the first place. Moreover, all pharmacy facilities from 3rd floor to 5th floor are moved to new building. Hence, all resource capacities of Key-in Prescription, Cashier, and Pharmacists from 3rd floor to 5th floor will be combined accordingly. The capacity allocations are as the following:

1. Triage process: triage capacities are allocated for both old and new building.
2. No–appointment Registration process: the capacities remain the same.
3. Clinical Registration process: the capacities remain the same.
4. Screening process: the capacities remain the same.
5. All thirteen Clinic processes: the capacities remain the same.
6. Pharmacy processes (Key-in Prescription, Cashier, Pharmacist processes) on 1st, 2nd floor, and 7th floor: the capacities remain the same on their floors.
7. Pharmacy processes (Key-in Prescription, Cashier, Pharmacist processes) from 3rd floor until 5thfloor: All will be combined and moved to the new building.

Table 4.2 New resource capacity for the alternative model

Process	Location	Capacity
Triage	Old Building	6:00 – 9:00: 4 | 9:00 –16:00: 1
	New Building	6:00 – 10:00: 2 | 10:00 – 11:00: 1
Lab Registration	Old Building	6:00 – 9:00:0 | 9:00 – 16:00:1
	New Building	6:00 – 10:30:2 | 10:30 – 16:00:0
Lab Cashier	Old Building	6:00 – 9:00:0 | 9:00 – 16:00:1
	New Building	6:00 – 10:30:4 | 10:30 – 16:00:0
Lab	Old Building	6:00 – 9:00:0 | 9:00 – 16:00:1
	New Building	6:00 – 10:30:9 | 10:30 – 16:00:0
X–ray Registration	Old Building	6:00 – 9:00:0 | 9:00 – 16:00:1
	New Building	6:00 – 10:30:2 | 10:30 – 16:00:0
X–ray Cashier	Old Building	6:00 – 9:00:0 | 9:00 – 16:00:1
	New Building	6:00 – 10:30:2 | 10:30 – 16:00:0

Table 4.2 New resource capacity for the alternative model (cont.)

Process	Location	Capacity
X-ray	Old Building	6:00 – 9:00:0 | 9:00 – 16:00:1
	New Building	6:00 – 9:00:5 | 9:00 – 11:00:4
Key-in Prescription	Old Building	*No key in prescription from F3 to F5*
	New Building	9:00 – 11:00:3 | 11:00 – 13:00:4 | 13:00 – 16:00:5
Pharmacy Cashier	Old Building	*No Cashier from F3 to F5*
	New Building	9:00 – 11:00:3 | 11:00 – 13:00:4 | 13:00 – 16:00:6
Pharmacists	Old Building	*No Pharmacist from F3 to F5*
	New Building	9:00 – 10:00:3 | 10:00 – 11:00:4 | 11:00 – 16:00:7

4.4 Simulation experiment

4.4.1 Number of replications

Simulation in Arena is random number. Therefore, the result from the models will not be reliable enough if the models are run with only one replication or insufficient number of replications (due to the variation of the output) (Kelton et al., 2008). The sufficient number of replications depends on the confident interval of the KPIs of the model. The number of replications can be calculated via the following equation.

$$n \cong n_0 \frac{h_0^2}{h^2}$$

n_0 = The number of initial replications.

h_0 = Half-Width of the KPI derived from the initial replications.

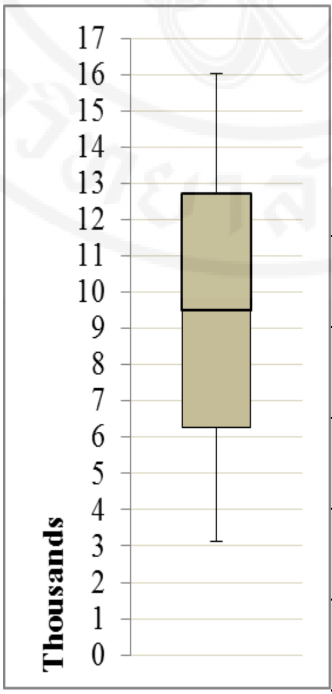
h = The “to be half width” of the KPI.

The KPI for the formula is the number of patients inside the hospital. By the initial running the simulation with 40 replications ($n_0 = 40$), the Half-Width of the KPI: $h_0 = 14.20$. Figure 4.9 shows the statistics summary of number of the patients for the initial replications.

Since in this thesis, the target Half-Width is not more than four patients on all seven floors of thirteen clinics. Therefore, the new number of replications can be calculated as

$$n \cong 40 \times \frac{14.2^2}{4^2} = 504.1 \approx 500$$

After running the simulation model with 500 replications, the new Half-Width of KPI is 4.09 which is acceptable. More importantly, 500-replication is sufficient enough which makes the arrival patients of individual clinics in basecase model are the same with arrival patients of individual clinics in alternative model. The more detail discussion related arrival patients is presented in Chapter 5, section 5.1. Therefore, 500-replication is used for both the base case model and the alternative.



Average	3207.98
Standard Deviation	44.41
0.95 C. I. Half-Width	14.20
Minimum Value	3113.72
Maximum Value	3287.38
Nubmer of Observation	40.00

Figure 4.10 The number of patients inside the hospital from 40 simulation replications

4.4.2 Terminating condition

In Arena simulation, there are three main approaches to end the simulation run. First, the simulation run can be ended by replication length. This means that the simulation will run for some period of time and it will end and provide the result. Second, the simulation run will end when the terminating condition is met. For this second approach, the terminating condition is normally an expression. Last, the simulation run will end when there is no entity inside the model (Kelton et al., 2008). For this research, terminating conditions by replication length is used. Hence, the simulation model will run until 600 minutes which is from 6:00 to 16:00.

CHAPTER V
SIMULATION RESULTS

5.1 Simulation results

5.1.1 Congestion

From the simulation output, the data is analyzed to see how congested the buildings is when the facilities allocated separately in different buildings. The congestion should be tested and analyzed with the same amount of patients arriving at the hospital. Therefore, the total amount of patients each clinic for both basecase and alternative model are tested. Statistics of arrival patients of each individual clinic has been collected from the basecase model and the alternative model. "Two-sample-t comparison of means" is used since the models have different logic number of modules although they have the same number of replications. From the data of 500-replication running of the both model, the arrival patients of each clinic of both models are tested at the significance level 5% by the following hypotheses. Since there are thirteen clinics, thirteen sets of the hypotheses have been tested.

H_0: arrival patients of a clinic, for example On Duty Clinic, in basecase model are the same with arrival patients of that clinic in alternative model. $(\mu_{bas} = \mu_{alt})$

H_1: arrival patients of a clinic, for example On Duty Clinic, in both models are not the same. $(\mu_{bas} \neq \mu_{alt})$

The hypotheses testing shows that arrival patients of the clinics in the basecase are the same with the arrival patients of the alternative (fail to reject H_0). Table 5.1 provides evidences for these hypothesis results.

Table 5.1 Comparison of arrival patients by clinics

Arrival patients	Mean	95% C.L Value		P-value	Result
OnD Basecase OnD Alternative	300.1 300.6	-2.26	1.71	0.68	Fail to reject H_0
Ort Basecase Ort Alternative	437.7 439.3	-4.34	1	0.23	Fail to reject H_0
Med Basecase Med Alternative	1500.5 1499.1	-3.4	6.3	0.59	Fail to reject H_0
Obs Basecase Obs Alternative	297.1 295.9	-0.79	3.33	0.23	Fail to reject H_0
Sur Basecase Sur Alternative	243.7 241.9	-0.11	3.65	0.06	Fail to reject H_0
PreM Basecase PreM Alternative	293.8 294.9	-3.2	1.17	0.36	Fail to reject H_0
Der Basecase Der Alternative	252.3 250.9	-0.71	3.37	0.20	Fail to reject H_0
ENT Basecase ENT Alternative	399.5 298.6	-1.57	3.38	0.47	Fail to reject H_0
Oph Basecase Oph Alternative	377.2 2.77.1	-2.33	2.46	0.96	Fail to reject H_0
Den Basecase Den Alternative	105.1 105.2	-1.41	1.11	0.81	Fail to reject H_0
Psy Basecase Psy Alternative	159.4 160.2	-2.36	0.75	0.31	Fail to reject H_0
Hem Basecase Hem Alternative	357.8 357.5	-2.04	2.61	0.81	Fail to reject H_0
Che Basecase Che Alternative	94.8 94.7	-1.1	1.39	0.81	Fail to reject H_0

After the arrival numbers are verified, now it is time to make a comparison of the total number of patients on the floor. After 500–replications running of both models, the average of total patients staying on the floors is used for the hypotheses of two-sample-t comparison of means. The hypotheses are stated as the following:

H_0: the number of patients on the floor is the same when the primary facilities are the separated from support facilities. $(\mu_{bas} = \mu_{alt})$

H_1: the number of patients on the floor is different when the primacy facilities are the separated from support facilities. $(\mu_{bas} \neq \mu_{alt})$

The hypotheses are tested at the significance level 5%, and the results of the seven floors are:

1. **The first floor:** the number of patients on the first floor is not the same at significance level 5% when the primary facilities are separated from the support activities. On the first floor, most of the Lab facilities namely Lab Registration, Lab Cashier, and Lab Counter for blood collection are moved to new building. Therefore, in the early working hours, the numbers of patients is going to get Lab services at new building. This has released the congestion at the first floor from the old building.

2. **The second floor:** the number of patients on the second floor is the same at significance level 5% when the primary facilities are separated from the support activities. In the basecase model, some of the patients of the first floor use the Lab facilities on the first floor of the same building. In alternative model, some of the second floor patients use Lab facilities at the first floor of new building. That is the reason there is no a big change of the number of patients on the floor in both models.

3. **The third floor:** the number of patients on the third floor is not the same at significance level 5% when the primary facilities are separated from the support facilities. This happens because on the third floor in basecase, there are X–ray facilities, X–ray register, X–ray cashier, and X–ray exam rooms. However, in the alternative model, those facilities are moved to new building on the third floor. Hence, some congestion caused by X–ray facilities can be released to the new building. More importantly, other support facilities of the third floor pharmacy, are also moved to new

building on the second floor. Therefore, very hug congestion can be released to new building.

4. The fourth floor: the number of patients on fourth floor is not the same at significance level 5% when the primary facilities and the support facilities are separated. On the fourth floor, the support facilities allocated to new building on the second floor are Pharmacy facilities (assistant pharmacists keying in prescription, cashier, and pharmacists). This allocation helps release the congestion from the floor of the old building when the patients are done with clinic examination.

5. The fifth floor: the number of patients on the fifth floor is not the same at significance level 5% when the primary facilities are separated from the support facilities. It is just like the fourth floor, the pharmacy facilities are moved to new building on the second floor.

6. The sixth and seventh floor: the number of patients on the sixth or seventh floors is the same at significance level 5% when the primary facilities and support facilities are separated. These two floors have the same situations as the second floor. The patients of these floors use the Lab and X–ray facilities in other floors in both basecase model and alternative model.

Table 5.2 provides the summary of the number of patients on each floor comparison between basecase model and alternative model.

Table 5.2 The number of patients comparison on each floor

The number of patients	Mean	95% C.L Value	P-value	Result
The 1st floor Basecase The 1st floor alternative	375.5 264.9	108.03 113.22	0.00	Reject H0
The 2nd floor basecase The 2nd floor alternative	642.9 639.5	0.1 6.7	0.43	Fail to reject H_0
The 3rd floor basecase The 3rd floor alternative	253.1 139.6	111.79 115.25	0.00	Reject H0
The 4th floor basecase The 4th floor alternative	256.9 145.6	109.38 113.21	0.00	Reject H0

Table 5.2 The number of patients comparison on each floor (cont.)

The number of patients	Mean	95% C.L Value		P-value	Result
The 5th floor basecase The 5th floor alternative	381.6 228.9	150.51	155.02	0.00	Reject H_0
The 6th floor basecase The 6th floor alternative	30.12 30.03	-0.58	0.75	0.79	Fail to reject H_0
The 7th floor basecase The 7th floor alternative	212.1 212.6	-2.30	1.41	0.64	Fail to reject H_0

5.1.2 Cycle Time

By moving the support facilities to an additional building, the congestion can be released. However, it also generates walking time (transfer time) which could make the total time or cycle time of the patients in the hospital longer. Therefore, "Two-sample –t comparison of means" is used to test whether the cycle time of the patients of each clinic becomes longer when all facilities located in the same building and when some support facilities are moved to a new building. At the significant level 5%, the hypotheses are stated as the following.

H_0: the cycle time of the patients of a clinic, for example On Duty Clinic, in basecase model is the same as the cycle time of the patients of that clinic in alternative model.

$(\mu_{bas} = \mu_{alt})$

H_1: the cycle time of the patients of a clinic, for example On Duty Clinic, in basecase model is greater (longer) than the cycle time of the patients of that clinic in alternative model.

$(\mu_{bas} > \mu_{alt})$

Table 5.3 Cycle time comparison of patients on each floor

The cycle time	Mean	95% C.L Value		P-value	Result
OnD Basecase OnD Alternative	136.81 107.67	28.13	30.15	0.00	Reject H_0
Ort Basecase Ort Alternative	211.03 219.39	-9.24	-7.47	1.0	Fail to reject H_0
Med Basecase Med Alternative	293.62 292.99	0.03	1.23	0.20	Fail to reject H_0
Obs Basecase Obs Alternative	270.2 268.5	0.36	3.03	0.006	Reject H_0
Sur Basecase Sur Alternative	303.9 302.5	-0.02	2.76	0.027	Reject H_0
PreM Basecase PreM Alternative	312.1 298.6	12.03	14.88	0.00	Reject H_0
Der Basecase Der Alternative	278.6 264.1	13.09	16.08	0.00	Reject H_0
ENT Basecase ENT Alternative	332.36 328.12	3.18	5.31	0.00	Reject H_0
Oph Basecase Oph Alternative	294.93 291.37	2.58	4.54	0.00	Reject H_0
Den Basecase Den Alternative	243.3 242.9	-1.49	2.36	0.23	Fail to reject H_0
Psy Basecase Psy Alternative	201.3 202.5	-2.76	0.43	0.92	Fail to reject H_0
Hem Basecase Hem Alternative	220.55 220.81	-1.34	0.84	0.68	Fail to reject H_0
Che Basecase Che Alternative	192.2 192.5	-2.34	1.75	0.61	Fail to reject H_0

From the Table 5.3, it can be observed that within 95% confidence level, the cycle time of the patients becomes shorter for seven clinics namely On duty, Obstetrics, Surgery, Preventive medicine, Dermatology, ENT, and Ophthalmology clinic while the cycle time of the others remains to be the same. This happens because the primary facilities and the support facilities are allocated differently. This has affected on pharmacy processes. In the basecase model, the patients of Obstetrics and Surgery clinic (3rd floor), Preventive medicine and Dermatology clinic (4th floor), and ENT and Ophthalmology (5th floor) clinic use the pharmacy facilities on their own floors. It can be called specialized pharmacy processes. The patients of a particular clinic on one floor are not allowed to get the pharmacy services on another floor. However, in the alternative model, all the 3rd floor, 4th floor, and 5th floor pharmacy facilities are integrated and allocated in one place. It is the generalized pharmacy processes. Within such practice, any patients can go to get the pharmacy services from any pharmacy resources. Therefore, the patients have shorter pharmacy waiting time which leads to shorter cycle time. Moreover, the cycle time of the patients does not change much or become longer because the patients, most of the time, are always waiting for the services from the pharmacy. Hence, if there is no walking time (transferring time), the patients need to spend more time waiting for the services anyway and stay congested in one place.

5.2. Capacity planning

In this thesis, the capacity is planned only for facilities at new building. At the new building, there are three main facilities: Lab on the 1st floor (Lab Register, Lab Cashier, Lab – Blood Collection Counters), X–ray on the 3rd floor (X–ray Register, X–ray Cashier, X–ray Examination), and Pharmacy on the 2nd floor (Assistants of the pharmacists who key in prescription, Cashiers, Pharmacists who give medicine to the patients).

According to the current situation of the patient flow, it is not a useful idea to improve capacities of Lab and X–ray faculties. The issue is that working hour of the doctor is very limited. It is not possible to change the working schedule of the doctors. Hence, although Lab and X-ray processes are improved, the patients will be in front of the clinics waiting the doctors anyways. Therefore, it is more beneficial to plan the capacity for the pharmacy facilities.

Based on Figure 5.1, current resource capacities of the pharmacy facilities are very busy all the time. It can be said that the facilities are having under capacities. To improve performance at the pharmacy, there is a need of adding some more capacities as few as possible, while objectives still can be achieved.

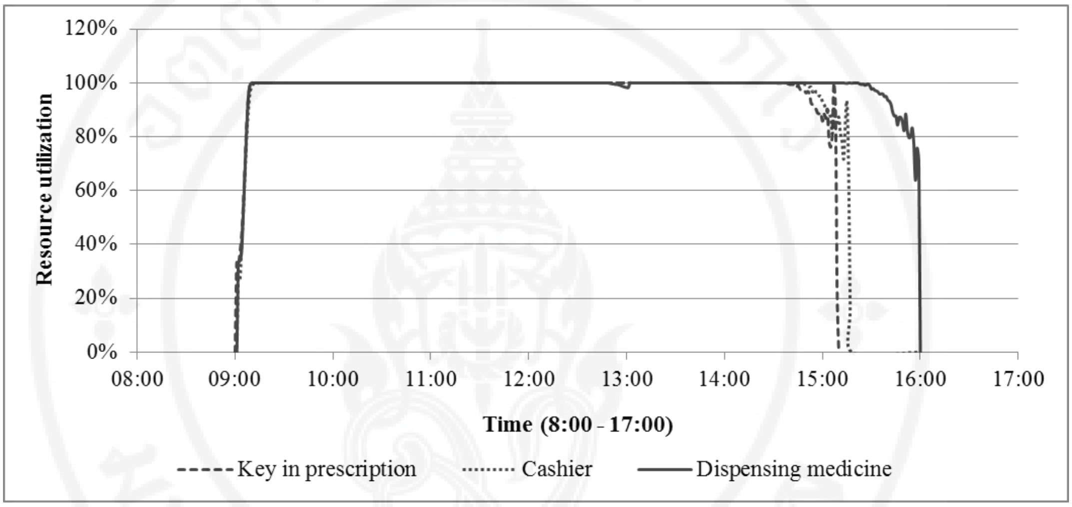


Figure 5.1 Resource utilization of the pharmacy facilities at new building

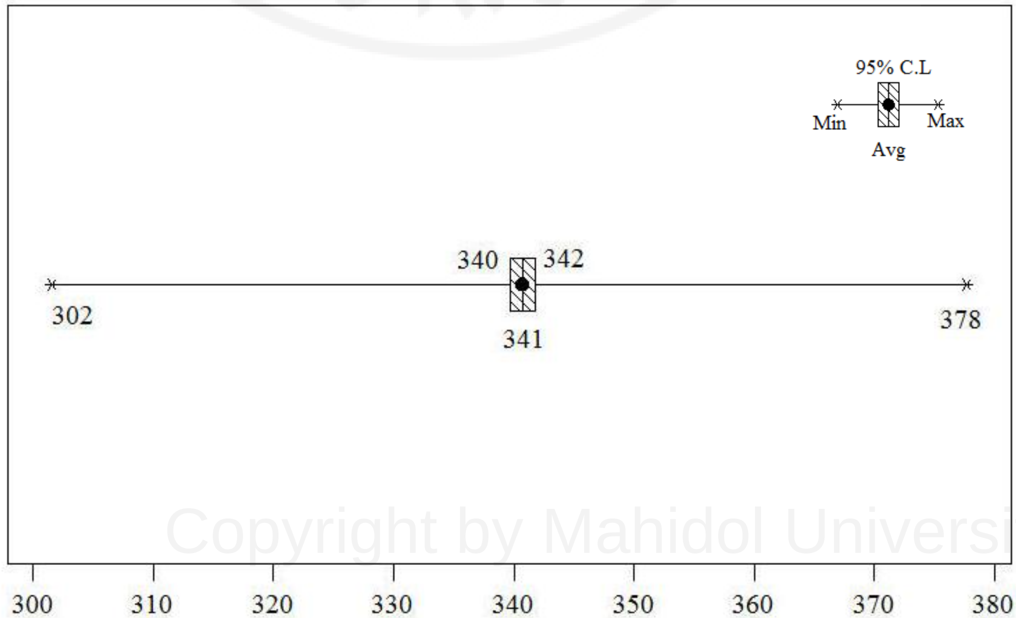


Figure 5.2 The number of the patients at pharmacy at new building

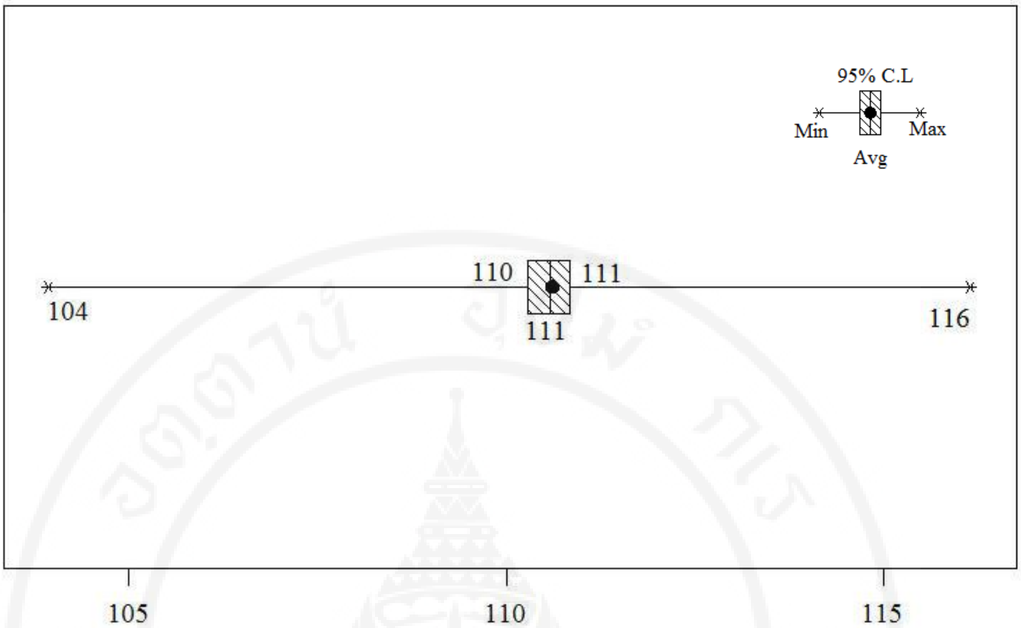


Figure 5.3 Cycle time of the patients at pharmacy at new building

Form Figure 5.2 and 5.3, the total number of patients and their total time on the floor are very high. In average, the number of patients on the floor is 341and they spend 111 minutes at the pharmacy. To decrease the total number and cycle time of patients on the floor, capacity planning is used. From the management team, the hospital wishes to have pharmacy system that the patients can finish all the pharmacy processes within 30 minutes after leaving the exam rooms. Moreover, based on the floor area of the pharmacy facilities at the new building, the total number of patients at the pharmacy facilities should not be in excess of 100. Therefore, the objectives of the capacity planning is to minimize new added capacities for the pharmacy facilities with constraints that the cycle time on the floor must not be more than 30 minutes and the total number of patients on the floor must be less than or equal to 100.

5.2.1 Capacity planning model

The schedule of resource capacities of the pharmacy facilities are classified into two shifts. The first shift is from 9:00 to 12:00, and the second shift starts from 12:00 to 16:00. Opt Quest of Arena is used to find the optimum capacities which needs to be added on each shift to the current capacities of the pharmacy facilities. The Opt Quest will run with the following mathematics model.

Notation

$i = facilities\ of\ the\ pharmacy; i = 1, 2, 3;$

$j = working\ shifts\ of\ the\ resources; j = 1, 2;$

$R_{ij} = Added\ resource\ capacities\ of\ facility\ i\ at\ working\ shift\ j$

$P_i = the\ total\ number\ of\ patients\ at\ facility\ i$

$T_i = the\ cycle\ time\ of\ the\ patients\ at\ facility\ i$

Dicision variables

R_{ij}

Objective function

$$Minimize\ \sum_{i}^{3}\sum_{j}^{2} R_{ij}$$

Constraint

$$\sum_{i}^{3} P_i \leq 100; the\ number\ of\ patients\ at\ the\ faciliteis\ constraint$$

$$\sum_{i}^{3} T_i \leq 30; the\ cycle\ time\ of\ the\ patients\ at\ the\ ficilities\ constraint$$

$$R_{ij} \leq 8; the\ maximum\ capacity\ to\ be\ added\ constraint;\ \forall i;\ \forall j$$

Before running the above model in Opt Quest, the schedule of the pharmacy facility resources needs to be arranged into two shifts.

1. Assistants of the pharmacists: there are three assistants of the pharmacists from 9:00 to 12:00, and five assistants of the pharmacists from 12:00 to 16:00 (Figure 5.4).

2. Cashiers: there are three cashiers from 9:00 to 12:00, and five cashiers from 12:00 to 16:00 (Figure 5.5).

3. Pharmacists: there are four pharmacists from 9:00 to 12:00, and seven pharmacists from 12:00 to 16:00 (Figure 5.6).

Moreover, six more variables are used to represent for the capacities of the facilities which need to be added to achieve the model objectives.

1. varAddAsstPha1: the number of pharmacist assistant capacities needs to be added from 9:00 to 12:00.

2. varAddAsstPha2: the number of pharmacist assistant capacities needs to be added from 12:00 to 16:00.

3. varAddCas1: the number of cashier capacities needs to be added from 9:00 to 12:00.

4. varAddCas2: the number of cashier capacities needs to be added from 9:00 to 16:00.

5. varAddPha1: the number of pharmacist capacities need to be added from 9:00 to 12:00.

6. varAddPha2: the number of pharmacist capacities need to be added from 12:00 to 16:00.

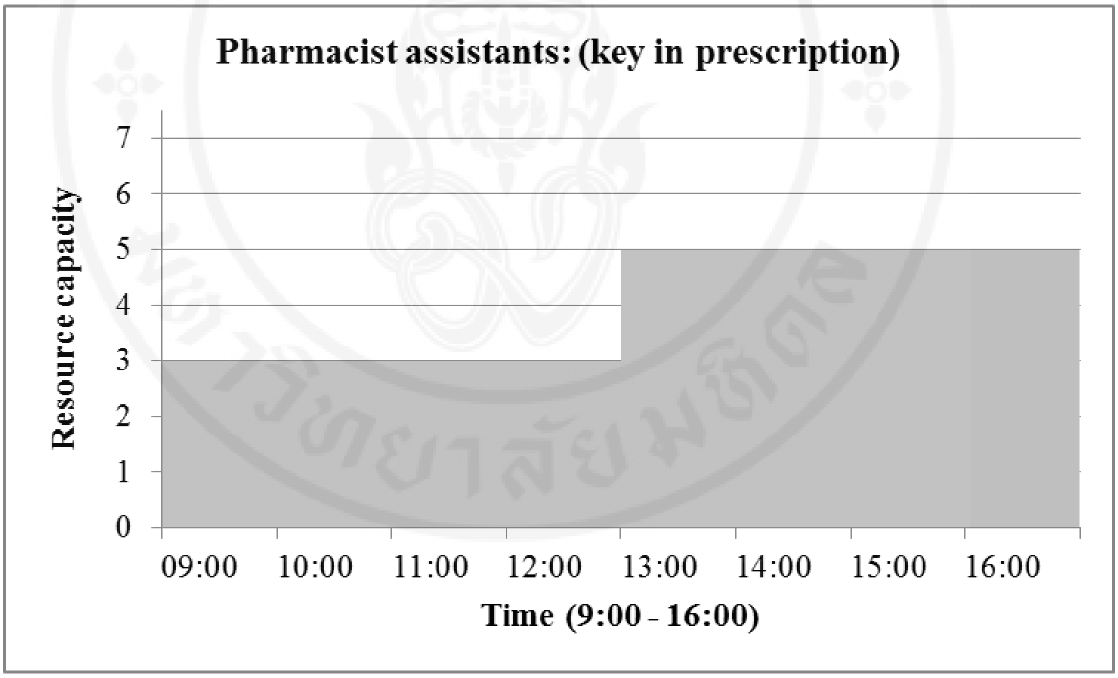


Figure 5.4 Pharmacist assistant resource working schedule

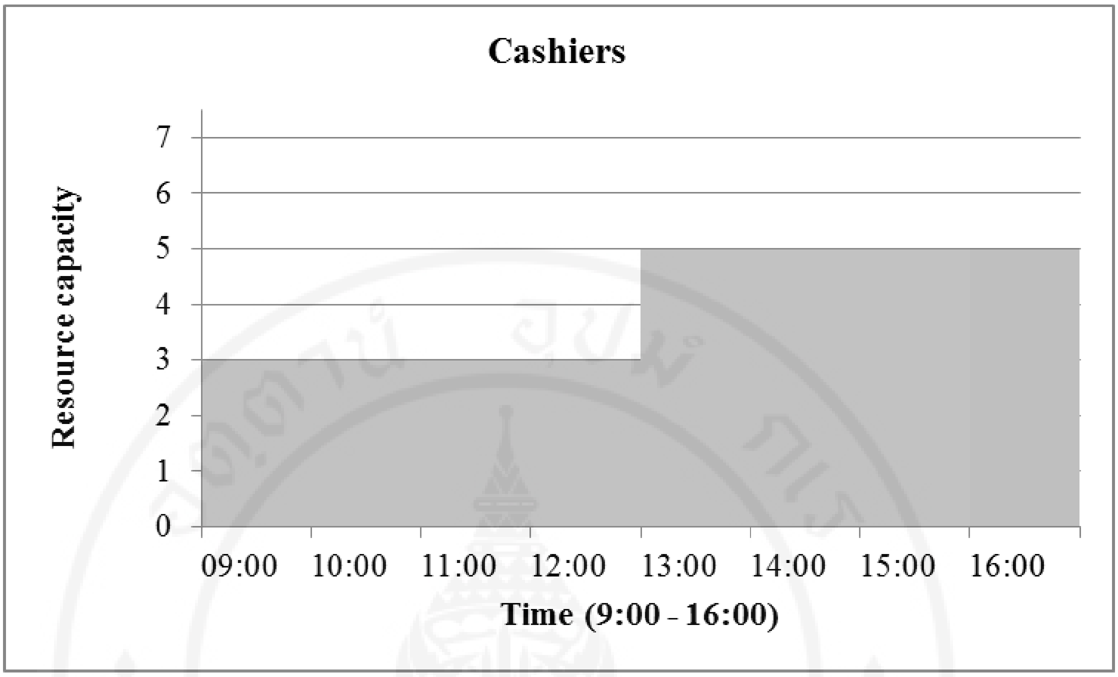


Figure 5.5 Cashier resource working schedule

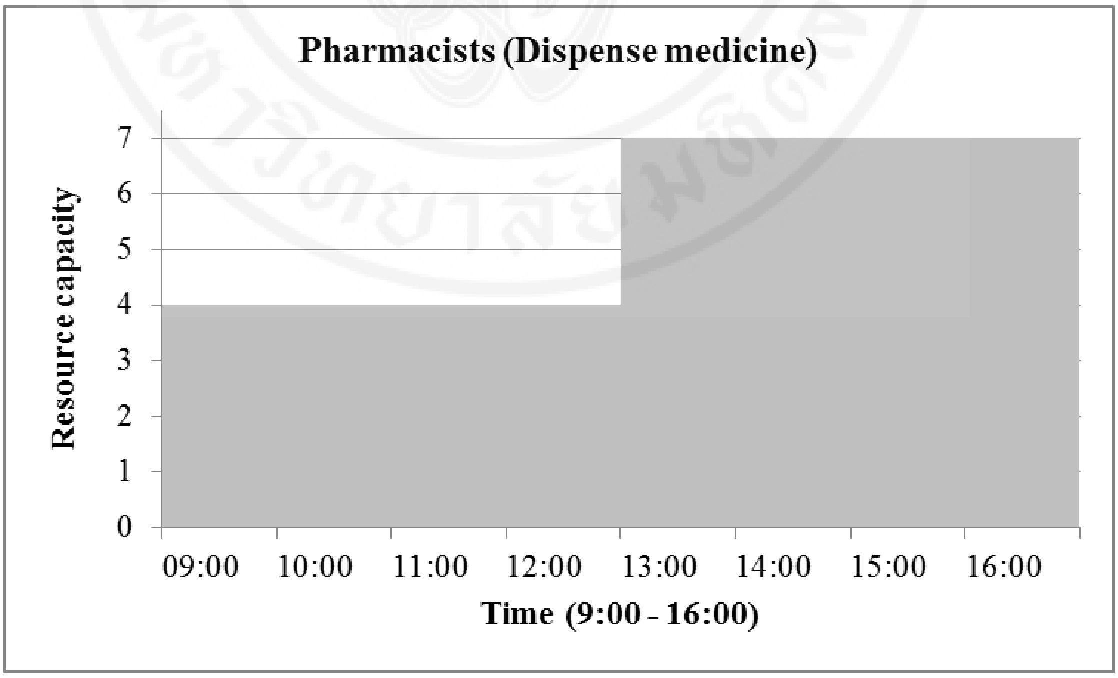


Figure 5.6 Pharmacist resource working schedule

In Opt Quest for Arena, some set up has been made. Firstly, 10-replication of running simulation in Opt Quest is used. Secondly, the control (the six variables namely varAddAsstPha1, varAddAsstPha2, varAddCas1, varAddCas2, varAddPha1, and varAddPha2) is set as the following.

Table 5.4 Opt Quest control summary

Control Name	Type	Low Bound	High Bound	Suggested Value
varAddAsstPha1	Integer	0	8	1
varAddAsstPha2	Integer	0	8	1
varAddCas1	Integer	0	8	1
varAddCas2	Integer	0	8	1
varAddPha1	Integer	0	8	1
varAddPha2	Integer	0	8	1

5.2.2 Capacity planning results

The Opt Quest running simulation has been stop mainly at the 348–running simulation because there is no any better results after the 62th running simulation (Figure 5.7). The results are shown in Table 5.5.

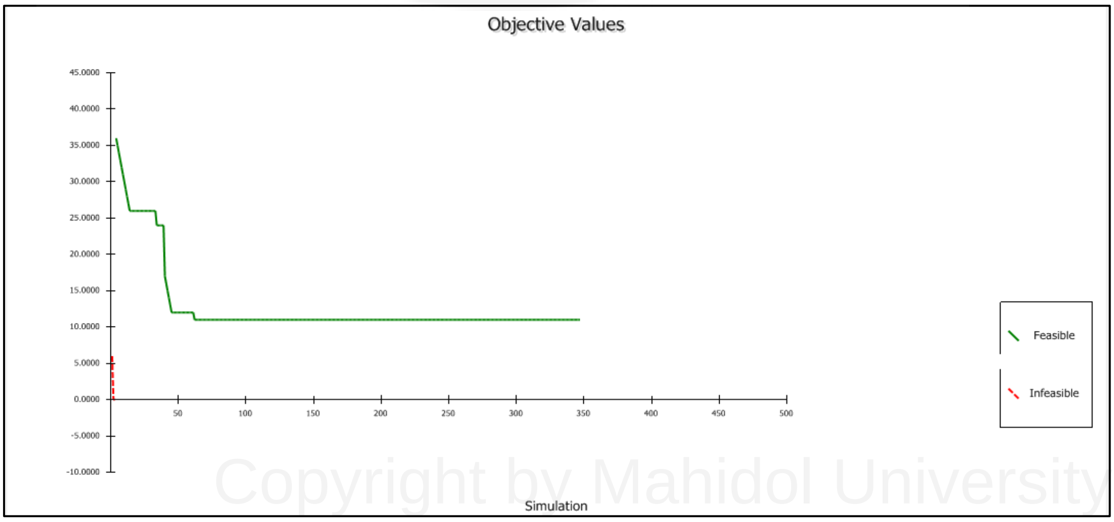


Figure 5.7 Optimization graph of minimizing the total added capacities

Table 5.5 Response summary

Name	Left Side	Right Side
Total added capacities	11 capacities	48 capacities
Cycle time of the patients at the pharmacy facilities	27.32 minutes	30 minutes
The total number of patients at the pharmacy	85.68 patients	100 patients
The assistants of pharmacist working from 9 to 12	3 capacities	8 capacities
The assistants of pharmacist working from 12 to 16	0 capacities	8 capacities
The cashiers working from 9 to 12	3 capacities	8 capacities
The cashiers working from 12 to 16	0 capacities	8 capacities
The pharmacists working from 9 to 12	5 capacities	8 capacities
The pharmacists working from 12 to 16	0 capacities	8 capacities

CHAPTER VI
DISCUSSION AND CONCLUSION

6.1 Discussion

6.1.1 Floor congestion

As in Chapter 1, the purposes of this research are to study facilities allocation and capacity planning for new build hospital. The research, therefore, is conducted for two main objectives. Firstly, it aims to investigate the congestion of the patients in Outpatient Department (OPD) within two conditions: (1) when all type of facilities are located in one building, and (2) when the facilities are classified as the primary facilities and the support faculties, and they are allocated in different building.

From the value chain concept and the practicing nature of healthcare service related to the patient flow in OPD, the outpatient flow value chain has been developed. In addition, the primary facilities and the support facilities serving the outpatients can be identified:

- Primary facilities: the primary facilities for the outpatients are clinics (facilities). In this research, seven OPD floors consisting of thirteen clinics have been studied The clinics are On Duty, Orthopedic, Medicine, Obstetrics, Surgery, Preventive Medicine, Ophthalmology, Ear Nose Throat (ENT), and Dental, Hematology, Psychiatry, and Chemical treatment clinic.
- Support facilities: the support facilities are Triage, Register, Lab, X–ray, Cashier, and Pharmacy.

Discrete event simulation has been used to model the patient flow when all the facilities are located in the same building and when most of the support facilities are moved to new building. The results show that floors which their support facilities are moved to new building are less congested. Since the allocated facilities are Lab, X–ray and Pharmacy, the floors have fewer patients before the clinic hours and after the clinic hours. As mentioned in chapter 5, the floors which the congestion is affected by separating the primary facilities from the support facilities are the 1st floor, the 3rd floor, the 4th floor and the 5th floor.

For the 1st floor, the congestion is released to new building in the beginning. It is because the Lab is moved from the 1st floor of old building to the 1st floor of new building (Figure 6.1). For the 3rd floor, the congestion on the floor before seeing the doctors is slightly released to new building (Figure 6.2). It is because the number of the patients who needs X-ray is in small amount.

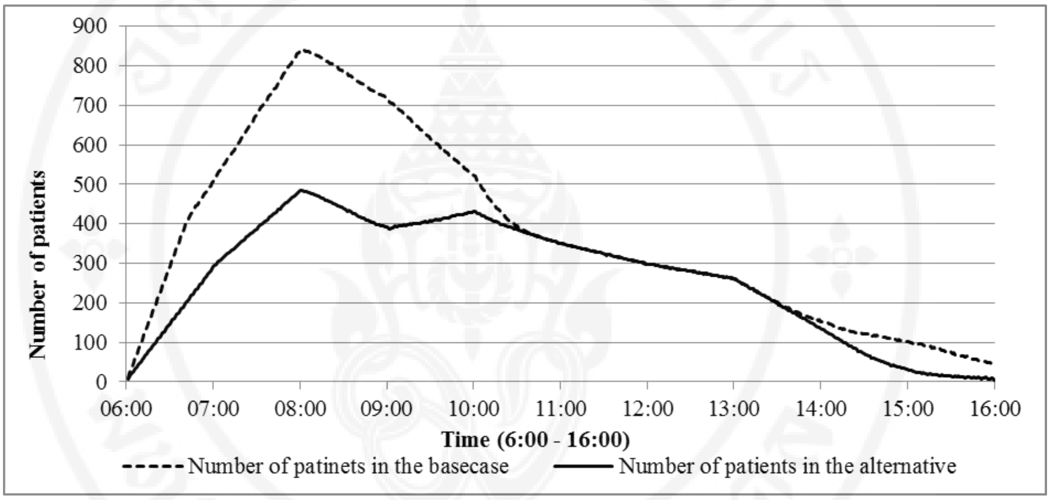


Figure 6.1 The number of patients on the 1st floor

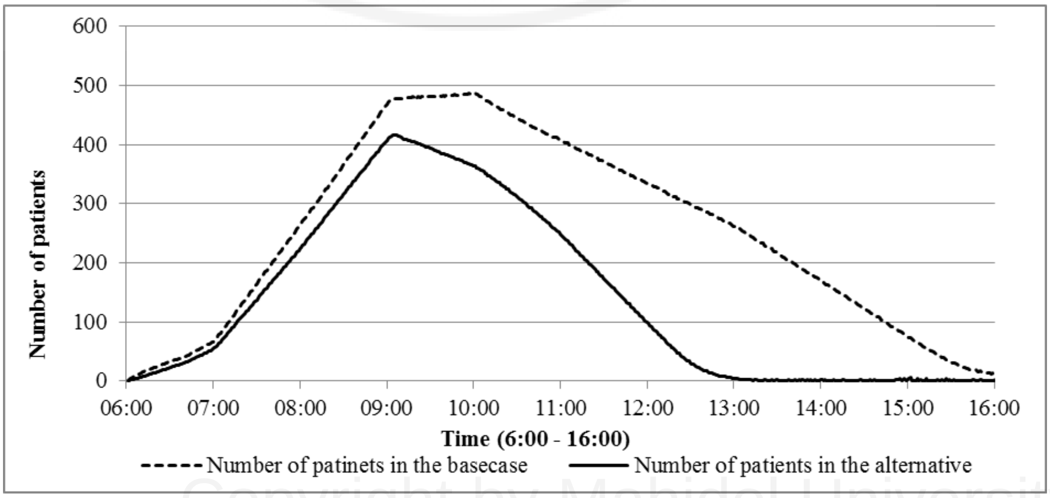


Figure 6.2 The number of patients on the 3rd floor

However, moving Lab and X-ray, which are the support facilities to the outpatients is very useful since Lab and X-ray, most of the time, are the first process the patients need to have before seeing the doctors. Therefore, the Lab and X–ray patients do not need to stay congested with other patients who just come to see the doctors first.

For the 4th and 5th floor, the congestion before the clinic-opening hour is quite the same regardless of the facilities allocation. However, since the pharmacy facilities of these two floors (as well as the 3rd floor) are moved to the new building, the congestion of all these floor starts be released dramatically to new building after the clinic-opening hour (Figure 6.2, Figure 6.3, and Figure 6.4). Therefore, the patients on the floors are mainly just the patients waiting to see the doctors. Others who are done with the clinics are moving to new building for the pharmacy processes. By moving the pharmacy facilities to the new building, the patients can flow smoother on the 3rd floor, 4th floor, and 5th floor because there are always patients coming and leaving. Therefore, the floors are not congested so much and in a long period.

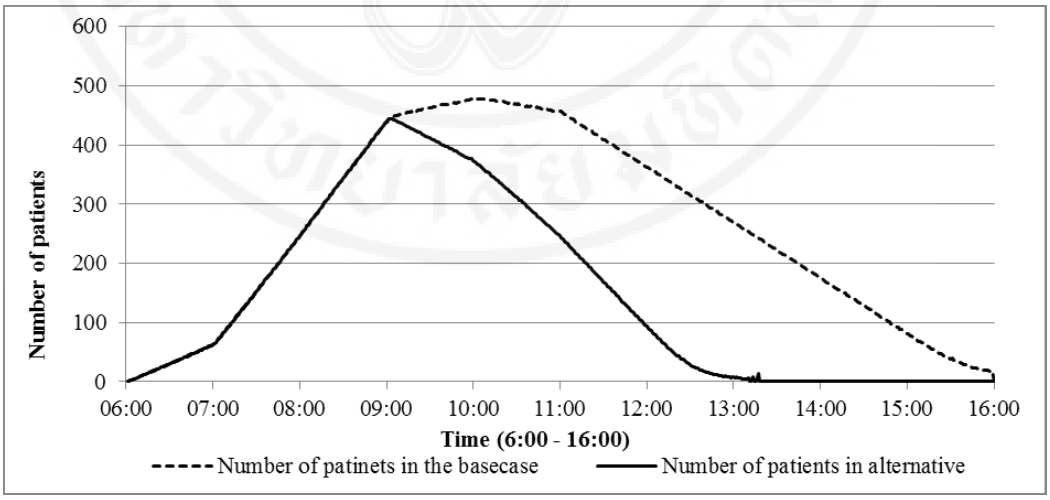


Figure 6.3 The number of patients on the 4th floor

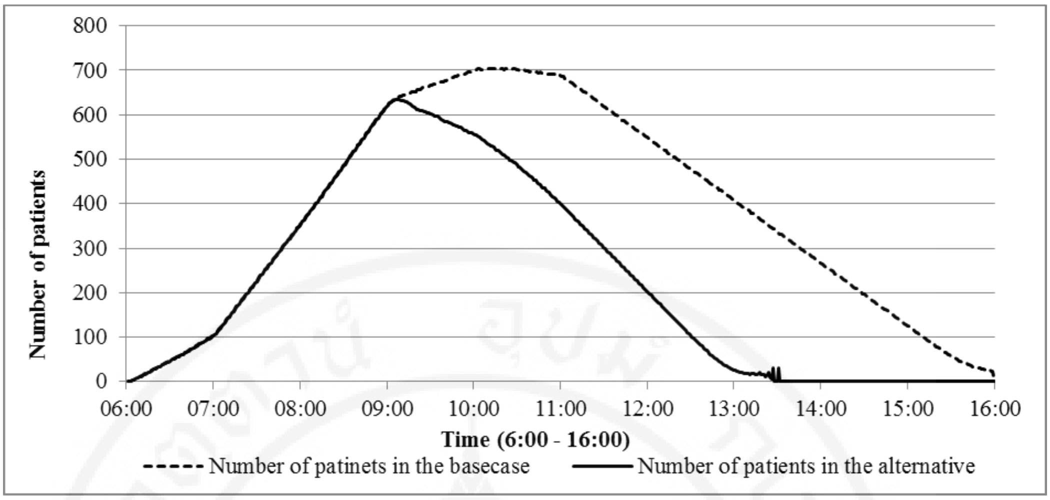


Figure 6.4 The number of patients on the 5th floor

6.1.2 Cycle Time

When the support facilities are separated from the primary facilities and moved to another location, transfer time is required. In this research, the support facilities are moved to the new building. However, the distance between old building and new building is not very far from each other. Hence, the transfer time should not impact the cycle time much. From the simulation output, the cycle time of the patients of each clinic is even better when the support facilities are moved away from the primary facilities. This happens because of two main reasons. Firstly, it is because of long waiting time of the pharmacy processes. In the alternative model, the patients need to travel from old building to new building to pick up medicine. This creates additional the transfer time. However, most of the patients are always waiting for the services from the pharmacy facilities, so the transfer time from old building to new building does not really affect the cycle time of the patients in the OPD. The other reason is that there is a change of pharmacy processes when the facilities are separated and allocated differently. In the basecase model, which the pharmacy facilities are located on same floor with the clinic exam room, the patients on one floor can only go to pick up the medicine from the pharmacy on that floor only. However, in the alternative model, three pharmacy resources from 3rd, 4th, and 5th floor are integrated to serve the patients from those three floors. It can be understood that pharmacy business process of these floors is changed from specialized business process to generalized business process. This helps the patients be served faster which lead to shorter cycle time. These are all the reasons which explain why the cycle time of the patients does not increase when the pharmacy facilities allocated away from the clinic facilities.

6.1.3 Capacity planning

For the second objective, this research aims to plan the optimum capacity at new building so that the patients do not need to stay in the hospital any longer after they are done with the clinics. The facilities allocated at the new building belong to Lab, X–ray and Pharmacy. However, there is no use to improve or plan the capacity of Lab and X–ray facilities because they are the processes which occur before any other processes. Although the patients could receive the services from Lab and X–ray very fast, they have to wait for the clinic working schedule anyway (9:00 to 13:00). Therefore, the potential and worth–improving facilities at new building are pharmacy facilities.

To achieve less than or equal to 30-minute cycle time which the patients spend at all the three pharmacy facilities, and less than or equal to100 of the number of patients staying on the pharmacy floor at new building, the capacities of three different facilities need to be added. First, the number of assistants of the pharmacist working from 9:00 to 12:00 needs to be added 3 more. Second, the number of cashiers working from 9:00 to 12:00 needs to be added 3 more. Last, the number of the pharmacists needs to be added 5 more. After having these additional capacities, the cycle time at the pharmacy facilities is 27.2 minutes in average and it can vary from 27 minutes to 27.3 minutes with 95% confident interval (Figure 6.5). In addition, the total number of patients on the pharmacy floor at new building is 83.7 in average, and it can vary from 83.2 to 84.2 patients with 95% confident interval (Figure 6.6). Although 11 more capacities are added, the utilization is not decreased (Figure 6.7). All of them are always busy serving the patients except several minutes after pharmacy-opening hours, around 9 to 9:20. Only the cycle time and the number patients on the floor are decreased.

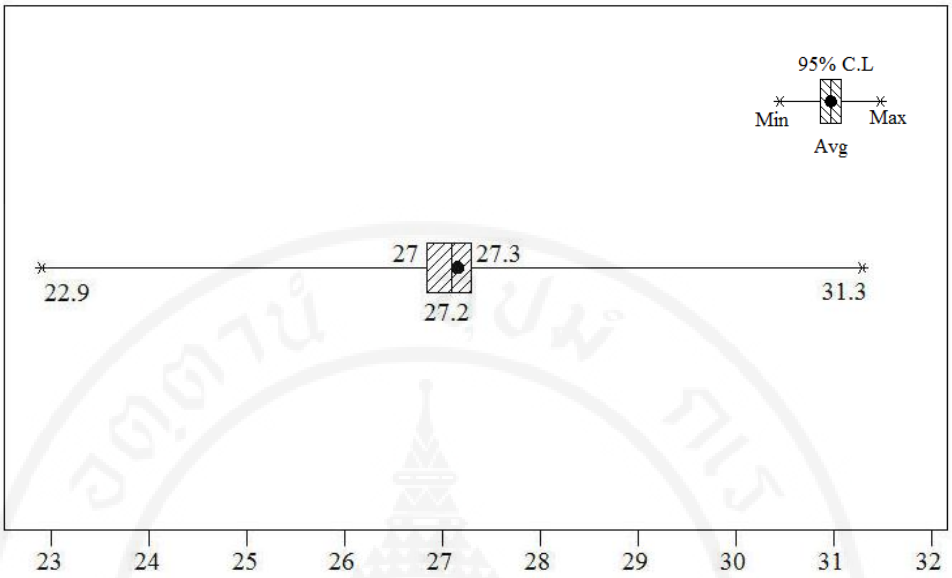


Figure 6.5 Optimum cycle time of the patients at the pharmacy

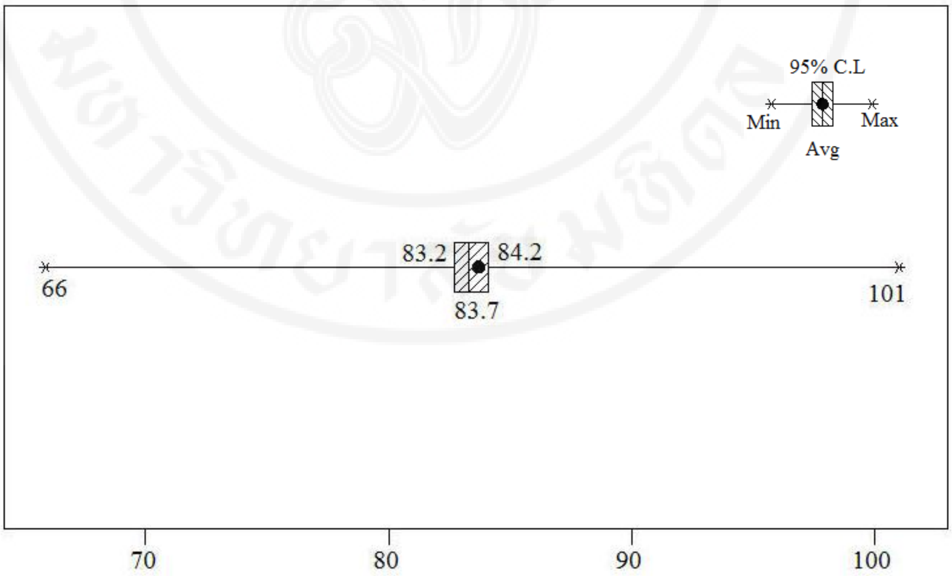


Figure 6.6 Optimum number of the patients at the pharmacy

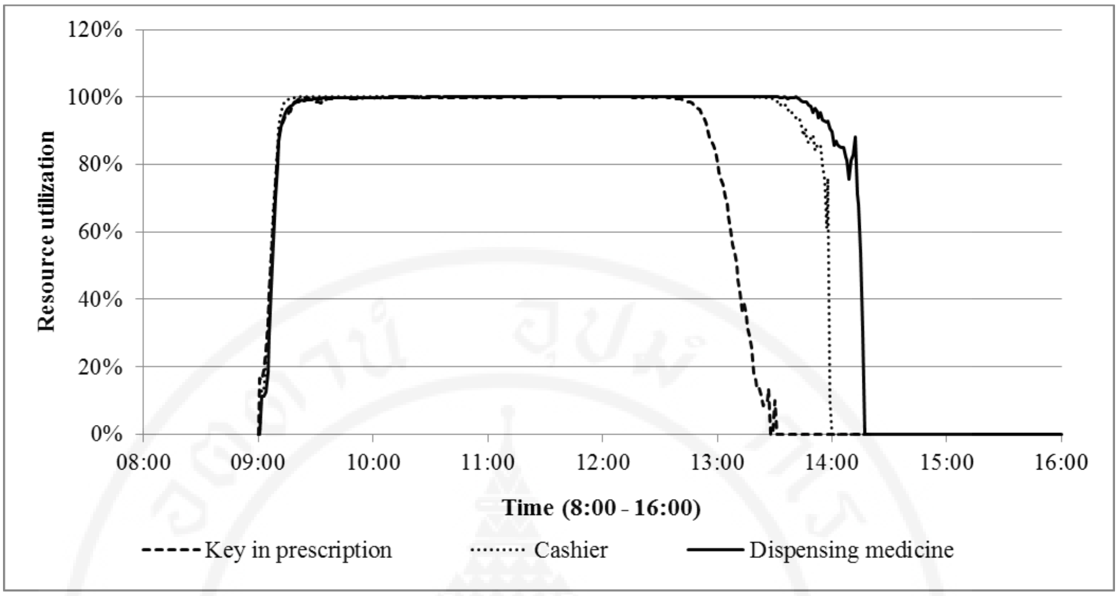


Figure 6.7 Pharmacy resource utilization

6.2 Conclusion

This study investigates the impact of separation between the primary facilities and the support facilities on the congestion of the floors at outpatient department. It shows that the patients can flow smoother in less congested environment when the support facilities are moved to new building. In addition, the study also provides the meaningful reasons on the selected support facilities at new building to do the capacity planning. As the result, when the capacity is improved, the patients can finish all the processes faster which lead to less floor congestion. More importantly, since the capacity is improved in the optimum amount, the resource utilization is still high, and even better as shown in Figure 6.6.

Thus, it is to be hoped that the research will be beneficial to the hospitals, especially the university hospitals which have so little ability to modify the processes related to the doctor working hours. Moreover, the hospitals can learn that when their size cannot handle the number of their customers, the outpatient flow value chain in this research can be a good guideline concerning the congestion release and capacity improvement.

As the recommendation from this study, when the hospital builds new building to allocate the facilities, it is more useful to separate the support facilities and primary facilities for the sake of congestion release. The support facilities which are to be moved to new building must be the facilities providing the first services to the patients or the facilities providing the last services to the patients.

This research has a few limitations. First, the study provides a good capacity planning at new building, but does not do the capacity improvement for the facilities at the old building. Actually, one of the four objectives of value chain is optimizing overall activities (Burns et al., 2002). In this research, only support activities after the primary activities were optimized. Therefore, future research should do primary activities optimization as well. Next, to have less cycle time and congestion, patients scheduling is also important. Admittedly, there are appointment patient arrivals in this study, but they are the Lab, X–ray, and clinic appointment. As the nature of the patients, they tend to come to hospital earlier then the appointment time for pre-processes before the clinics. It will be very useful if the patients know the time to show up at the hospital. Therefore, future research should consider these factors. Last, this study has not focused on the detail of the information of outpatient department. Next research should consider this factor as well, so lack of information sharing among the facilities can be avoided.

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APPENDICES

APPENDIX A
QUEUE OF PATIENTS AT EACH CLINIC

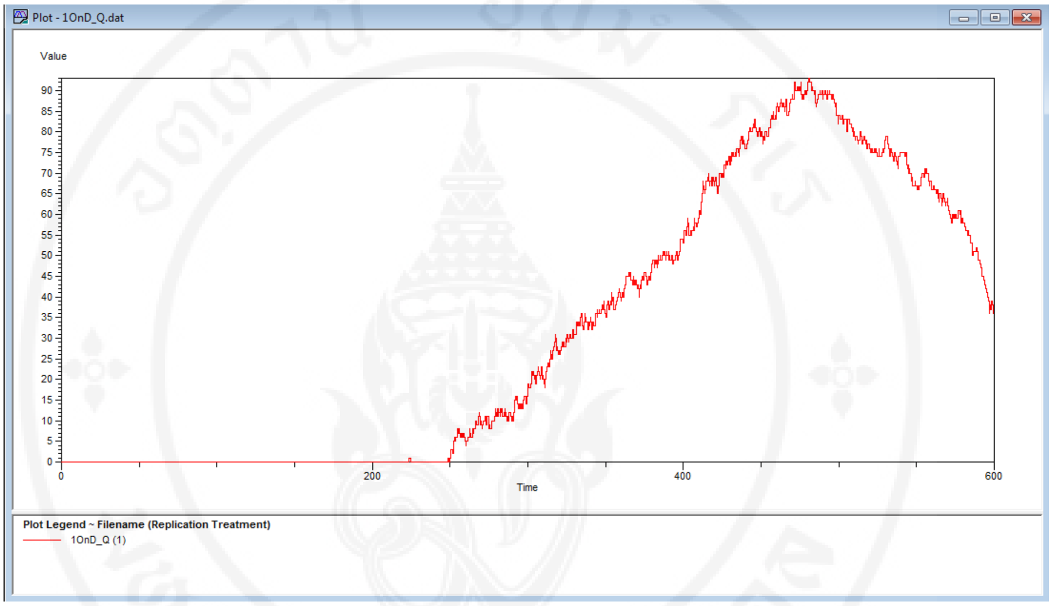

Figure A.1 The number of patients waiting at On Duty clinic

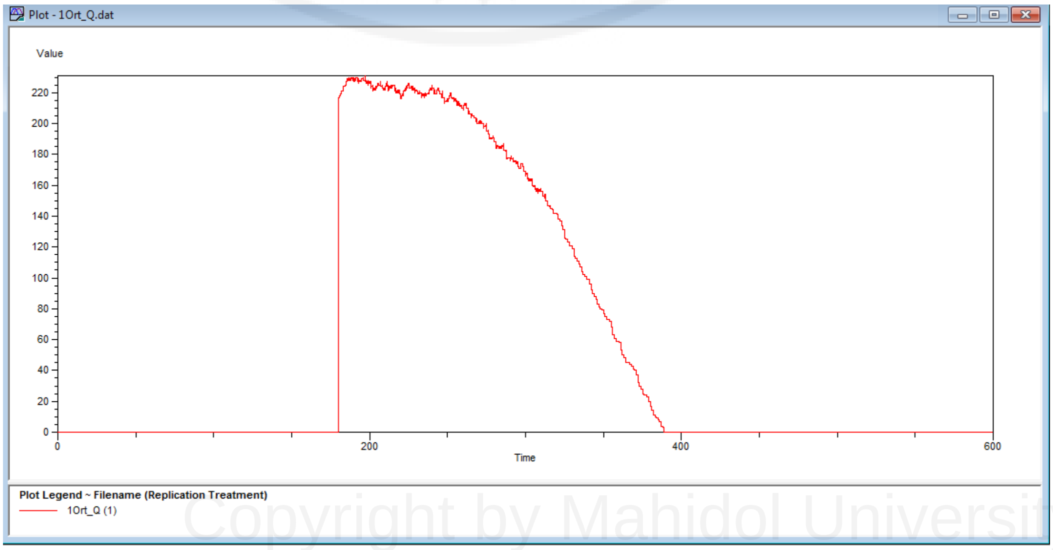

Figure A.2 The number of patients waiting at orthopedic clinic

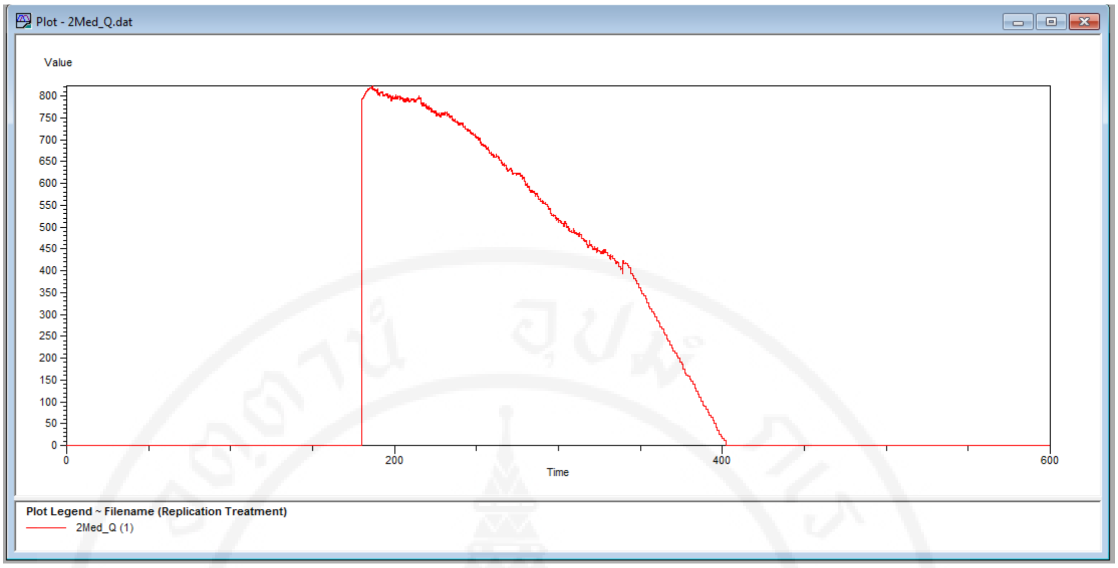

Figure A.3 The number of patients waiting at Medicine clinic

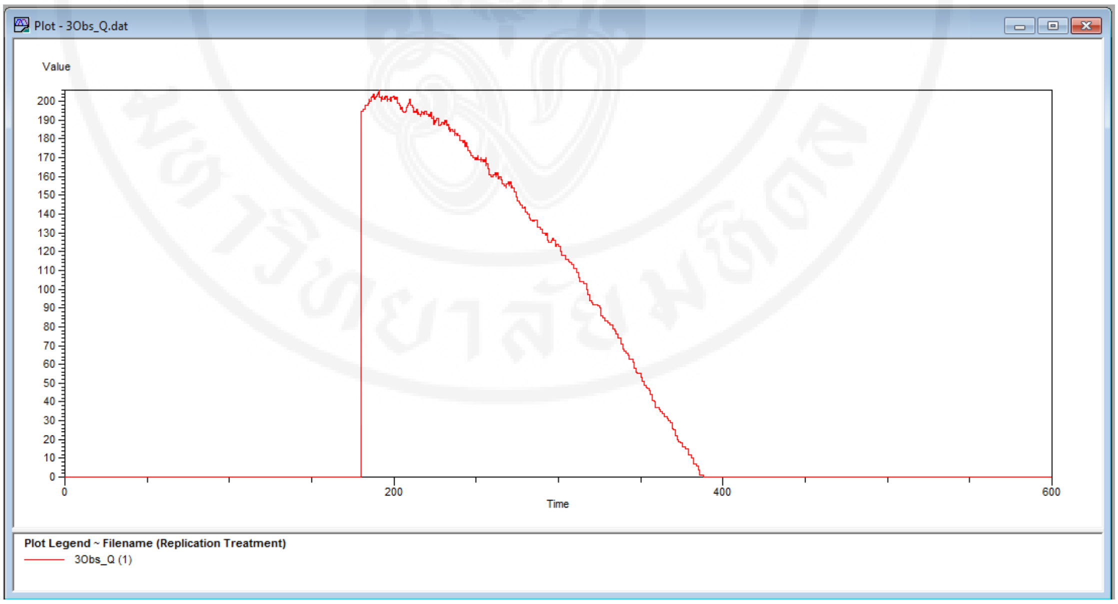

Figure A.4 The number of patients waiting at Obstetric clinic

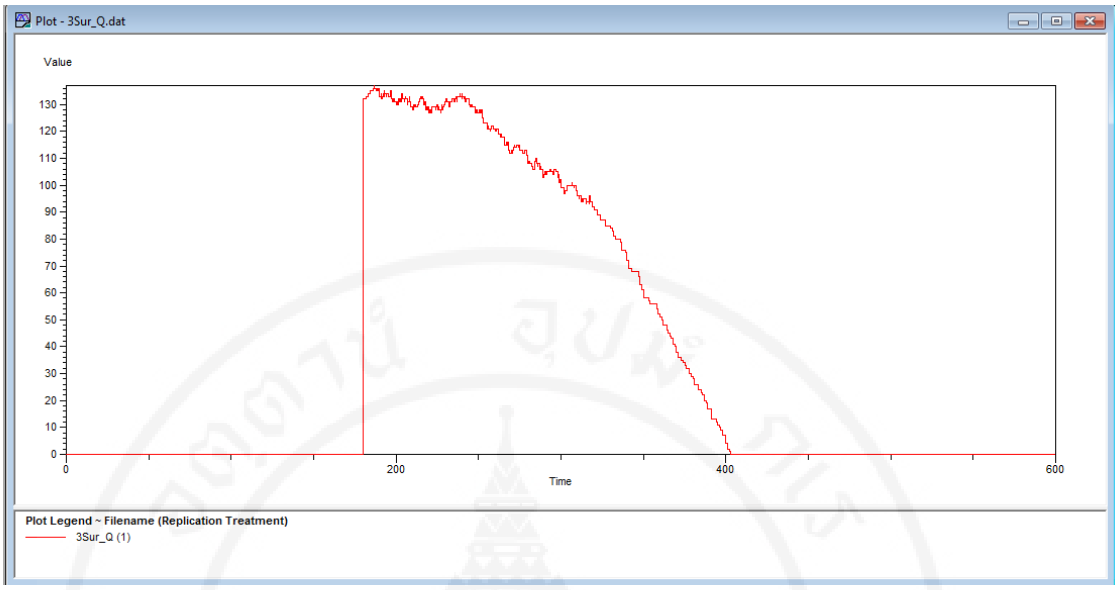

Figure A.5 The number of patients waiting at Surgery clinic

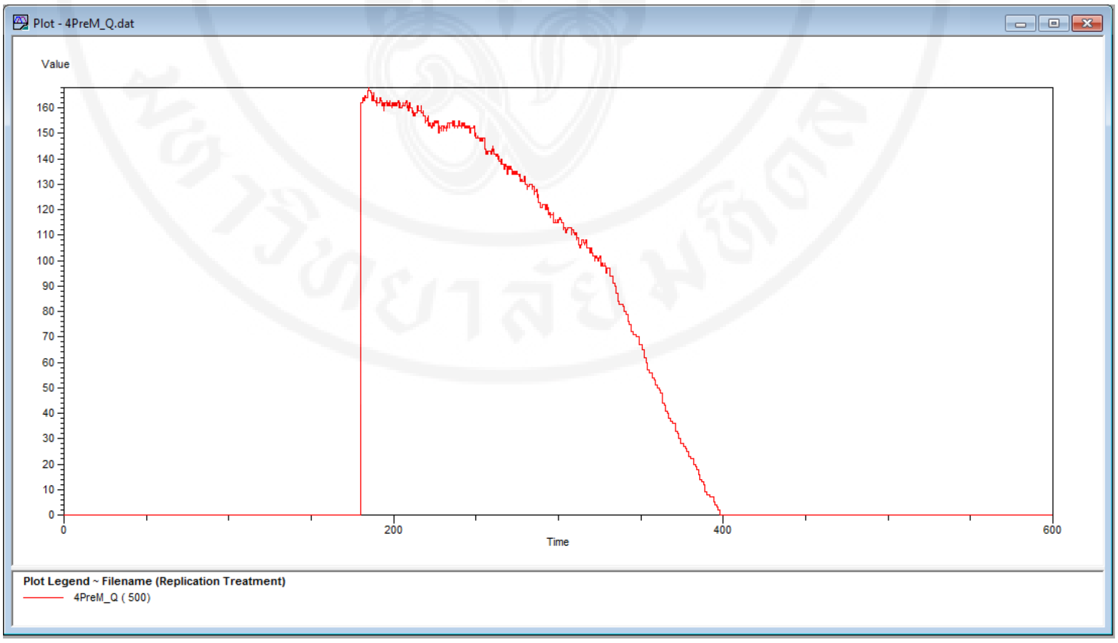

Figure A.6 The number of patients waiting at Preventive Medicine clinic

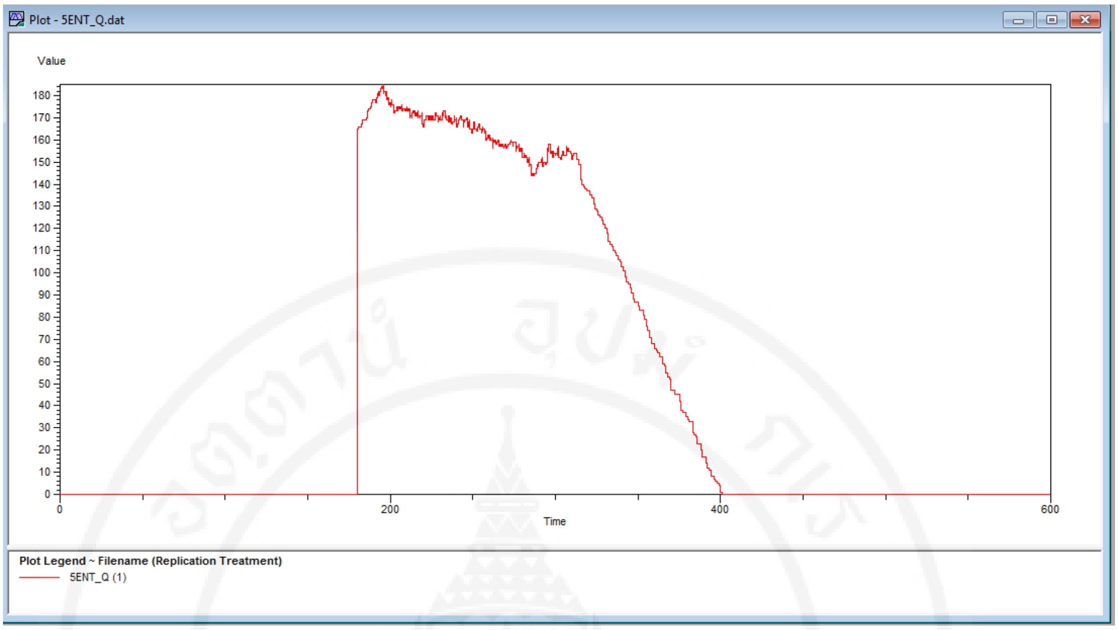

Figure A.7 The number of patients waiting at Dermatology clinic

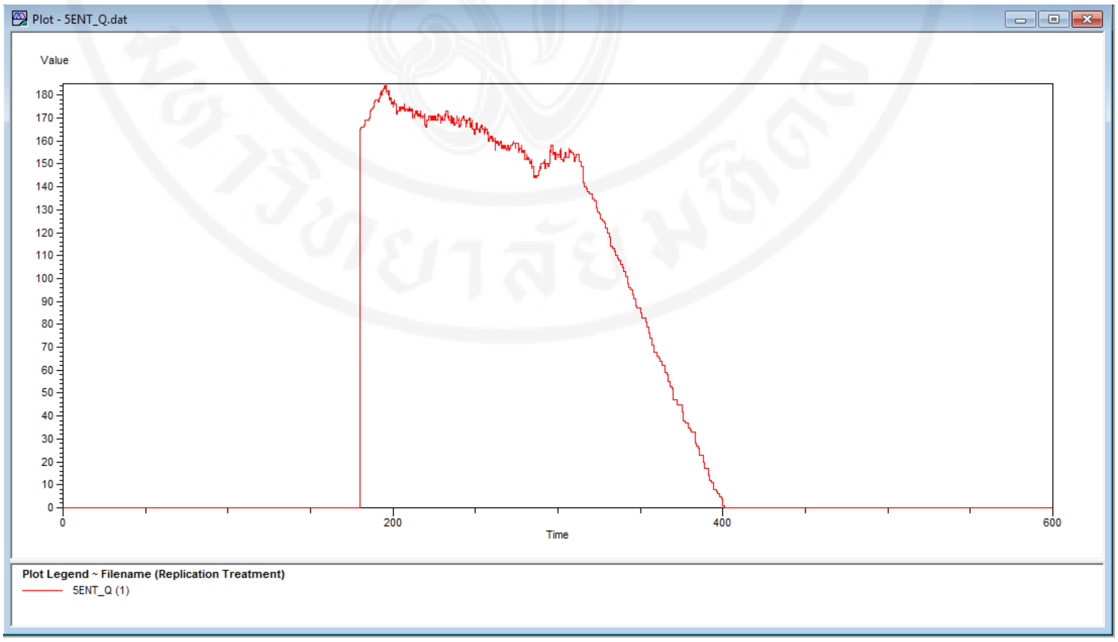

Figure A.8 The number of patients waiting at Ear Nose Throat clinic

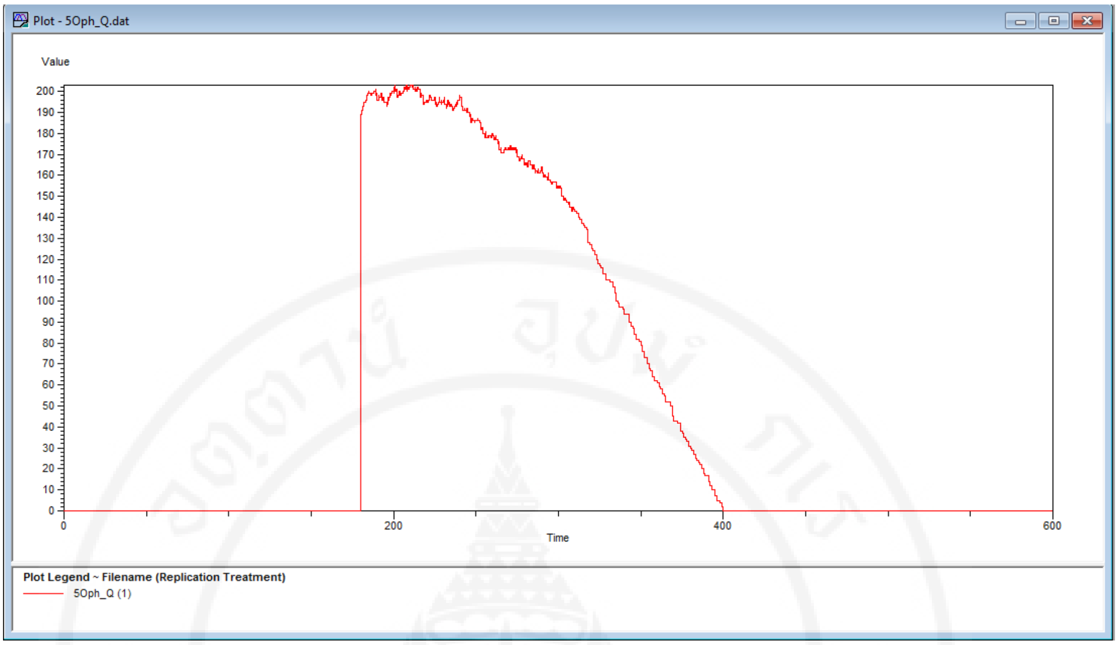

Figure A.9 The number of patients waiting at Ophthalmology clinic

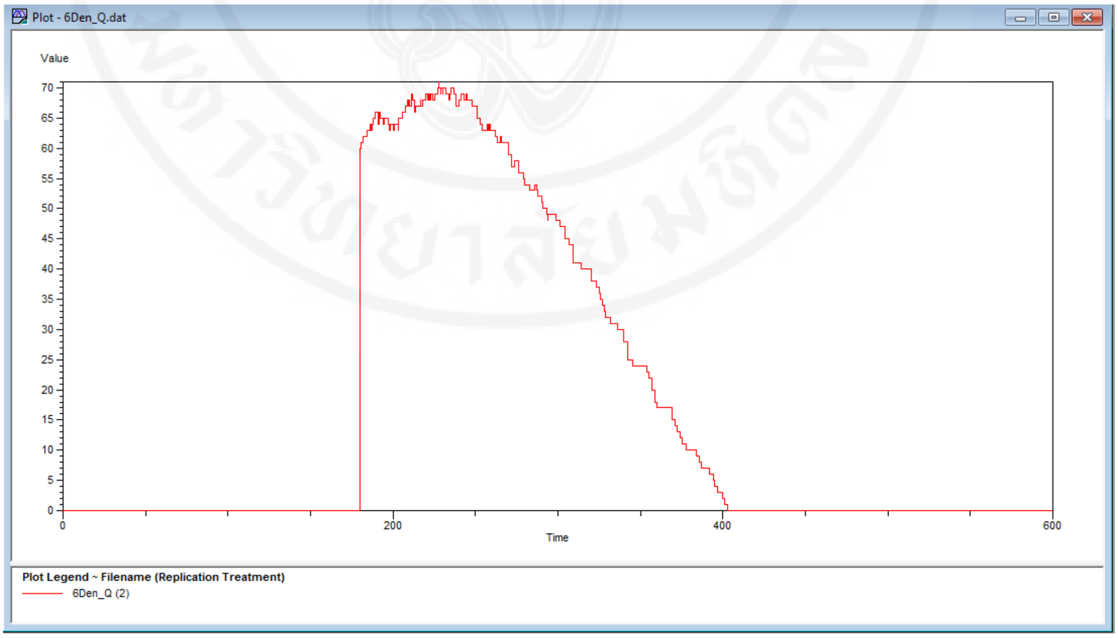

Figure A.10 The number of patients waiting at Dental clinic

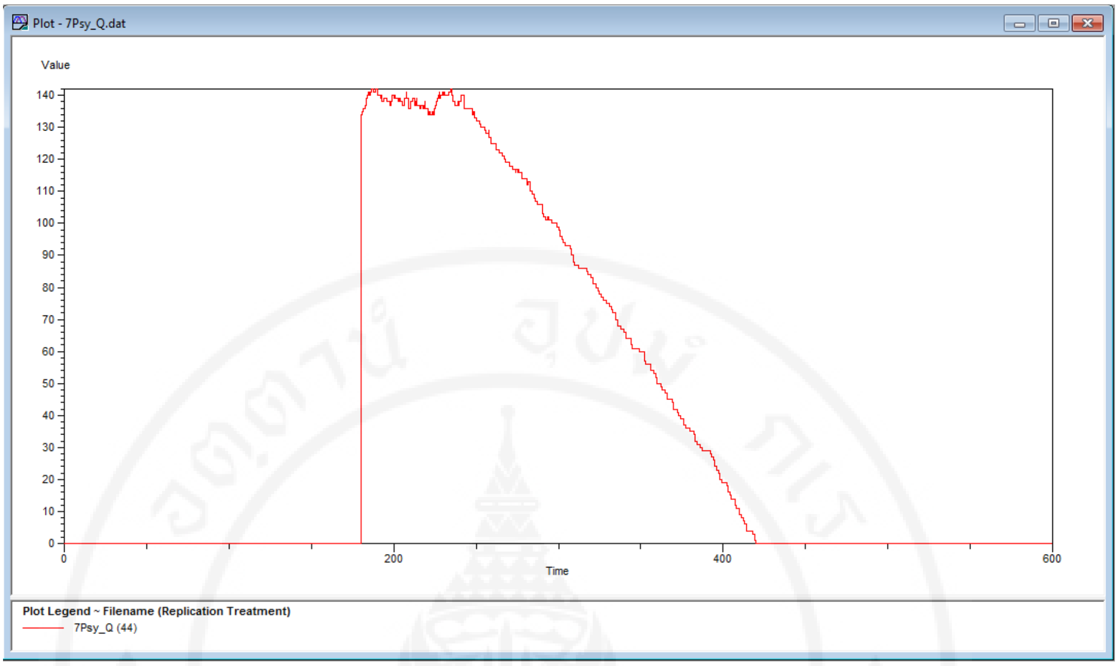

Figure A.11 The number of patients waiting at Psychiatry clinic

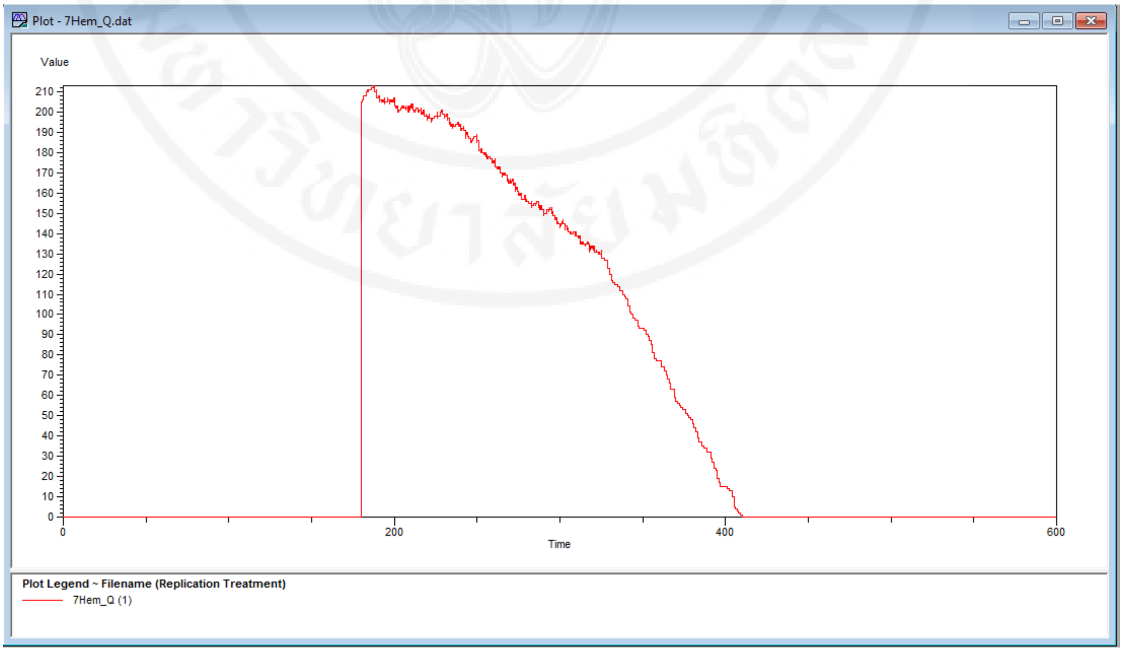

Figure A.12 The number of patients waiting at On Duty clinic

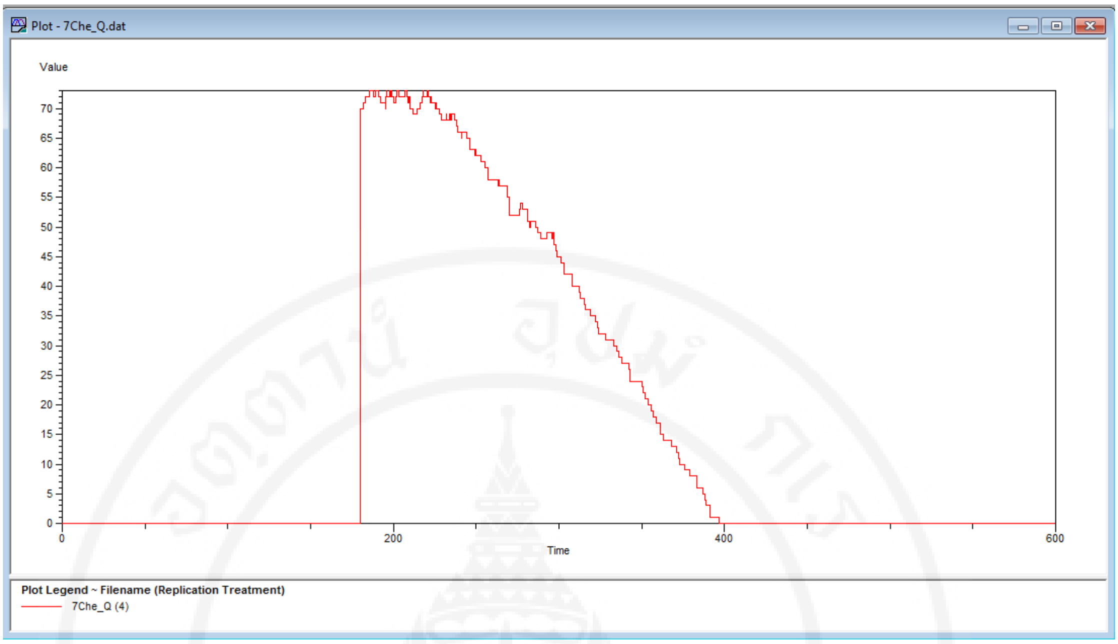

Figure A.13 The number of patients waiting at Chemical Treatment clinic

APPENDIX B

QUEUE OF PATIENTS AT PHARMACY

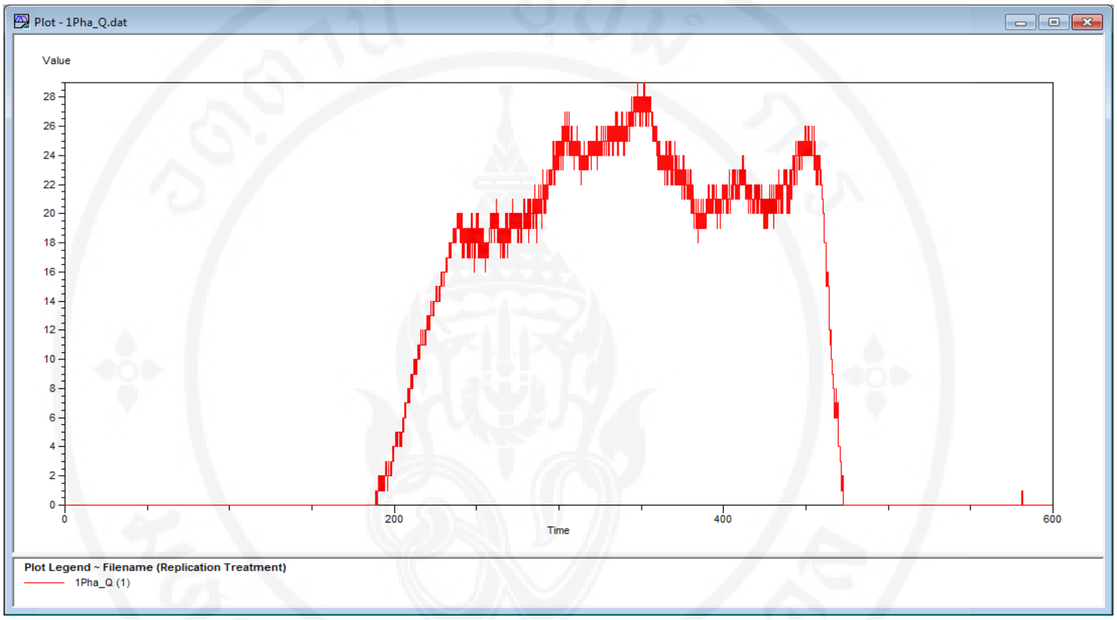

Figure B.1 The number of patients waiting at the 1st floor Pharmacy

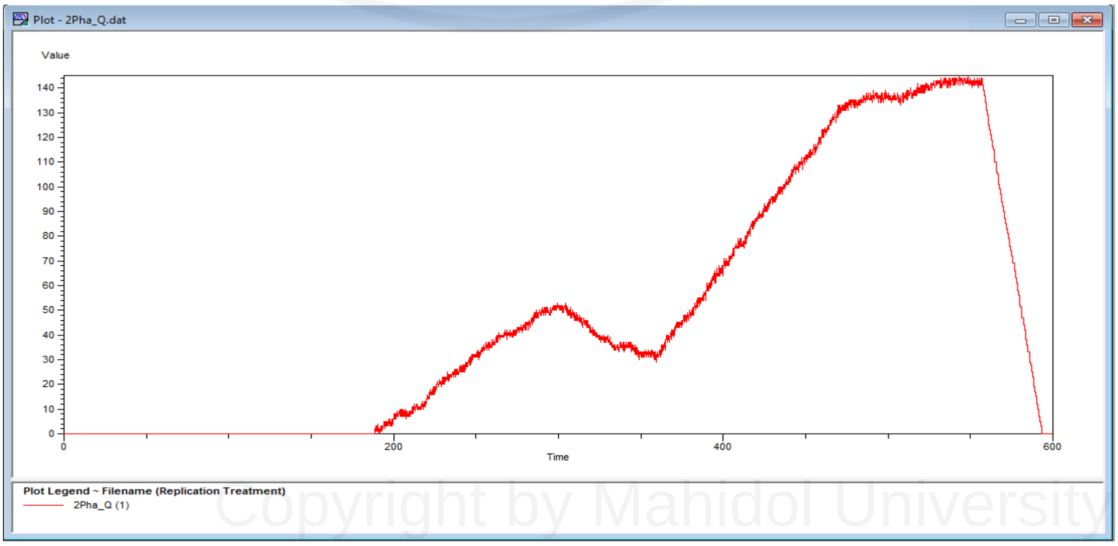

Figure B.2 The number of patients waiting at the 2nd floor Pharmacy

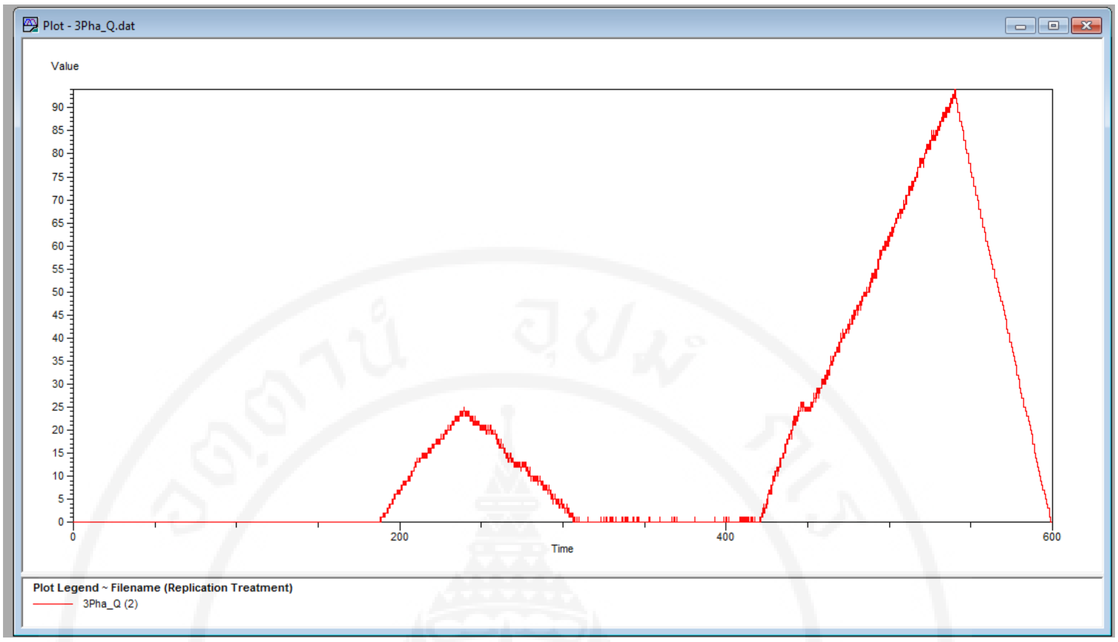

Figure B.3 The number of patients waiting at the 3rd floor Pharmacy

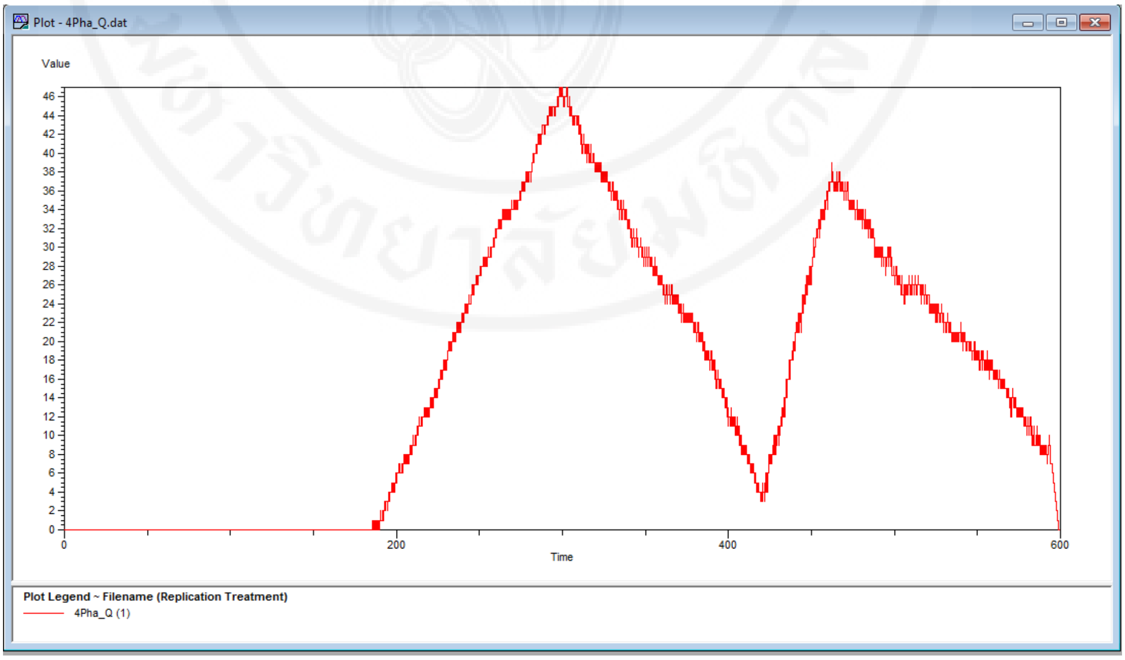

Figure B.4 The number of patients waiting at the 4th floor Pharmacy

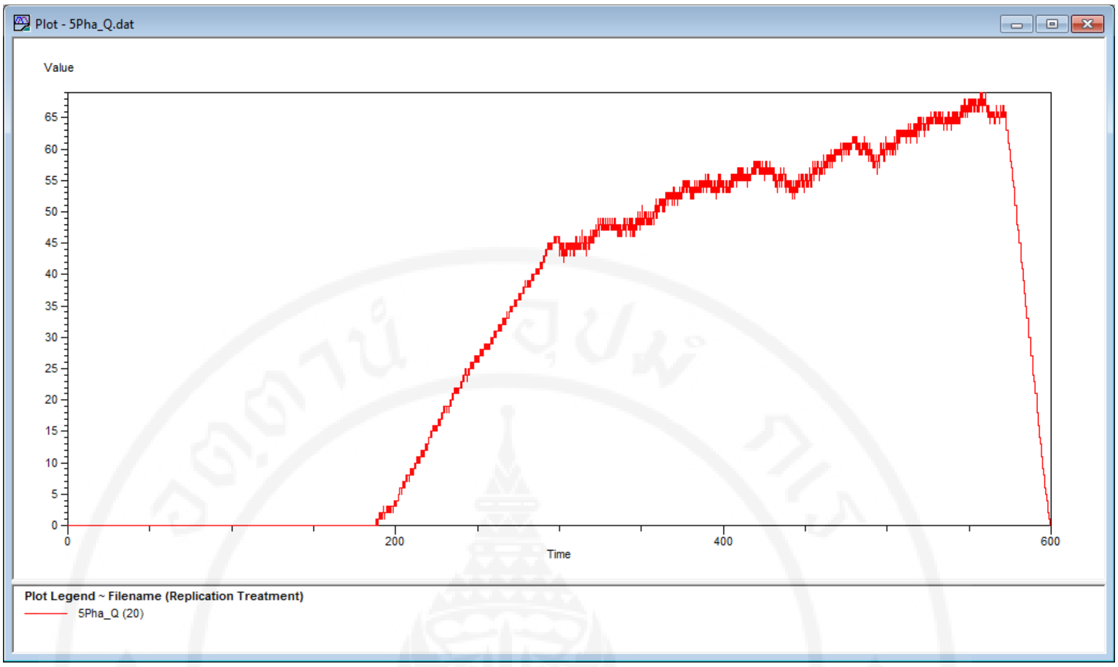

Figure B.5 The number of patients waiting at the 5th floor Pharmacy

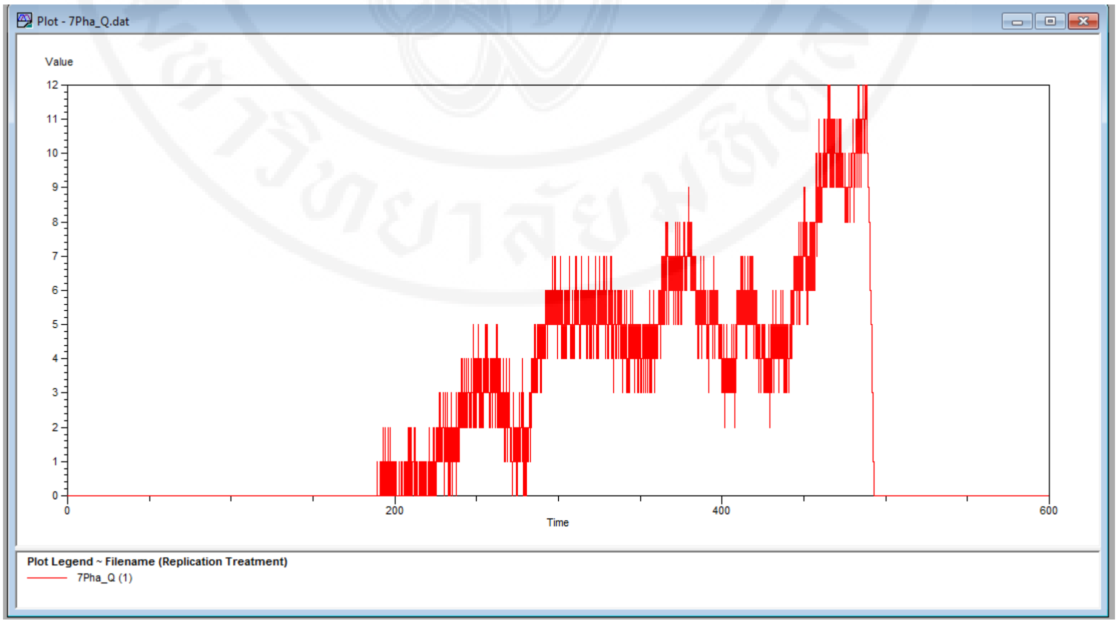

Figure B.6 The number of patients waiting at the 7th floor Pharmacy

APPENDIX C
UTILIZATION OF THE CLINIC

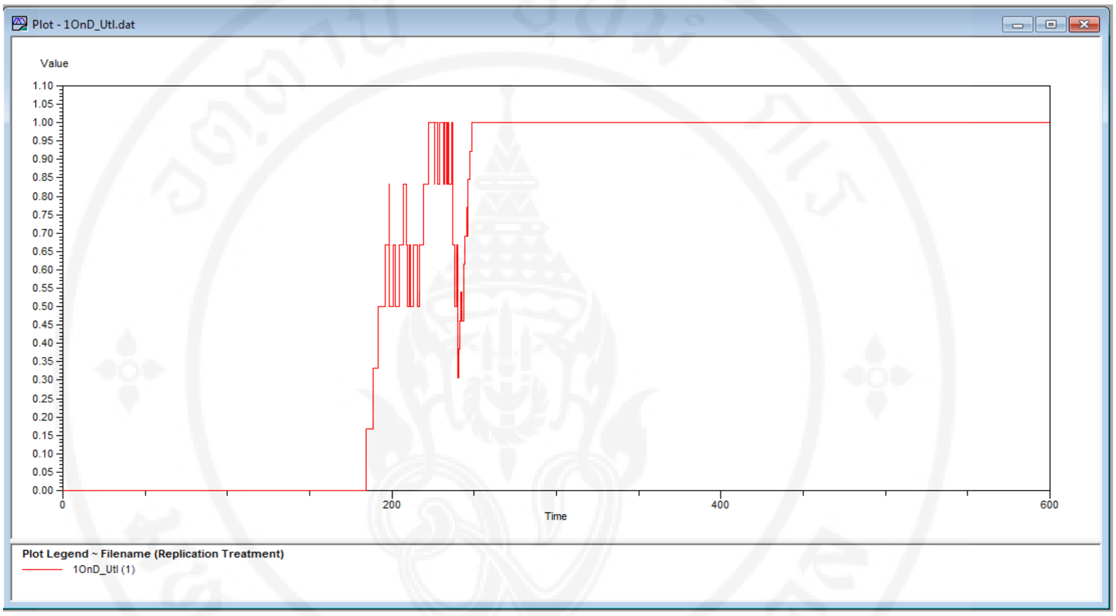

Figure C.1 On Duty clinic resource utilization

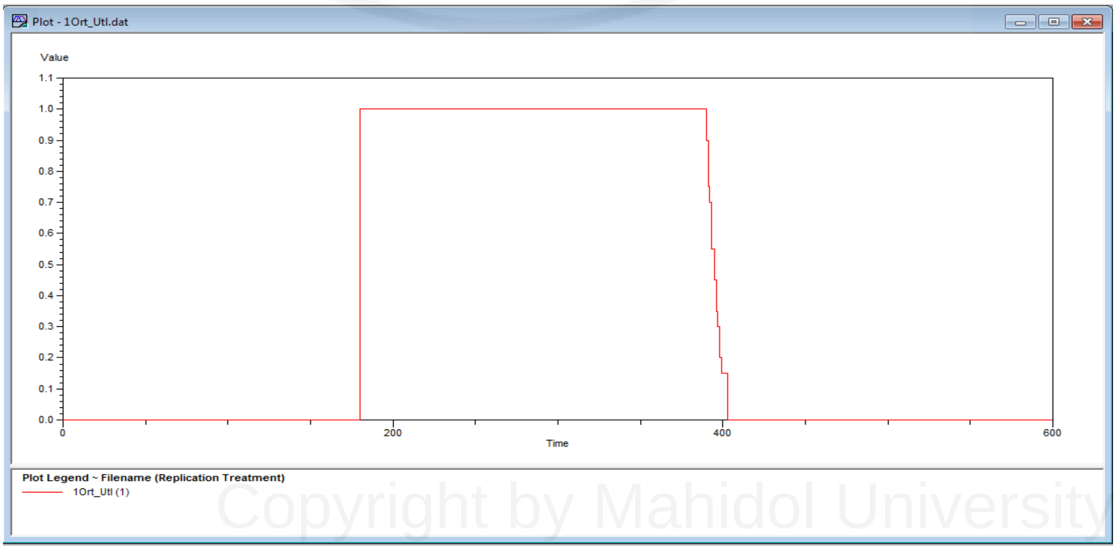

Figure C.2 Orthopedic clinic resource utilization

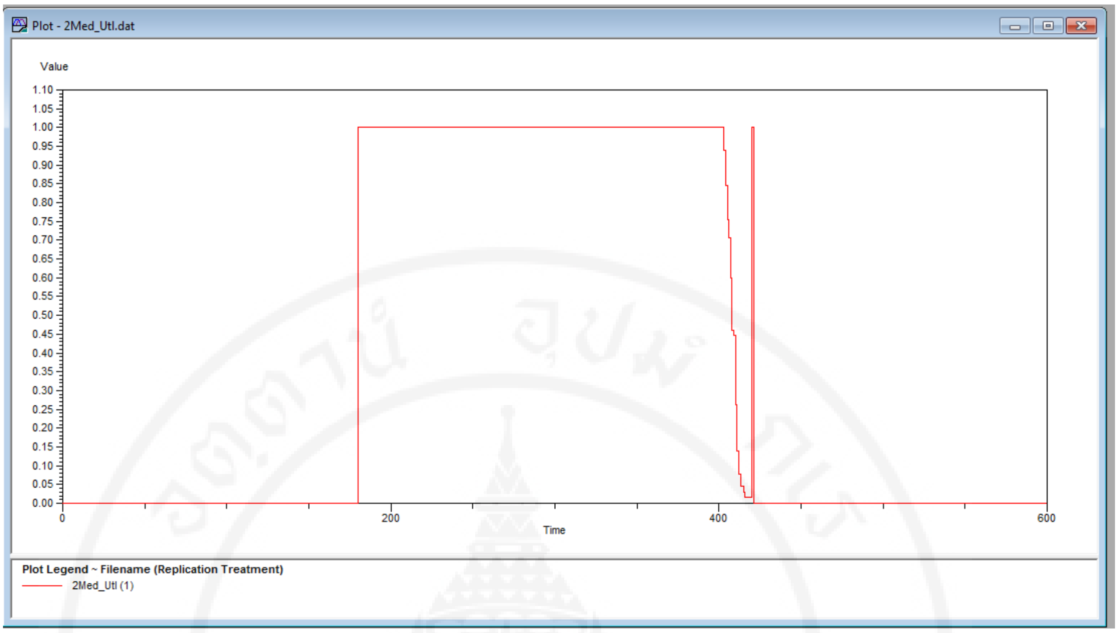

Figure C.3 Medicine clinic resource utilization

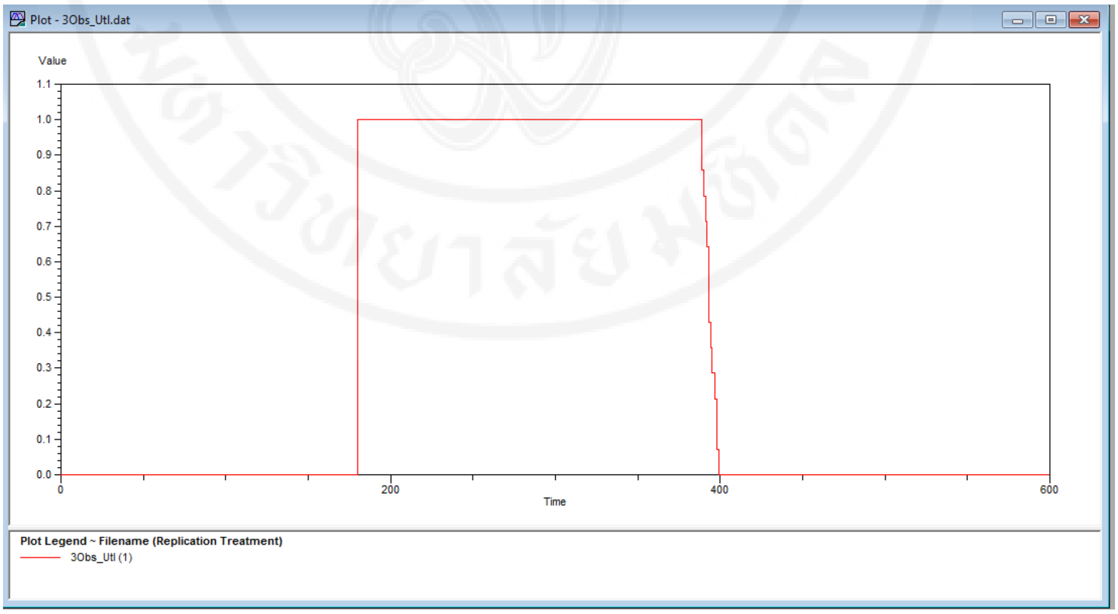

Figure C.4 Obstetric clinic resource utilization

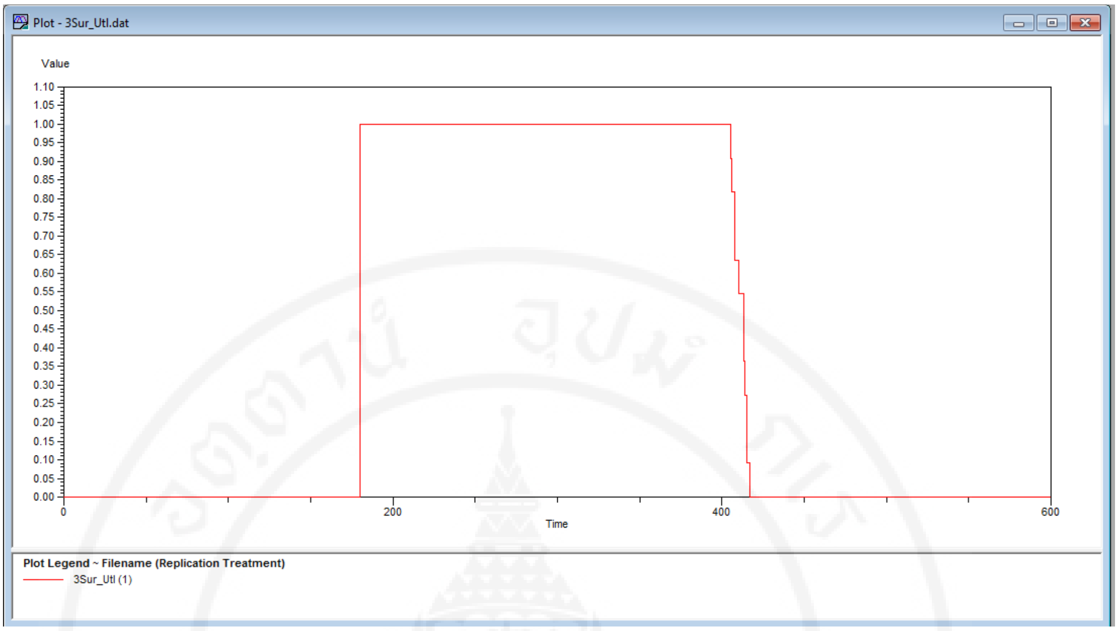

Figure C.5 Surgery clinic resource utilization

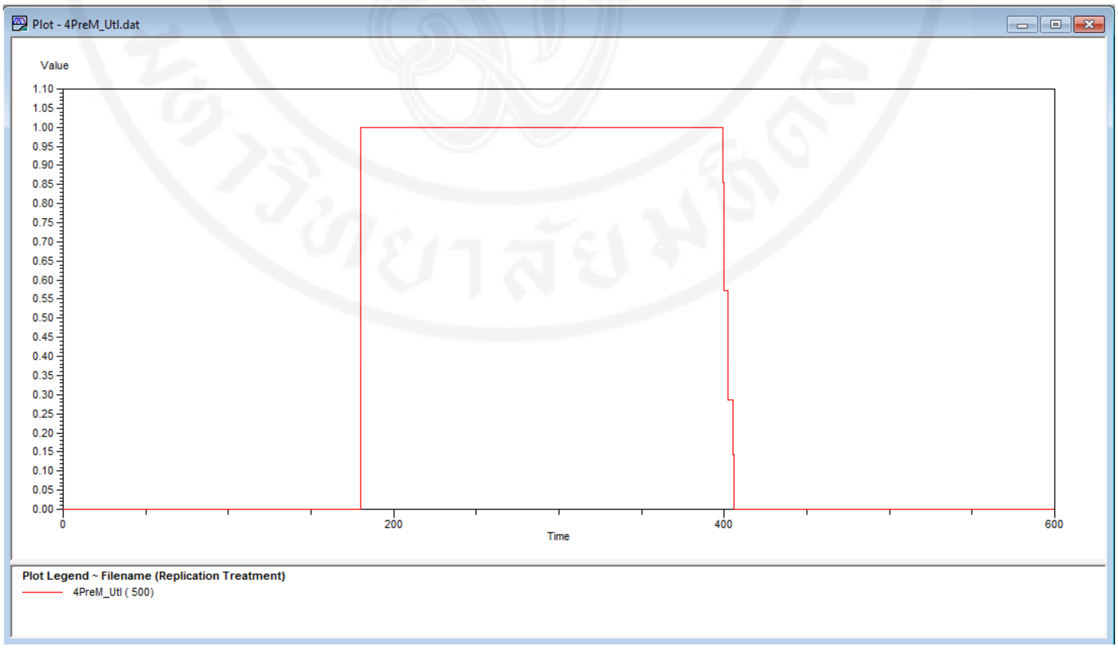

Figure C.6 Preventive Medicine clinic resource utilization

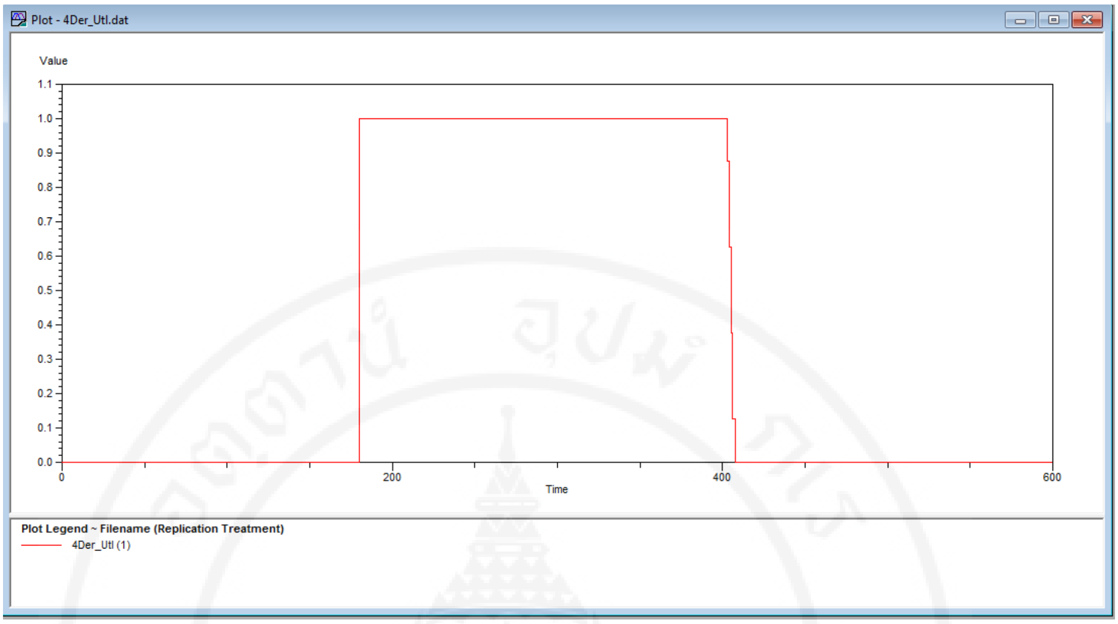

Figure C.7 Dermatology clinic resource utilization

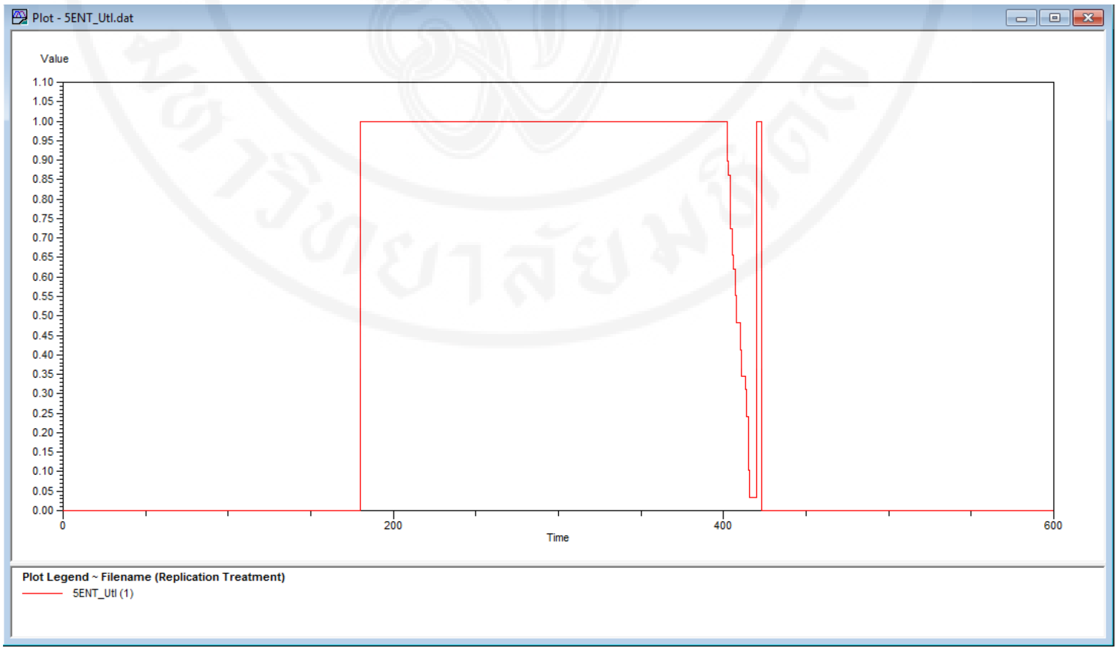

Figure C.8 Ear Nose Throat clinic resource utilization

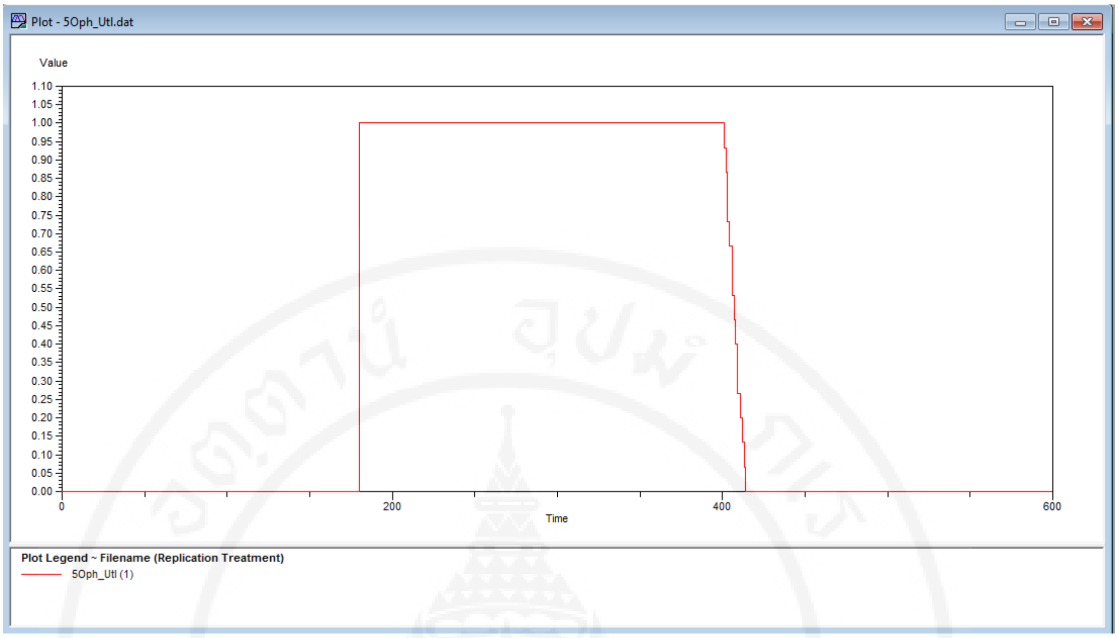

Figure C.9 Ophthalmology clinic resource utilization

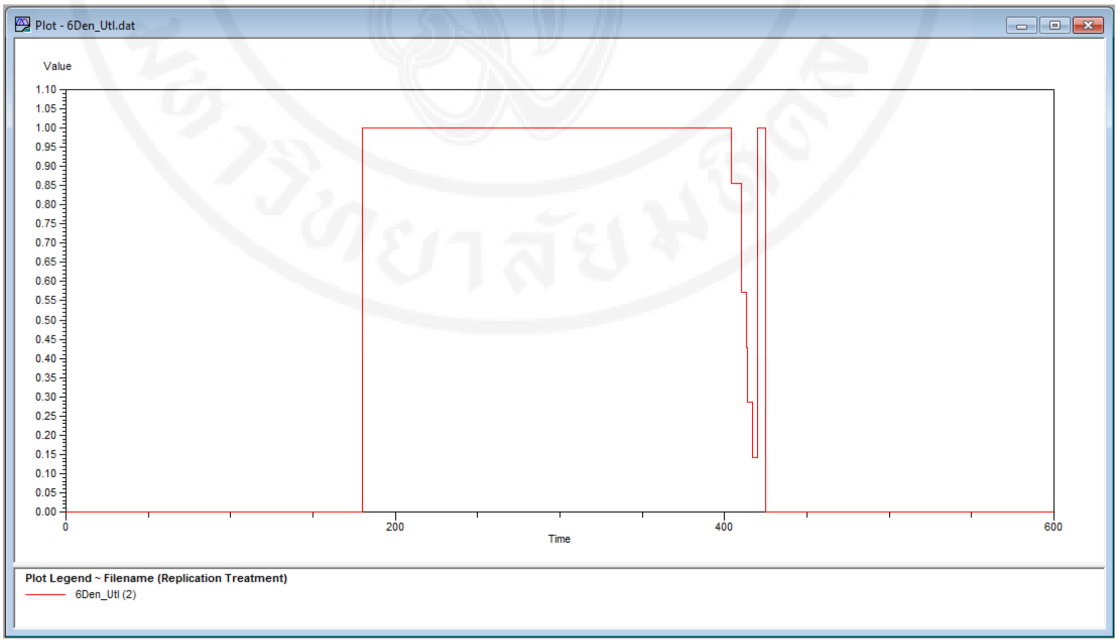

Figure C.10 Dental clinic resource utilization

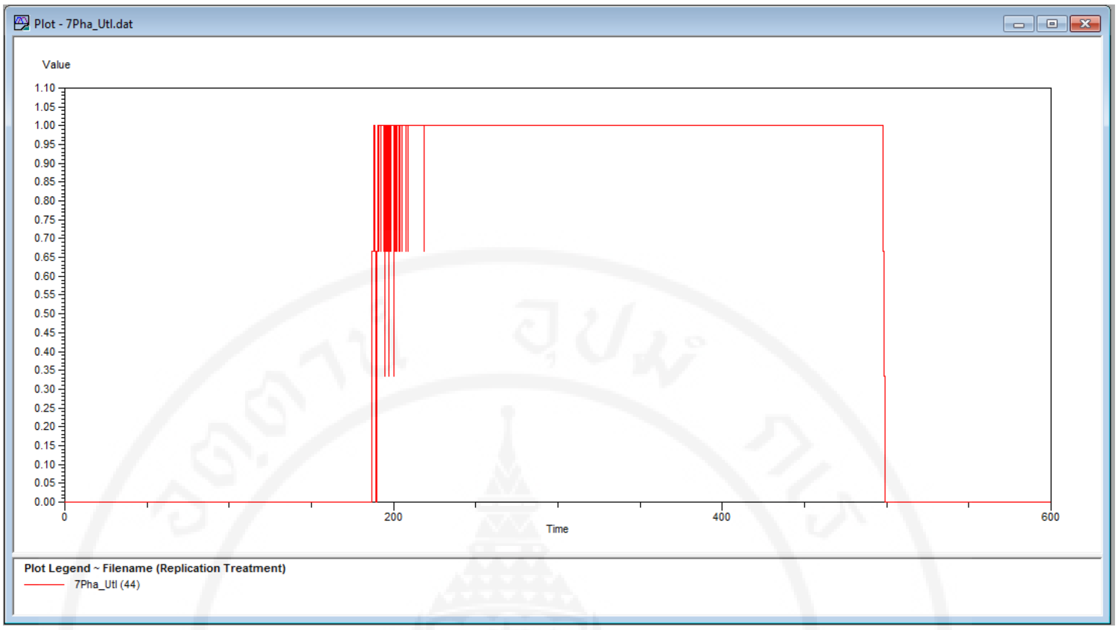

Figure C.11 Psychiatry clinic resource utilization

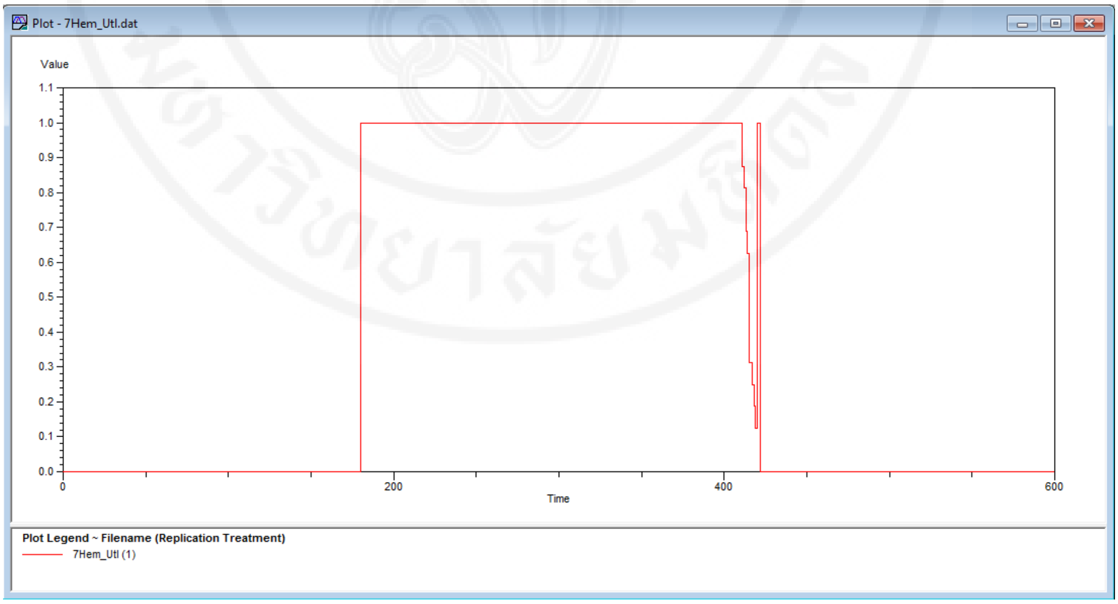

Figure C.12 Hematology clinic resource utilization

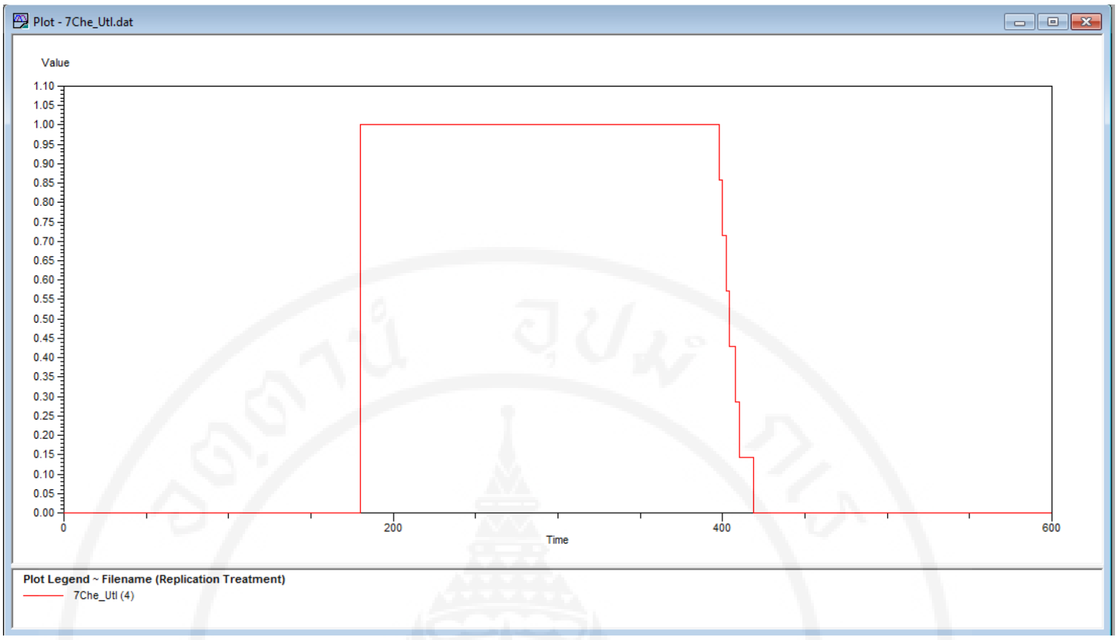

Figure C.13 Chemical Treatment clinic resource utilization

APPENDIX D
UTILIZATION OF THE PHARMACY

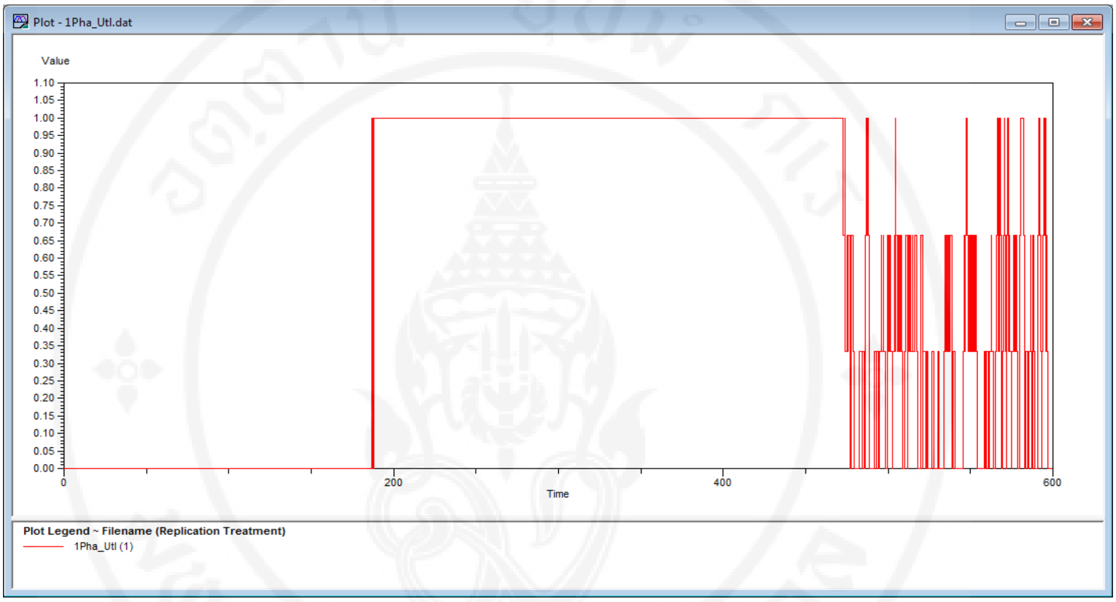

Figure D.1 1st floor Pharmacy resource utilization

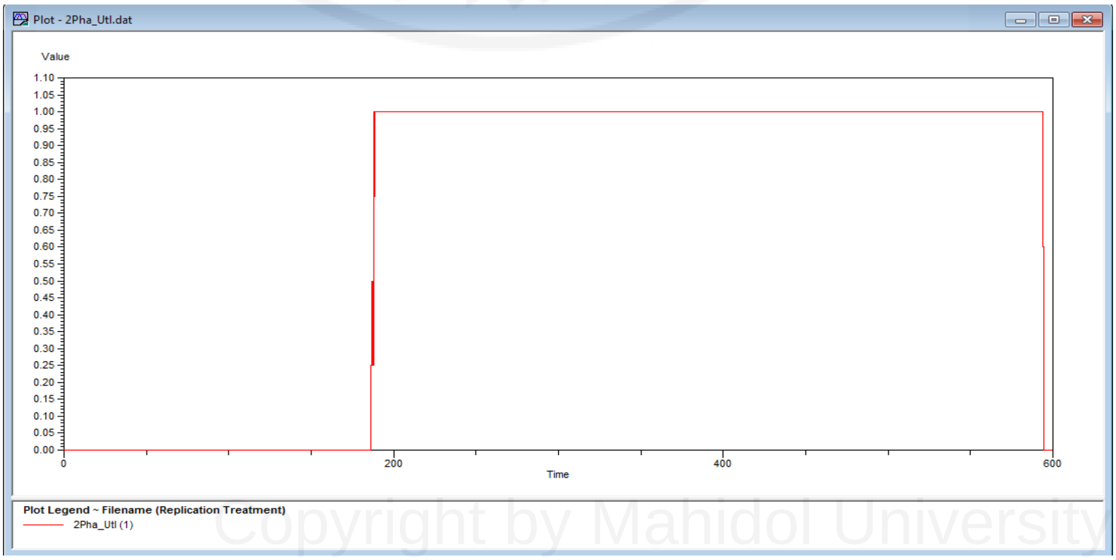

Figure D.2 2nd floor Pharmacy resource utilization

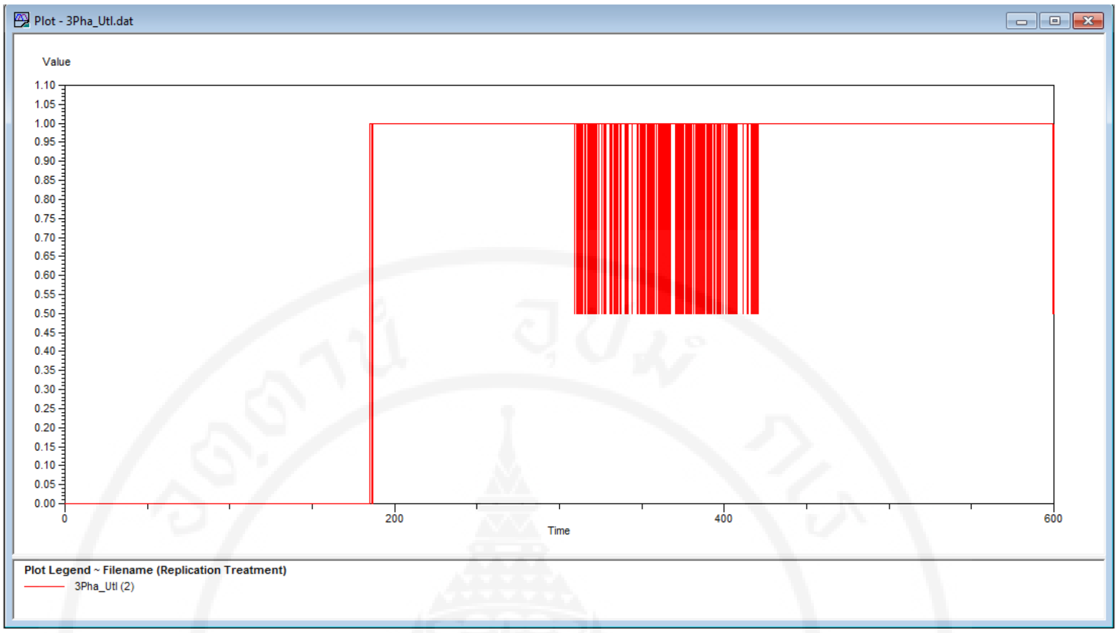

Figure D.3 3rd floor Pharmacy resource utilization

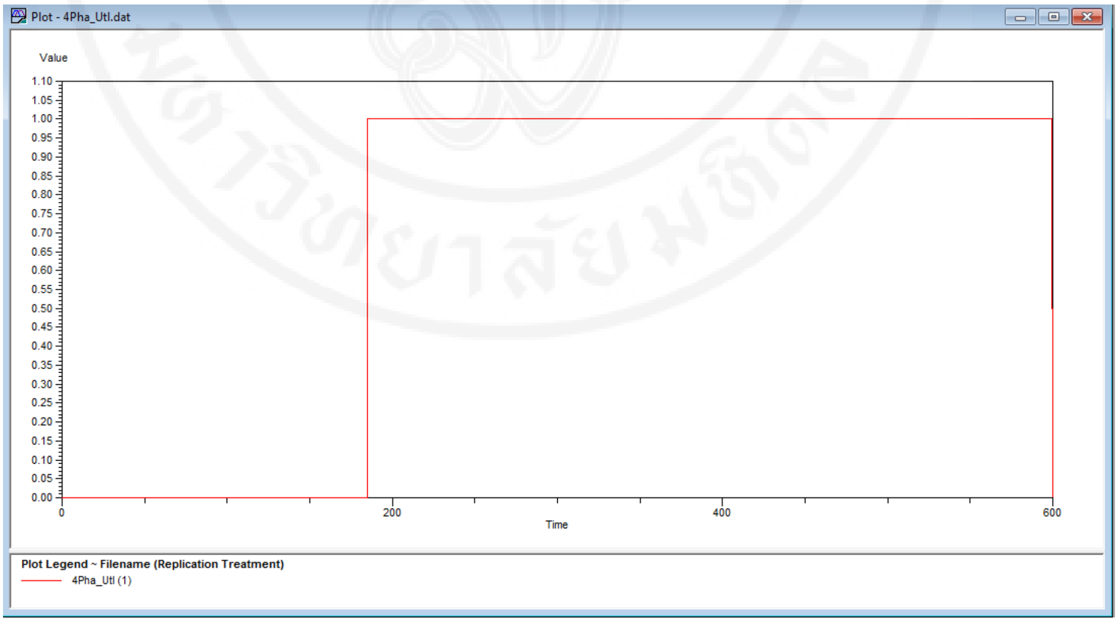

Figure D.4 4th floor Pharmacy resource utilization

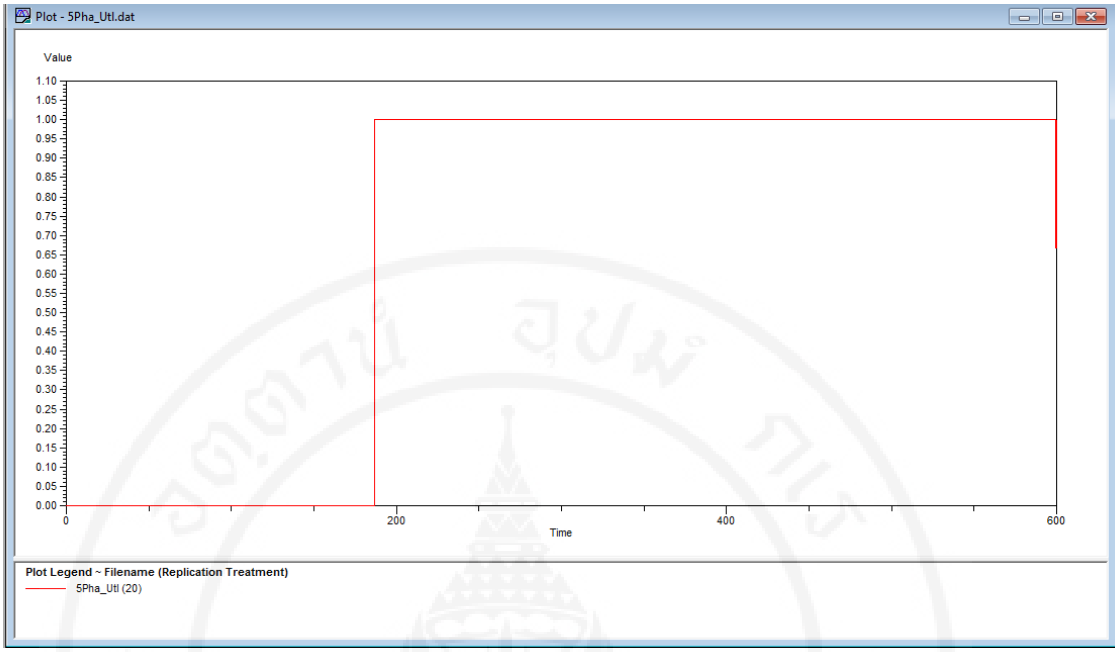

Figure D.5 5th floor Pharmacy resource utilization

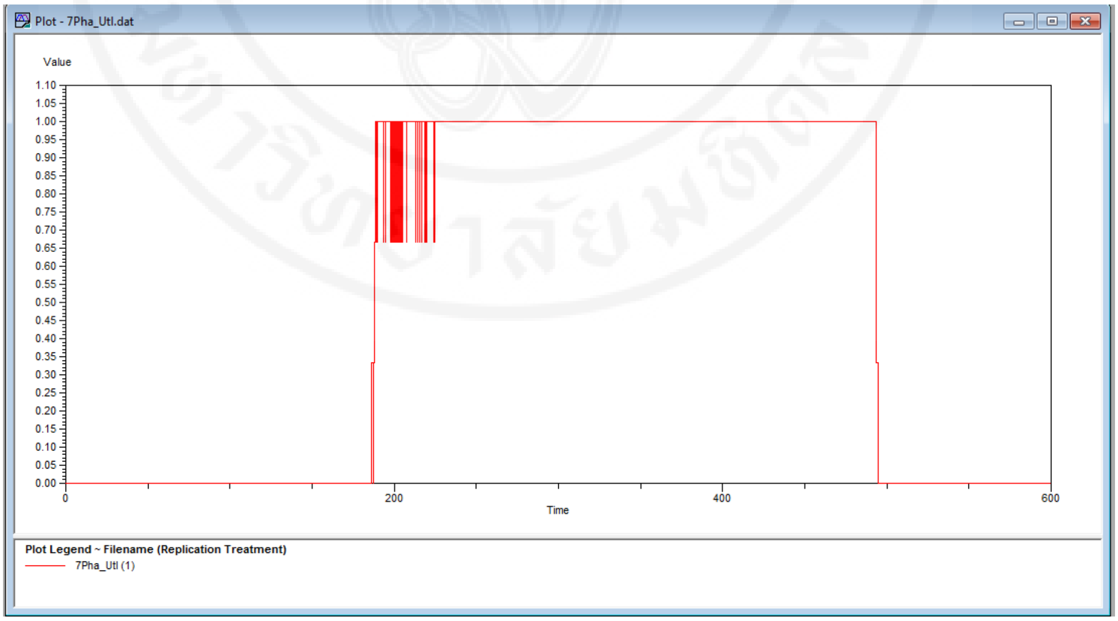

Figure D.6 7th floor Pharmacy resource utilization

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