EXPLORING STRATEGIES TO IMPROVE THE FLOW OF PATIENTS: A CASE STUDY OF THE PEDIATRICS OUTPATIENT DEPARTMENT OF A LARGE PUBLIC UNIVERSITY HOSPITAL

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ABSTRACT

This research studies the characteristics of outpatient flow and analyzes the service problems of the pediatric department at a large public university hospital. The results from observation show that the outpatients spend their time waiting for about 80.45 and 76.20 percent of the total time in the system in the morning and afternoon sessions, respectively. In particular, patients spend more than half an hour awaiting the service in the diagnosis process in both the morning and afternoon sessions. The very long waiting time leads to patient dissatisfaction. The research then modeled the patient flow and used discrete event simulation to analyze the effectiveness of three improvement strategies; i.e., increasing the number of physicians, staggering of physicians' working hours, and improving the patient appointment system. The simulation results revealed that the staggering strategy is likely to be the better choice to improve the efficiency of the service system.

KEY WORDS: OUTPATIENT / PEDIATRICS / SIMULATION / PATIENT FLOW ANALYSIS / HEALTH CARE

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การวิเคราะห์กลยุทธ์เพื่อปรับปรุงการไหลของผู้ป่วยกรณีศึกษาของผู้ป่วยนอกแผนกกุมารเวชศาสตร์ ณ โรงพยาบาลของมหาวิทยาลัยแพทยศาสตร์ขนาดใหญ่ของรัฐแห่งหนึ่ง

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บทคัดย่อ

งานวิจัยนี้เป็นการศึกษาการไหลของผู้ป่วย นอกและวิเคราะห์ปัญหา การให้บริการของแผนกกุมารเวชศาสตร์ในโรงพยาบาลของมหาวิทยาลัยแพทยศาสตร์ขนาดใหญ่ของรัฐแห่งหนึ่ง โดยผลจากการเก็บรวบรวมข้อมูลพบว่า ผู้ป่วยนอกของแผนกกุ มารเวชศาสตร์ต้องใช้เวลาในการรอคอยถึงร้อยละ 80.45 และ 76.20 ของเวลาทั้งหมดที่ ใช้ในระบบ สำหรับการเข้ารับบริการในช่วงเช้าและช่วงบ่ายตามลำดับ โดยเฉพาะอย่างยิ่ง ผู้ป่วยจะเสียเวลามากกว่าครึ่ง ชั่วโมงไปกับการรอคอยเพื่อเข้าพบแพทย์ทั้งในช่วงเช้าและช่วงบ่าย ดังนั้นงานวิจัยนี้จึงสร้างแบบจำลองการไหลของผู้ป่วยนอกและใช้การจำลองสถ านการณ์มาวิเคราะห์ ประสิทธิผลของ กลยุทธ์ 3 ประการ ซึ่งได้เสนอแนะ เพื่อใช้ปรับปรุงการให้บริการแก่ผู้ป่วย ได้แก่ การเพิ่มจำนวนแพทย์ การเลื่อนเวลาทำงานของแพทย์ และการปรับปรุงระบบนัดหมายผู้ป่วย ซึ่งผลลัพธ์จากการจำลองสถานการณ์ พบว่า การเลื่อนเวลาทำงานของแพทย์นั้นเป็นกลยุทธ์ที่ดีที่สุดสำหรับการปรับปรุงประสิทธิภาพของระบบการให้บริการ

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CHAPTER I
INTRODUCTION

1.1 Importance and background of problems

Nowadays, there are a lot of problems in the world, which have both physically and mentally effects on people. No matter what the effects are, they definitely have impacts on human health. As a result, human are contracting many diseases. If we look at Table 1.1, we clearly see that the numbers of both outpatients and inpatients who come to public health centers increased every year. In addition, this table shows that the number of outpatients is higher than that of inpatients. This occurs mainly in 2009 where the ratio of outpatients to the total number of population is 2,639:1,000. This indicates that one patient gets more than one treatment for an illness and/or a syndrome. Because the government provides public health insurance for the citizens, there are more patients coming to the public health centers and this worsens the quality of service. Although the government has increased the health service throughout the country, getting the service is still difficult. While private hospitals provide a better service, the fees are so expensive that only the minority is able to pay to get the service.

Bureau of Policy and Strategy, Office of Permanent Secretary for Public Health (2010) states that the World Health Organization (WHO) declared manpower shortages in public health to be a critical problem in 2006. The proportion of medical personnel to Thailand's population is 30:100,000 which is quite low. These manpower shortages are getting more serious, partly due to an increasing number of physicians' leaving for working at a private hospital. Another cause of the problem is the policy to promote Thailand as the medical hub which aimed to obtain revenue from providing medical services to wealthy foreigners.

Table 1.1 Numbers and rates of inpatients and outpatients from public health centers in Thailand between 2005 and 2009.

Year	Inpatients (75 groups of causes)		Outpatients (21 groups of causes)	
	Quantity	Ratio (per 100,000 population)	Quantity	Ratio (per 1,000 population)
2005	7,749,734	-	106,251,652	-
2006	8,092,741	-	118,422,898	-
2007	8,911,696	15,572	130,741,335	-
2008	9,497,993	16,518	140,078,456	2,436
2009	10,307,684	17,849	152,428,645	2,639

Source: http://service.nso.go.th/nso/nso_center/project/search_center/23project-th.htm

Due to a large number of patients and manpower shortages, there are more patients waiting to get treatment, and the health centers or hospitals become crowded. This happens, especially, in large public hospitals where many people trust. In order for the public hospitals to efficiently provide service and meet the patients' demand, we must take patient flow into consideration. Patient flow needs to be efficiently managed throughout the process.

System design and development usually use a model as a necessary tool to help analyze the tasks before practical performance. Considering only the modeling of operation system in hospitals, "this modeling has been studied for more than 30 years" (Swisher et al., 2001). Previous researches were conducted in many different units of a hospital such as outpatient clinic (Côte, 1999; Su and Shih, 2003), mammography clinic (Coelli et al., 2007), ambulatory care unit (ACU) (Santibáñez et al., 2009), emergency department (Ahmed and Alkhamis, 2009; Brenner et al., 2010), and nephrology outpatient department (Jerbi and Kamoun, 2011). All of the researches considered patient satisfaction and resources utilization in the department. The objective of these researches was to find out how to provide service with efficiency and no interference in the real operation system. However, previous researches were usually carried out on the units which had not many patients, so there are only few people who may benefit from these researches. To get the highest benefit, a research study was conducted at Ramathibodi Hospital which is a large public university hospital in Thailand. This hospital absolutely cares about the patients' demand and expectation. There are more than 1.3 million outpatients per year, who go to this hospital for treatment (Division of Policy and Planning, Office of the Dean, Faculty of Medicine Ramathibodi Hospital, Mahidol University, 2007). Moreover, this research studied the outpatients whose number is very large. In addition, the outpatient department treats patients who do not have serious symptoms. They do not stay any nights, and/or can come back for an examination later (Auaychai, 2001). This makes it easy for the researcher to follow up on the outpatients throughout the service. The department which was the case study in this research was the pediatrics department because this department manages its service in the form of one-stop service which the patients have a medical examination and buy prescription drugs in the same area. This is very convenient for data collection. Furthermore, the problems of patient flow have occurred all over the country for a long time, but they have not been improved. From now on, if the problems are neglected, they will be chronic problems in health care area continuously. Unfortunately, they may affect to the patients' life if the patients have an acute symptom and must wait to see physicians for a long waiting time.

1.2 Research objectives

This research has two main objectives as follows:

1) To study and understand characteristics of service and flow of outpatients in the case study hospital.
2) To analyze problems and suggest possible solutions to decrease the total waiting time and total time in the system of the outpatients.

1.3 Scope of the research

The scope of study is as follows:

1) This research only studied the flow of outpatients.
2) This research studied a large public university hospital and analyzed the service of the Pediatrics Department in this hospital.

This chapter has shown the importance and causes of problems, objectives, and scopes. It provides clear understanding about the service in the public health centers in Thailand. Consequently, the next chapter will review theories and researches related to this research.

CHAPTER II
LITERATURE REVIEW

The objectives of this research are to understand the service and patient flow of outpatients in a hospital, and to suggest possible solutions to increase the efficiency of the service. Therefore, it is important to study theories and researches about patient flow and tools for improving the service. Then, the researcher studied related theories, and national and international researches to obtain more data and knowledge regarding the simulation, patients flow analysis, key performance indicators and analytical tools.

2.1 Health care service in Thailand

Health care service is a service which focuses on patients, and has interaction with the patients continuously (Li and Benton, 2003). Recently, there are a lot of health centers where people can get this service in Thailand. Moreover, Bureau of Policy and Strategy, Office of Permanent Secretary for Public Health (2010) states that 134 hospitals passed the Hospital Accreditation (HA) in 2005, but getting the service in public health centers is still difficult. While private health centers provide a better service, the fees are so expensive. Therefore, only a minority of people can afford to get the service.

For public health's budget point in 2005, the Total Health Expenditure (THE) of Thailand is approximately 3.6% of the Gross Domestic Product (GDP). Conversely, an average THE of international level is 7.7% of GDP. In other words, Thai people have spent only 3,974 Baht per year for THE. There is an increase in proportion of the budget for personnel while proportion of the budget for an operation decreases by 15%. In addition, the government has a problem to allocate the budget to health centers. For these reasons, many health centers run into debt, and the debt will become health expenditure of the government later (Bureau of Policy and Strategy, Office of Permanent Secretary for Public Health, 2010).

Because of these problems, health centers have been trying to improve themselves to be able to deal with the problems. First, the public health centers, as well as the private ones, have tried to improve their service. For instance, they organize special clinics which serve a better service, and the patients do not have to spend as much money as they do in the private health centers. Moreover, they try to improve the patient flow in order to reduce patient's waiting time. Second, the public health centers try to manage their existing resources instead of employing new personnel. Consequently, they can cut costs and use their manpower efficiently.

2.2 Patient flow

Patient flow can be described as a network which begins when patients are first diagnosed or where patients arrive at a health center. The patient flow is finished when the patients leave the health center (Côté, 2000). It can be considered as a patient's journey which patients will pass through processes or stations in the health center. The resources in health centers such as examination rooms, nurses, or medical equipment are used throughout the flow (Koo et al., 2010). Each department or health center may have a different flow because it has different medical treatment and level of complication. Moreover, there are inpatient department (IPD) and outpatient department (OPD) which have different characteristics of flow. The IPD is a unit in a health center where patients are admitted in and stay overnight to obtain the health service. In contrast, the OPD is a unit in a health center which provides health service to patients who do not stay overnight there. An example of patient flow is shown in Figure 2.1 which is a flow in an outpatient department of a large general hospital (Wijewickrama and Takakuwa, 2005). It begins when patients arrive at the department and register. Patients may have a laboratory test and X-ray before consulting a doctor. Next, they may need a second consultation and can be hospitalized. If they have a follow-up visit, they will make an appointment for their next visit. The last step is billing and/or fax prescription to the pharmacy, and then patients leave the department. In the same Figure, if the patients consult their doctor and are hospitalized, they will be the patients of the IPD.

There are numerous researches which studied the patient flow. To illustrate, Sepúlveda et al. (1999) studied patient flow throughout the unit, and analyzed the patient flow and demand of resources in a new building. Medeiros et al. (2008) improved patient flow to reduce waiting time in the hospital's emergency department. Koo et al. (2010) analyzed the main factors which are the causes of inefficient patient flow at a gastrointestinal endoscopy unit by using the simulation model. These researches were aimed to improve the patient flow owing to problems about waiting time and patient satisfaction. In fact, an unsystematic patient flow results in an increase in waiting time (Potisek et al., 2007; Koo et al., 2010), a decrease or an increase in resources utilization, a reduction in service quality, and an increase in service cost. Therefore, a patient flow which has a lot of patient throughput, fast service, and low waiting time is an efficient patient flow (Koo et al., 2010).

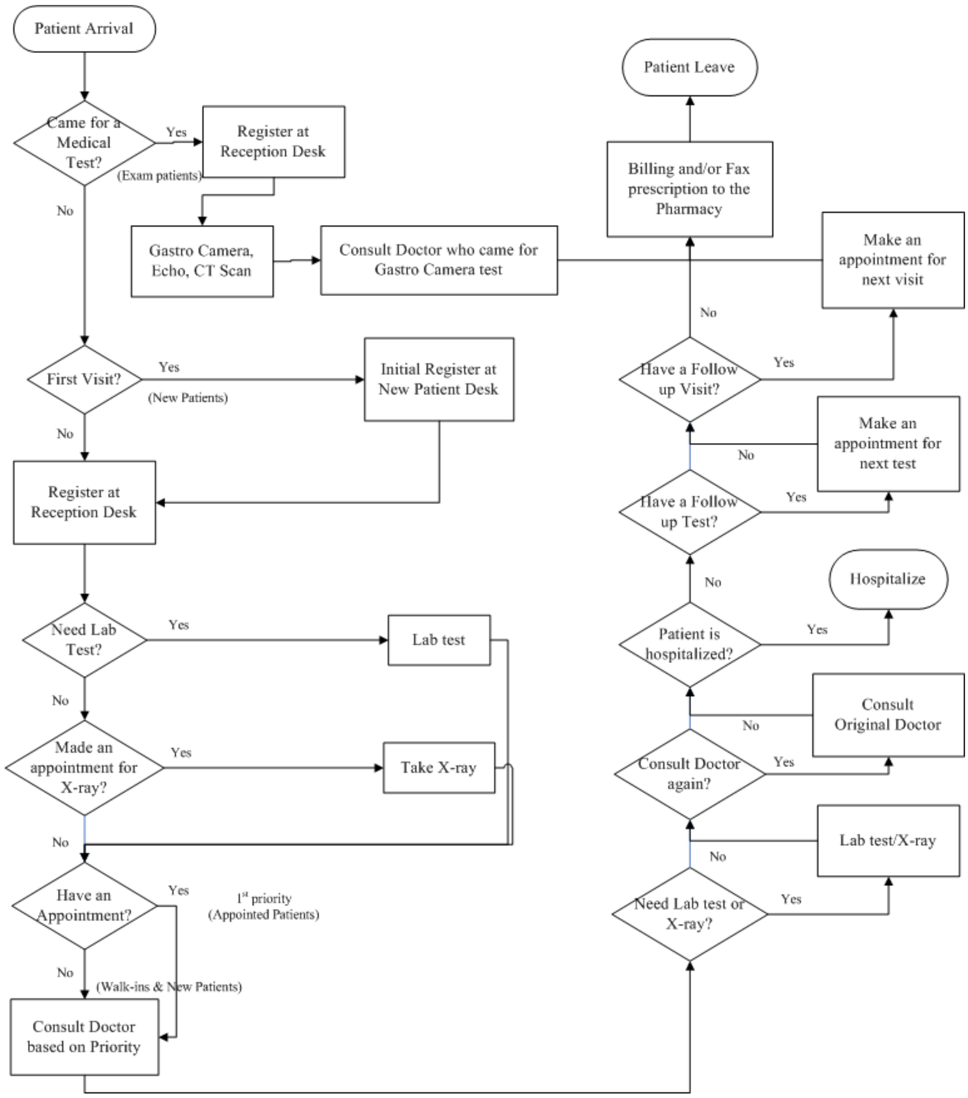


Figure 2.1 Patient flow diagram in outpatient department

(Source: Wijewickrama and Takakuwa, 2005)

2.3 Key Performance Indicators (KPIs) in health care

As a result of the problems in the patient flow, the researchers found a variable called Key Performance Indicators (KPIs) which are used for indicating the most efficient alternatives that can be applied in the real world system. In other words, the KPIs are tools which are used to evaluate the process in the health care system. Therefore, they are required in an improvement of performance (Stannard et al., 2008). Miller et al. (2009) stated that modeler must choose the KPIs carefully and describe them clearly. For example, ED LOS is the length of stay of emergency department patients. It is computed for patients who are admitted to IPD and/or released from the emergency department. In many health care researches, there are three preferential KPIs, i.e., lengths of stay, waiting time, and resources utilization.

2.3.1 Length of Stay (LOS) / Total time in the system

Length of stay (LOS) refers to the total time which patients spend in health centers. In simpler words, it is a time period when patients register to obtain a service up to the period when they leave the health centers. For example, Siegel et al. (2009) studied in the emergency department of eight hospitals and found duration from triage to discharge, or LOS, is 3.7 hours. It is used to measure a performance of health centers such as in medical assessment unit (Oddoye et al., 2009) and emergency department (McCarthy et al., 2009). When the LOS is extended, patient satisfaction will be decreased (Schneider et al., 2003; Finamore and Turris, 2009). Similar to what McCarthy et al. (2009) said, many researchers found an increase in LOS related to crowding, so it makes patients unsatisfied. Moreover, the LOS is also increased by long waiting time (Beck et al., 2009). For these reasons, it can affect patient satisfaction and can evaluate the quality in health care system. Obviously, health centers should organize theirs system efficiently because an origin of LOS's problem is in their own systems (Siciliani et al., 2009).

2.3.2 Waiting time

Waiting time refers to a non-value added time which patients spend to wait in stations to obtain service at health centers. In patient flow, it usually has many durations of waiting time at different points such as b, d, f1, and g in Figure 2.2 which is a patient flow in Ambulatory Care Unit (Santibáñez et al., 2009). A long waiting time has been a major problem in health care service for many years. It shows lack of ability to deliver health care in this system (Gupta et al., 2007). Murray and Berwick (2003) said long waiting time is a common problem which patients and physicians have experienced in a health care center. Several public health centers choose to have their patients wait instead of decreasing queues by investing in resources (Leung et al., 2006). British Columbia Cancer Agency's ambulatory care unit tried to reduce the patients' waiting time. In the best case, they reduced waiting time by starting the clinic on time, increasing 30% of appointment durations, and entering add-ons schedule at the end of the day (Santibáñez et al, 2009). The waiting time varies according to various factors such as types of patients, lack of medical equipment and/or personnel, and inefficiency of the system. For instance, patients' cases affect waiting times as emergency patients have less waiting time than non-emergency patients (Kennedy et al., 2004; Finamore and Turris, 2009). Moreover, hospitals located at the low socioeconomic area (Hoot and Aronsky, 2008), have a large number of patients (more than 30,000 visits per year). The teaching hospital has increased the waiting time more than others (Finamore and Turris, 2009). Above all, the long waiting time should be reduced to lower than current situation because it affects patient satisfaction significantly (Thompson et al., 1996). Some patients decided to leave without being seen (Hoot and Aronsky, 2008).

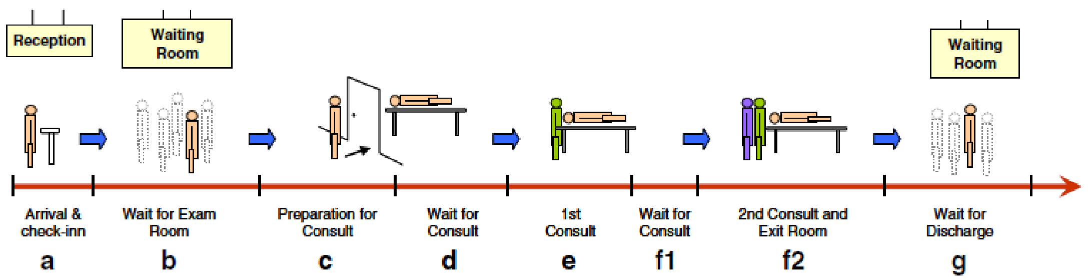


Figure 2.2 Patient process for an ACU appointment
(Source: Santibáñez et al., 2009)

2.3.3 Resource utilization

Resource utilization refers to work's volume of a resource (Cardoen et al., 2010). It measures the performance of the system (Santibáñez et al., 2009; Banks et al., 2010; Centeno et al., 2010; Eitel et al., 2010). For instance, Santibáñez et al. (2009) used resource utilization, waiting room occupancy and examination room utilization, to estimate the performance of their scenarios. In addition, not only do resources refer to work's volume of equipment but they also refer to work's volume of personnel. Similarly, Oddoye et al. (2009) used utilization of physicians and nurses to measure the performance of health centers. The resource utilization is calculated as a ratio of the actual working time to the total time in system. More simply, it is described as a proportion of resource's busy time (Banks et al., 2010). The resource utilization also determines bottlenecks and redundant resource capacity in the system (Law, 2007). If the resource utilization is very low, that resource maybe unnecessary for the system. In contrast, if the resource utilization is nearly 100 per cent, the bottleneck occurs at that resource. For example, triage process in emergency department is overcrowded because triage nurse has a lot of work in the current situation. Therefore, the triage nurse utilization exceeds 80 percent and can go up to 99 percent (Khurma et al., 2008). Without a doubt, the resource utilization can help an analyst to decide on an investment in expensive equipment and/or to cut off the unnecessary personnel like Siciliani et al. (2009) said hospital cost depends on the resource utilization. However, when resource utilization is low, the system can work smoothly. Therefore, an analyst should use different utilization levels to analyze the performance of the system (Efe et al., 2009).

To summarize, these three key performance indicators (KPIs): length of stay, waiting time, and resource utilization, are related to one another. When resource utilization is very high or there is lack of resources, patients must spend time waiting. Conversely, if resources are used effectively, the length of stay will be reduced (Aktaş et al., 2007). For this reason, health centers must improve their patient flow system circumspectly in order to decrease the length of stay and waiting time, and increase resource utilization.

2.4 Simulation

Simulation is a behavioral duplication of a real-world system. It is usually used to analyze results if an actual system is changed from present situation or used to learn about an interesting system before the system is built in real operating system. Thus, simulation is a tool for solving problems in the system. The steps for studying it which is written by Banks et al (2010) are shown in Figure 2.3. The areas of simulation application are various such as manufacturing applications, business processing, logistics, and health care (Banks, 2010). Above all, there are many advantages according to Banks et al. (2010) that Pegden, Shannon, and Sadowski (1995) indexd the following advantages

- It can find new policies, procedures, decision making, etc. without interfering the operations in real-world system.
- It can test new design, plan, and system of transportation without using resources of real-world system.
- It can examine hypothesis about how/why phenomenon occurs?
- It can analyze bottlenecks of the system which cause delay.
- It can answer what-if questions.

On the other hand, it also has disadvantages. It takes a lot time and costs to build the simulation model. Furthermore, model builders will be trained for some time and they must study throughout their experience.

There are several ways to categorize the simulation models, but the popular ways are Static vs. Dynamic, Deterministic vs. Stochastic, and Continuous vs. Discrete (Law and Kelton, 2000; Law, 2007; Kelton et al., 2008 and Banks et al., 2010). Especially, Discrete-event Simulation (DES) is used as a decision tool in many health care researches.

DES involves a system modeling and the system changes at only countable points in time. These countable points are the points where an event happens, and a system's state may be changed at the points (Law, 2007). Above all, entities, like patients, are allowed in a system to have interaction with each other (Ramwadhdoebe et al., 2009). An application of DES in health care has been recognized by decision makers since there are many successful DES researches (Hall, 2006). For example, Wijewickrama and Takakuwa (2006) developed DES for studying doctor schedules and appointment schedules in an outpatient department. Coelli et al. (2007) defined optimal conditions for operating the case study clinics and found the most sufficient capacity by using DES. Gibson (2007) used DES to make decisions for designing buildings in a hospital. Ashby et al. (2008) used DES to analyze the impacts when they changed capacity and process in the inpatient unit. Huschka and Denton (2008) used DES to design an Outpatient Procedure Center (OPC) for decreasing waste of resource and improving flow of patients.

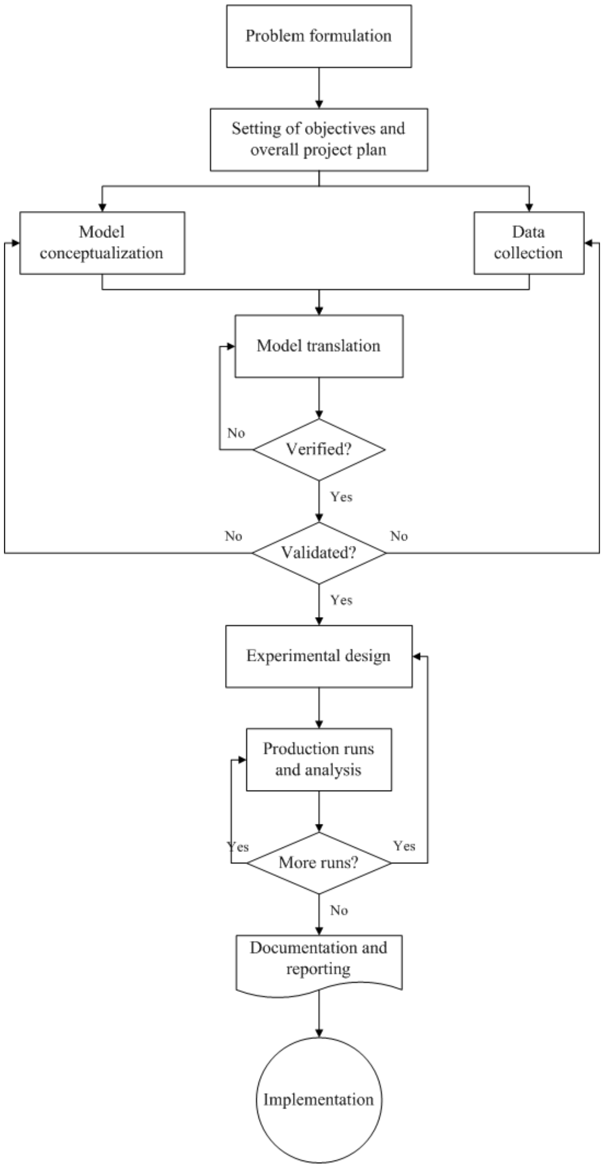


Figure 2.3 Steps in a simulation study

(Source: Banks et al., 2010)

These researches show many advantages of DES such as being fast and having low cost (Coelli et al., 2007). Moreover, decision makers can make mistakes on a model, so they can decrease the cost for system correction in real world (Ramwadhdoebe et al., 2009).

Not only do the researches published the applications of DES, but they also reported about the simulation software. The researchers can use different software to build a model although they study the same department. In particular, emergency department can be modeled by Extend (Miller et al., 2003), Rockwell Arena (Samaha et al., 2003), SIMUL 8 (Brenner et al., 2010), or Unified Modeling Language (UML) (Martin et al., 2010). Likewise, model builders can use MedModel software (Su and Shih, 2003; Coelli et al., 2007; Vos et al., 2007), VBA programs (Angelis et al., 2003; Guo et al., 2004; Wijewickrama and Takakuwa, 2006; Wijewickrama and Takakuwa, 2008) and other software to build a model of any health center. Banks et al. (2010) gave suggestions for selecting software that is easy to use, accurate, vendor-support, and suitable. However, model builders should pay attention to the selection of software that will give accurate outputs.

Table 2.1 List of the relevant simulation researches

Author (year)	Country	The subject health center	Number of patients / Size of health center	Objective of the research	Analytical tools
Assefzadeh (1996)	Islamic Republic of Iran	Paediatric outpatient department	Not available	Assess the patient's waiting time	Patient flow analysis (PFA)
Moreno et al. (1998)	Spain	Nuestra Señora de Candelaria Hospital.	Not available	Create an information system with the capability to generate the dynamics of the organization	- Petri nets - MODSIM programs - Microsoft Access
Côté (1999)	The United State	Family practice clinic of a large health maintenance organization (HMO)	Patient base is approximately 60,000	Examine the relationship between examining room capacity and patient flow	SIMAN IV

Table 2.1 List of the relevant simulation researches (continued)

Author (year)	Country	The subject health center	Number of patients / Size of health center	Objective of the research	Analytical tools
Sepúlveda et al. (1999)	The United State	The M.D. Anderson Cancer Center Orlando (MDACCO)	Not available	- Analyze patient flow throughout the unit - Evaluate the impact of alternative floor layouts, using different scheduling options - Analyze resources and patient flow requirements of a new building	- Rockwell Arena 3.0 - Visio Technical 5.0 - AutoCAD
Angelis et al. (2003)	Italy	Health care centre	Not available	Address a design and management problem in health care systems	Microsoft Visual Basic
Martin et al. (2003)	Norway	The geriatric department in Ullevaal University Hospital	- 45,000 admissions - 450,000 outpatient consultations per year (whole hospital)	Demonstrate how simulation is contributing to increasing efficiency and rates of return	ProModel's simulation software

Table 2.1 List of the relevant simulation researches (continued)

Author (year)	Country	The subject health center	Number of patients / Size of health center	Objective of the research	Analytical tools
Miller et al. (2003)	The United State	Emergency department	Not available	Review and identify problematic areas with patient flow, patient arrival, department policies and procedures	- Microsoft Visio - Extend - Microsoft Access
Samaha et al. (2003)	The United State	Emergency department at The Cooper Health System	544 licensed bed	Reduce the length of stay in the emergency department	Rockwell Arena
Su and Shih (2003)	Taiwan	Urology clinics in Su-Ten Urology Hospital	56,000 – 60,000 patients per year	Analyze several scheduling solutions and found that setting the appropriate arrival time interval for preregistered patients significantly impacts queuing problems	MedModel software

Table 2.1 List of the relevant simulation researches (continued)

Author (year)	Country	The subject health center	Number of patients / Size of health center	Objective of the research	Analytical tools
Guo et al. (2004)	The United State	Division of Pediatrics Ophthalmology at Cincinnati Children's Hospital Medical Center	Not available	Present a simulation framework for evaluating and optimizing scheduling rules	- Rockwell Arena version 8.0 - Microsoft Visual Basic
Wijewickrama and Takakuwa (2005)	Japan	Outpatient department in a large general hospital	Over 2,000 patients per week	Develop an appointment system in a health care organization	Rockwell Arena
Wijewickrama and Takakuwa (2006)	Japan	Outpatient department	525 patients per day	Identify a schedule option by integrating a doctor schedule mixed with an appointment schedule	- VBA program - OptQuest optimization program - Rockwell Arena
Coelli et al. (2007)	Brazil	Mammography clinic of The National Cancer Institute of Brazil	15 patients per day	Develop a discrete-event computer simulation model for analyzing performance of a mammography clinic	MedModel software 6.0

Table 2.1 List of the relevant simulation researches (continued)

Author (year)	Country	The subject health center	Number of patients / Size of health center	Objective of the research	Analytical tools
Potisek et al. (2007)	The United State	UNC General Internal Medicine (UNC-GIM) practice	30,000 visits per year	Test a method to improve efficiency of patient visit	Patient flow analysis (PFA)
Vos et al. (2007)	Netherlands	Outpatient clinic	Not available	Test a method and illustrate it by a case	MedModel
Yeh and Lin (2007)	Taiwan	Emergency department at Show-Chwan Memorial Hospital	Not available	Evaluate how the system is impacted by nursing schedules	- Simulation model - genetic algorithm (GA)
Huschka and Denton (2008)	The United State	Outpatient Procedure Center (OPC) at Mayo Clinic	Not available	Reduce resource waste and improve patient flow through the system	Rockwell Arena
Khurma et al. (2008)	Canada	Emergency department	- 278-bed facility - 140,000 visits per year	Improve a patient's experience over emergency department stay	- Lean tools - ProModel

Table 2.1 List of the relevant simulation researches (continued)

Author (year)	Country	The subject health center	Number of patients / Size of health center	Objective of the research	Analytical tools
Medeiros et al. (2008)	The United State	Emergency department at Hershey Medical Center	Not available	Estimate resource requirements, patient census and patient waiting time when the new approach is in place	Rockwell Arena
Song et al. (2008)	Taiwan	Large hospital system	Not available	Improve the efficiency of a screening physical examination service of a large hospital system	SIGMA
Takakuwa and Wijewickrama (2008)	Japan	Department of an outpatient hospital ward of the Nagoya University	Not available	Identify some of the best doctor schedules; integrated the simulation model into an optimization program in order to reduce patient waiting time	Rockwell Arena
Wijewickrama and Takakuwa (2008)	Japan	Medicine department in Nagoya University Hospital	525 visits per day	Evaluate appointment systems by incorporating appointment rules into patient characteristics	- VBA programs - Rockwell Arena

Table 2.1 List of the relevant simulation researches (continued)

Author (year)	Country	The subject health center	Number of patients / Size of health center	Objective of the research	Analytical tools
Beck et al. (2009)	The United State	Emergency department	Not available	- Using a simplified model for determining the optimal mix of resources for different arrival rates - Test a widely recommended process change	Discrete-event simulation
Miller et al. (2009)	The United State	Emergency department	Not available	Determine the impact of various patient surge levels	Simulation model
Santibáñez et al. (2009)	Canada	Ambulatory Care Unit in the Vancouver Center of the British Columbia Cancer Agency	200 patients per day	Analyze the simultaneous impact of scheduling, operating, and resource allocation changes on system performance	Rockwell arena version 11
Brenner et al. (2010)	The United State	Emergency department at the University of Kentucky Chandler Hospital	48,000 patients per year	Identify bottlenecks and investigate the optimal numbers of human and equipment resources	SIMUL 8

Table 2.1 List of the relevant simulation researches (continued)

Author (year)	Country	The subject health center	Number of patients / Size of health center	Objective of the research	Analytical tools
Centeno et al. (2010)	The United State	Endoscopy Center in Miami, Florida	98 patients per day	Increase the throughput at an Endoscopy center	Rockwell arena
Martin et al. (2010)	Australia	Emergency department	- 43,122 patients per year - 118 patients per day	Identify bottlenecks	Unified Modelling Language (UML)

2.5 Model validation

Validation is an important step in a simulation study as shown in Figure 2.3. Law (2007) identified the comparison with an existing system, expert opinion, another model, and animation are the ways to validate the simulation model. The researcher reviewed the researches about the validation process. These researches briefly explain their method as summarized in Table 2.2. The researcher found that the time in system, waiting time, and process times are numerical statistics that were preferred to use in the validation process. The frequently-used approaches for the validation are hypothesis testing with 95% confidence interval and the computation of percentage error. The past researches did not clearly explain about the criteria that they exactly use to justify the model. Seemingly, the highest percent of error is 15%. Consequently, the researcher adopted the approaches to validate the simulation model.

Table 2.2 List of the relevant researches which described about the validation process

Author (year)	Title	Validation method	Key performance indicators	Criteria of the validation
González et al. (1997)	Improving the quality of service in an emergency room using simulation-animation and total quality management	- Validation through talking with the supervisor, nurses, and doctors of the emergency room - Compare results from the simulation model with the ones of the actual system	- Number of patients in the system - Patients cycle time - Server utilization - Queue time	
Aytuğ and Doğan (1998)	A framework and a simulation generator for Kanban-controlled manufacturing systems	Validated using the trace capability of SIMAN.	- Queue lengths - Resource utilization - Cycle times - Completed order	

Table 2.2 List of the relevant researches which described about the validation process (continued)

Author (year)	Title	Validation method	Key performance indicators	Criteria of the validation
Grangeon et al. (1999)	Generic simulation model for hybrid flow-shop	The results from the investigation were compared to the results from Simula and C++ models.	- Storage per stage - Different machines per stage - FIFO, LIFO, SPT and LPT priority rules for job dispatching - Deterministic processing times	
Hung and Chang (1999)	Using an empirical queueing approach to predict future flow times	The simulation results were compared with those predicted by the iterative approach by using 95% confidence interval	Flow time (the difference between the time when a lot is released into shop-floor and the time when the lot is finished)	95 % confidence interval

Table 2.2 List of the relevant researches which described about the validation process (continued)

Author (year)	Title	Validation method	Key performance indicators	Criteria of the validation
Rotab Khan et al. (1999)	Computer simulation of production systems for woven fabric manufacture	The model validation has been accomplished through the hypothesis tests with 95% confidence interval.	Mean of the production rates	95 % confidence interval
Sepúlveda et al. (1999)	The use of simulation for process improvement in a cancer treatment center	Showing the simulation animation and results to the process improvement team and asked their opinion about different aspects of the system	- Queue length - Number of busy exam rooms - Number of busy treatment chairs	
Rossetti et al. (2000)	Simulation of robotic courier deliveries in hospital distribution services	- Validated with the hospital administrators - Examined the sensitivity of the model	The cycle times	

Table 2.2 List of the relevant researches which described about the validation process (continued)

Author (year)	Title	Validation method	Key performance indicators	Criteria of the validation
Su and Shih (2002)	Resource reallocation in an emergency medical service system using computer simulation	- Showing the model to the specialists of the emergency medical service - Compared the simulation data with the system's empirical data	- The total number of events reported - Processing (treatment) time at the scene - Turnaround times - Total number of idle errands	
Martin et al. (2003)	Proposals to reduce over-crowding, lengthy stays and improve patient care: study of the geriatric department In norway's largest hospital	- Face validity - Compared the model output with the actual data	- The number of patient arrivals - The interarrival times as well as the length of average stays	

Table 2.2 List of the relevant researches which described about the validation process (continued)

Author (year)	Title	Validation method	Key performance indicators	Criteria of the validation
Arisha et al. (2004)	A simulation model to characterize the photolithography process of a semiconductor wafer fabrication	- Compared the output from the simulation model with the actual data - Check the output through a trace file - Considered by the experts and manufacturing people	Cycle time per wafer/lot	4.00 % gap
Masterson et al. (2004)	Using models and data to support optimization of the military health system: A case study in an intensive care unit	Validated by comparison of the model results with the historical performance of the hospital.	- Patient arrivals - Length of stay - Patient transfers - Beneficiary categories - Patient types - Patient mortality - Closure policy - Patient blocking	

Table 2.2 List of the relevant researches which described about the validation process (continued)

Author (year)	Title	Validation method	Key performance indicators	Criteria of the validation
Ballard and Kuhl (2006)	The use of simulation to determine maximum capacity In the surgical suite operating room	Compared the simulation output with the actual data by using a two-sample t-test with $\alpha = 0.05$	- The average of the patient's time in the operating room - Time in system	95 % confidence interval
Lee et al. (2006)	Development of timed Colour Petri net simulation models for air cargo terminal operations	Compared the actual data with the simulation results.	Servicing times	0.10 - 7.30 % error
Liu et al. (2006)	Parameter inference of queueing models for IT systems using end-to-end measurements	Calibrated the model by comparing the modeling results with the results from previous experiment.	The mean end-to-end response times	
Gómez et al. (2007)	Modeling of pervaporation processes controlled by concentration polarization	The simulation results of the model were validated by the comparison of experimental data.	Downstream profiles of concentration and temperature	10.00 % error

Table 2.2 List of the relevant researches which described about the validation process (continued)

Author (year)	Title	Validation method	Key performance indicators	Criteria of the validation
Gupta et al. (2007)	Capacity planning for cardiac catheterization: A case study	Testing the accuracy of the model by compared the actual value with the simulated value.	Waiting time	
Jain (2007)	Value of capacity pooling in supply chains with heterogeneous customers	Compared the simulation model results with the exact data.	Inventory cost	Average percentage absolute deviation is 1.20 %
Rohleder et al. (2007)	Modeling patient service centers with simulation and system dynamics	Compared the output by using an agreement of the staff.	The clock time with the length of the waiting line	
Tannock et al. (2007)	Data-driven simulation of the supply-chain—Insights from the aerospace sector	The outputs were compared with real system outputs in two ways—visual and statistical.	Weekly throughput	95 % confidence interval

Table 2.2 List of the relevant researches which described about the validation process (continued)

Author (year)	Title	Validation method	Key performance indicators	Criteria of the validation
VanBerkel and Blake (2007)	A comprehensive simulation for wait time reduction and capacity planning applied in general surgery	Compared the simulation results with the historical data by using 95% confidence intervals.	- Patient length of stay - OR time - Arrival rates	95 % confidence intervals
Yeh and Lin (2007)	Using simulation technique and genetic algorithm to improve the quality care of a hospital emergency department	- Validated through conversations with the supervisor, nurses, and doctors of the emergency department. - Compare the results from simulation model with the actual system by using Welch's two-sample t test	- The number of patients passing through the system - Patients' cycle time	
Zhang and Zhang (2007)	Design and simulation of demand information sharing in a supply chain	Evaluate the simulation results with theoretic values by using t-test via SPSS.	- Service level - Inventory level	The confidence interval was 95%

Table 2.2 List of the relevant researches which described about the validation process (continued)

Author (year)	Title	Validation method	Key performance indicators	Criteria of the validation
Cimino et al. (2009)	A multimeasure-based methodology for the ergonomic effective design of manufacturing system workstation	- Analyzing and discussing the simulation model with the workers and employees - Compared the real data and the output obtained using the simulation model	Process time	6.00 % error
Marjamaa et al. (2009)	What is the best workflow for an operating room? A simulation study of five scenarios	Compared the output from model with the data in the previous study	- Surgery times - Non-operative times	
Oddoye et al. (2009)	Combining simulation and goal programming for healthcare planning in a medical assessment unit	Compared the observed data with the simulation results	System length of stay times	

Table 2.2 List of the relevant researches which described about the validation process (continued)

Author (year)	Title	Validation method	Key performance indicators	Criteria of the validation
Bard et al. (2010)	Validating vehicle routing zone construction using Monte Carlo simulation	Used a paired-samples t-test with the null hypothesis being no difference between the expected value and the average simulated value.	Service time plus time-to-next-customer	A significance level of 5.00 %
Mahfouz et al. (2010)	Practical simulation application: Evaluation of process control parameters in Twisted-Pair Cables manufacturing system	- Face validation - Comparison testing	Average flow time	10.00 % average percentage of the deviation
Can and Heavey (2011)	Comparison of experimental designs for simulation-based symbolic regression of manufacturing systems	Compared the results from the DES model with the exact results	Throughput rate	0.01-0.11 % error

Table 2.2 List of the relevant researches which described about the validation process (continued)

Author (year)	Title	Validation method	Key performance indicators	Criteria of the validation
Fialho et al. (2011)	Using discrete event simulation to compare the performance of family health unit and primary health care centre organizational models in Portugal	Compared the results of model with the real data by using 95% confidence interval	Total number of medical consultations	95 % confidence interval
Lu et al. (2011)	A simulation study to improve performance in the preparation and delivery of antineoplastic medications at a community hospital	Compared the simulation model results with the collected data (considered the percent discrepancy)	Average process time for medication preparation and delivery	2.70 % discrepancy
Mallor and Azcárate (2011)	Combining optimization with simulation to obtain credible models for intensive care units	Compared the simulation results with the real data by using t-test	Bed occupancy	

Table 2.2 List of the relevant researches which described about the validation process (continued)

Author (year)	Title	Validation method	Key performance indicators	Criteria of the validation
Negrão et al. (2011)	A semi-empirical model for the unsteady-state simulation of reciprocating compressors for household refrigeration applications	Compared the measured values with the computed values	Mass flow rate	15.00 % error
Reynolds et al. (2011)	Using discrete event simulation to design a more efficient hospital pharmacy for outpatients	- Validated by the face validity method (conversations with the project team, service managers, and dispensary staff) - Comparison of baseline models with real-life observations by using 95% confidence interval	- Prescription turnaround times - Percentage completed in less than or equal to 45 minutes	95 % confidence interval

Table 2.2 List of the relevant researches which described about the validation process (continued)

Author (year)	Title	Validation method	Key performance indicators	Criteria of the validation
Tunali et al. (2011)	Setting order promising times in a supply chain network using hybrid simulation-analytical approach: An industrial case study	The actual data was compared with value from simulation	Average batch completion times	95 % confidence interval
Woldeyohannes and Majid (2011)	Simulation model for natural gas transmission pipeline network system	Compared the results of simulation model with the results from the previous models	- Percentage error of unknown pressure - Percentage error of unknown flow parameters	1.80 % and 5.10 % error
Brailsford et al. (2012)	Incorporating human behaviour in simulation models of screening for breast cancer	- Face validity - Operational validity	Average proportion of screen detected cancers	1.00 % error
Pojtaveekeat and Pisuchpen (2012)	The improvement of service efficiency in the health check-up department by using simulation	Using T-Test : Two-Sample Ausseming Unequal Variances	Cycle time	

Table 2.2 List of the relevant researches which described about the validation process (continued)

Author (year)	Title	Validation method	Key performance indicators	Criteria of the validation
Segev et al. (2012)	Modeling the impact of changing patient transportation systems on peri-operative process performance in a large hospital: insights from a computer simulation study	Compared the result from simulation with the actual data	- Travel times - Transporter numbers - Arrival deadlines and definitions of lateness	
Wang et al. (2012)	Modeling and analysis of work flow and staffing level in a computed tomography division of University of Wisconsin Medical Foundation	Compared the results of model with the observed data by using % difference $[((LOS_{model} - LOS_{actual}) / LOS_{actual})*100\%]$	The system length of stay	

Table 2.2 List of the relevant researches which described about the validation process (continued)

Author (year)	Title	Validation method	Key performance indicators	Criteria of the validation
Wua and McGinnis (2012)	Performance evaluation for general queueing networks in manufacturing systems: Characterizing the trade-off between queue time and utilization	- Model validation through regression analysis - Model validation through historical data approach	The cycle time	1.38 - 11.87 % error
Abo-Hamad and Arisha (2013)	Simulation-based framework to improve patient experience in an emergency department	- Face validation - Comparison testing Hypothesis testing	- Average waiting time - Average length of stay for discharged patients - Average length of stay for admitted patients	the deviation from 1.00 – 9.00 %
Melouk et al. (2013)	Simulation optimization-based decision support tool for steel manufacturing	Compared the historical data with output from the model.	Outcomes	95 % confidence interval

The related theories, researches, and data reveal the problems in health care area as long length of stay, long waiting time, and very low/high resource utilization. Especially, these problems usually occur in public health centers where have a lot of patients come to get a service. In Table 2.1, it shows the list of researches which studied in health care service. An objective of them is to improve health centers to be able to deal with the problems. Moreover, they used the simulation model as an analytical tool. The simulation model has many advantages, and it is compatible with these researches. In addition, case studied health centers are usually not a large hospital, or there are not numerous patients like in Thai public hospitals. Actually, a large public hospital in Thailand has a problem in patient crowding. If a researcher can analyze a system of the hospital, and find strategies to deal with the problem, the hospital will have an efficient system. Furthermore, there are many patients who will be satisfied in a better service. Therefore, the research "Exploring strategies to improve flow of patients: A case study of pediatrics outpatient department of a large public university hospital" is proposed here in.

This research is aimed to improve a system in a large public hospital and helps the hospital to have a better health care service, and make patients happy when they leave the hospital. Even though this research studied in the area of health center similar to the researches listed in Table 2.1, the case studied hospital in this research is different from them. The case studied hospital is a large public hospital and also a university hospital. Thus, there are many patients come to obtain the medical service from all over the country. In the Annual Report 2007 of the Faculty of Medicine Ramathibodi Hospital, Mahidol University (2007) stated that the case studied hospital had 1,354,284 outpatients and 36,029 inpatients came to visit in 2007. In contrast, the greatest quantity of patient in Table 2.1 is just 450,000 outpatients per year in Ullevaal University Hospital (Martin et al., 2003). In other words, the patient's quantity of the case studied hospital has triple more than Ullevaal University Hospital. Since it has numerous patients who are waiting to see a physician in an appointment schedule, it should manage its system to deal with the patient satisfaction. Having inappropriate strategies of system's management may affect to patients' lives. Consequently, this research would be very useful. Above all, researches about simulation modeling in health care system can hardly be found in Thailand, although it has been studied for more than 30 years in other countries (Swisher et al., 2001). The research like this case study will provide a good lesson for other subsequent researches and the development of the health care system in Thailand.

This chapter describes about the health care service in Thailand, patient flow, key performance indicators (KPIs) in health care and simulation. The researcher reviewed this knowledge from the related theories, national and international researches, and data from the ministry. In fact, the present health care service in Thailand still has problems for being difficult to obtain the service from the public health centers. Several health centers run into debt which will become the heavy burden for the government soon. For these reasons, the health centers worked harder to improve the service and patient flow, and manage their resources. From many researches which the researcher has reviewed, they have guided a clear idea about patient flow to the researcher. Because of this, this research considers studying an improvement of patient flow. Discrete-event simulation (DES) which involves a system modeling and has been recognized by decision makers is chosen as a main analytical tool of this research. The next chapter will explain a research methodology which includes research data, analytical tools, method of research, and research planning.

CHAPTER III
RESEARCH METHODOLOGY

In Chapter 2 the researcher has described the theories and researches which are related in this research. Moreover, the researcher explained about the research ideas that obtain from many researches in the literature review. Then, those ideas have been developed to be this current research. This chapter will reveal research methodology which includes research data, analytical tools, method of research, and research planning. The details are as follows.

3.1 Research data

3.1.1 Data characteristics

The data of the research are categorized into two main parts. First part is the data which involve a chain of patient service. It begins from the first activity to the last activity. Thus, these data are the entire service activities and the entire resources in the department. Second part is the data about an opinion of personnel who deal with patients, and know about the problems in the department. Both parts are important data which help to understand the service's characteristics and outpatient flow. In the end, the researcher can propose ways to improve the system by analyze both parts of the data.

3.1.2 Population

A population concludes above interested things. Thus, the population of this research is the outpatients in the Pediatrics Department at Ramathibodi Hospital. An average number of outpatients who come to treat their illnesses is 255 people per day (Medical Statistics Department Ramathibodi Hospital, 2010)

3.1.3 Sample

Sample is a unit that represents all the population. In this research, 30-50 outpatients in the Pediatrics Department are the samples. The data collecting process started on 9th September 2010. The data of sample was recorded in patient tracking form which is in Appendix A. Then, the researcher will use the data for preliminary study in the next chapter.

3.1.4 Method of sample selection

This research has more restrictive factors which are the time of study, budget, location, and interference to personnel. Therefore, sample selection methods of research are quota sampling and convenience sampling. The first one is a method for selecting sample until sample quantity is full of the fixed quota. Thus, there are 30-50 samples which were selected in each process. The second one is the selection which has an availability of collector as a criterion (Sriwittayarak et al., 1997). Moreover, a nurse who has worked at the registration counter selected samples for collectors. And the collectors also selected the samples, too. Therefore, the sample selection is depending on fixed quota, the nurse, and the collectors.

3.1.5 Method of data collection

The methods for collecting the data are divided according to each type of data as follows.

1) Primary Data

This data type is collected from patient service system directly by survey, observation and patient tracking. The patient tracking is a follow-up process, which starts from the beginning activity that patients come to register at the department until the final activity after which patient can leave. In addition, patient tracking must not disturb and/or interfere any activity in the patient flow. Moreover, interviewing and sub-meeting with personnel of the department are used to collect opinions about patient service. All above is following this detail.

- Service process of outpatients in the pediatrics department.
- Type(s) of outpatients in the pediatrics department.

- Process time which outpatients use to do any activity in the hospital system.
- Distance and time which outpatients use to travel from one station to another in the hospital.
- Number of resources in the pediatrics department.
- Layout of the pediatrics department.
- Units/Departments where patient comes to get the service.

2) Secondary Data

Secondary data is the data which was collected and recorded previously. The main data in this research was collected by the Medical Statistics Department at Ramathibodi Hospital. These data are the number of outpatients each day, and also the data from related researches.

3.2 Analytical tools

Analytical equipment which is used in this research can be divided into two types as follows.

3.2.1 Hardware

Computer is an important tool for the research. It used to make all documents and run programs which are explained in the next section. In part of the data collection, the researcher uses a patient tracking which is a follow-up process starting from the beginning activity to the ending activity. The patient tracking form (in Appendix A) is designed for recording the data about outpatient service such as activities and time spent in each activity. Furthermore, there is a stopwatch for recording time spent in every activity throughout the patient tracking.

3.2.2 Software

In part of recording numeral and statistical data, Microsoft Office Excel was used to keep and organize the data to be available in subsequent analyses. In addition, Microsoft Office Visio was used to draw the outpatient flow, and also a layout of the pediatrics department. In an important part of the research that is a modeling, the researcher used Rockwell Arena software to build the model of outpatient's service system. This software can be used to model both discrete and continuous systems. Moreover, it can create a graphic for illustrating queue, resources' status, and flow of system's entity that obviously displays a change in the model (Banks et al., 2010).

3.3 Method of research

This research was started from data collection, model building, until the alternative (scenario) design which was proposed to improve the system. The following steps detail the method of research.

1) Study theories and related literature both national and international levels.
2) Plan for the data collection and design a survey form for data recording in patient tracking.
3) Understand the system of outpatient flow in the pediatrics department.
4) Collect the data.
5) Analyze time that patients spent in each activity, the analysis is categorized into three parts; i.e.,
   - Statistical analysis on the collected data such as minimum, maximum, average time, standard deviation, and other descriptive statistics.
   - Distribution of arrival by analyzing data of patient arrival to find an appropriate distribution.
   - Distribution of service time by analyzing time duration which individual patients spent in each process to find an appropriate distribution.
6) Simulation modeling followed the three steps; i.e.,
   - Build the simulation model of pediatrics department using Rockwell Arena software.
   - Model verification by checking the correctness of the flow.

- Model validation by comparing model's outputs with the observed data.

7) Design alternatives (strategies) for improving the system of outpatient's service.
8) Analyze the strategies and recommend the efficient strategy to be operated in the real-world system.

In Figure 3.1, it shows the flowchart of research plan. This research was carried out between July, 2010 and April, 2013. The total time of the research is about two years and nine months.

In summary, this chapter explained about the data of the research including primary and secondary data. The population of the research is outpatients of the Pediatrics Department at Ramathibodi Hospital. The researcher studied by selecting 30-50 patients to be tracked in order to understand their flows. The tools that were used in this analysis are divided into hardware and software. The hardware is mainly the computer system and a stop watch for time collection. The software includes Microsoft Office Excel, Microsoft Office Visio, and Rockwell Arena software. The steps of research are also explained. In Chapter 4, the researcher will bring the method from this chapter to apply to a case study in the Pediatrics Department at Ramathibodi Hospital.

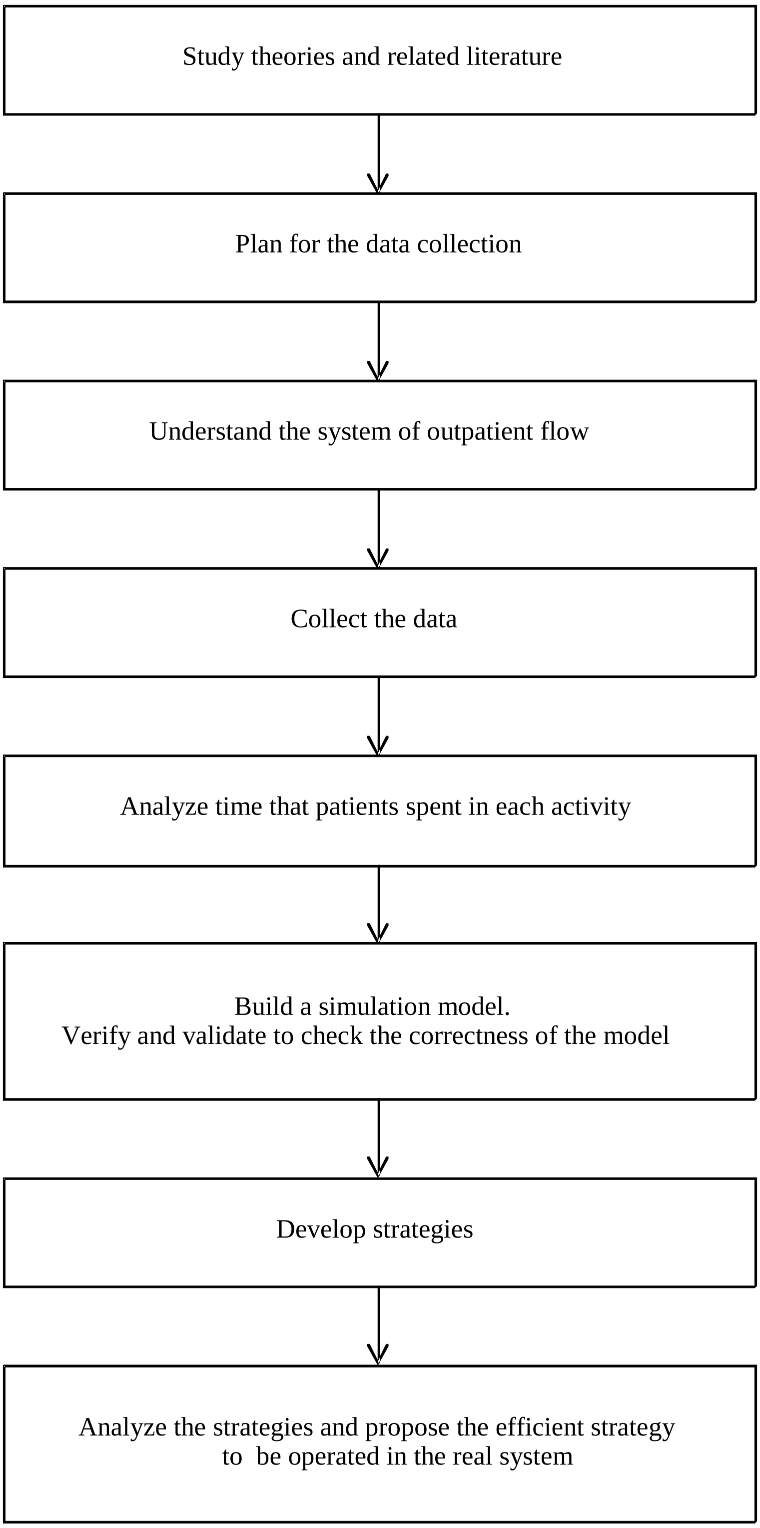


Figure 3.1 Flow chart of research steps

CHAPTER IV
RESULTS AND DISCUSSION

In Chapter 3, the researcher stated about the research data, analytical tools, and method of research which are applicable to the study to understand the outpatients' service of studied hospital. This chapter reveals the details of the case studied hospital; i.e., general service characteristics, flow of patient, arrival and process time characteristics, and expectation / suggestion for the hospital administrator. The researcher uses the collected data to evaluate efficiency and waste of the hospital's service system, and creates three strategies for improving the patient flow. Finally, the researcher reports the results and discussion of the strategies.

4.1 Case study: the Pediatrics Department at Ramathibodi Hospital

Ramathibodi Hospital is a very large public university hospital in Thailand. It was located on Rama VI Road at Toong Phayathai, Ratchathewi, Bangkok. The mission of this hospital is to produce graduates in medicine, carry out researches, provide medical and academic services and health campaign to the society. The hospital administrator gives precedence to the requirement and expectation of patients. Therefore, the hospital has conducted the annual survey about patients' satisfaction as a key performance indicator (KPI). A KPI's goal of outpatients and inpatients are 80% and 90% respectively. In 2007, the hospital achieved its goal for the inpatient department because the satisfaction level is at 94.70 percents. While the outpatient satisfaction level is well below the goal at only 76.20 percents (Division of Policy and Planning, Office of the Dean, Faculty of Medicine Ramathibodi Hospital, Mahidol University, 2007)

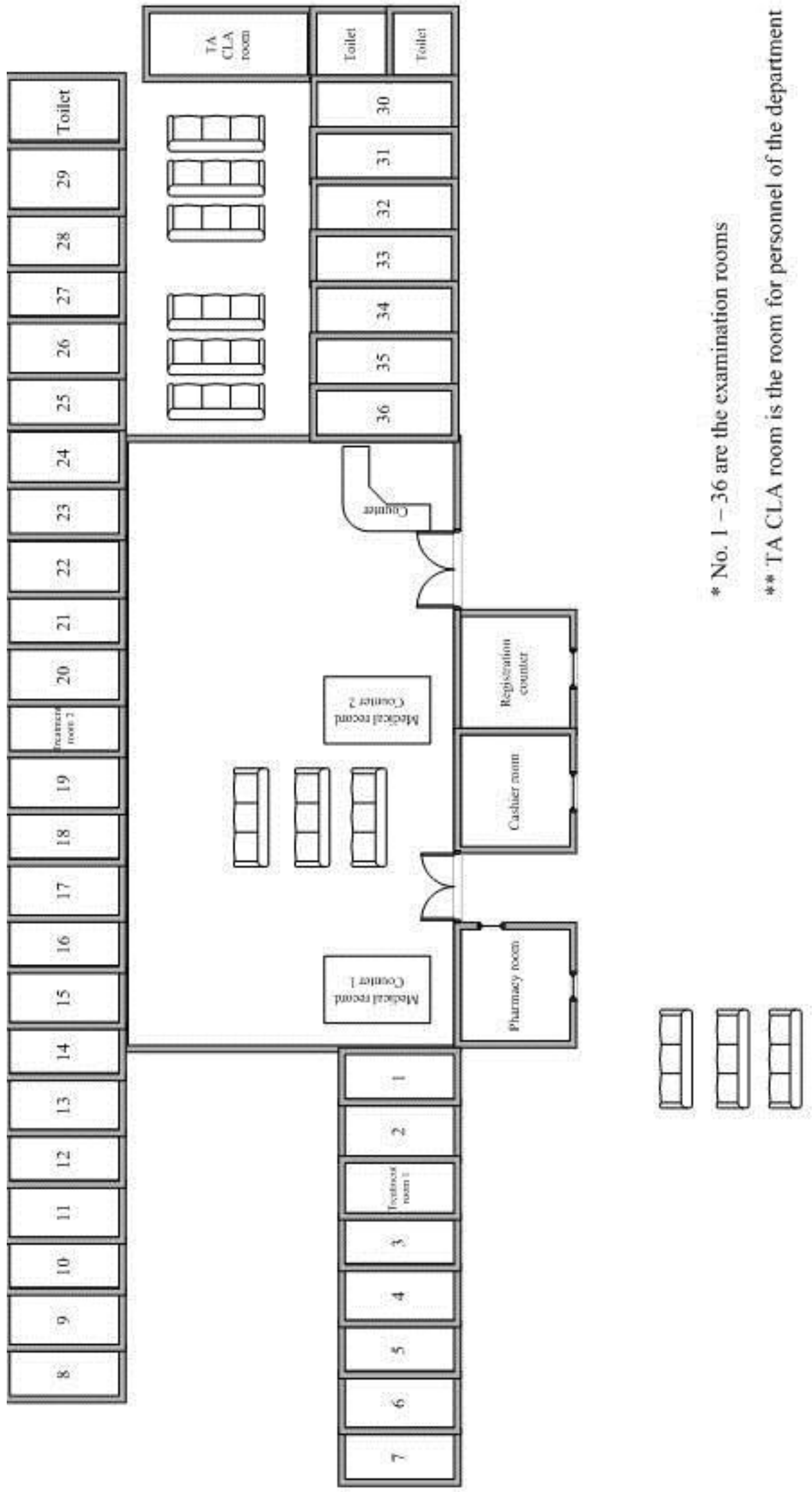
A pediatrics department as shown in Figures 4.1 and 4.2 is one of many departments in this hospital. The department was located on the second floor of Building 1. It opens to provide medical services for two periods which are

1) Morning session: 9.00 - 12.00 AM
2) Afternoon session: 1.00 - 3.00 PM

There are thirty-six examination rooms, two treatment rooms, and two special examination rooms. The department has its own cashier room and pharmacy room in front of the department. In other words, this department has provided the so-called “one – stop service”. Figure 4.3 shows the layout of the department where patients come to obtain the service.

Figure 4.1 Entrance of the pediatrics department

Figure 4.2 Front of the department



* No. 1 – 36 are the examination rooms

** TA CLA room is the room for personnel of the department

Figure 4.3 The layout of the pediatrics department

Figure 4.4 Patients wait for obtain the service in the department

4.2 Data collection

4.2.1 General service characteristics

For understanding with the characteristics of the department, the researcher had meetings with the registered nurse who is the head of the department in September, 2010. She explained the outpatient flow of the department. In addition, she told about working hours, types of patient, percents of each types of patient, and resources of the department. It was observed that there are so many patients waiting to see the physician that the department becomes crowded, as depicted in Figure 4.4, this is especially true for the morning shift.

4.2.2 Flow of patient

After the meeting with the head of the department and understanding with the outpatient flow, the researcher observed the flow by patient tracking method (the follow-up process that starts from the beginning activity until the final activity). The sample selection methods of research are quota sampling and convenience sampling. These sample selection are depending on an availability of the collector. In simpler words, the collector selected the first patient who comes to the department when they were available. The researcher selected 50 samples in each process. This sample size is 24.27 and 33.33 percents of the daily number of patients in the morning and afternoon sessions, respectively.

The data collecting process started on 9th September 2010. The collectors collected the data from 7 AM until the closing-time of the department. From the data collection, the researcher has the clear idea about the outpatient flow process of the pediatrics department and can describe it into flow chart.

4.2.3 Arrival and process time characteristics

There are two types of data which are very important in the step of simulation building; i.e., patient arrival and process time. The researcher obtained the patient arrival data from the medical statistics department of the hospital. The medical statistics department collected the hourly patient numbers of the pediatrics department on June, 2010. In fact, many patients usually come to the department very early in the morning session, but the numbers of patients in the afternoon session are not different across the individual hours.

The second one, process time data, is obtained from the observation while tracking the patients. The collectors tracked patient path throughout the flow and collected the service time of every process. This data collection started from September, 2010, and re-checked in January, 2012. Afterward, the researcher got 50 data, and found that an individual patient takes different time to obtain the service.

Moreover, different process has different variation of time. Without a doubt, the process time is absolutely less than the waiting time.

4.2.4 Expectation / suggestion of the administrators

The researcher participated in the project of patient service improvement of the case study hospital. The researcher had an opportunity to meet with the administrators of the hospital in September, 2010. They expect the patients to satisfy with their service, and they think the patient flow should be improved. Furthermore, they had some ideas to improve the service. For example, they suggest that if the service starts earlier than the present system, it might help spread the number of patients over longer period; hence, reduce the congestion at the department. Certainly, the researcher adapted the suggestion to be the strategy for analyzing the outpatient flow improvement.

4.3 Patient flow analysis

The beginning of patient flow in the pediatrics department is the patients' arrival. First, the patient gives an appointment card or registers at the registration counter. Second, the patient is checked for weight and height at the counter inside the department. Then the patient must wait to see the physician. If the proceeding patient finishes the diagnosis process early, he/she is called to see the physician in an examination room. Next, the patient is diagnosed by the physician. There is a practical nurse in an examination room to assist the physician in the diagnose process. Afterwards, the patient brings the medical record to return at the medical record counter, and receives the appointment card or prescription / payment bill / counsel. Then the patient brings the prescription to hand at the pharmacy room, and pays an expense at the cashier room. Finally, the patient may receive medicine at the pharmacy room. Besides, if the physician orders the patient to have the x-ray or blood test, the patient will go to the diagnostic radiology or the OPD lab respectively. More simply, the outpatient flow is shown in Figure 4.5, and the completed patient flow process which explained all types of the patient is shown on a swim lane diagram in

Appendix B. Furthermore, the department manages priority of patients by severity. Therefore, an emergency patient, an appointment patient, and a walk-in patient has the first, second and third priority, respectively.

Visiting patients at the department are divided into three main groups; i.e., emergency patients, appointment patients, and walk – in patients. After the researcher had collected the data of patients flow and observed the activities, the researcher found that these three types of patient may also obtain service at other departments. For instances, patients may have to go to the OPD lab for blood test, or diagnostic radiology for x-ray test. Patients who obtain services from other departments may not have to come back to the pediatrics department if they do not need to see a physician again or are scheduled to see in a next time. Tables 4.1 and 4.2 show all types of patients in the morning and afternoon sessions, respectively.

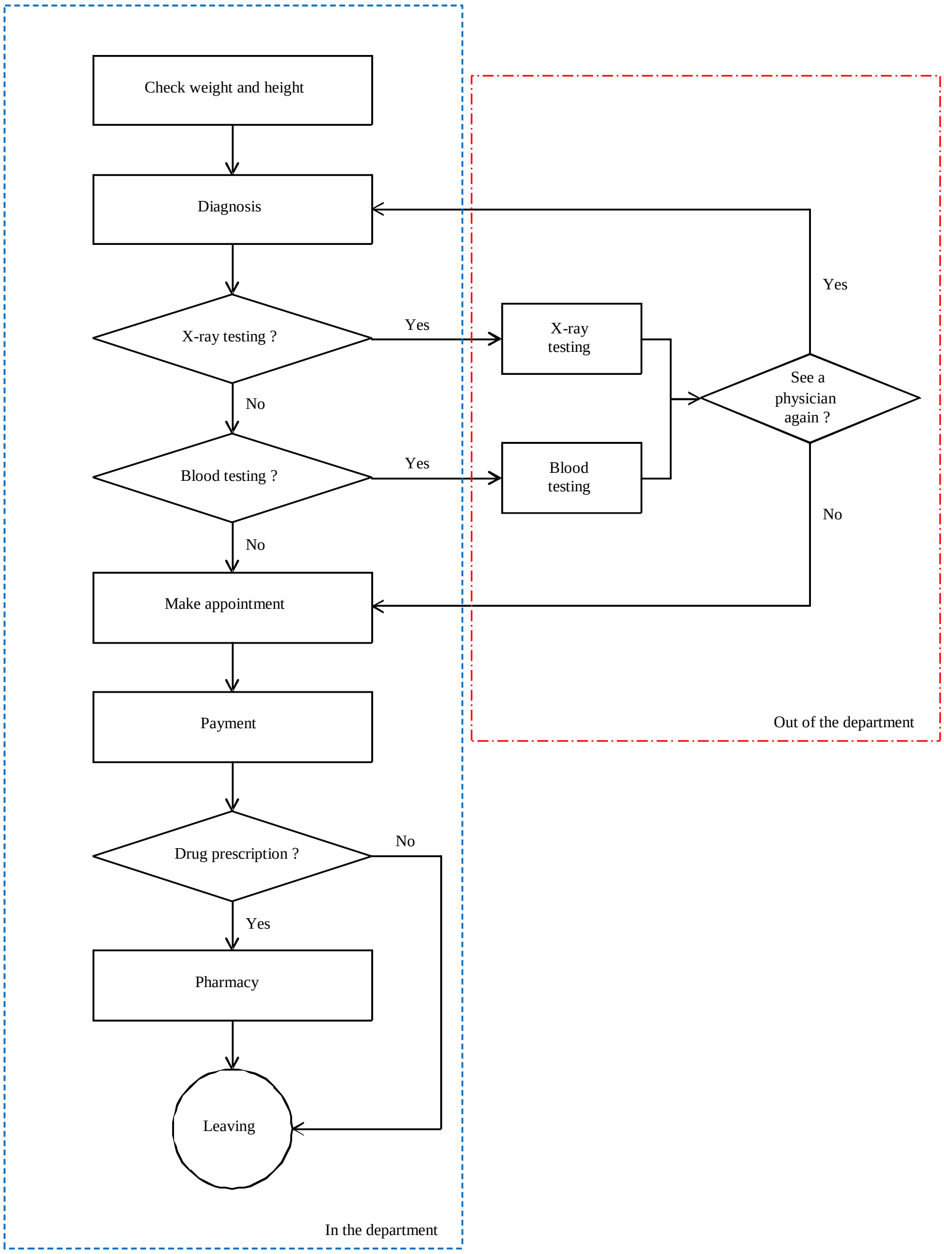


Figure 4.5 Outpatient flow of the pediatrics department

Table 4.1 Patient types at the pediatrics department (morning session)

Type No.	Type of patient	Quantity (%)	Description
1	Normal emergency	2.00	Patients who have a severe symptom and want to see the physician immediately
2	Normal appointment	57.58	Patients who have been appointed in advance
3	Special normal appointment	2.98	Patients who have a developmental disorder and have been appointed in advance
4	x-ray appointment and back	3.15	Patients who have been appointed in advance, have the x-ray testing, and need to see the physician two times
5	Blood appointment and back	6.30	Patients who have been appointed in advance, have the blood testing, and need to see the physician two times
6	Normal walk-in	24.22	Patients who have not been appointed in advance
7	x-ray walk-in and back	1.26	Patients who have not been appointed in advance, but have x-ray testing, and need to see the physician two times
8	Blood walk-in and back	2.52	Patients who have not been appointed in advance, but have the blood testing, and need to see the physician two times

Source: Sub-meeting with the registered nurse who is the head of the department

Table 4.2 Patient types at the pediatrics department (afternoon session)

Type No.	Type of patient	Quantity (%)	Description
1	Normal emergency	2.00	Patients who have a severe symptom and want to see the physician immediately
2	Normal appointment	83.30	Patients who have been appointed in advance
3	x-ray appointment and back	4.90	Patients who have been appointed in advance, have the x-ray testing, and need to see the physician two times
4	Blood appointment and back	9.80	Patients who have been appointed in advance, have the blood testing, and need to see the physician two times

Source: Sub-meeting with the registered nurse who is the head of the department

In the morning session, resources of the department include a scale, a practical nurse (PN) at the counter inside the department, thirty-six physicians, thirty-six examination rooms, eighteen practical nurses at the examination rooms, a practical nurse, a clerk, and a registered nurse (RN) at the medical record counter, a cashier at the payment room, and three pharmacists at the pharmacy room.

In the afternoon session, it uses the similar resources as in the morning session. However, there are only twelve physicians, twelve examination rooms, and six practical nurses at the examination rooms. Details of these resources categorized by the service process are shown in Table 4.3.

Table 4.3 Resources of each process

Process	Resource									
	RN1	PN1	PN2	PN	Clerk1	Physician	Cashier	Pharmacist	Scale	Examination room
Check weight and height		1							1	
Diagnosis				1		1				1
Make appointment	1*		1*		1*					
Payment							1			
Pharmacy								1		

Note: * Patient obtains service from an idle resource.

4.4 Characteristics of patient arrival

On average 255 patients visited the medical service at the department daily in June 2010. The weekly numbers of patients are shown in Table 4.4. Hourly patients are shown in Table 4.5. Patients continuously come to the department at 7.01 AM until 12.00 AM in the morning session, and during 1.01 PM to 3.00 PM in the afternoon session. The peak periods are from 8.01 AM to 9.00 AM in the morning session and 2.01 PM to 3.00 PM in the afternoon session. The time periods which have the lowest numbers of patients are 11.01 AM to 12.00 PM in the morning session and 12.01 AM to 1.00 PM in the afternoon session. The hourly numbers of patients are inputted into the schedule module as the patient arrival of the simulation model. Pisuchpen (2008) found that the distribution of the patient arrival are the exponential distribution.

Table 4.4 Average daily numbers of patients (in June 2010)

Day	Number of patients
Monday	309
Tuesday	270
Wednesday	443
Thursday	262
Friday	208
Saturday	254
Sunday	40
Average	255

Source: Medical Statistics Department, Ramathibodi Hospital (2010)

Table 4.5 Hourly numbers of patients in the morning session

Time period	Number of patients
7.01 – 8.00	58
8.01 – 9.00	72
9.01 – 10.00	54
10.01 – 11.00	18
11.01 – 12.00	4
Total	206

Source: Medical Statistics Department, Ramathibodi Hospital (2010)

Table 4.6 Hourly numbers of patients in the afternoon session

Time period	Number of patients
12.01 – 1.00	43
1.01 – 2.00	51
2.01 – 3.00	56
Total	150

Source: Medical Statistics Department, Ramathibodi Hospital (2010)

4.5 Characteristics of service time

4.5.1 Descriptive statistics

Having understood the flow of patient, the researcher collected the service process time at individual stations throughout the flow. There are five processes in the morning session and the afternoon session which are collected for building a simulation model. The researcher collected the data on process time, and analyzed to obtain its descriptive statistics such as the average, minimum, maximum, and standard deviation values as shown in Tables 4.7 and 4.8. They show that the patients spent the longest processing time in the diagnosis process; i.e., 11.91 and 10.87 minutes in the morning and afternoon sessions, respectively. Meanwhile, the longest waiting time is in the check weight and height process (32.19 minutes) in the morning session and in the diagnosis process (37.90 minutes) in the afternoon session.

Table 4.7 Process time in the morning and afternoon sessions

Process	No. of samples	Morning session (minute)				Afternoon session (minute)			
		Average	Min	Max	SD.	Average	Min	Max	SD.
Check weight and height	50	0.56	0.17	1.53	0.30	0.57	0.22	1.18	0.25
Diagnosis	50	11.91	3.10	122.00	16.82	10.87	2.82	36.00	5.25
Make appointment	50	2.66	1.12	5.63	1.28	2.78	1.03	5.83	1.05
Payment	50	0.82	0.18	2.50	0.47	0.74	0.33	1.80	0.32
Pharmacy	50	3.28	1.38	6.19	1.10	5.15	2.03	9.05	1.49
Overall	50	19.23	10.49	128.57	16.72	20.11	13.12	47.23	5.80

Table 4.8 Waiting time in the morning and afternoon sessions

Process	No. of samples	Morning session (minute)				Afternoon session (minute)			
		Average	Min	Max	SD.	Average	Min	Max	SD.
Check weight and height	30	32.19	14.30	55.75	10.60	10.13	1.08	23.28	5.96
Diagnosis	30	31.45	13.10	58.58	12.28	37.90	7.24	56.45	14.93
Make appointment	30	3.96	1.03	9.39	2.48	5.47	1.18	19.00	4.17
Payment	30	3.28	0.59	8.45	1.84	3.35	1.29	7.13	1.31
Pharmacy	30	8.27	4.20	13.47	2.77	7.55	4.48	12.20	2.00
Overall	30	79.15	37.31	102.29	15.71	64.40	37.31	92.91	14.36

Having observed the time which patients spent in the overall process, the researcher found that they spent a lot of time for waiting. As shown in Figure 4.6, the waiting times are approximately 80.45 percents of the total time in the patient flow for the morning session. Meanwhile, patients spent times approximately 76.20 percents of the total time for waiting in the afternoon session as shown in Figure 4.7. These waiting times are non value-added which creates dissatisfaction in the service. Therefore, the administrators of the hospital want to improve the service in order to achieve an efficient operational system. Above all, patients will be satisfied with the improved service.

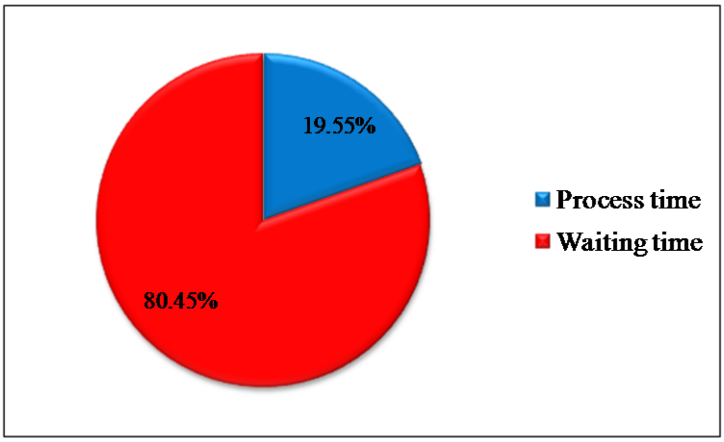


Figure 4.6 Proportion of process time and waiting time in the morning session

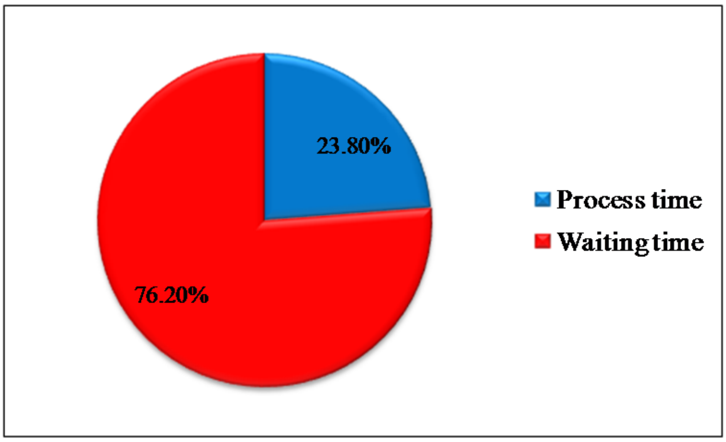


Figure 4.7 Proportion of process time and waiting time in the afternoon session

4.5.2 Data filtering

After the researcher analyzed the characteristics of the department, the next step is the model building. Most importantly, the distribution of service time at the individual process is necessary to be the input of the simulation model. When the researcher analyzed the raw data of service time, it was found that they have wide variation. Because of this, the step of curve fitting for the service distribution is difficult. Thus, an additional step is called “data filtering” is used to arrange the data. Figure 4.8 shows the flow to obtain the candidate service time distribution.

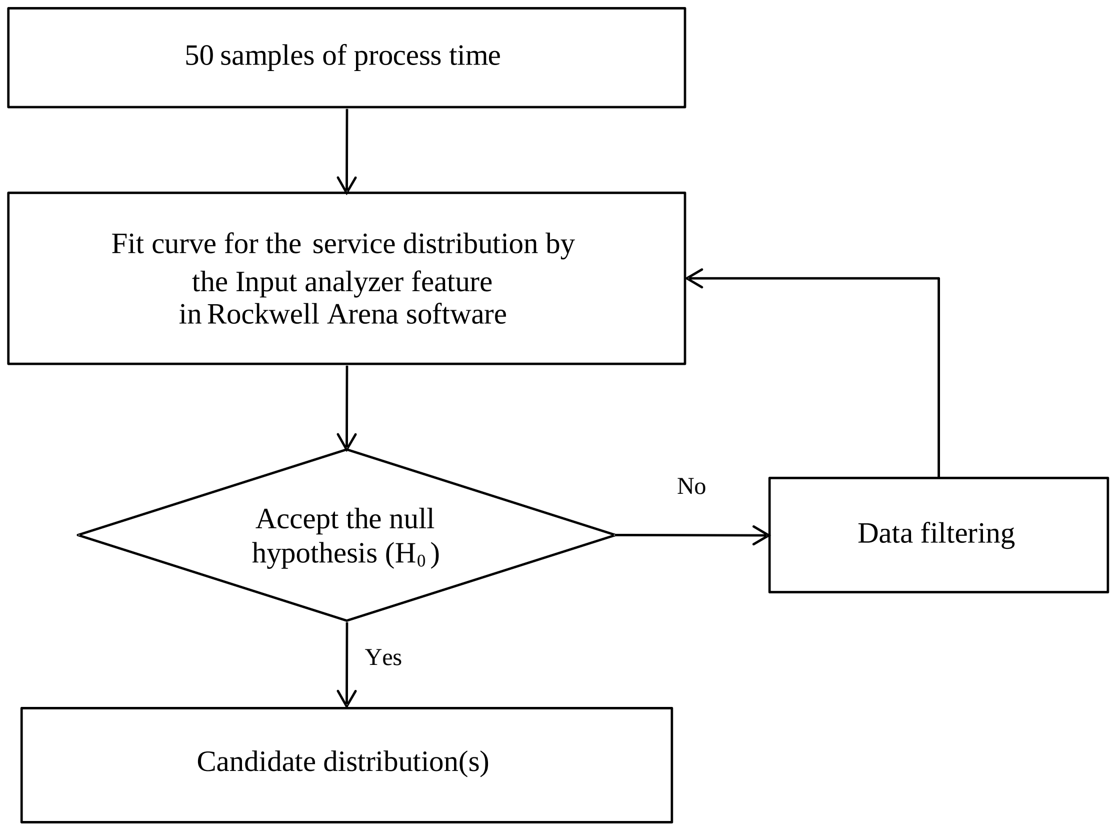


Figure 4.8 Flow chart for obtaining the service distribution

There are 50 samples of process time data which were collected by the observation at the pediatrics department. Initially, all 50 samples are fed into the Input Analyzer to fit the distribution. In the case that all available distributions are statistically rejected, the data is filtered a bit to facilitate the fit. The researcher filters the data by the following steps.

1) The first step is to calculate the median value of the service time.

2) An individual data is calculated to find an absolute difference between its value and the median.

3) The data is ordered ascendingly from minimum to maximum value based on the differences in step 2).

4) These data which already ordered are used to fit the distribution curve by the Input analyzer feature of Rockwell Arena software. If the program shows an acceptance of null hypothesis (H_0), or corresponding p-value more than 0.05, based on both Chi-square test and Kolmogorov-Smirnov test, the distribution can be used as an input of the simulation model.

5) On the other hand, if the program shows a rejection, the data which has the maximum difference from the median (may be the suspected outlier) is taken out from the group. Then, the remaining data are used to fit for the distribution again. This step is repeated until the program shows the acceptance of some distributions. Note that the number of suspected outliers must not be more than few data points.

4.5.3 Distribution of service time

The service distribution of the individual process is fitted by the Input Analyzer feature of Rockwell Arena software. It is possible that the data may be fitted by more than one candidate distribution. There are nine possible distributions; i.e., beta, Erlang, exponential, gamma, lognormal, normal, triangular, uniform, and weibull. Thus, the first step, the researcher chose all distributions which had more than 0.05 corresponding p-value because they showed the acceptance of the null hypothesis (H_0) based on Chi-square test and Kolmogorov-Smirnov test. Second, in the case that there were more than one distribution which accept H_0, the researcher considered a mean square error (MSE) of the distribution. The distribution which had the lowest MSE is selected. The researcher explained an example of choosing the distribution in Appendix C, and showed the distribution of each process, which accepted and rejected H_0, in both the morning and the afternoon sessions in Tables C.1 – C.13. There are also the expression of the distribution, test statistics, and p-value.

The lists of the appropriate distributions for the individual processes which are chosen based on the above criteria are presented in Table 4.9 (morning session) and Table 4.10 (afternoon session).

Table 4.9 Distribution of service time for each process in the morning session

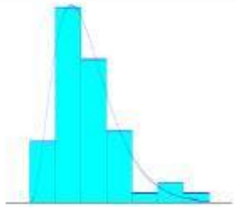
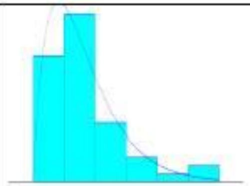
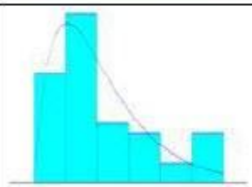
Process	No. of Samples	Histogram	Selected Distribution	Test Statistic		p-value		Time (min)				Accept H_0	MSE
				Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test	Minimum	Maximum	Average	SD.		
Check weight and height	50		0.03 + GAMM(0.146, 3.62)	0.0827	0.0771	> 0.75	> 0.15	0.17	1.53	0.56	0.30	✓	0.00242
Diagnosis	48		3 + ERLA(3.14, 2)	1.01	0.0752	0.341	> 0.15	3.10	122.00	11.91	16.82	✓	0.00713
Make appointment	46		1 + GAMM(0.724, 1.96)	2.52	0.103	0.12	> 0.15	1.12	5.63	2.66	1.28	✓	0.0159

Table 4.9 Distribution of service time for each process in the morning session (continued)

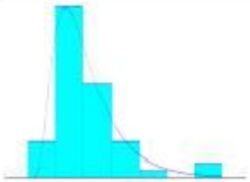
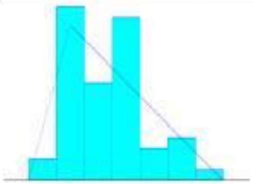
Process	No. of Samples	Histogram	Selected Distribution	Test Statistic		p-value		Time (min)				Accept H_0	MSE
				Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test	Minimum	Maximum	Average	SD.		
Payment	50		LOGN(0.818, 0.465)	0.52	0.109	0.481	> 0.15	0.18	2.50	0.82	0.47	✓	0.00409
Pharmacy	50		TRIA(1, 2.22, 6.68)	6.36	0.105	0.0966	> 0.15	1.38	6.19	3.28	1.10	✓	0.029

Table 4.10 Distribution of service time for each process in the afternoon session

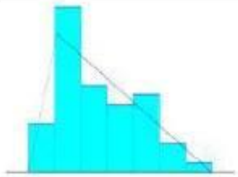
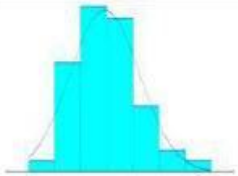
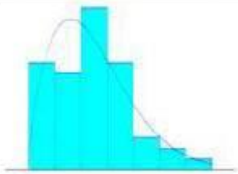
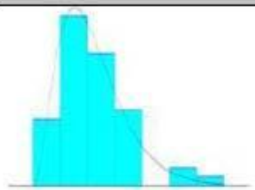
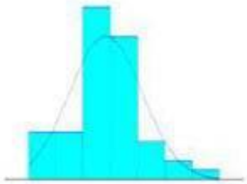
Process	No. of Samples	Histogram	Selected Distribution	Test Statistic		p-value		Time (min)				Accept H_0	MSE
				Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test	Minimum	Maximum	Average	SD.		
Check weight and height	50		TRIA(0.12, 0.299, 1.28)	2.8	0.0921	0.438	> 0.15	0.22	1.18	0.57	0.25	✓	0.0107
Diagnosis	49		NORM(10.4, 3.79)	0.576	0.136	0.465	> 0.15	2.82	36.00	10.87	5.25	✓	0.00472
Make appointment	50		1 + WEIB(1.98, 1.66)	3.79	0.0877	0.167	> 0.15	1.03	5.83	2.78	1.05	✓	0.0158

Table 4.10 Distribution of service time for each process in the afternoon session (continued)

Process	No. of Samples	Histogram	Selected Distribution	Test Statistic		p-value		Time (min)				Accept H_0	MSE
				Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test	Minimum	Maximum	Average	SD.		
Payment	50		0.18 + GAMM(0.168, 3.31)	0.219	0.0638	0.667	> 0.15	0.33	1.80	0.74	0.32	✓	0.00423
Pharmacy	50		NORM(5.15, 1.47)	3.66	0.118	0.0579	> 0.15	2.03	9.05	5.15	1.49	✓	0.0185

4.6 Simulation modeling

4.6.1 Number of testing replications

The models which are run by different number of replications can report different outputs. That is simply the variation. In order to control the variation in the output of final model, the researcher determined the steady state of the model by running different number of replications. First, the researcher tried to run the model by varying the number of replications between 1 - 1,500. Then, the researcher obtained process times and waiting times at different number of replications. The chart then is plotted with the number of replication on the x-axis and the corresponding time on the y-axis. The steady state may be observed on the chart where the fluctuation converts to a horizontal line. The point is considered to be an appropriate number of replications for simulation.

Totally, the researcher plotted ten charts in Figures 4.9 – 4.13 for the morning session and Figures 4.14 – 4.18 for the afternoon session. These charts are used to decide what number of replications should be the steady state in each process. A dashed line in every figure indicated the steady state of each process. Table 4.11 summarizes the number of replications at the steady state observed from these charts. The researcher considered that the steady state of the check weight and height process in the morning and afternoon sessions are at 1,160 and 1,140 replications, respectively. The steady state of the diagnosis process in the morning and afternoon sessions are at 1,360 and 1,200 replications, respectively. The steady state of the make appointment process in the morning and afternoon sessions are at 550 and 780 replications, respectively. The steady state of the payment process in the morning and afternoon sessions are at 750 and 1,280 replications, respectively. The steady state of the pharmacy process in the morning and afternoon sessions are at 830 and 750 replications, respectively. As a result, a maximum number is 1,360 replications. The researcher considered to round up the number of replications to be 1,400 and decided to use this number to run the simulation model of the case study in both morning and afternoon sessions.

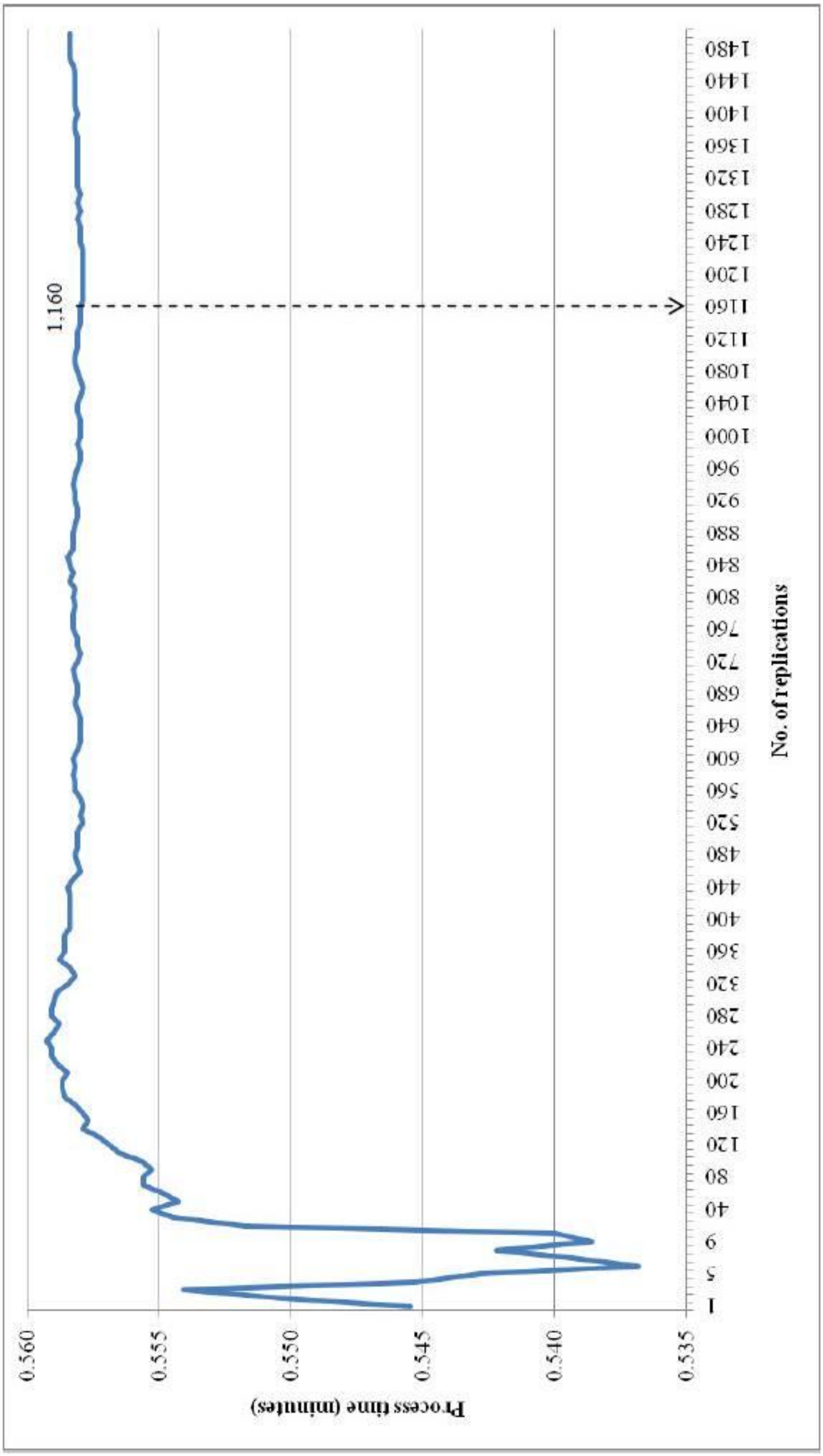


Figure 4.9 Resulting check weight and height's process time by the different number of replications (morning session)

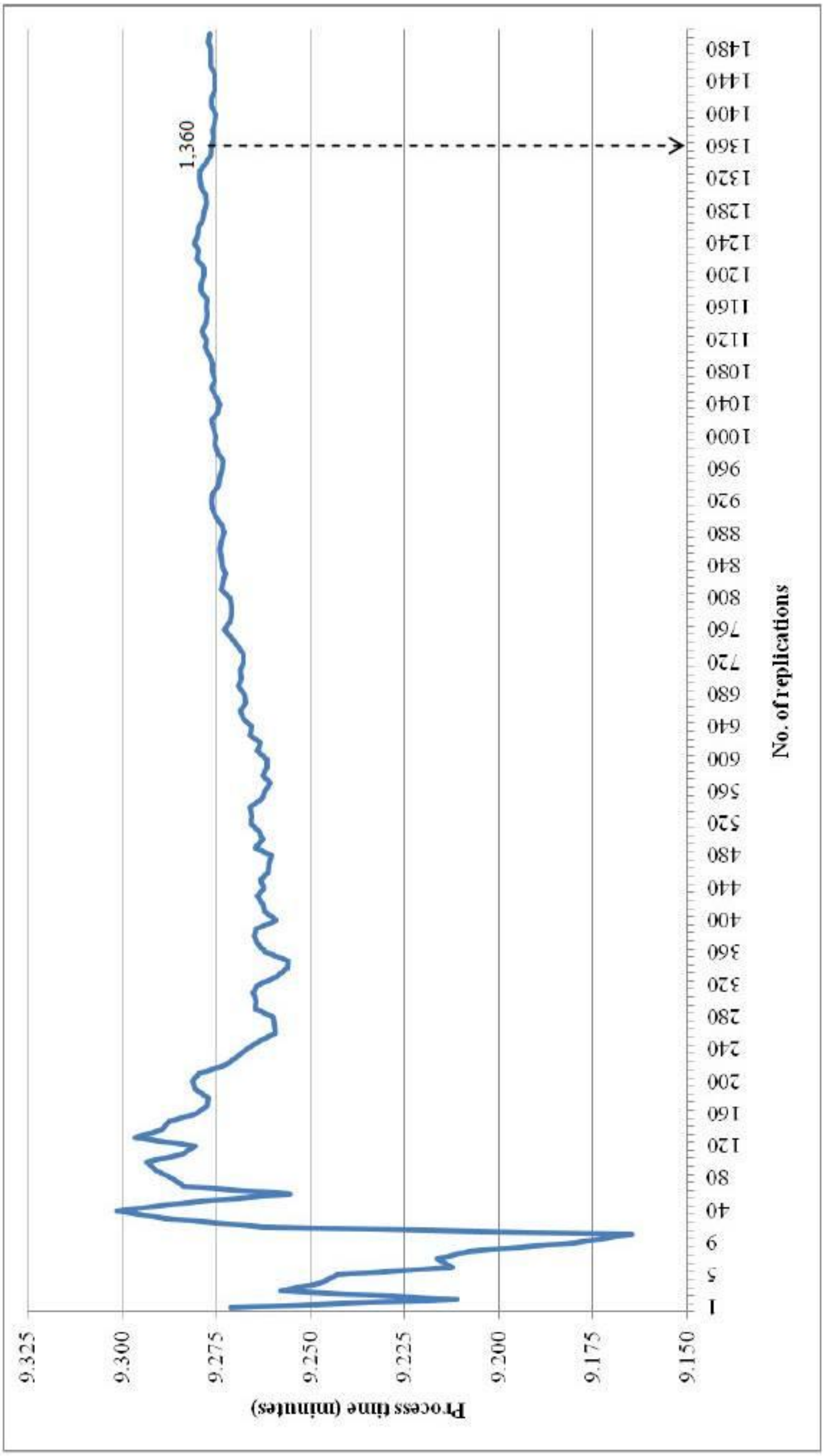


Figure 4.10 Resulting diagnosis’s process time by the different number of replications (morning session)

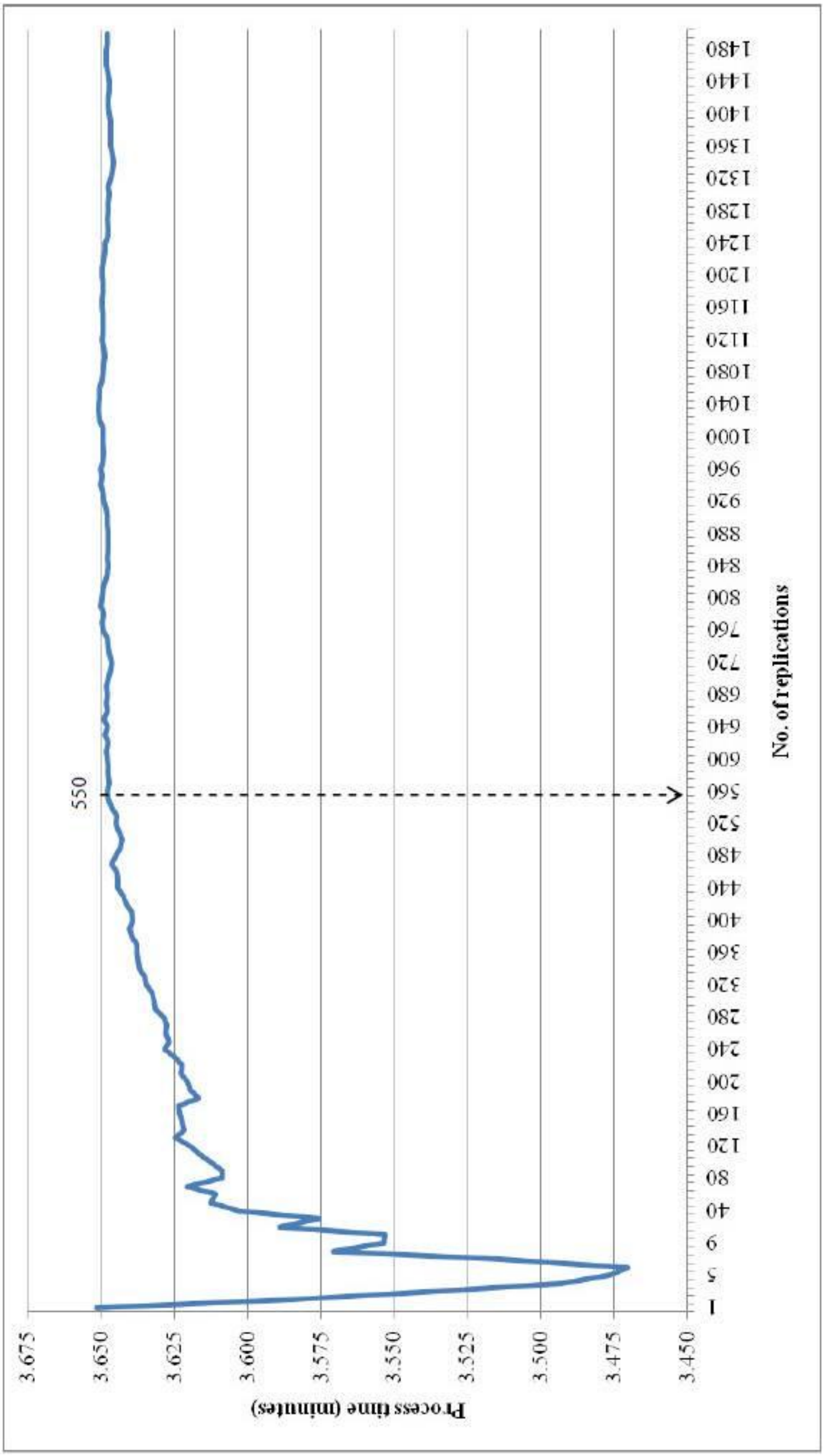


Figure 4.11 Resulting make appointment's process time by the different number of replications (morning session)

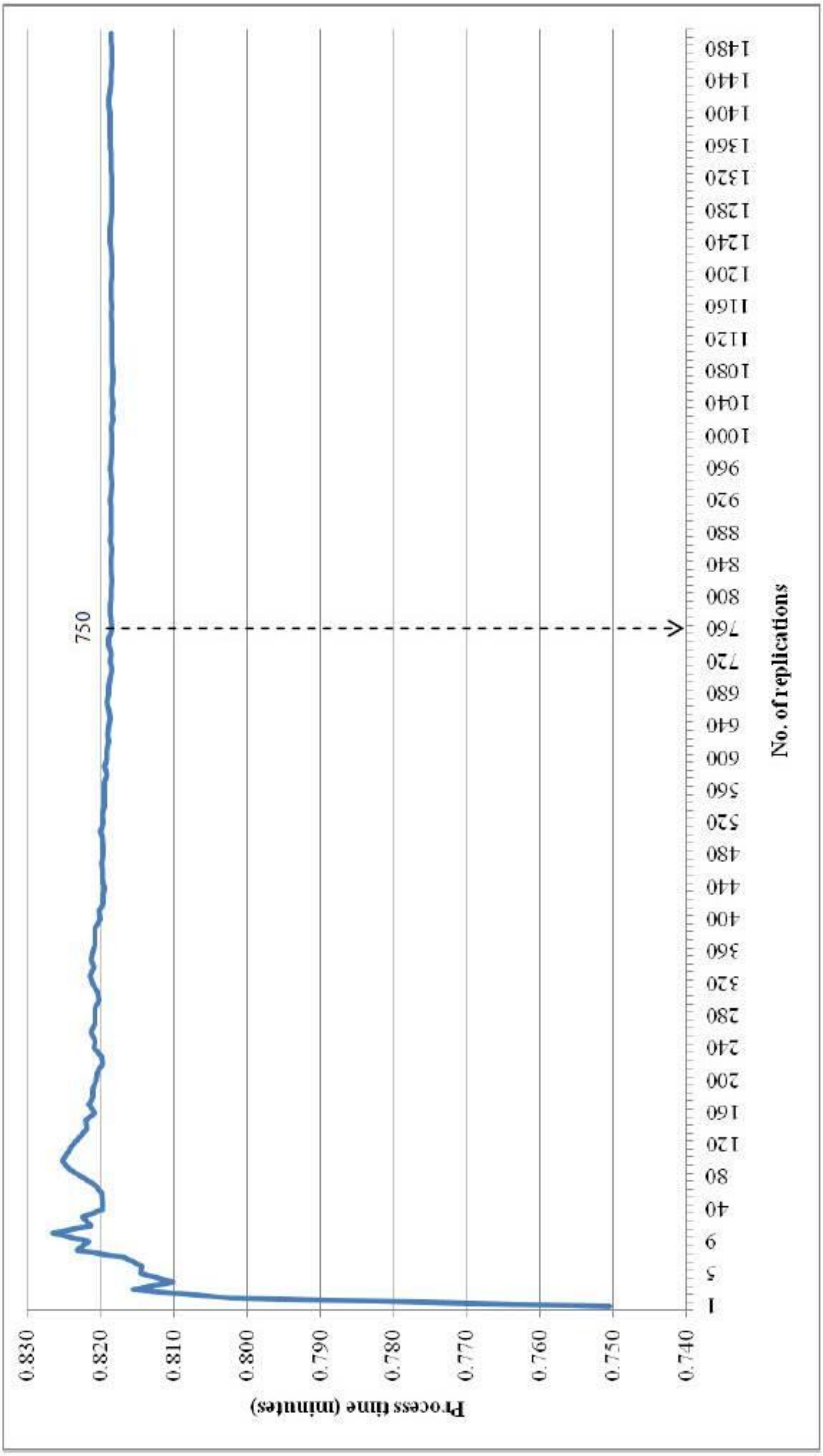


Figure 4.12 Resulting payment's process time by the different number of replications (morning session)

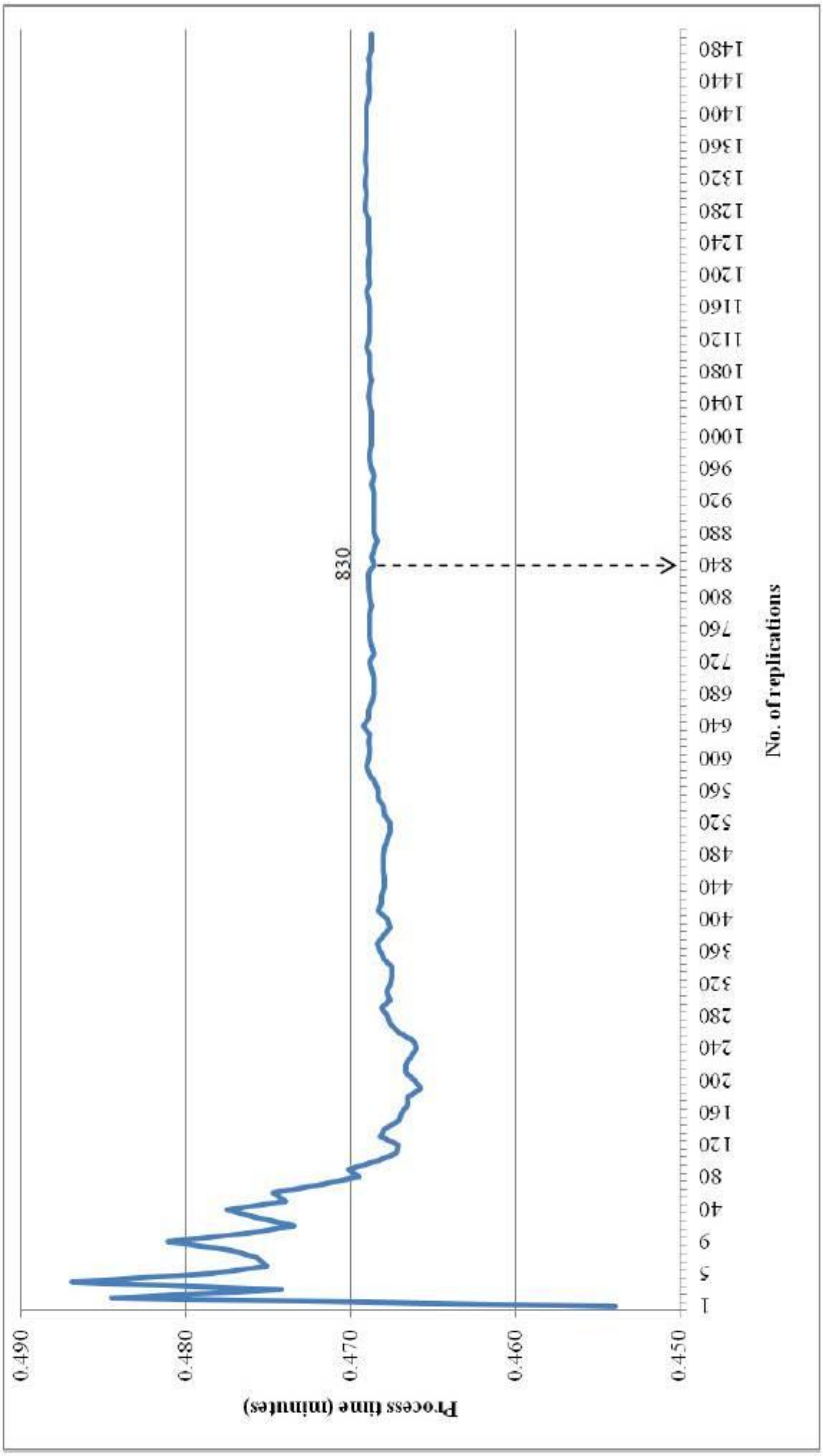


Figure 4.13 Resulting pharmacy's process time by the different number of replications (morning session)

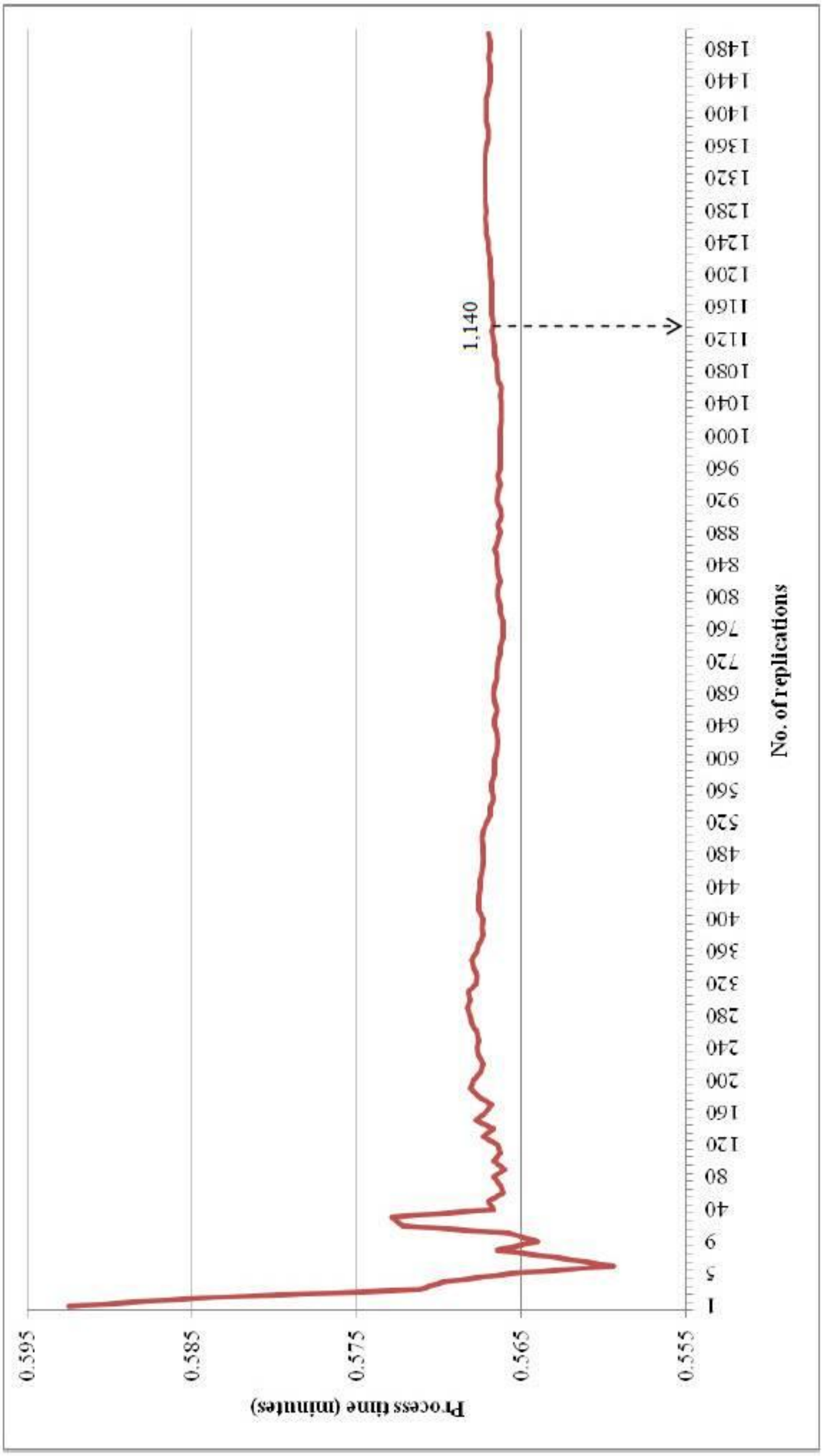


Figure 4.14 Resulting check weight and height's process time by the different number of replications (afternoon session)

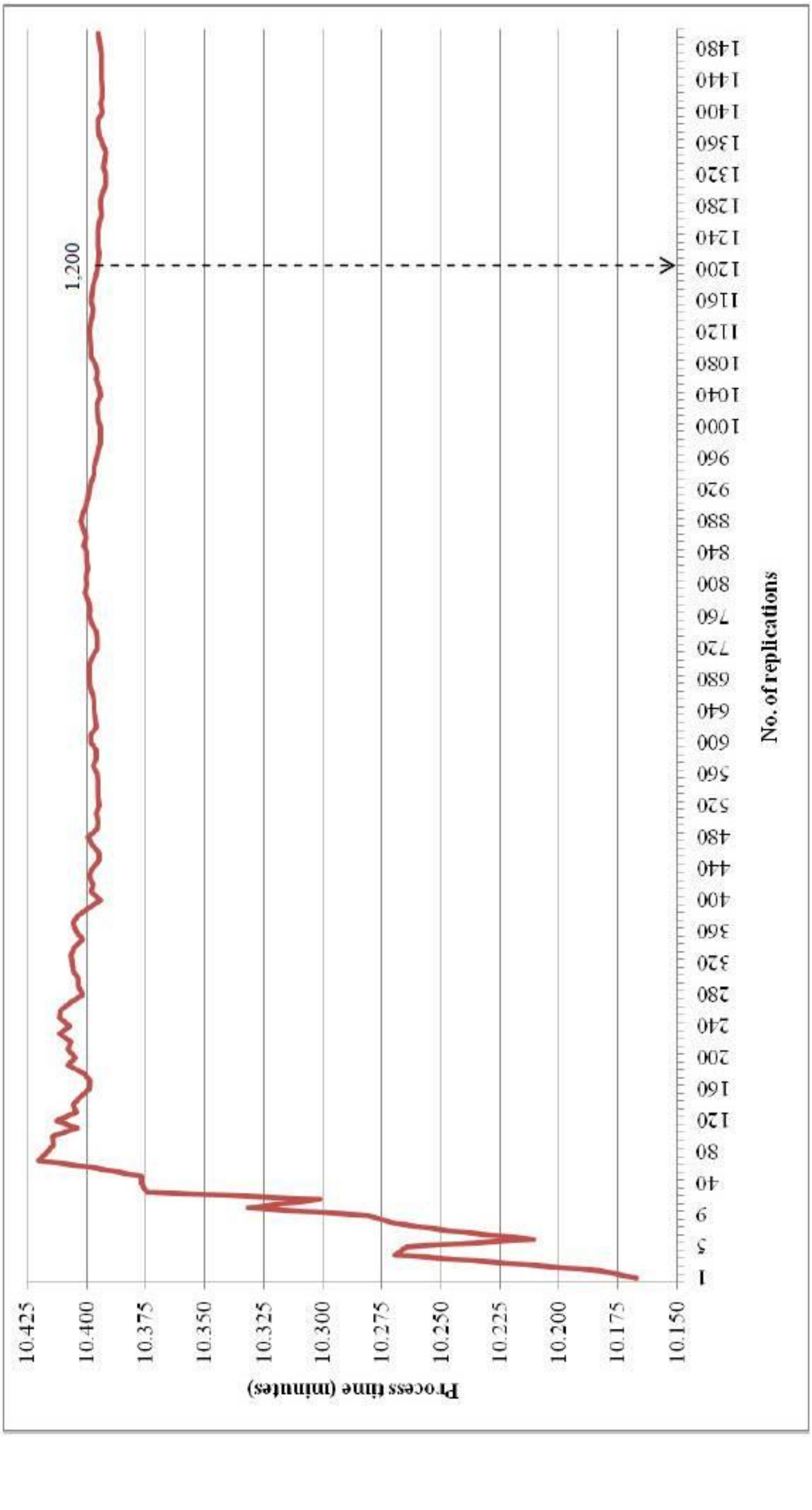


Figure 4.15 Resulting diagnosis's process time by the different number of replications (afternoon session)

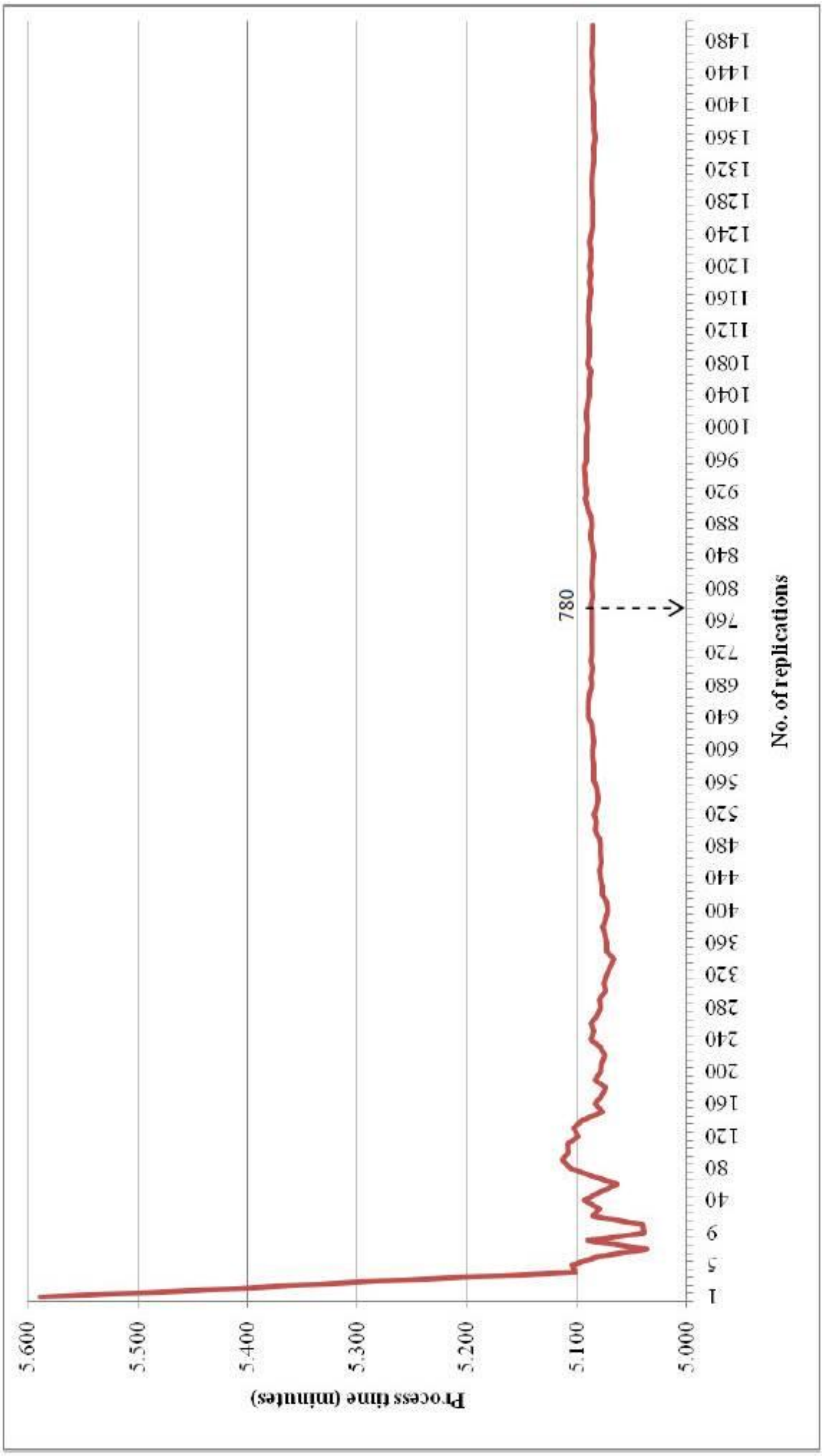


Figure 4.16 Resulting make appointment's process time by the different number of replications (afternoon session)

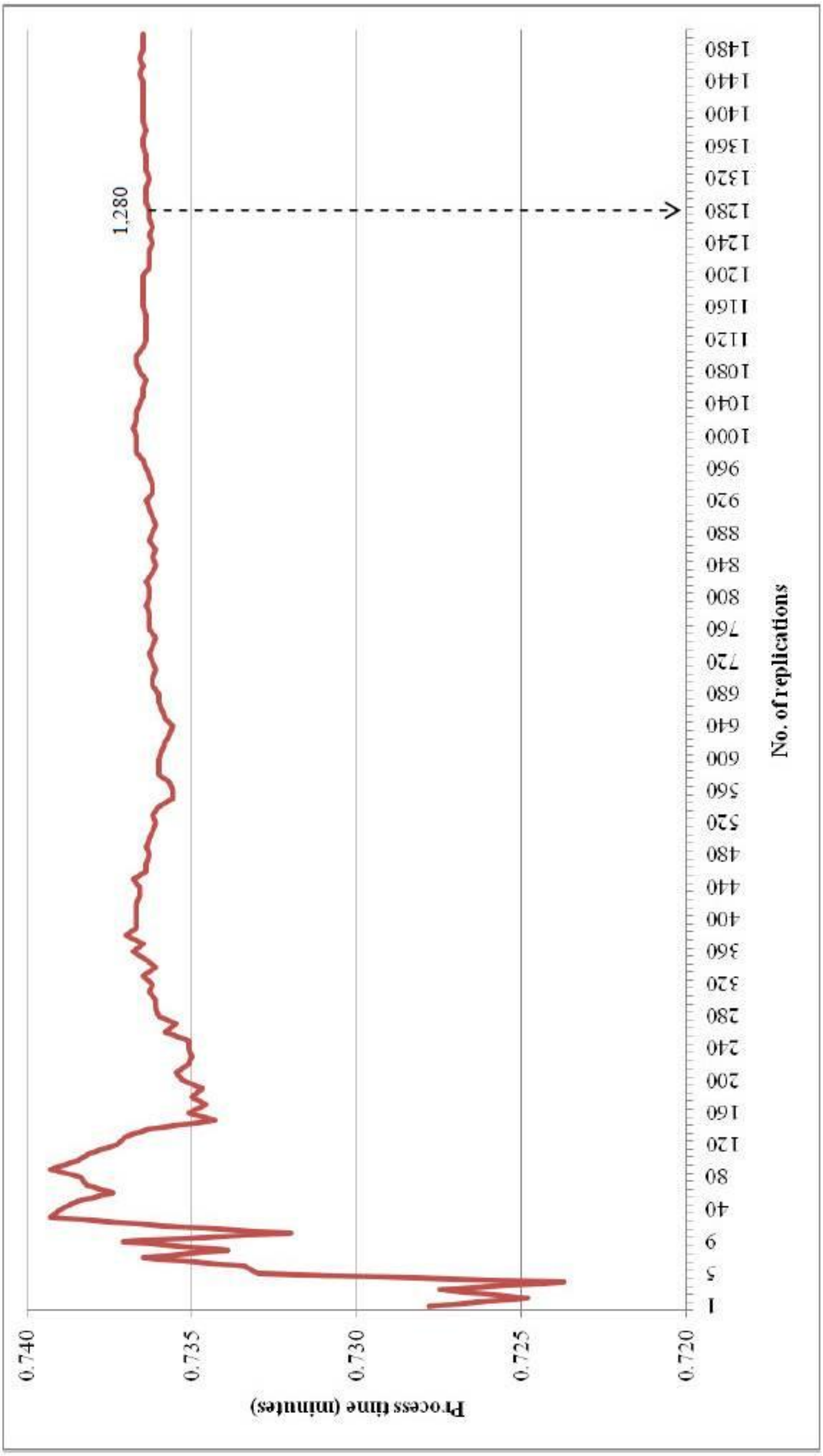


Figure 4.17 Resulting payment’s process time by the different number of replications (afternoon session)

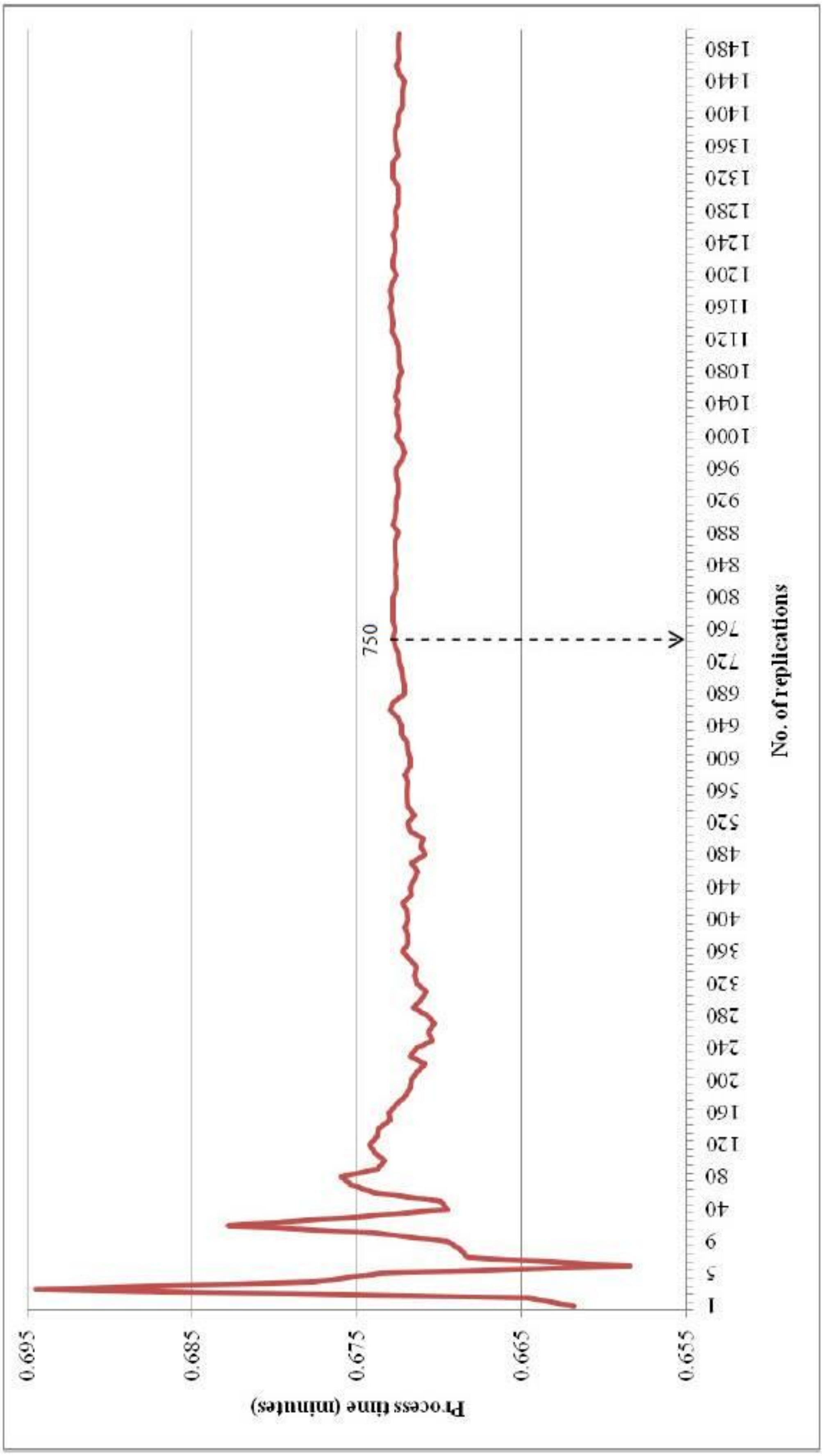


Figure 4.18 Resulting pharmacy's process time by the different number of replications (afternoon session)

Table 4.11 Identification of number of replications at the steady state

Session	Process	Testing number of replications	Number of replications at steady state
Morning	Check weight and height	1 – 1,500	1,160
	Diagnosis		1,360
	Make appointment		550
	Payment		750
	Pharmacy		830
Afternoon	Check weight and height	1 – 1,500	1,140
	Diagnosis		1,200
	Make appointment		780
	Payment		1,280
	Pharmacy		750

4.6.2 Model building

There are requisite inputs which are the type of patient (in Tables 4.1 and 4.2), resources of each process (in Table 4.3), hourly number of patients (in Tables 4.5 and 4.6), distribution of service time (in Tables 4.9 and 4.10), and traveling time (in Table 4.12) for building the simulation model. Once having these inputs completely, the researcher can use them to build the model of the pediatrics department. Equally important, the researcher must understand the patient flow of this department to build the model correctly. In addition, the model must be validated until it gives a similar output to the observed values from the real system.

Table 4.12 Patients' traveling time between two service stations

Origin	Destination	Time (seconds)
Examination room	Medical record counter	48
Examination room	Diagnostic radiology	63
Medical record counter	Pharmacy room	20
Pharmacy room	Cashier room	6

In the first step of modeling, the researcher generates the arrival of patients in the system from 7.01 AM to 12.00 AM in the morning session, and 12.01 PM to 3.00 PM in the afternoon session. These patients are divided into eight types (Table 4.1) and four types (Table 4.2). Next, the patients go to the process according to their types. In each process, there are resources which are stationed and to provide the service to the patients. Finally, when the patients obtain the service completely, they will leave from the system. To illustrate, the Figures 4.19 is the overview of the simulation model that the researcher built to duplicate the flow of outpatients at pediatrics department in the morning session.

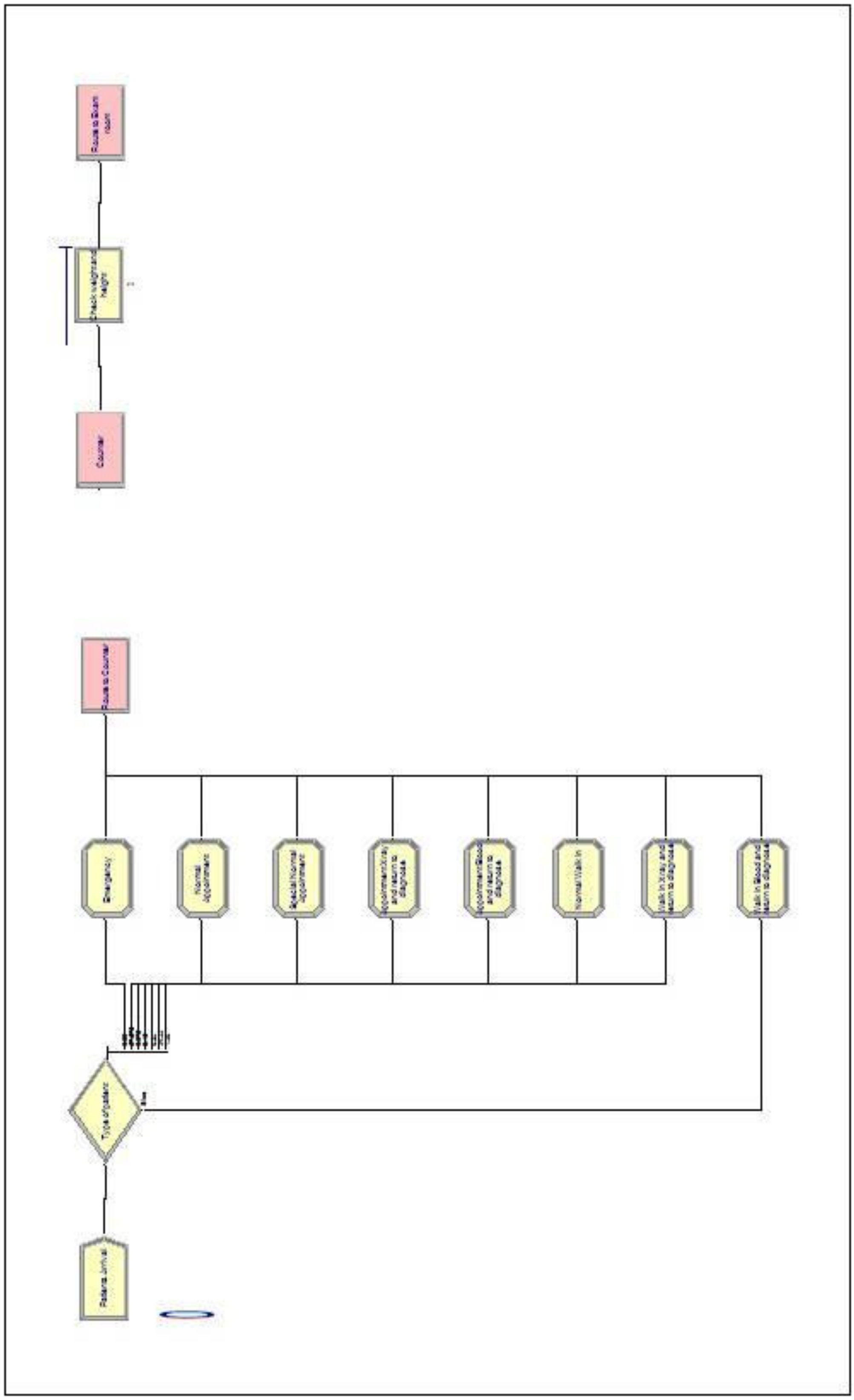


Figure 4.19 Overview of the simulation model for the morning session

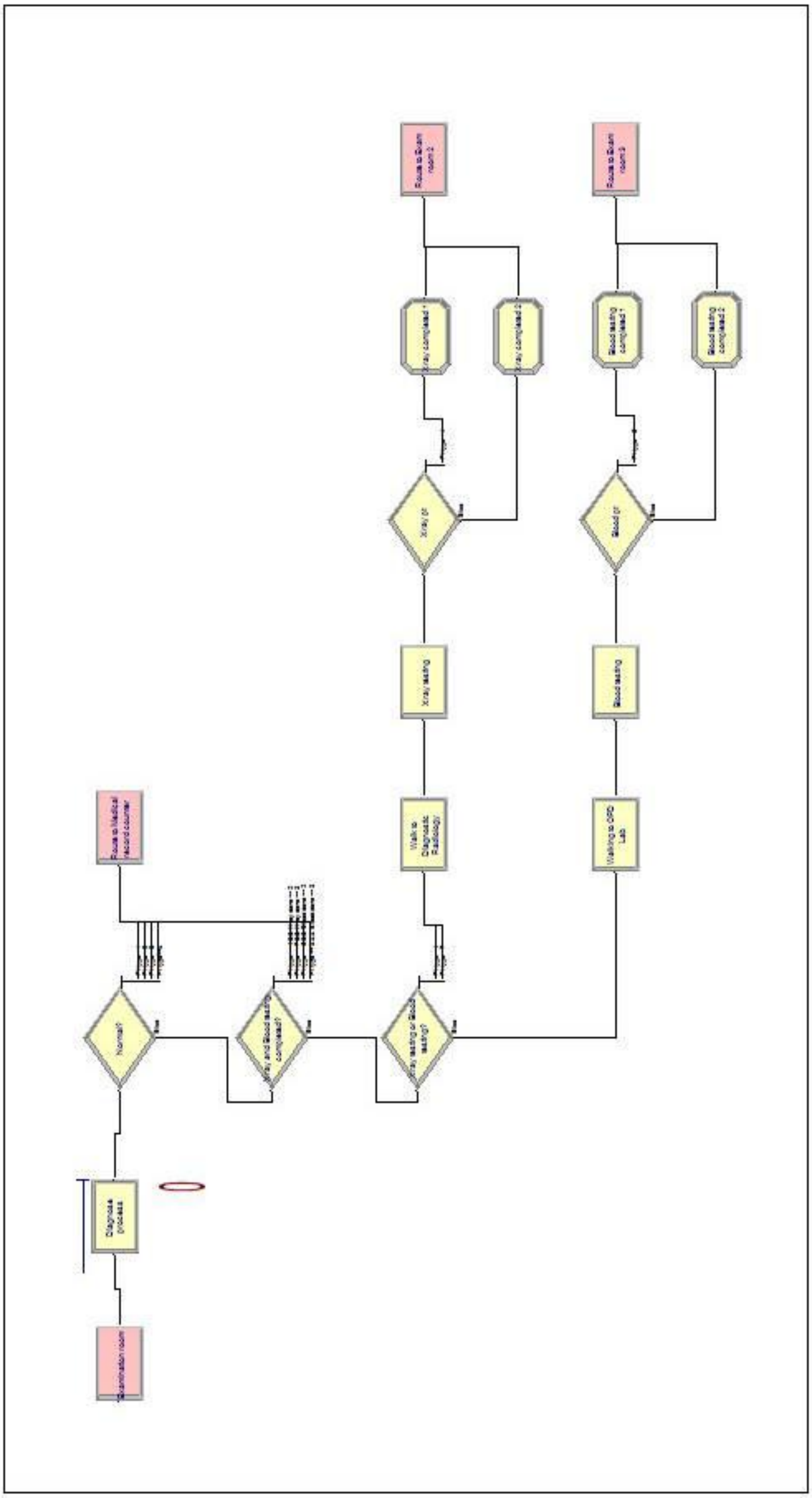


Figure 4.19 Overview of the simulation model for the morning session (continued)

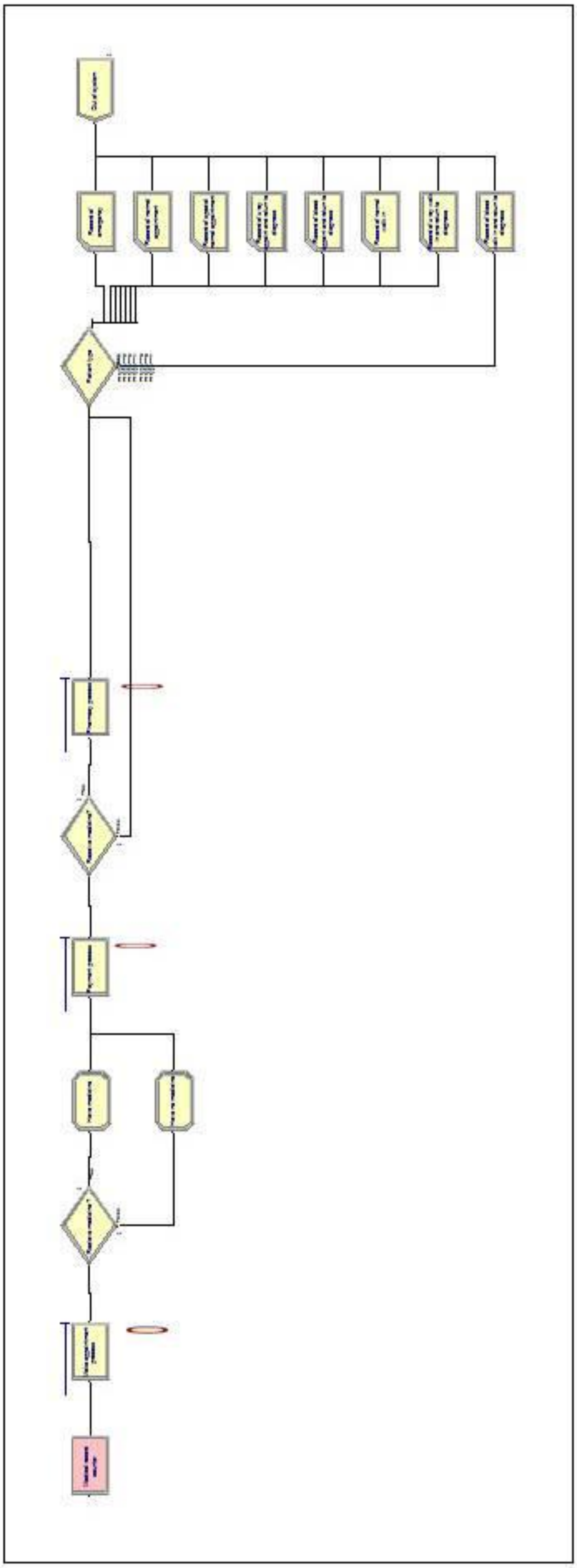


Figure 4.19 Overview of the simulation model for the morning session (continued)

Actually, there are many details in the process of simulation building. A large number of modules are used to build the simulation model, as shown by the dialog boxes in the Figures 4.20 – 4.69. Figures 4.20 – 4.33 show the dialog boxes of the modules which are in the Figure 4.19. The first module in Figure 4.19 is the create module, showing that patients arrived at the department by the schedule. Then, patients are divided to eight types by the percentage of individual type (Figure 4.21). The researcher assigned the attribute of patient type, entity picture, and attribute of record time for each patient type as seen in Figures 4.22 – 4.29. Next, the patients go to counter station by route module (Figure 4.30). The counter station is the place where the patients checked their weight and height by using the resources at the station (Figure 4.31). The service time of check weight and height process is in the dialog box in Figure 4.32. After the patients finished the check weight and height process, they will go to examination room by route module (Figure 4.33).

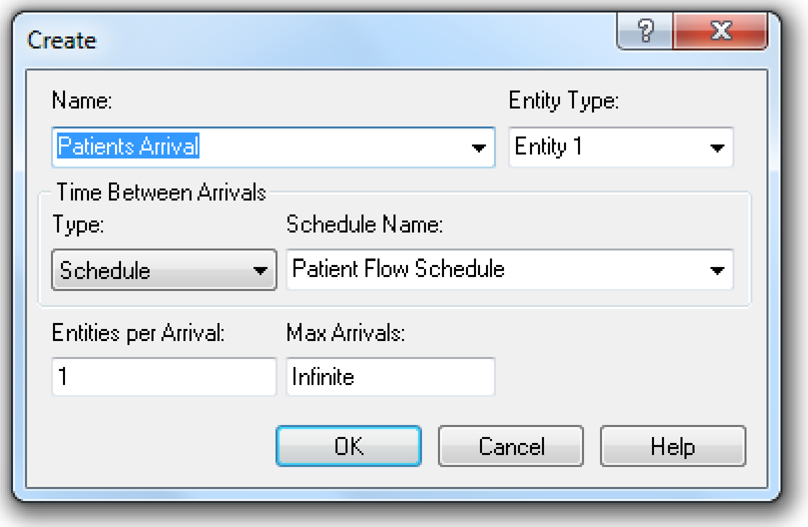


Figure 4.20 Patients arrival dialog box

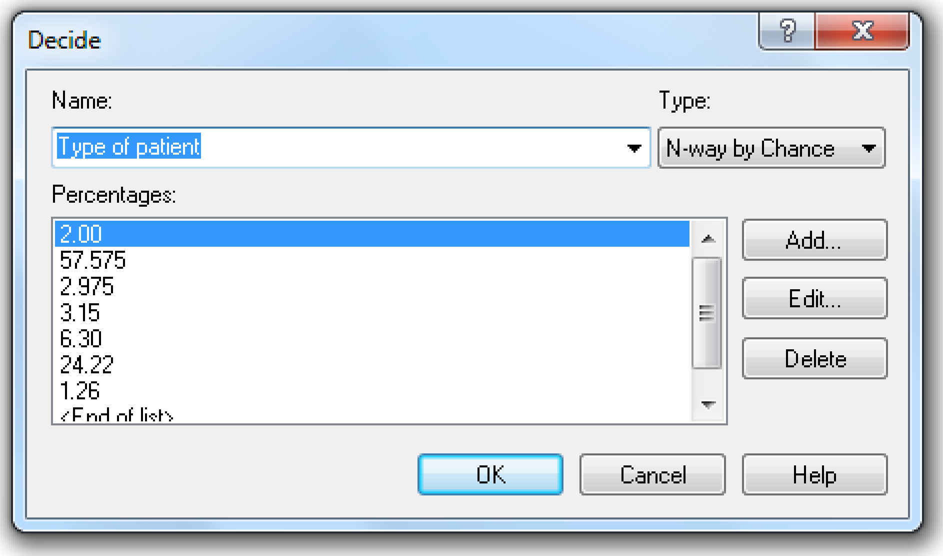


Figure 4.21 Type of patient dialog box

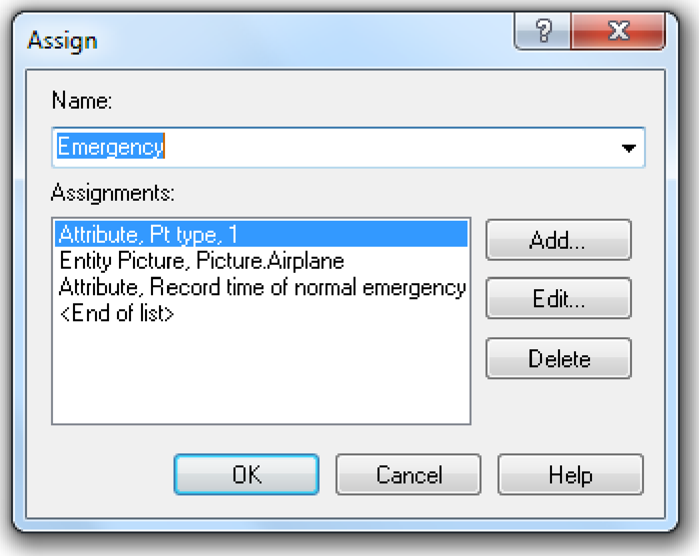


Figure 4.22 Assign of emergency patient dialog box

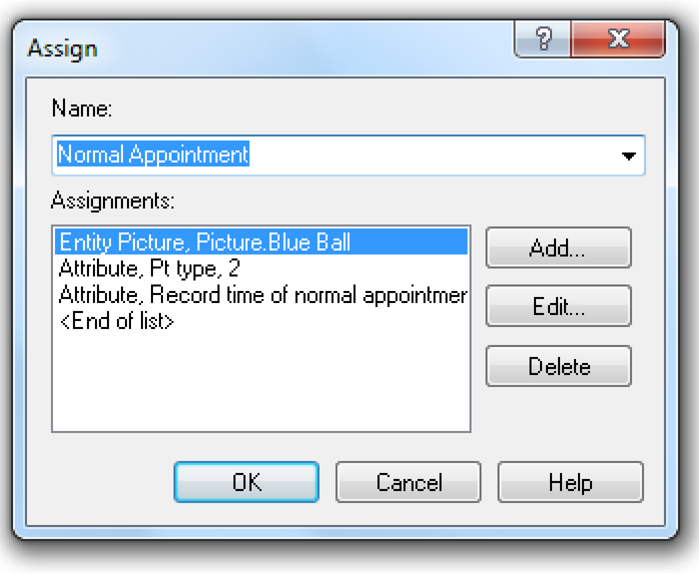


Figure 4.23 Assign of normal appointment patient dialog box

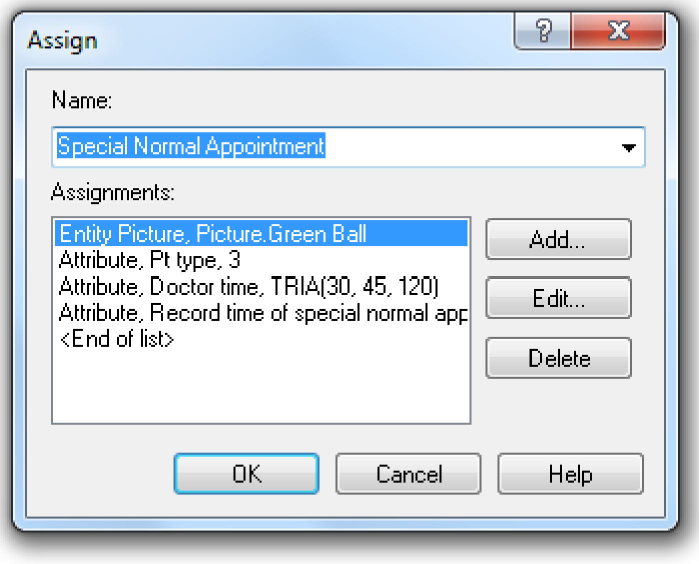


Figure 4.24 Assign of special normal appointment patient dialog box

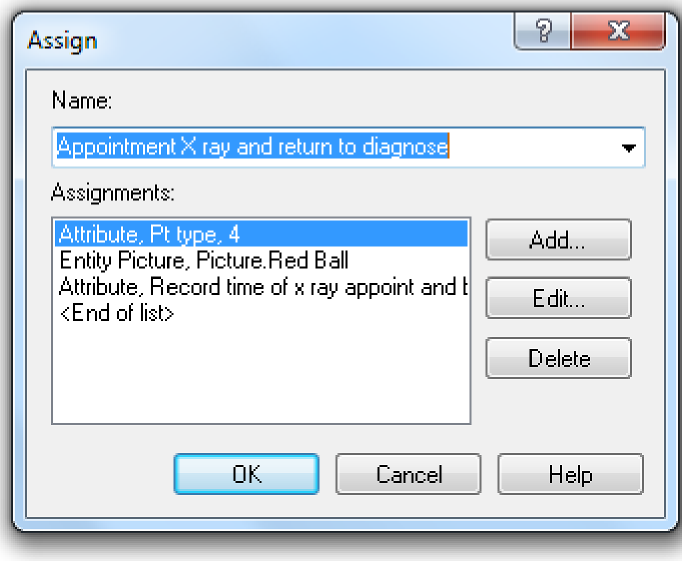


Figure 4.25 Assign of appointment and x-ray testing patient dialog box

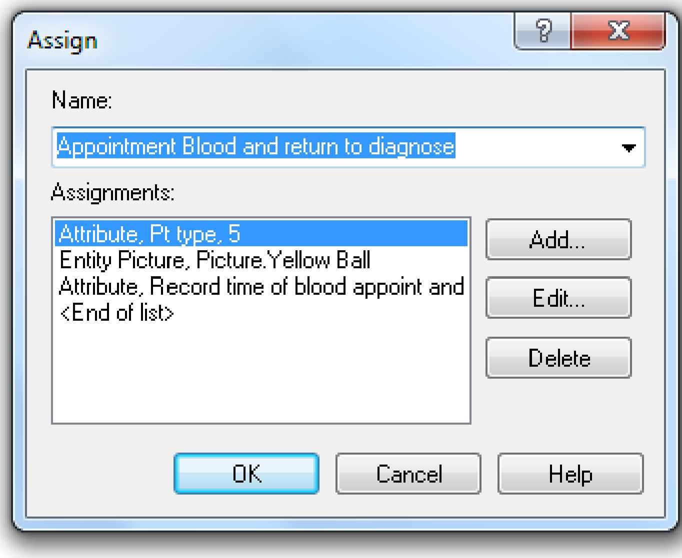


Figure 4.26 Assign of appointment and blood testing patient dialog box

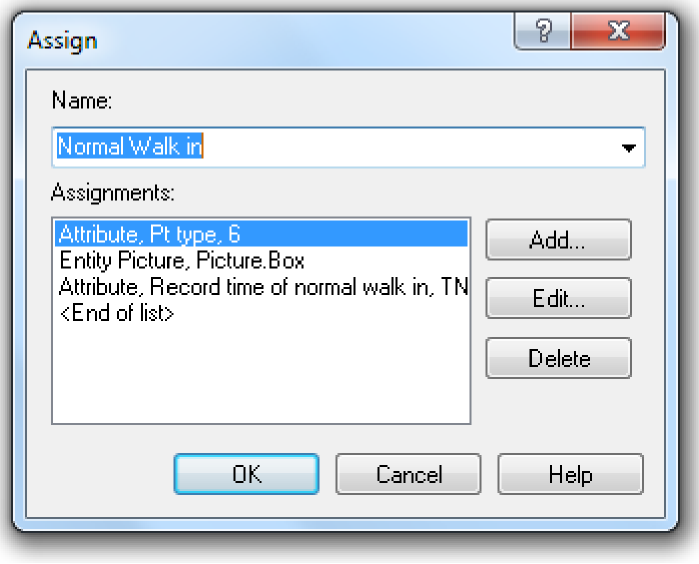


Figure 4.27 Assign of normal walk-in patient dialog box

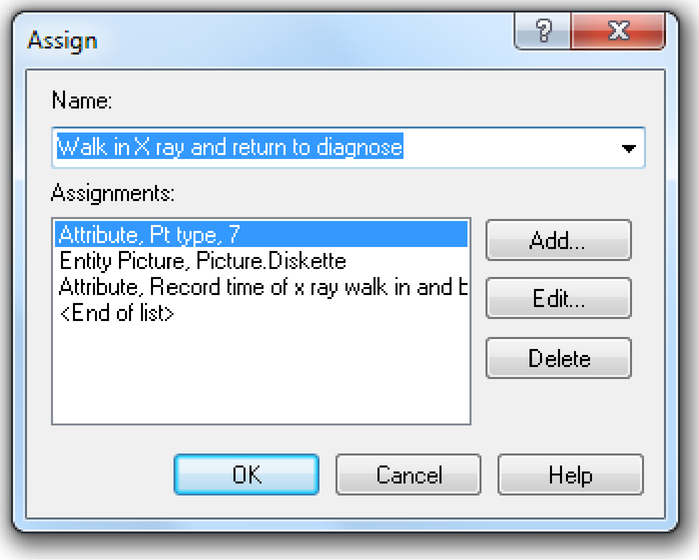


Figure 4.28 Assign of walk-in and x-ray testing patient dialog box

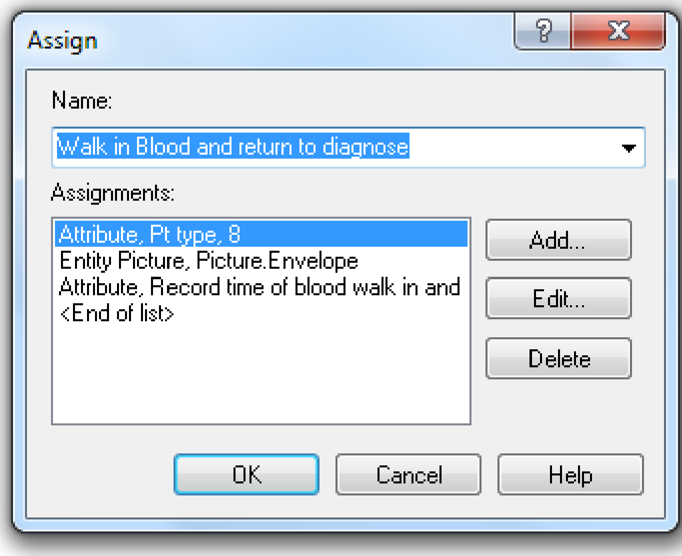


Figure 4.29 Assign of walk-in and blood testing patient dialog box

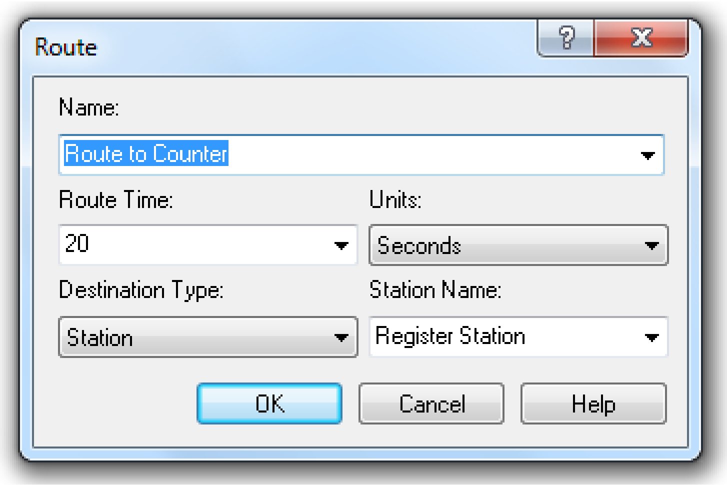


Figure 4.30 Route to counter dialog box

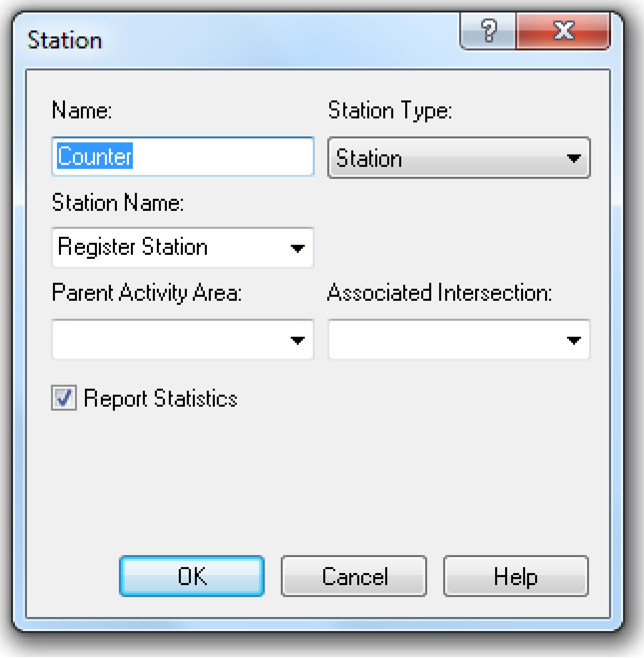


Figure 4.31 Counter station dialog box

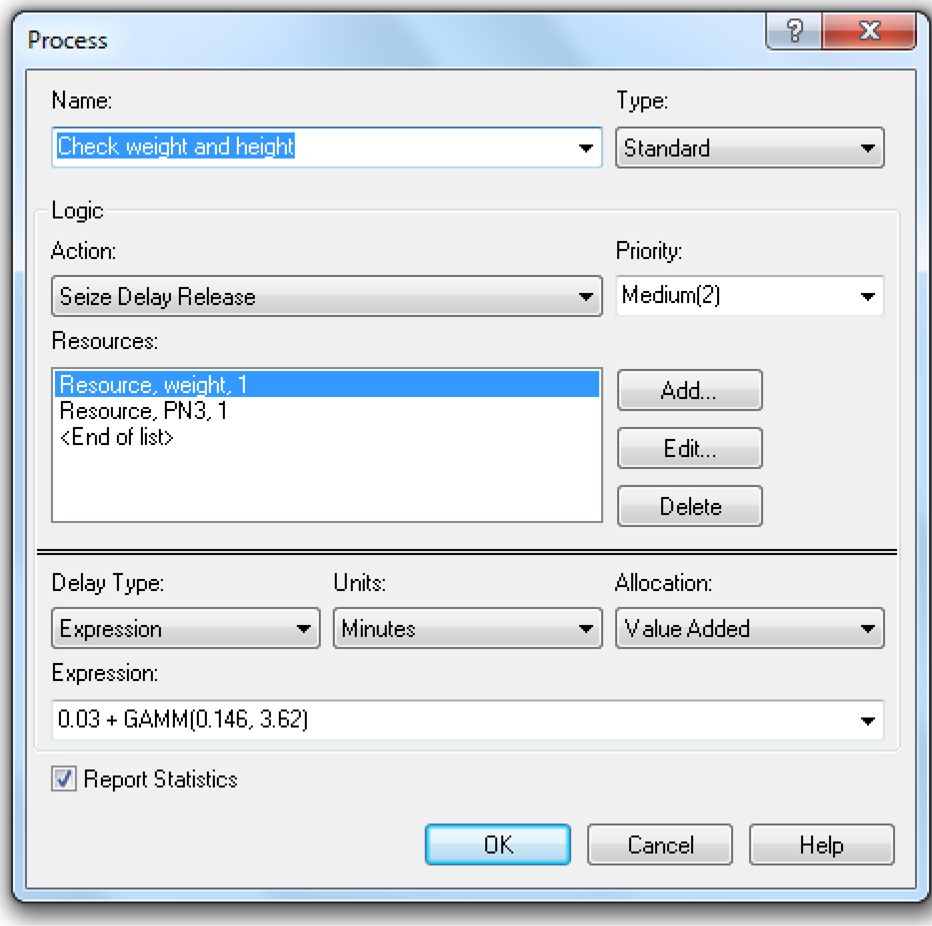


Figure 4.32 Check weight and height process dialog box

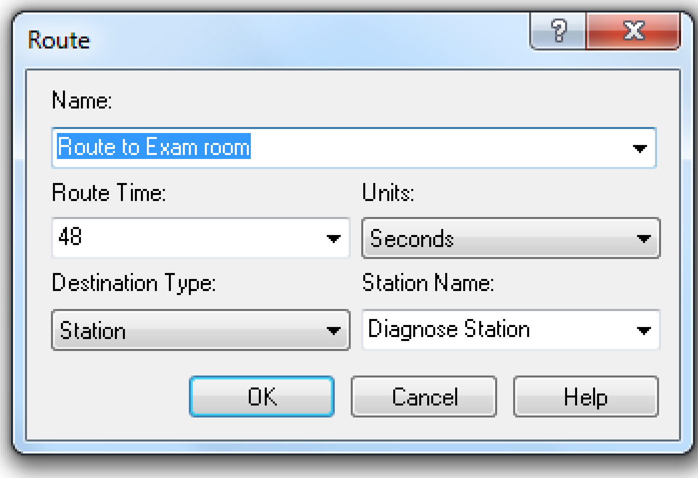


Figure 4.33 Route to examination room dialog box

The patient is diagnosed by the physician at the examination room station in Figure 4.34. The input about diagnosis process is shown in dialog box in Figure 4.35. If the patients are the normal type, they will be screened by the decide module (Figure 4.36) and go to the medical record counter station after finished the diagnosis process (Figure 4.37). In contrast, the other patients are screened again by decide module (Figure 4.38). In addition, the dialog box of decide module in Figure 4.39 is so important. It disallows the patients who finished from the x-ray / blood test to come back to see the physician repeatedly. Patients who have x-ray test will take 80 seconds for walking to diagnostic radiology as seen in dialog box in Figure 4.40, and take 28.18 minutes for x-ray test in Figure 4.41. In addition, the patients who finished the x-ray test are assigned attribute to ensure that they completed in this step. Moreover, they are divided into two types of patient that are the appointment and walk-in patients in Figure 4.42. The appointment patient is assigned in the dialog box in Figure 4.43. However, the walk-in patient is assigned in dialog box in Figure 4.44. Next, both of appointment and walk-in patients will walk back to the examination room by the route module (Figure 4.45). In the same way, patients who have blood test will walk to the OPD lab for 63 seconds (Figure 4.46), and spend 60 minutes for blood test (Figure 4.47). The patients who finished the blood test are assigned attribute, and they are divided into two types of patient, the same as the patients who finished the x-ray test (Figure 4.48). The appointment patient is assigned in the dialog box in Figure 4.49 while the walk-in patient is assigned in the dialog box in Figure 4.50. The appointment and walk-in patients will walk back to the examination room by the route module (Figure 4.51).

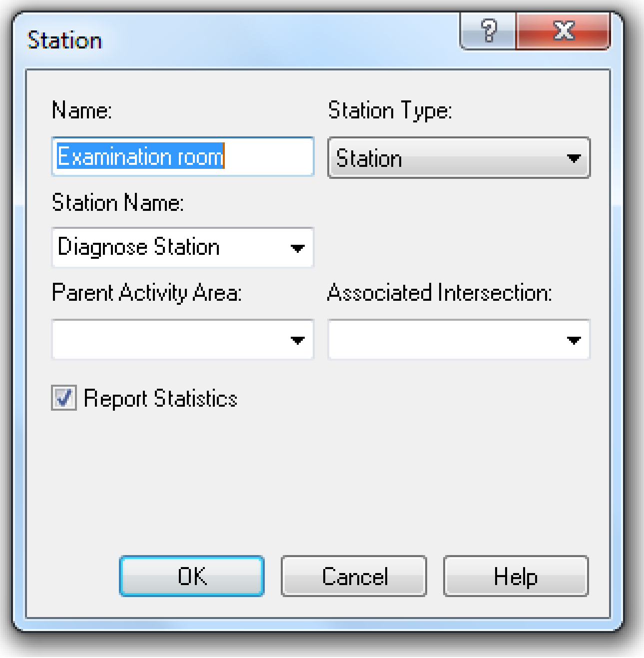


Figure 4.34 Examination room station dialog box

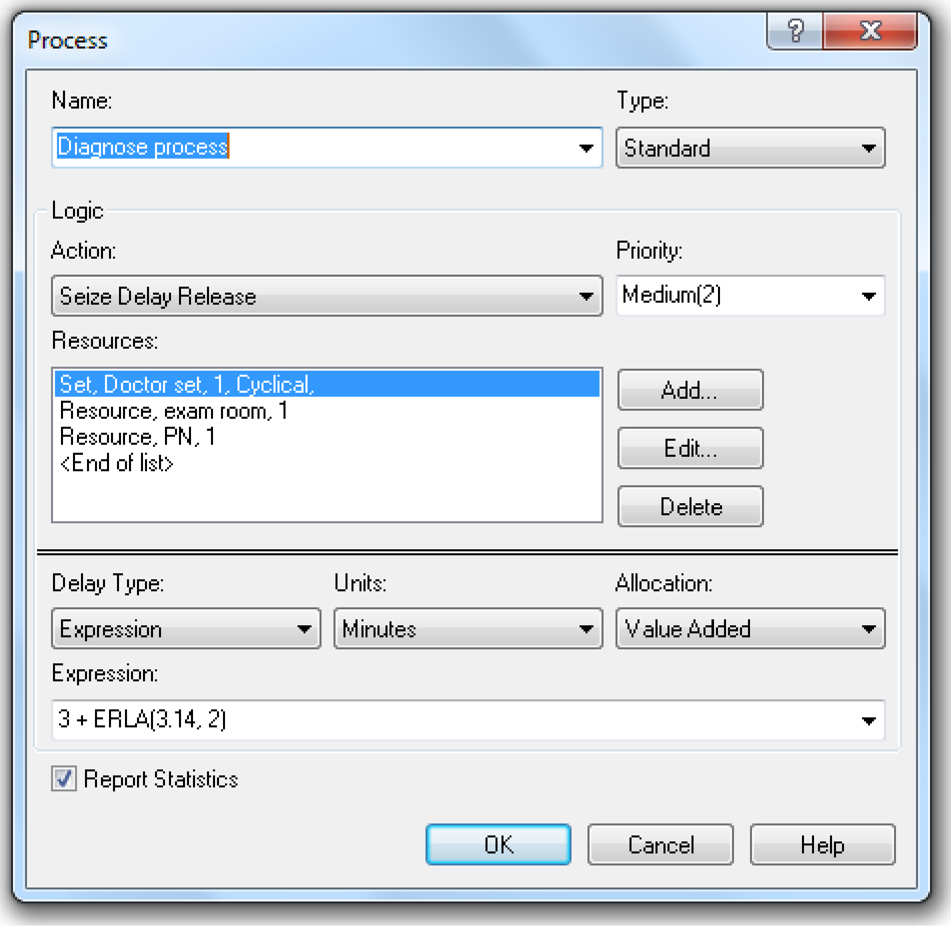


Figure 4.35 Diagnosis process dialog box

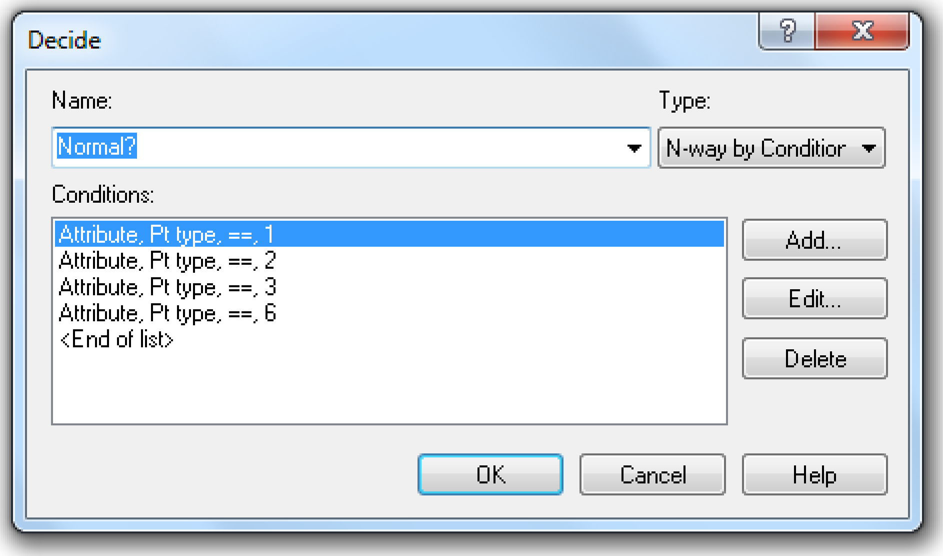


Figure 4.36 Decide of normal patient dialog box

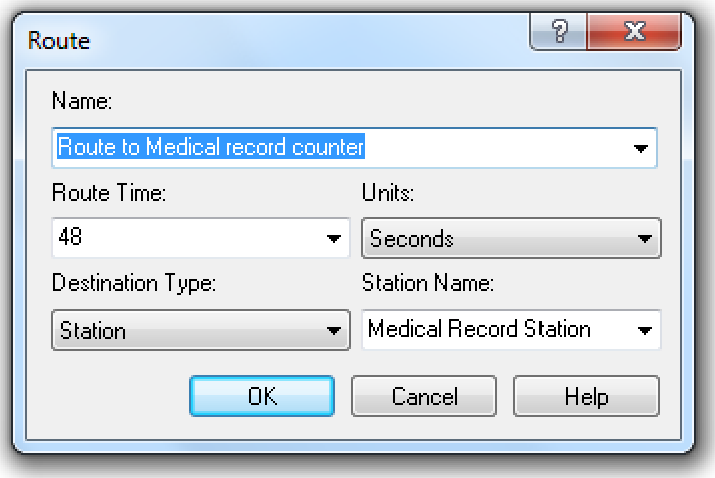


Figure 4.37 Route to medical record counter dialog box

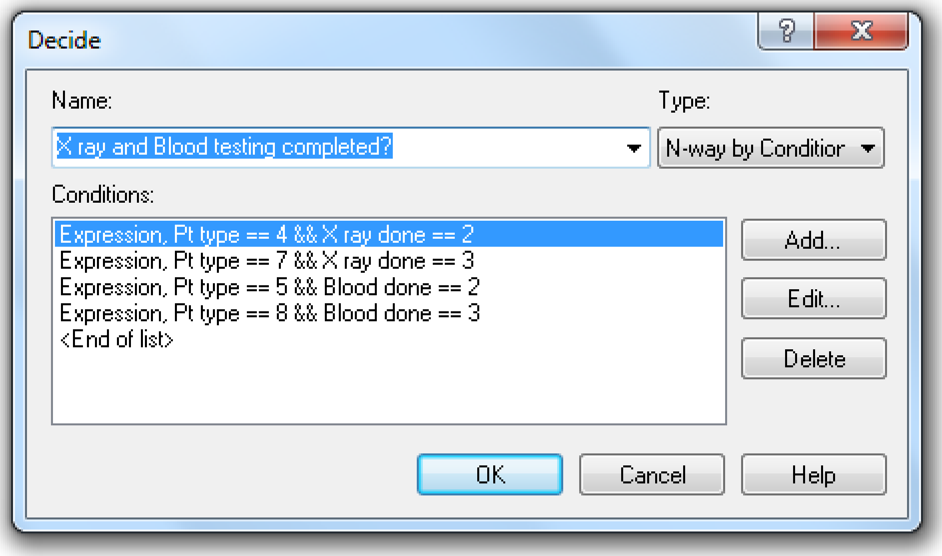


Figure 4.38 Decide of x-ray and blood testing completed dialog box

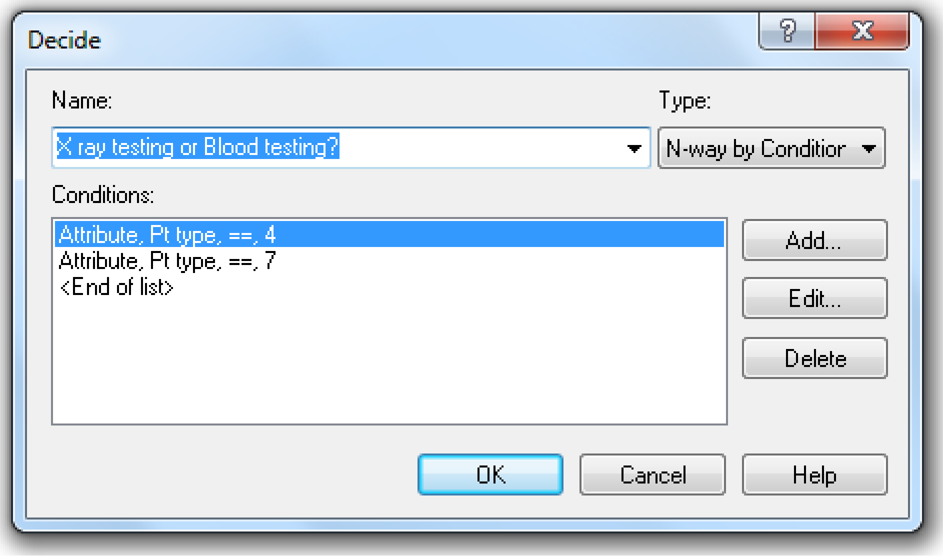


Figure 4.39 Decide of x-ray or blood testing dialog box

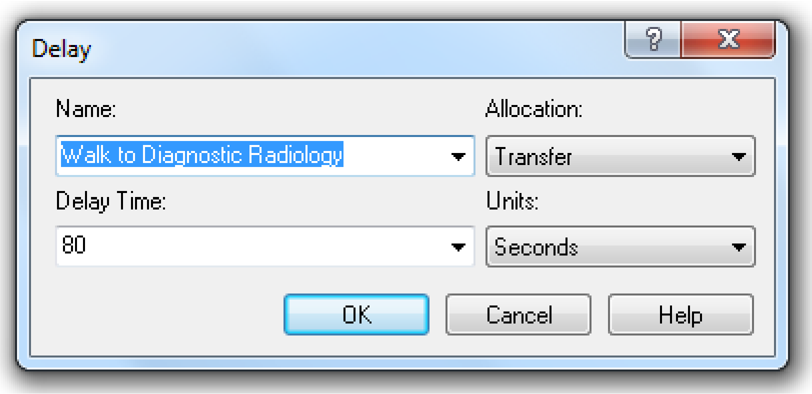


Figure 4.40 Delay of walk to diagnostic radiology dialog box

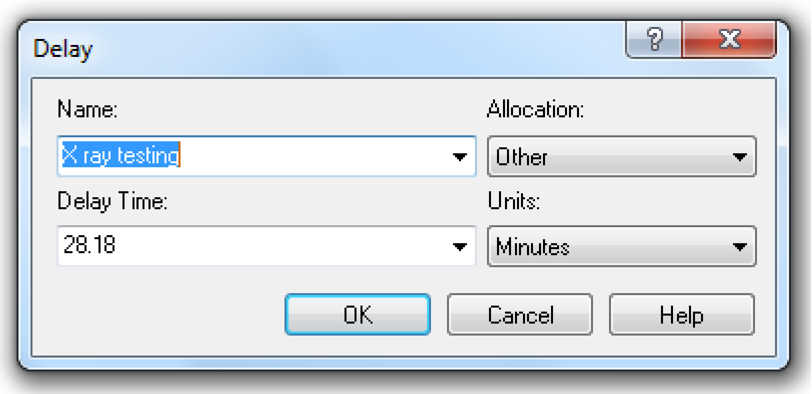


Figure 4.41 Delay of x-ray testing dialog box

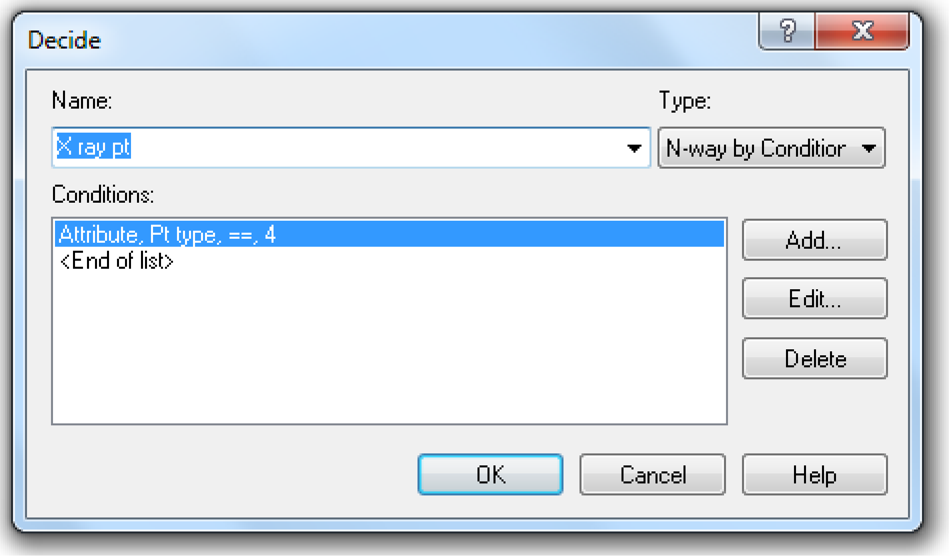


Figure 4.42 Decide of x-ray testing patient dialog box

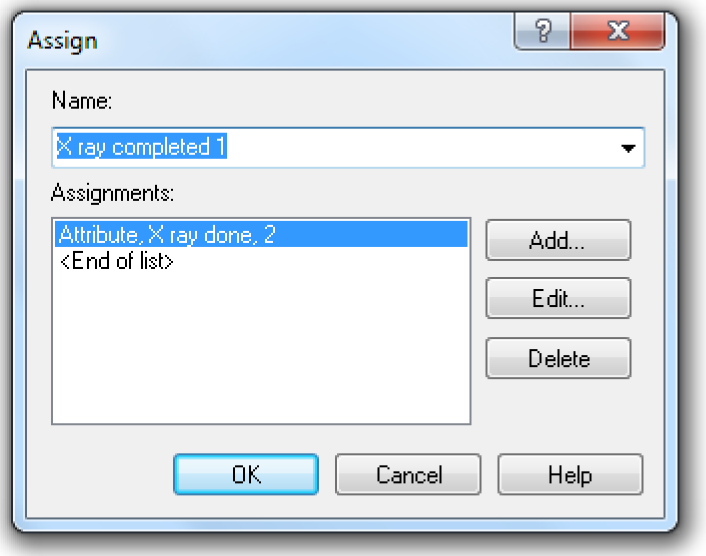


Figure 4.43 Assign of x-ray completed (1) dialog box

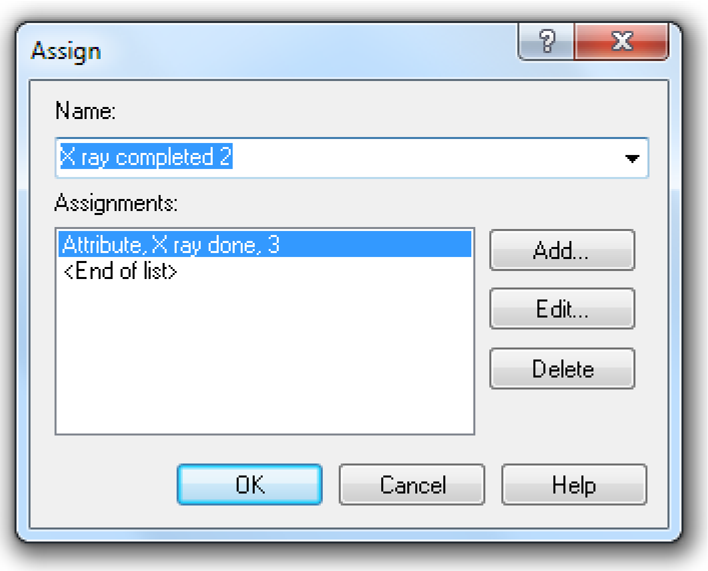


Figure 4.44 Assign of x-ray completed (2) dialog box

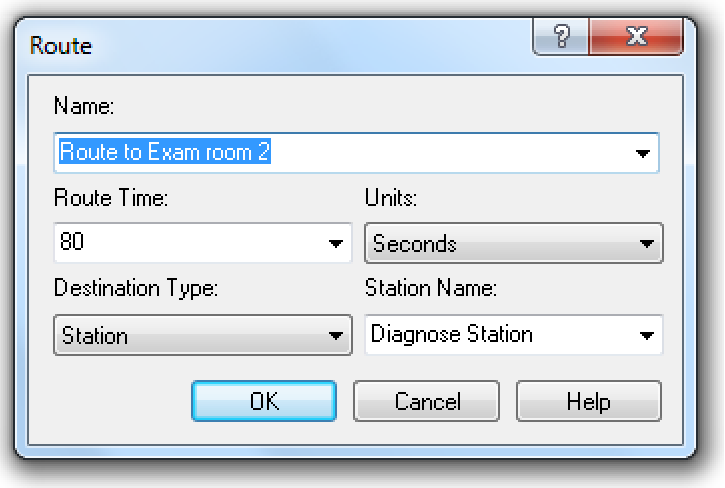


Figure 4.45 Route to examination room (2) dialog box

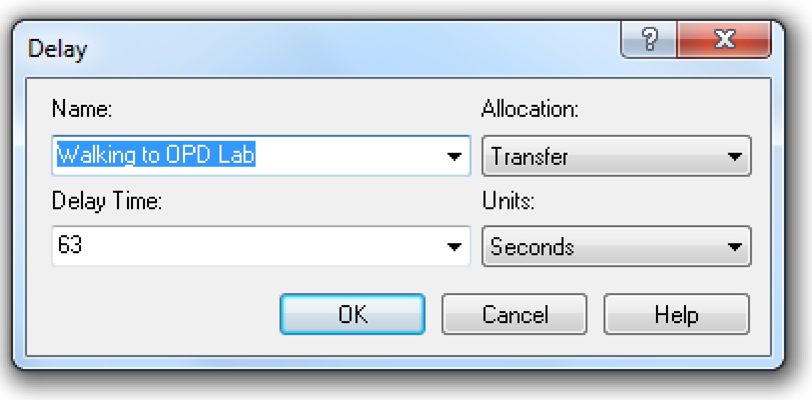


Figure 4.46 Delay of walk to OPD lab dialog box

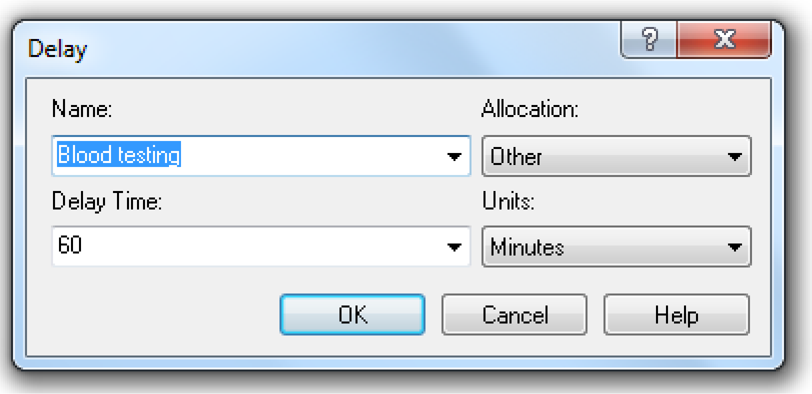


Figure 4.47 Delay of blood testing dialog box

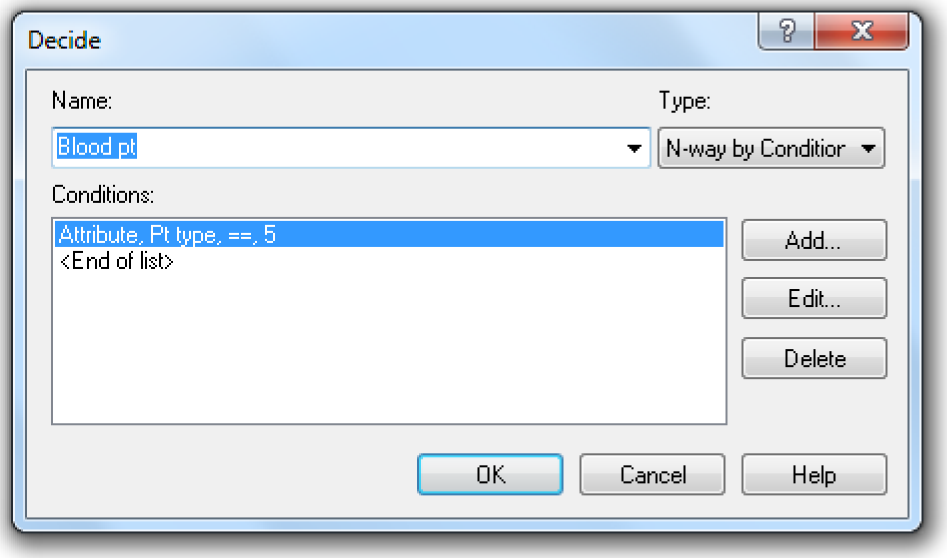


Figure 4.48 Decide of blood testing patient dialog box

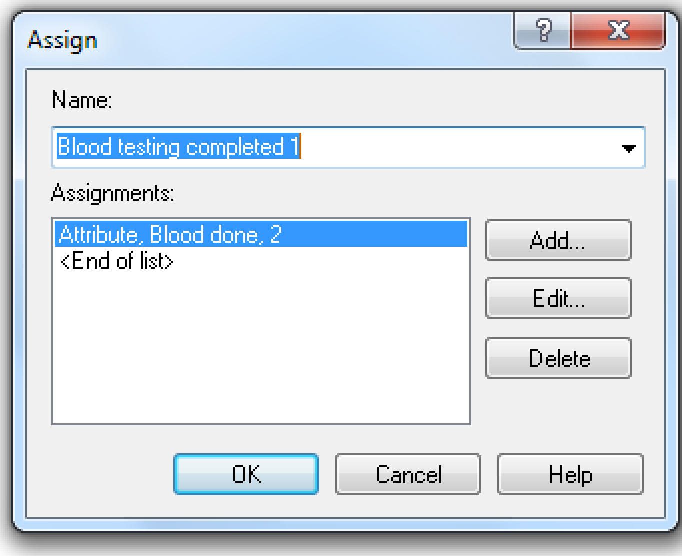


Figure 4.49 Assign of blood testing completed (1) dialog box

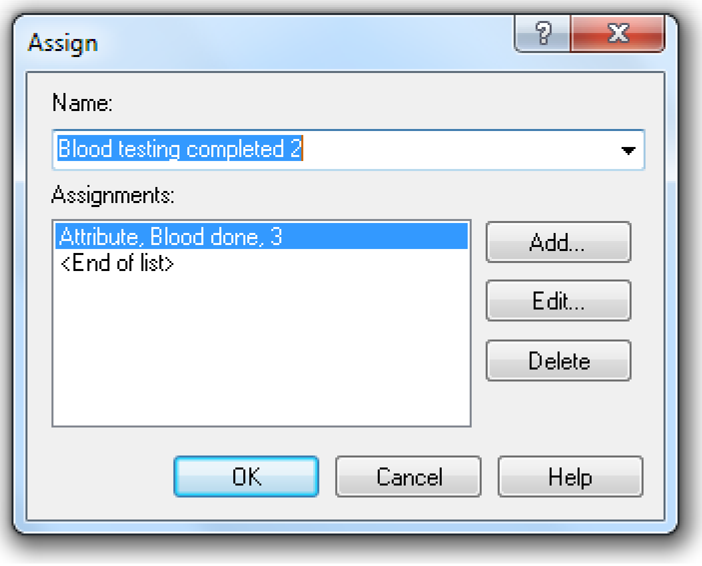


Figure 4.50 Assign of blood testing completed (2) dialog box

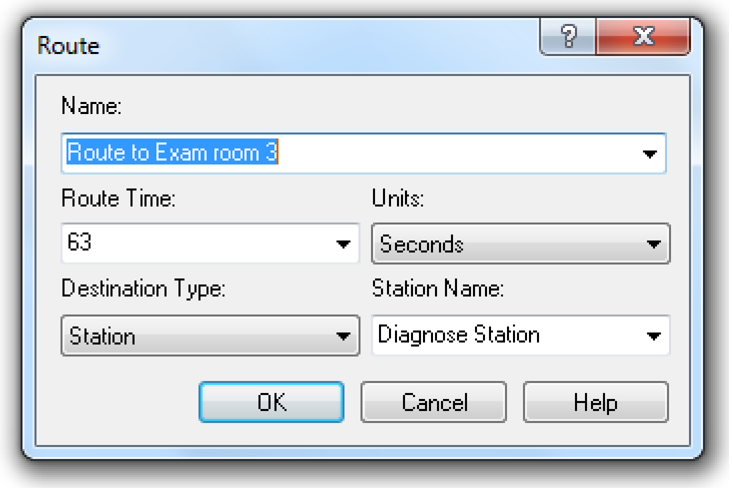


Figure 4.51 Route to examination room (3) dialog box

Having finished the diagnosis process, the patients go to the medical record counter station (Figure 4.52). The patients make their appointment at this station and the details of this process are shown in Figure 4.53. Then, the patients are divided into two groups; i.e., having prescription and none. About seventy percents of the patients receive medicine, as shown in Figure 4.54. The patients who have medicine and have no medicine are assigned attribute as shown in Figures 4.55 and 4.56, respectively. Next, all of patients must pay their service fee in the payment process (Figure 4.57). The patients who have medicine are decided again by their attribute (Figure 4.58), and they will go to receive medicine in the pharmacy process (Figure 4.59). Conversely, the patients who have no medicine can leave from the system after they finished their payment. Finally, the patients who finished the overall process will be decided the patient type (Figure 4.60), and they are recorded the time that they have spent in the system. The record module keeps the total time in the system of all the patient types, as shown in Figures 4.61 – 4.68. All patients will leave the system by the dispose module as shown in Figure 4.69.

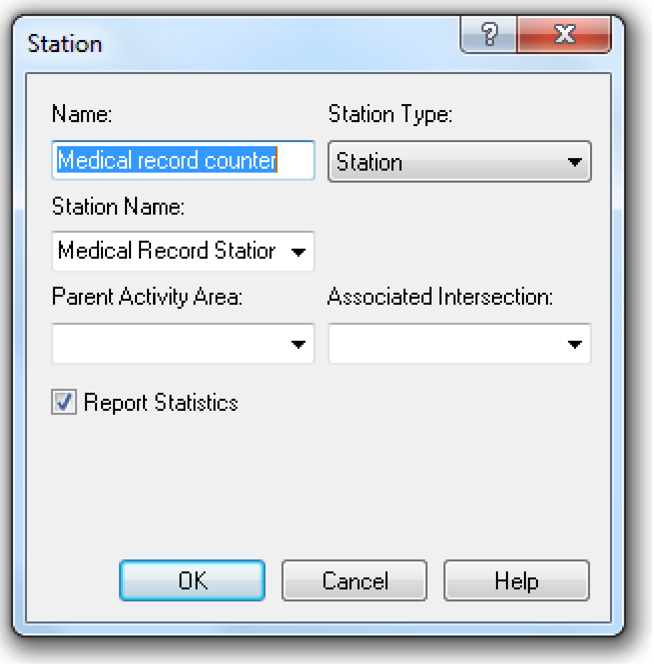


Figure 4.52 Medical record counter station dialog box

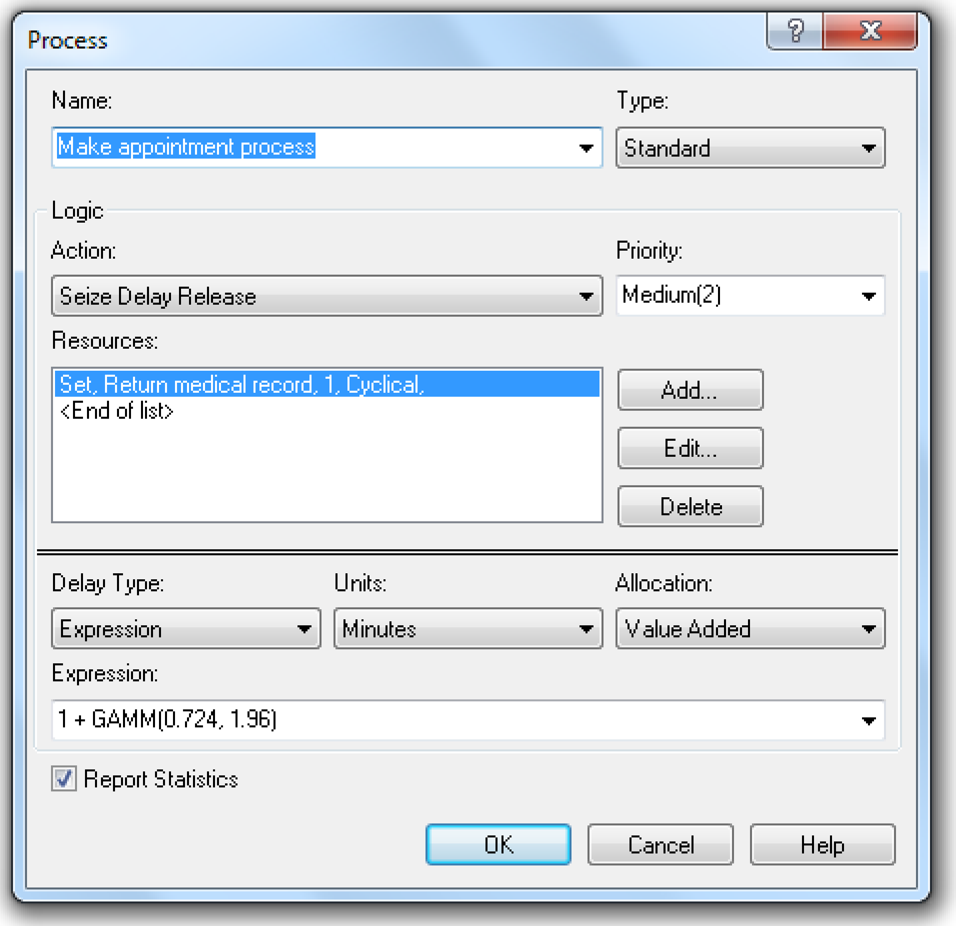


Figure 4.53 Make appointment process dialog box

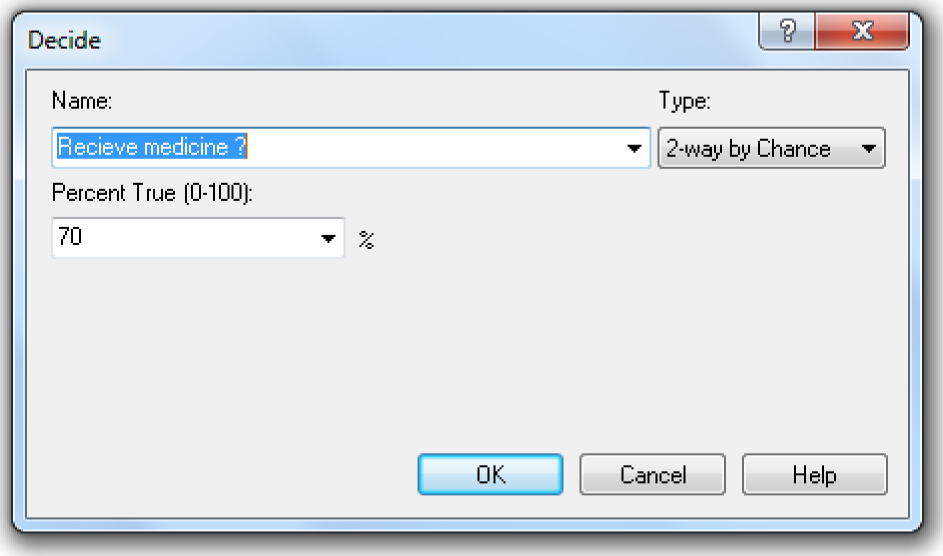


Figure 4.54 Decide of receive medicine (1) dialog box

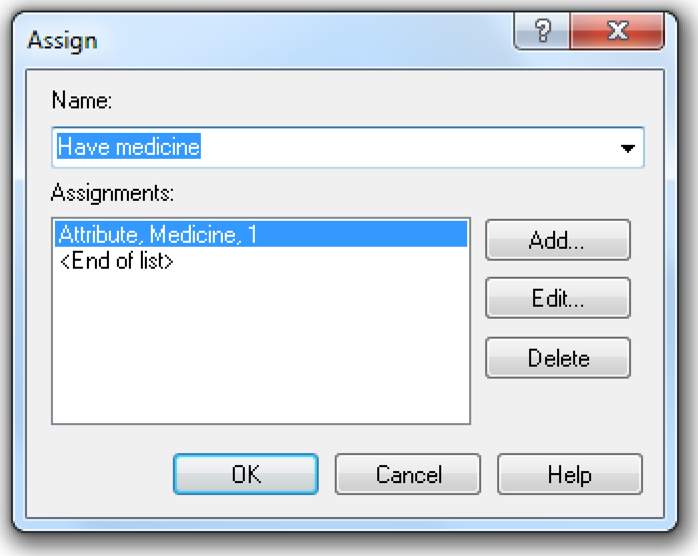


Figure 4.55 Assign of have medicine dialog box

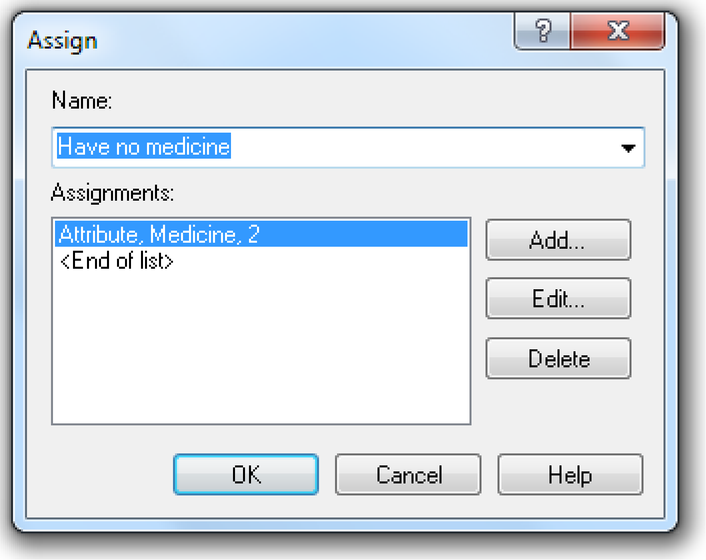


Figure 4.56 Assign of have no medicine dialog box

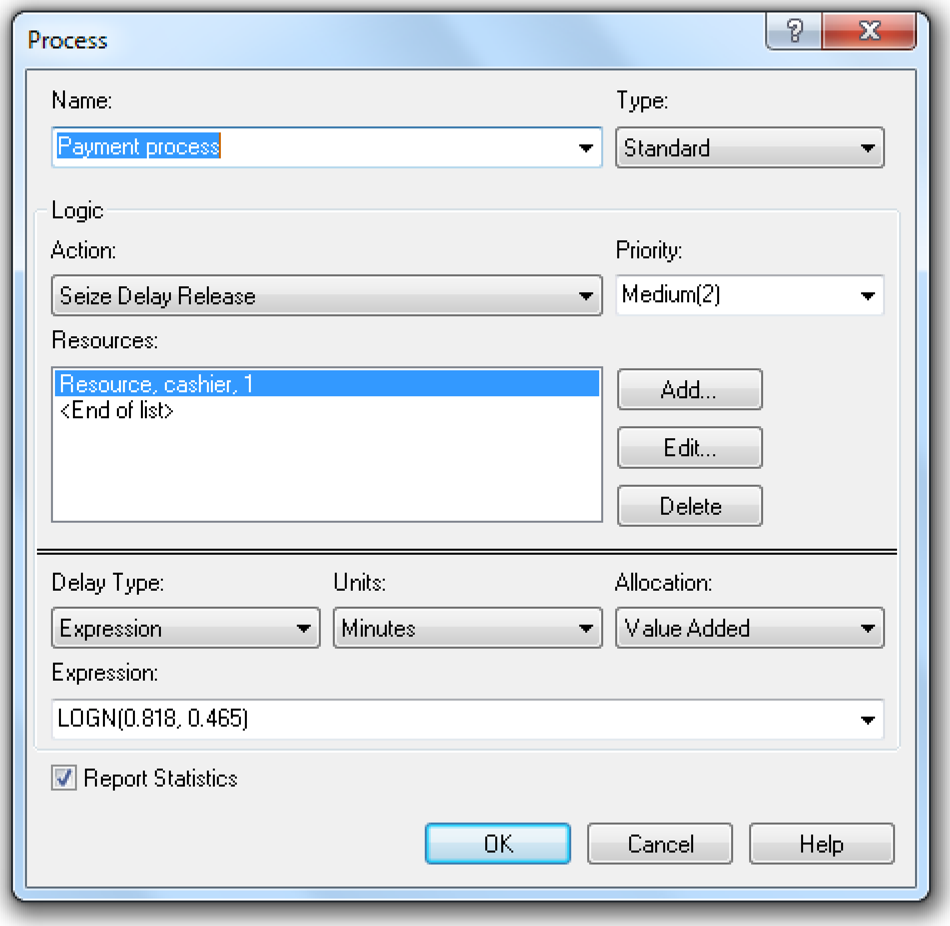


Figure 4.57 Payment process dialog box

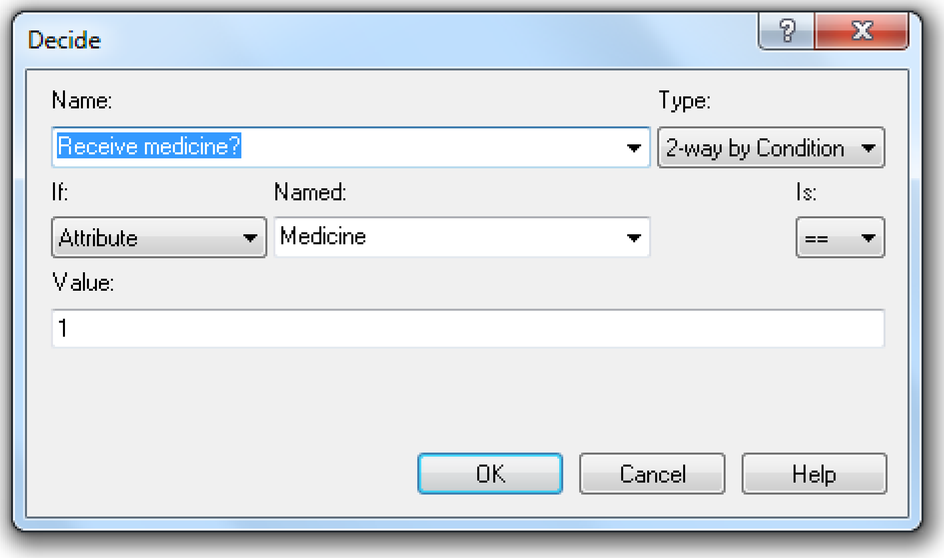


Figure 4.58 Decide of receive medicine (2) dialog box

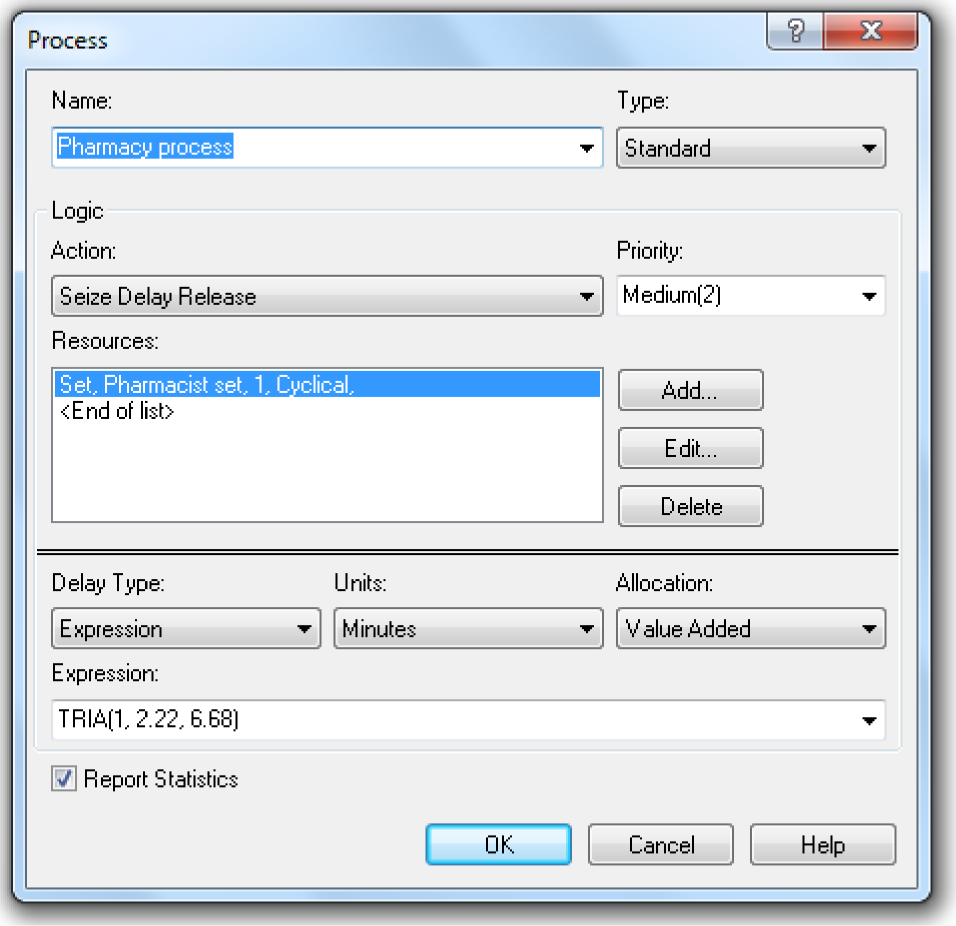


Figure 4.59 Pharmacy process dialog box

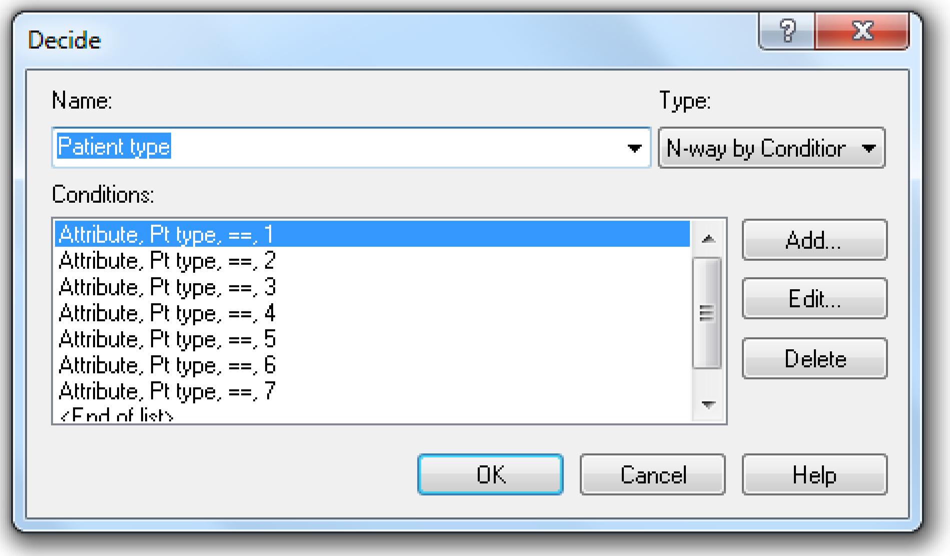


Figure 4.60 Decide of patient type dialog box

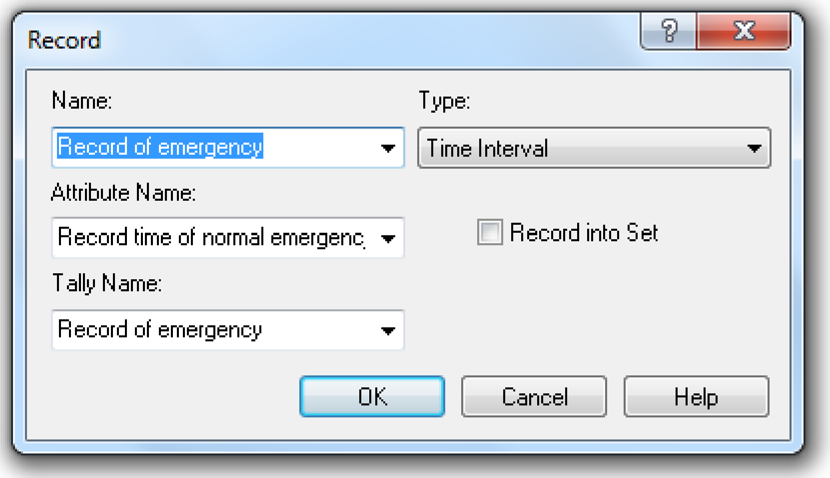


Figure 4.61 Record of emergency patient dialog box

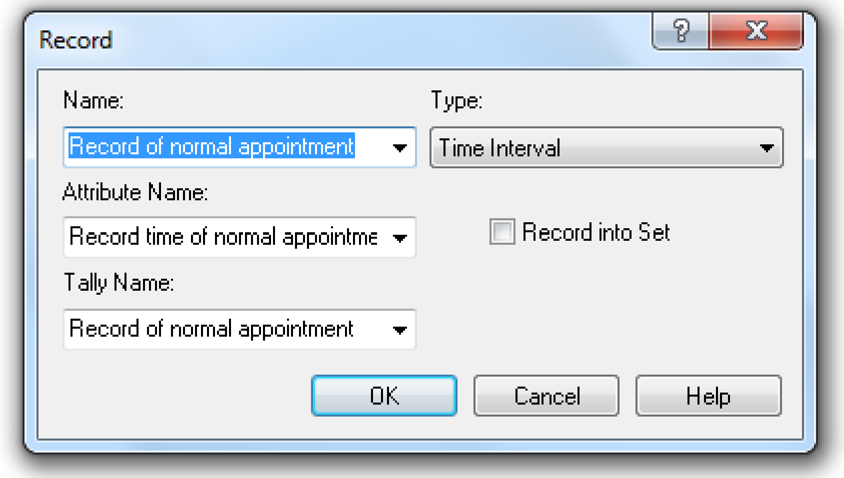


Figure 4.62 Record of normal appointment patient dialog box

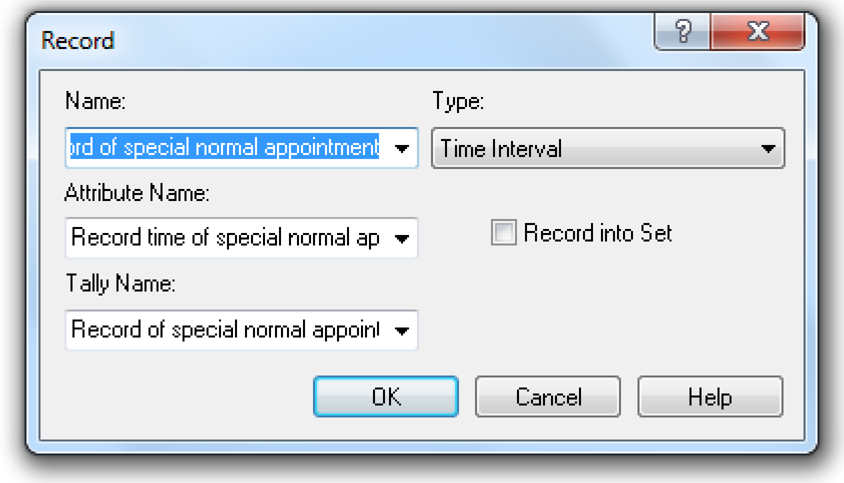


Figure 4.63 Record of special normal appointment patient dialog box

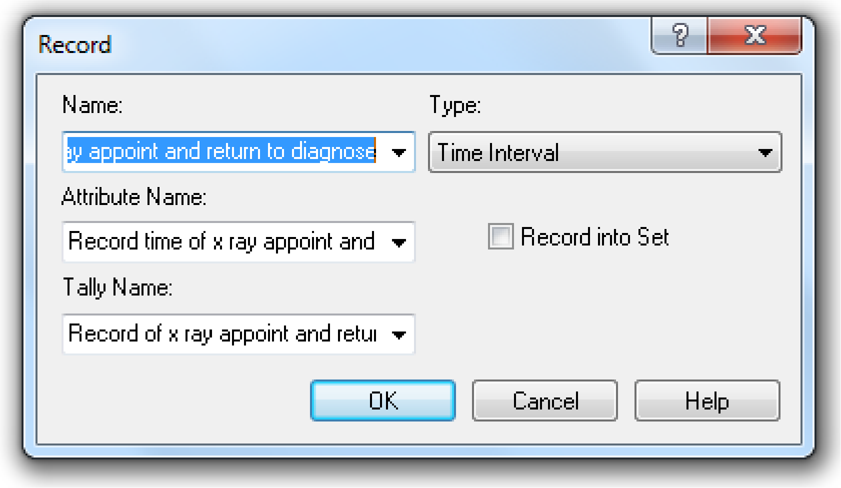


Figure 4.64 Record of appointment and x-ray testing patient dialog box

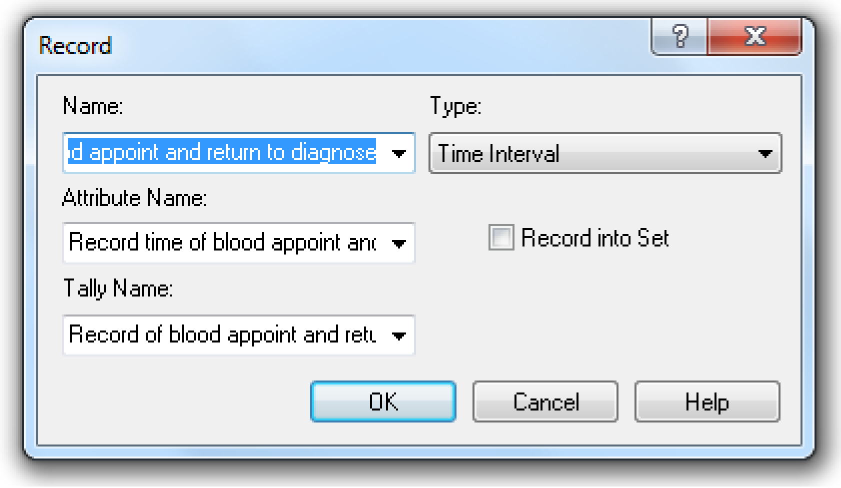


Figure 4.65 Record of appointment and blood testing patient dialog box

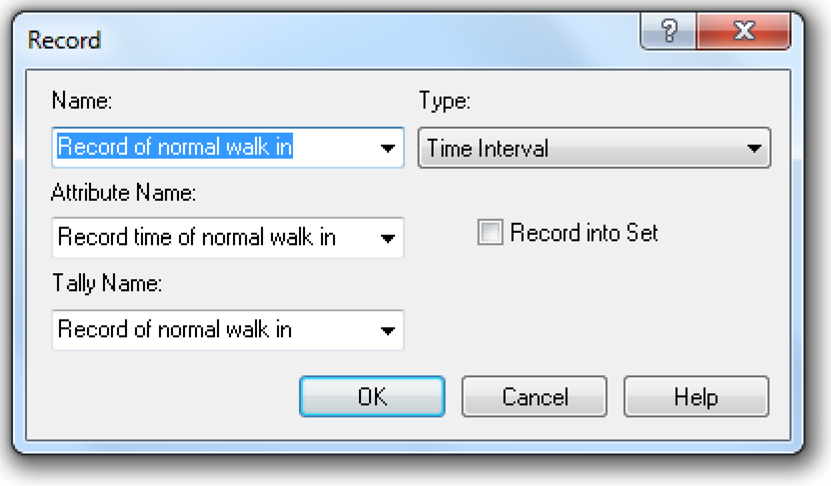


Figure 4.66 Record of normal walk-in patient dialog box

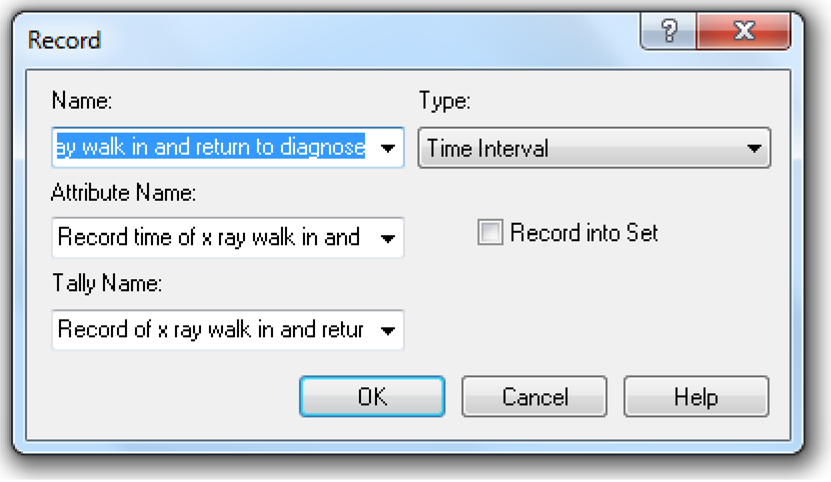


Figure 4.67 Record of walk-in and x-ray testing patient dialog box

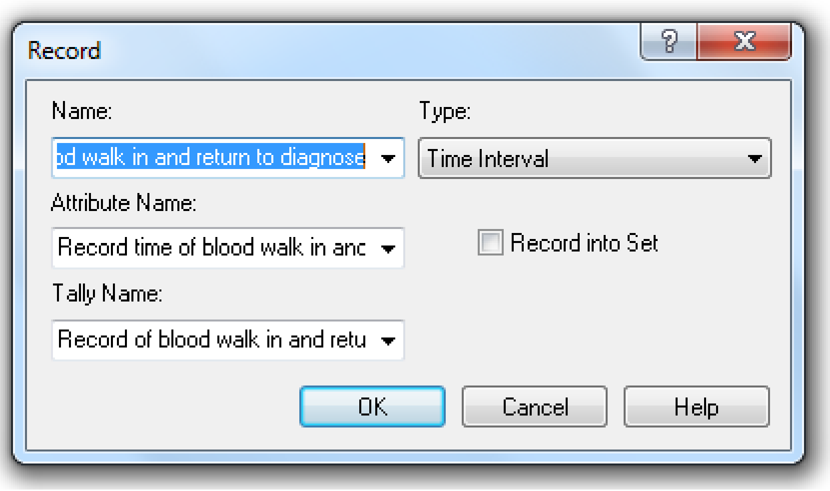


Figure 4.68 Record of walk-in and blood testing patient dialog box

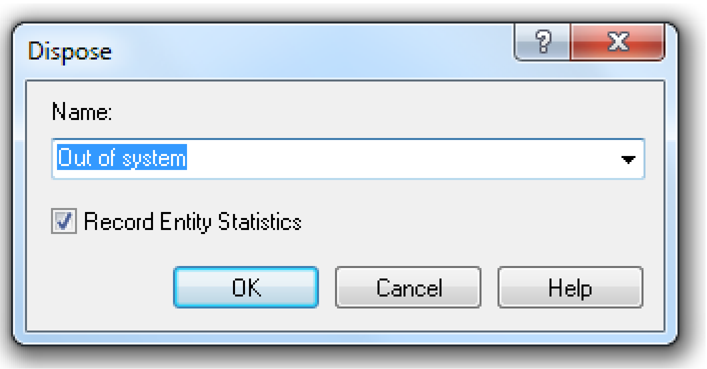


Figure 4.69 Dispose dialog box

Similarly, the simulation model for the afternoon session follows the approach as in the morning session. The researcher uses the different set of inputs from the morning session. There are changes in patient types, patient arrival, distribution of service time, and resources. The patient types of the afternoon session are from Table 4.2. The patient arrival is from Table 4.6. The distribution of service time is from Table 4.10. Finally, the different resources from the morning session are the physicians, the examination rooms, and practical nurses at the examination room.

4.6.3 Model verification

Having finished building the model, it must be checked for the correctness and debugged the simulation program. This step is called model verification. The model is verified by checking the flow of patient. First, the researcher runs the model and gradually checks the flow throughout the system. Each type of entity (patient) was traced from the beginning to the last activity. If that entity (patient) in the model flows correctly similar to the real system, the verification is completed. Moreover, the Rockwell Arena program has a menu for checking the correctness of the model as shown in Figure 4.70. When the model has no error, it shows the dialog box "No errors or warnings in model" like in Figure 4.71. After finished these two steps, the model will be able to operate without an error.

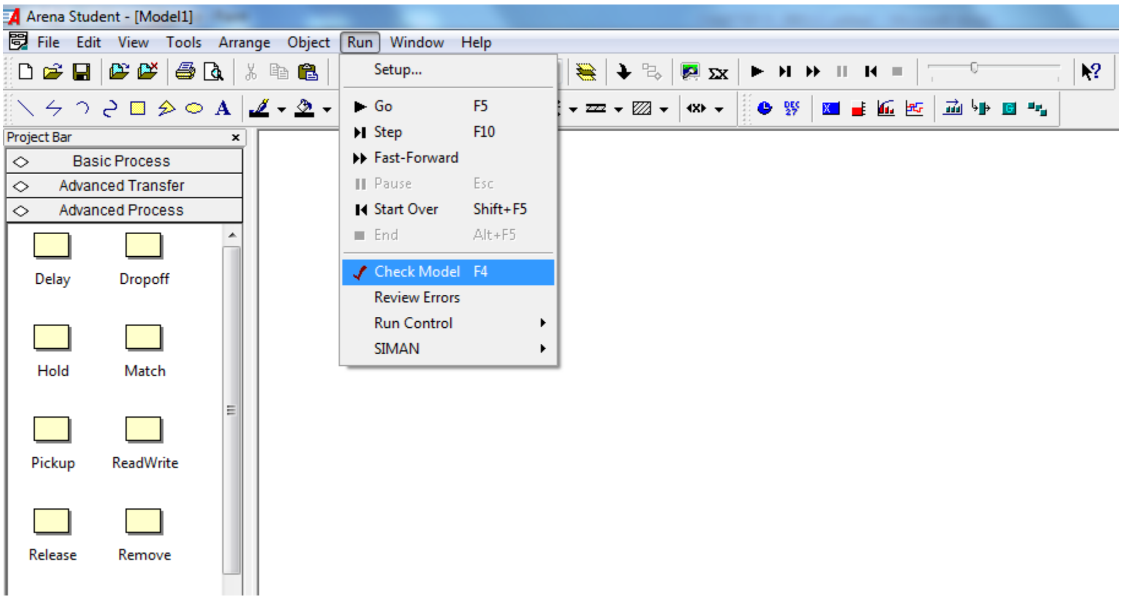


Figure 4.70 Check model menu in the Rockwell Arena software

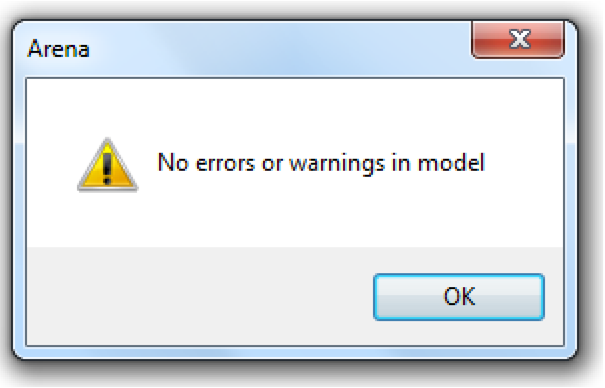


Figure 4.71 No errors or warnings in the model dialog box

4.6.4 Model validation

Another step for checking the correctness the model is called model validation. Law (2007) suggested that the comparison with an existing system, expert opinion, another model, and animation are the ways to validate the simulation model. In case of this research, the outputs from the simulation model were compared with the observed data from the existing system. If the outputs correspond to the real data, the simulation model is considered valid. The researcher reviewed the researches about the validation process. These researches are summarized in Table 2.2 (Chapter 2). The researcher found that the time in system, waiting time, and process times are numerical statistics that were preferred to be used in the validation process. Here, the process time and the waiting time were chosen to be the key performance indicators to validate the simulation model of the pediatrics department. The frequently-used approaches for the validation are the hypothesis testing with 95% confidence interval and the computation of percentage error. The past researches did not clearly explain about the criteria that they used to justify the model. The acceptable highest percent of error seems to be 15%. Consequently, the researcher adopted the reviewed approaches to validate the simulation model.

The researcher checked outputs from the model by running the model for 1,400 replications. This number of replications is determined to provide the steady state results as explained in Section 4.6.1. Then, the researcher compares the outputs with the observed values by using two methods; i.e., hypothesis testing and percentage error, concurrently. First, the hypothesis testing on the total process time and the total waiting time is done by the two-sample t-test procedure. Since the number of sample is quite large, the z score is used instead of t-statistics. The researcher used the two-tailed test with 95% confidence level. A calculated method of the z statistics is shown in Appendix C (page 206). The Table 4.13 showed that the total waiting time of the morning and afternoon sessions are not accepted. Then, the service distribution of the process which has the problem must be modified. The researcher changed to another service distribution with the second best mean square error (MSE). This method is repeated until the output of that process well approximates the observed value. If there is no distribution that suitable for the model, the researcher resorts to the data filtering process (Section 4.5.2). Again, the distribution with the lowest MSE is selected to be used in the simulation model. The process which consists of changing the service distribution and data filtering process is repeated until the outputs of the model are accepted. The final results are shown in Tables 4.13. In the end, the simulation model contains some changes in the distribution of process time as shown in the Tables 4.14 and 4.15. The resulting simulation model is then a good representative of the real system.

Second, the researcher computed the percent of error in each process time, waiting time, total process time, and total waiting time via the equation (4.1). The percent of error should be as least as possible. Table 4.16 showed the percent of error in the initial model that is still high so some service distributions need to be adjusted or fine tuned. After the service distributions are changed, the percent of error are changed accordingly, as shown in the final model column in Table 4.16.

$$\%\text{error} = \frac{\left|\text{time}_{\text{model}} - \text{time}_{\text{observed}}\right|}{\text{time}_{\text{observed}}} \times 100\% \qquad (4.1)$$

Table 4.13 Model validation results

Variable	Observed value	Initial model				Final model			
		Model output	Critical value	z-statistics	Accept H_0 (95% CI)	Model output	Critical value	z-statistics	Accept H_0 (95% CI)
Morning session									
Total process time	19.23	16.44	± 1.96	1.18	✓	16.38	± 1.96	1.21	✓
Total waiting time	79.15	86.26	± 1.96	-2.47	×	84.35	± 1.96	-1.81	✓
Afternoon session									
Total process time	20.11	19.63	± 1.96	0.59	✓	18.59	± 1.96	1.85	✓
Total waiting time	64.40	77.48	± 1.96	-4.96	×	64.06	± 1.96	0.13	✓

Table 4.14 The distributions of service time of the validated model: morning session

Process	Number of data	Distributions of service time
Check weight and height	50	0.03 + GAMM(0.146, 3.62)
Diagnosis	48	3 + WEIB(6.85, 1.34)
Make appointment	46	1 + ERLA(0.709, 2)
Payment	50	ERLA(0.204, 4)
Pharmacy	50	TRIA(1, 2.22, 6.68)

Table 4.15 The distributions of service time of the validated model: afternoon session

Process	Number of data	Distribution of service time
Check weight and height	50	TRIA(0. 12, 0.299, 1.28)
Diagnosis	45	TRIA(4, 7, 16)
Make appointment	50	NORM(2.78, 1.04)
Payment	50	0.18 + WEIB(0.632, 1.86)
Pharmacy	50	TRIA(2, 4.77, 9.76)

Table 4.16 Percentage error of the model

Process	Percent of error (%)			
	Process time		Waiting time	
	Initial model	Final model	Initial model	Final model
Morning session				
Check weight and height	0.36	0.29	84.45	84.46
Diagnosis	22.03	22.01	68.26	67.72
Make appointment	6.84	8.99	461.54	415.21
Payment	0.21	0.45	23.94	25.52
Pharmacy	0.63	0.47	75.44	74.85
Total	14.50	14.82	8.98	6.57
Afternoon session				
Check weight and height	0.00	0.77	96.94	96.92
Diagnosis	4.32	17.20	101.64	63.41
Make appointment	0.00	0.13	97.99	97.35
Payment	0.00	0.35	94.93	93.95
Pharmacy	0.19	6.83	93.77	80.59
Total	2.39	7.54	20.31	0.53

Similarly, for the afternoon session, the validation follows the approach like in the morning session. Some inputs are different from the morning session; i.e., patient types, patient arrival, distribution of service time, and resources. After finished the validation step, the distribution of service time by process in the afternoon session is summarized in Table 4.15.

Above all, Tables 4.17 and 4.18 are the simulation results of the patient flow at the pediatrics department. It shows that the outpatients spend the longest total time at the diagnosis process. This long total time undoubtedly leads to patient's dissatisfaction. Because of these results, the researcher proposes strategies to decrease the time that patients waste in the department, and hence improve the patient flow.

Table 4.17 Average time in the process: morning session

Process	N	Process time (min.)		Waiting time (min.)		Total time (min.)	
		Average	SD.	Average	SD.	Average	SD.
Check weight and height	1,400	0.56	0.02	5.00	1.50	5.56	1.50
Diagnosis		9.29	0.31	52.75	4.39	62.04	4.50
Make appointment		2.42	0.07	20.40	4.20	22.82	4.24
Payment		0.82	0.03	4.12	2.36	4.93	2.38
Pharmacy		3.30	0.10	2.08	1.40	5.37	1.44
Total		16.38	0.33	84.35	7.98	100.73	8.01

Table 4.18 Average time in the process: afternoon session

Process	N	Process time (min.)		Waiting time (min.)		Total time (min.)	
		Average	SD.	Average	SD.	Average	SD.
Check weight and height	1,400	0.57	0.02	0.31	0.11	0.88	0.11
Diagnosis		9.00	0.19	61.93	9.45	70.93	9.49
Make appointment		2.78	0.08	0.15	0.04	2.93	0.11
Payment		0.74	0.03	0.20	0.04	0.95	0.05
Pharmacy		5.50	0.16	1.47	0.94	6.97	1.01
Total		18.59	0.26	64.06	9.50	82.65	9.54

4.7 Improvement strategies

The long waiting time in the process dissatisfied the patients. Therefore, the patient flow should be improved to decrease the waiting time in the system. In addition, the administrators wished that patients would be satisfied in their service. Thus the researcher created strategies for improving the patient flow. There are three strategies which are 1) increasing the number of physicians 2) staggering of physicians' working hours and 3) improving the patient appointment system.

4.7.1 Strategy 1: increasing the number of physicians

As the simulation indicated, patients had to spend their time awaiting for the service, especially at the diagnosis process. It may be intuitive to add more physicians into the system in order to increase the number of servers in the simulation model. In fact, this is the idea that may always come into patients' mind every time they have to wait for too long to be diagnosed. Thus, the researcher tested this strategy by increasing the number of physicians in the system. This strategy explores if adding more resource (physician) into the system can decrease the waiting time.

Currently, there are 36 physicians in the morning session and 12 physicians in the afternoon session in the typical system of the pediatrics department. In order to test such strategy, the researcher gradually increased the number of physicians by one at a time as shown in Tables 4.19 and 4.20 for morning and afternoon sessions, respectively. Consequently, there are 37 – 40 physicians for the morning session, and 13 – 14 physicians for the afternoon session. More simply, a name of this strategy is assigned to "I", it stands for a word "increasing".

Table 4.19 Description of strategy 1 for the morning session

Sub-strategy	Number of physicians
IM-1	37
IM-2	38
IM-3	39
IM-4	40

Table 4.20 Description of strategy 1 for the afternoon session

Sub-strategy	Number of physicians
IA-1	13
IA-2	14

4.7.2 Strategy 2: staggering of physicians' working hours

The hourly numbers of patients in Table 4.5 reveal that many patients usually arrive at the hospital very early in the morning and wait to obtain the service although it is not the physicians' working time. Thus, the researcher considered changing the working schedules of the physicians. It might help spread the number of patients over a longer period; hence, reducing the congestion at the department. In fact, the administrator also has such an idea since several physicians usually start working before 8 AM. It may not be difficult to persuade some physicians to start the shift earlier.

Therefore, this strategy changes the working hours of the physicians. The researcher tried to stagger one to four physicians to start working an hour earlier in the morning session so there are four sub-strategies as shown in Table 4.21. In the afternoon session, there are two sub-strategies which stagger one to two physicians to start working an hour earlier as in Table 4.22. More simply, a name of this strategy is assigned to "S", it stands for a word "staggering".

Table 4.21 Description of strategy 2 for the morning session

Sub-strategy	Number of physicians		
	8 - 9 AM	9 - 11 AM	11 - 12 AM
SM-1	1	36	35
SM-2	2	36	34
SM-3	3	36	33
SM-4	4	36	32

Table 4.22 Description of strategy 2 for the afternoon session

Sub-strategy	Number of physicians		
	12 - 1 PM	1 - 2 PM	2 - 3 PM
SA-1	1	12	11
SA-2	2	12	10

4.7.3 Strategy 3: improve the patient appointment system

The present appointment system of the pediatrics department does not appoint a patient arrival at a specific time, but it appoints a group of patients during a time slot. For this reason, a lot of patients come to the department at the same time. This may cause the congestion in the system. The administrator is interested in the alternative appointment system, which assigns a specific time to an individual patient. This is to prevent the flow of patients in a big batch. The researcher herein compared two sub-strategies regarding the appointment system.

First, the researcher created the strategy in which patients came to obtain the service with the exponential distribution. In other words, patients came to the department like in the present system, but this strategy changed the number of patients in a period. This strategy is called “schedule system”. More simply, a name of this strategy is assigned to “SS”, it stands for a word “schedule system”.

Second, the other strategy fixed different appointment times for different patients. As a consequence, the department appointed any individual patient at a specific time. This strategy is called “constant system”. A name of this strategy is assigned to “CS” that stands for a word “constant system”.

The researcher specified time interval of 12 minutes to any individual patient for both the morning and afternoon sessions. Twelve minutes or five patients / hours / physician are currently the average service time that the department is using. Consequently, there are two sub-strategies in Tables 4.23 and 4.24. The numbers of patients who leave from the system in the morning session are different from the afternoon session because the number of physicians and the number of patients who come to obtain the service are dissimilar. For example, the researcher specified 12 minutes to an individual patient so there are five patients per hour per physician. The schedule system (SS) appointed five patients at 9 AM., 10 AM., and 11 AM. in the morning session as shown in Figure 4.72. The constant system (CS) also appointed five patients, but the department fixed five different times for five individual patients. As seen in Figure 4.72, a patient is appointed at 9 AM, 9.12 AM, 9.24 AM, 9.36 AM, 9.48 AM, 10 AM, 10.12 AM, 10.24 AM, 10.36 AM, 10.48 AM, 11 AM, 11.12 AM, 11.24 AM, 11.36 AM, and 11.48 AM.

Table 4.23 Description of strategy 3 for the morning session

Sub-strategy	Number of hourly patients
SSM	180
CSM	180

Table 4.24 Description of strategy 3 for the afternoon session

Sub-strategy	Number of hourly patients
SSA	60
CSA	60

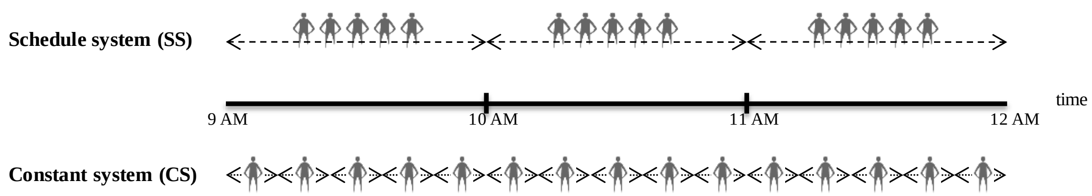


Figure 4.72 Comparison between the sub-strategy SSM and CSM

4.8 Exploring the three improvement strategies

4.8.1 Exploring strategy 1: increase the number of physicians

Having tested this strategy with the final simulation model, the researcher obtained results as shown in Tables 4.25 and 4.26. In the morning session, although the department tried to add more physicians in the system, the total process time and the total waiting time of the proposed sub-strategies are still persistent. The process time of the individual process was not different from the present system. The waiting time of the diagnosis process decreased when the number of physicians increased. On the other hand, the waiting time of the make appointment process increased. For the payment and pharmacy process, the waiting time in the sub-strategies was larger than the waiting time at present.

In the afternoon session, the total process time was like the present in every sub-strategy while the total waiting time decreased. The researcher found the waiting time of check weight and height process was not different from that in the present, but the waiting time of the diagnosis process significantly decreased. If the only one physician added to the system, the waiting time of the diagnosis process dropped about 14 minutes. Despite the decrease of the waiting time in the diagnosis process, the waiting time of the three following processes increased. Especially, for the waiting time of pharmacy process, it increased twice as much. In conclusion, increasing the number of physicians does decrease the total time in the system.

Table 4.25 Simulation results of strategy 1 (increasing number of physicians) for the morning session

Sub-strategy	Process time (minute)						Waiting time (minute)						Total time in the system
	Check weight and height	Diagnosis	Make appointment	Payment	Pharmacy	Total	Check weight and height	Diagnosis	Make appointment	Payment	Pharmacy	Total	
present	0.5584	9.2891	2.4209	0.8163	3.2953	16.3800	5.0010	52.7472	20.4024	4.1171	2.0796	84.3473	100.7273
IM-1	0.5578	9.2904	2.4207	0.8152	3.3003	16.3844	5.0110	50.6395	22.5006	4.1250	2.1934	84.4695	100.8539
IM-2	0.5578	9.2904	2.4207	0.8152	3.3003	16.3844	5.0110	50.6395	22.5006	4.1250	2.1934	84.4695	100.8539
IM-3	0.5578	9.2946	2.4199	0.8151	3.3005	16.3879	5.0075	48.6567	24.6118	4.1631	2.2047	84.6438	101.0317
IM-4	0.5578	9.2946	2.4199	0.8151	3.3005	16.3879	5.0075	48.6567	24.6118	4.1631	2.2047	84.6438	101.0317

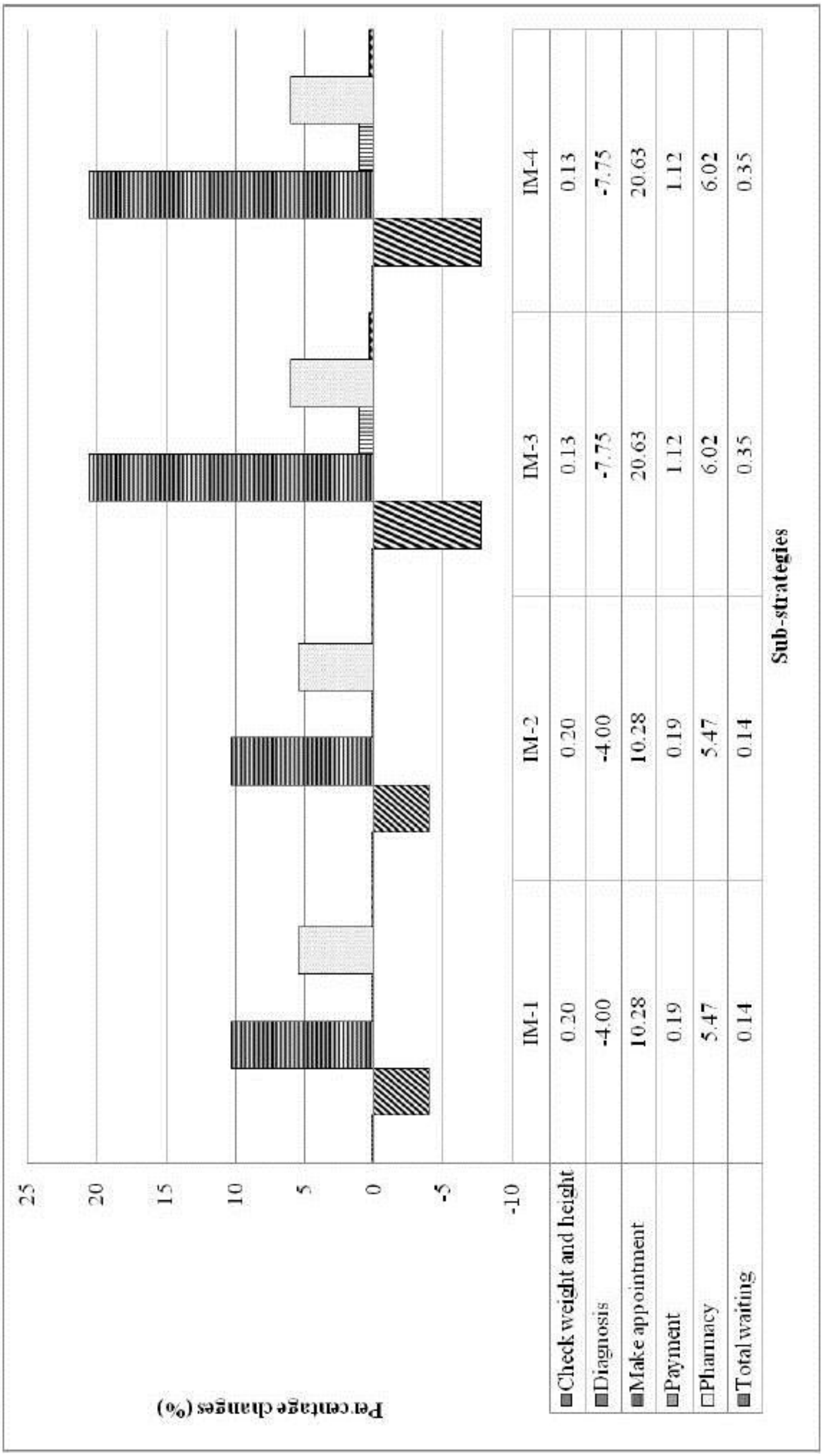
Table 4.26 Simulation results of strategy 1 (increasing number of physicians) for the afternoon session

Sub-strategy	Process time (minute)						Waiting time (minute)						Total time in the system
	Check weight and height	Diagnosis	Make appointment	Payment	Pharmacy	Total	Check weight and height	Diagnosis	Make appointment	Payment	Pharmacy	Total	
present	0.5656	9.0007	2.7835	0.7426	5.5015	18.5939	0.3124	61.9338	0.1451	0.2028	1.4653	64.0594	82.6533
IA-1	0.5656	9.0037	2.7846	0.7406	5.5059	18.6004	0.3103	47.8932	0.2802	0.2507	4.4568	53.1912	71.7916
IA-2	0.5656	9.0037	2.7846	0.7406	5.5059	18.6004	0.3103	47.8932	0.2802	0.2507	4.4568	53.1912	71.7916

Figures 4.73 and 4.74 show percentage changes in the waiting time. The negative numbers indicate that the waiting time decreased while the positive numbers indicate that the waiting time increased. Figure 4.73 depicts that the waiting time of make appointment process in the morning session increased when the number of physicians increased. Conversely, the waiting time of the diagnosis process gradually decreased. If the administrators want to decrease the waiting time particularly in the diagnosis process, they can increase the number of physicians as many as they want. However, the present system performs better than this strategy because its total waiting time is shorter.

Figure 4.74 shows percentage changes in the waiting time in the afternoon session. The check weight and height and diagnosis process are the processes in which the waiting time will decrease when more physicians are added to the system. In contrast, the waiting time of other processes increase. Especially, the waiting time of pharmacy process sharply increased more than 200%. Although there are two processes in this strategy that can decrease its waiting time, the total waiting time is less than that in the present. Therefore, the department should add the physician to the afternoon session of the system.

As a result, the analysis showed that this strategy is not so effective. It also illustrated that increasing the number of physicians in the diagnosis process may not be a solution to the problem. The total waiting time and total time in the system which patients must spend did not decrease. Even though the total waiting time of the afternoon session was less than the present one, it may be not worthwhile to add more physicians to the system. In addition, it can be said that the waiting time is carried over to the next process. Thus, the strategy did not satisfy the department, so the researcher considered the next strategy.



	IM-1	IM-2	IM-3	IM-4
Check weight and height	0.20	0.20	0.13	0.13
Diagnosis	-4.00	-4.00	-7.75	-7.75
Make appointment	10.28	10.28	20.63	20.63
Payment	0.19	0.19	1.12	1.12
Pharmacy	5.47	5.47	6.02	6.02
Total waiting	0.14	0.14	0.35	0.35

Figure 4.73 Percentage changes in waiting time by strategy 1 for the morning session

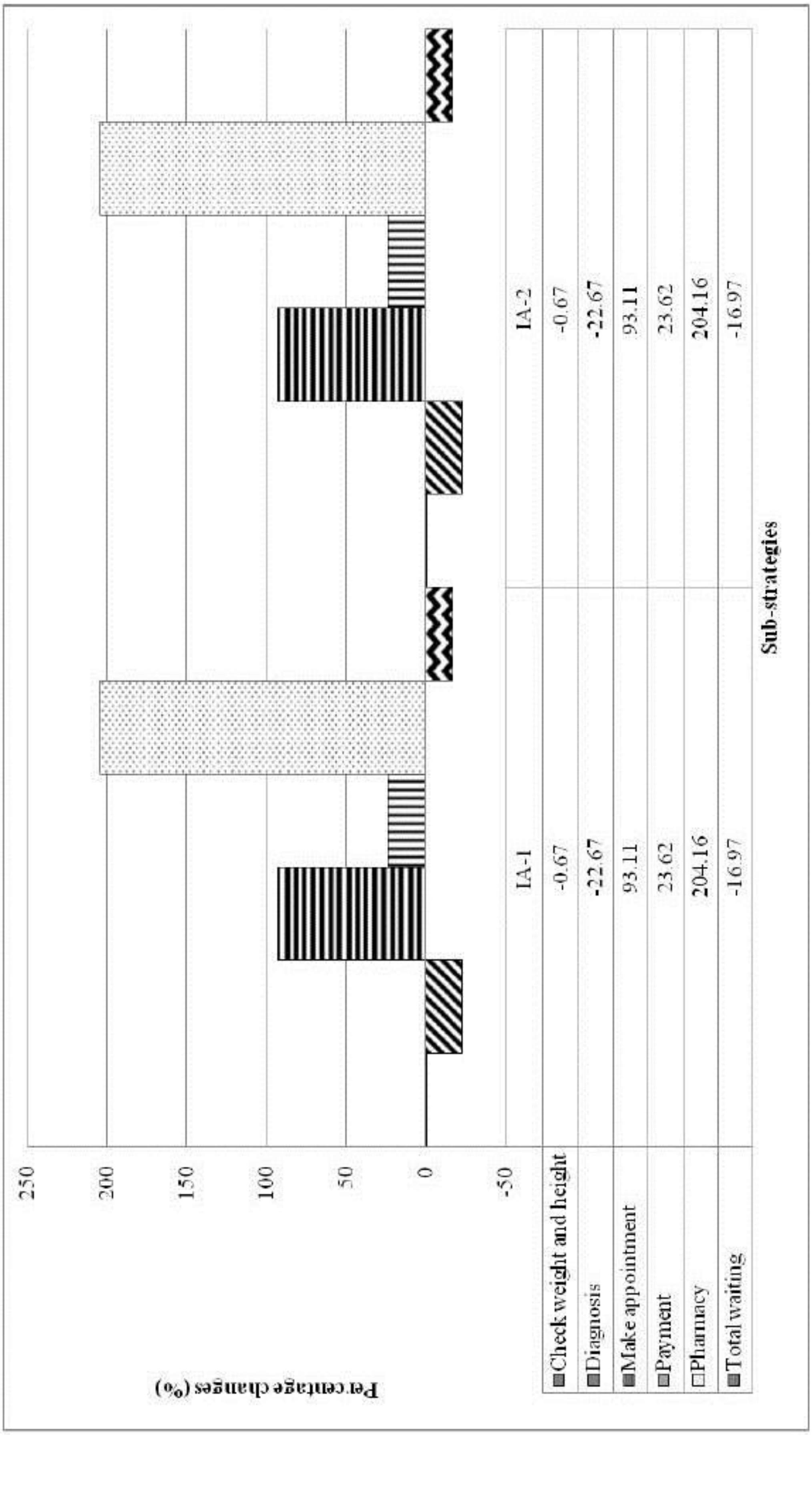


Figure 4.74 Percentage changes in waiting time by strategy 1 for the afternoon session

4.8.2 Exploring strategy 2: staggering of physicians' working hours

Tables 4.27 and 4.28 show the simulation results of this strategy for morning and afternoon sessions, respectively. In the morning session, the total process time and the individual process time are not different from the present system. The waiting time of check weight and height process is not different from the present one, but the waiting time of the diagnosis and make appointment processes decreased gradually when there were more physicians who staggered their working hours. In contrast, the waiting time of the payment and pharmacy processes increased. When there were between one and three physicians staggering the working hours, the total waiting time gradually decreased. On the other hand, when there are four physicians staggering their working hours, the total waiting time decreased only little, as shown in sub-strategy SM-4 in Table 4.27.

For the afternoon session, the result was almost identical to the morning session. The total process time and the individual process time were not different from the present system. The waiting time of check weight and height process was not different from the present one. The waiting times of diagnosis and make appointment processes decreased, but the waiting time of the payment and pharmacy processes increased. However, the total waiting time decreased when there were more physicians who staggered their working hours.

Table 4.27 Simulation results of strategy 2 (staggering of physicians' working hours) for the morning session

Sub-strategy	Process time (minute)						Waiting time (minute)						Total time in the system
	Check weight and height	Diagnosis	Make appointment	Payment	Pharmacy	Total	Check weight and height	Diagnosis	Make appointment	Payment	Pharmacy	Total	
present	0.5584	9.2891	2.4209	0.8163	3.2953	16.3800	5.0010	52.7472	20.4024	4.1171	2.0796	84.3473	100.7273
SM-1	0.5576	9.2971	2.4163	0.8166	3.2999	16.3875	4.9899	49.1983	18.3304	4.7892	2.0925	79.4003	95.7878
SM-2	0.5579	9.2960	2.4180	0.8145	3.3038	16.3902	5.0030	45.9245	16.4751	7.0553	2.5257	76.9836	93.3738
SM-3	0.5577	9.2762	2.4227	0.8153	3.3031	16.3750	4.9947	42.5088	14.8577	11.5748	2.6581	76.5941	92.9691
SM-4	0.5585	9.2800	2.4197	0.8146	3.3040	16.3768	4.9913	39.3304	13.1582	16.5485	2.8802	76.9086	93.2854

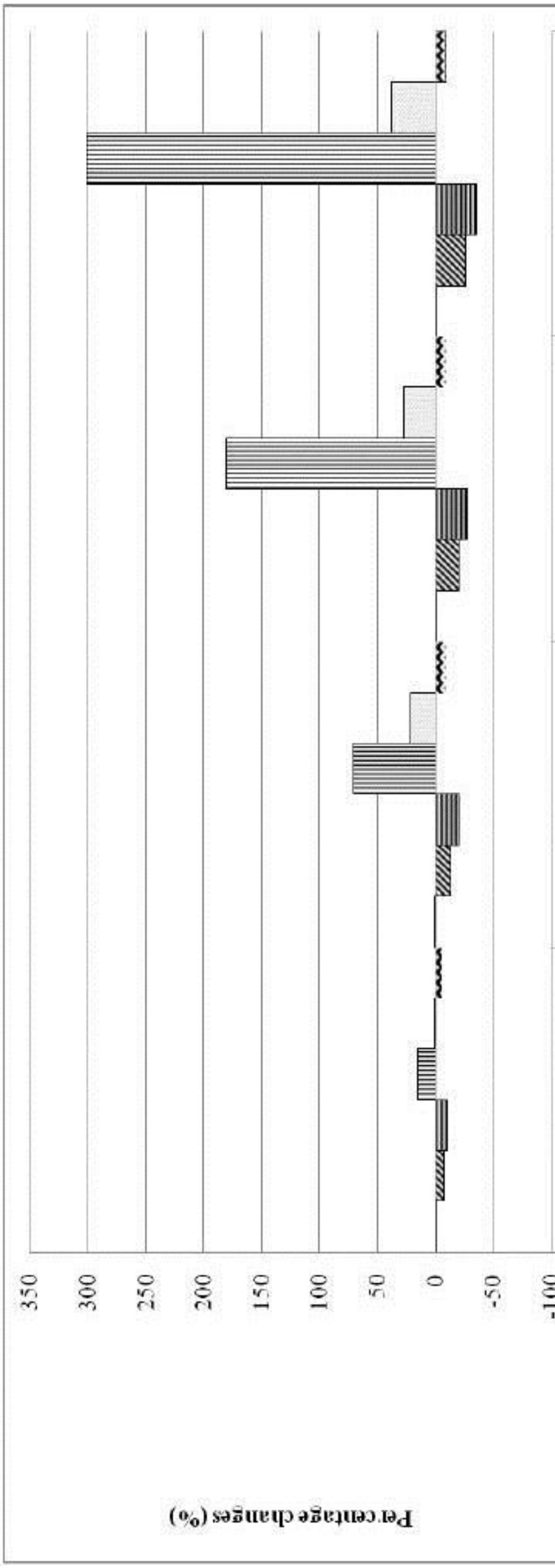
Table 4.28 Simulation results of strategy 2 (staggering of physicians' working hours) for the afternoon session

Sub-strategy	Process time (minute)						Waiting time (minute)						Total time in the system
	Check weight and height	Diagnosis	Make appointment	Payment	Phamacy	Total	Check weight and height	Diagnosis	Make appointment	Payment	Phamacy	Total	
present	0.5656	9.0007	2.7835	0.7426	5.5015	18.5939	0.3124	61.9338	0.1451	0.2028	1.4653	64.0594	82.6533
SA-1	0.5665	8.9908	2.7800	0.7423	5.5146	18.5942	0.3105	52.8292	0.1397	1.1186	1.4807	55.8787	74.4729
SA-2	0.5672	8.9925	2.7823	0.7399	5.5137	18.5956	0.3129	44.4378	0.1295	2.1519	2.3151	49.3472	67.9428

The percentage changes in the waiting time of strategy 2 for the morning and afternoon sessions are shown in Figures 4.75 and 4.76, respectively. The negative numbers indicate that the waiting time decreased whereas the positive numbers indicate that the waiting time increased. Figure 4.75 shows the waiting time of the payment process in the morning session dramatically increased while the waiting time of the diagnosis and the make appointment processes gradually decreased. However, the total waiting time decreased. In order to decrease the total waiting time of the system, the department should stagger working hours of three physicians as in sub-strategy SM-3.

Figure 4.76 shows percentage changes in the waiting time of the afternoon session. It reveals that the waiting time of the payment process significantly increased. When more physicians staggered their working hours, the waiting time of the diagnosis and the make appointment processes gradually decreased. Similarly, the total waiting time of the system also gradually decreased. Therefore, the department should stagger working hours of two physicians in this session.

The simulation outputs revealed that this strategy may help decrease the total waiting time and the total time in the system. This is based on the assumption that patients usually come to see physicians before the current working time (9 AM), so staggering physicians' working hours may help to spread the number of patients over a longer period of time. Therefore, this strategy is a better option than strategy 1 to improve the system efficiency.



	SM-1	SM-2	SM-3	SM-4
Check weight and height	-0.22	0.04	-0.13	-0.19
Diagnosis	-6.73	-12.93	-19.41	-25.44
Make appointment	-10.16	-19.25	-27.18	-35.51
Payment	16.32	71.37	181.14	301.95
Pharmacy	0.62	21.45	27.82	38.50
Total waiting	-5.87	-8.73	-9.19	-8.82

Figure 4.75 Percentage changes in waiting time by strategy 2 for the morning session

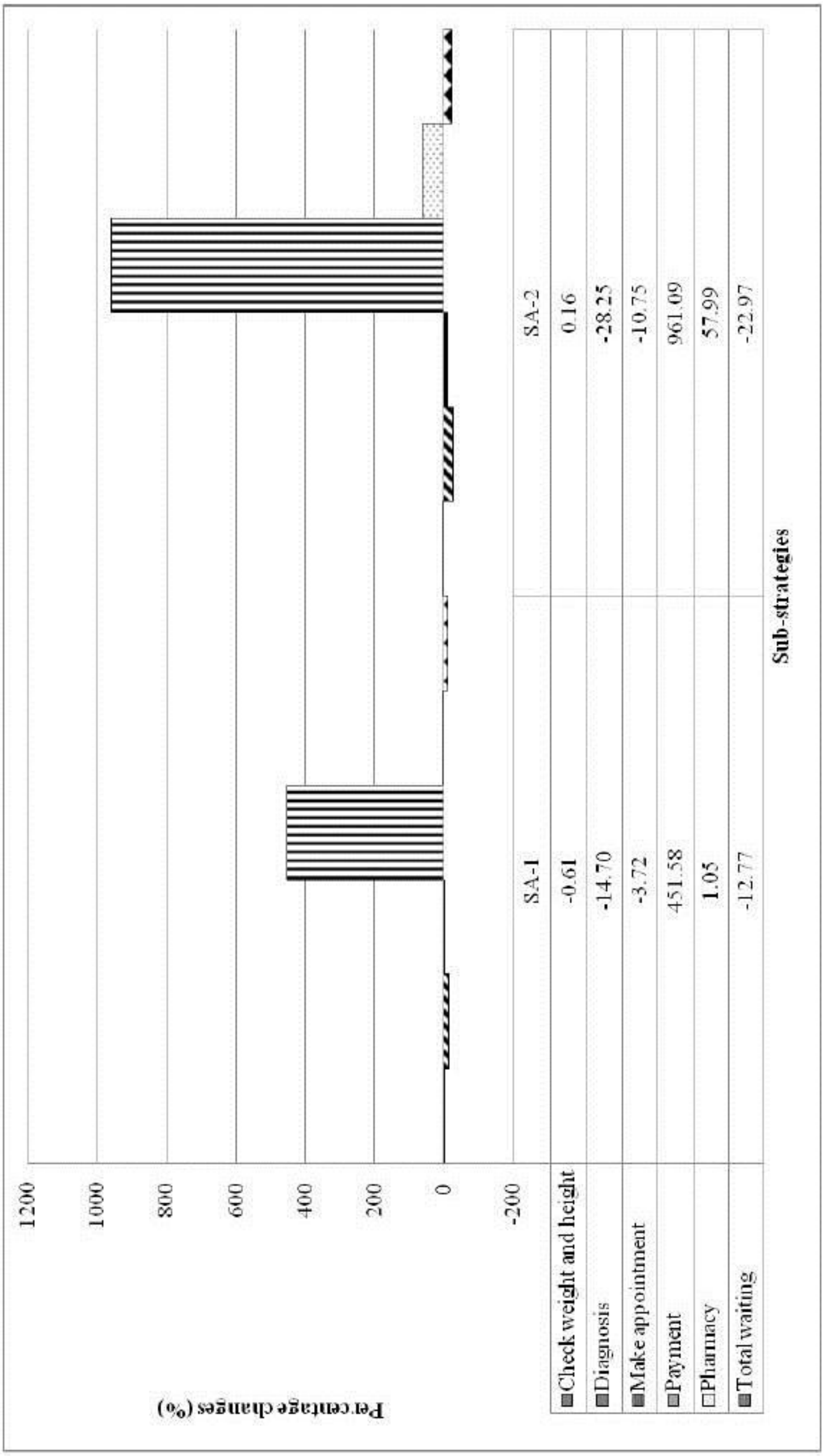


Figure 4.76 Percentage changes in waiting time by strategy 2 for the afternoon session

4.8.3 Exploring strategy 3: improve the patient appointment system

The simulation results of strategy 3 in the morning and afternoon sessions are shown in Tables 4.29 and 4.30, respectively. The total process time and the individual process time of the morning session are not different from the present system. In the schedule system, the waiting time of check weight and height and make appointment processes increased sharply. On the other hand, the waiting time of the diagnosis process decreased dramatically. However, the total waiting time of the schedule system significantly increased. Likewise, the characteristic of output in the constant system is quite similar to the schedule system, but the waiting time of the check weight and height and diagnosis processes are longer than the schedule system. Certainly, the total waiting time of the constant system is also longer than the schedule system.

For the afternoon session, the total process time and the individual process time are quite similar to the present system. For the schedule system, the waiting time of all process increased. Especially, the waiting time of the diagnosis process that is decreased almost 50% from the present. Therefore, the total waiting time of the schedule system significantly decreased. In the constant system, the waiting time of the check weight and height process dramatically increased when the waiting times of the four following processes decreased. For this reason, the total waiting time of the constant system is longer than the present system.

Table 4.29 Simulation results of strategy 3 (improve the patient appointment system) for the morning session

Sub-strategy	Process time (minute)						Waiting time (minute)						Total time in the system
	Check weight and height	Diagnosis	Make appointment	Payment	Pharmacy	Total	Check weight and height	Diagnosis	Make appointment	Payment	Pharmacy	Total	
present	0.5584	9.2891	2.4209	0.8163	3.2953	16.3800	5.0010	52.7472	20.4024	4.1171	2.0796	84.3473	100.7273
SSM	0.5580	9.2955	2.4192	0.8161	3.2994	16.3882	31.4655	17.2606	47.6773	6.7616	2.9430	106.1080	122.4962
CSM	0.5586	9.2851	2.4201	0.8155	3.2994	16.3787	60.3743	28.4755	47.7947	6.6793	2.9258	146.2496	162.6283

Table 4.30 Simulation results of strategy 3 (improve the patient appointment system) for the afternoon session

Sub-strategy	Process time (minute)						Waiting time (minute)						Total time in the system
	Check weight and height	Diagnosis	Make appointment	Payment	Pharmacy	Total	Check weight and height	Diagnosis	Make appointment	Payment	Pharmacy	Total	
present	0.5656	9.0007	2.7835	0.7426	5.5015	18.5939	0.3124	61.9338	0.1451	0.2028	1.4653	64.0594	82.6533
SSA	0.5653	9.0015	2.7852	0.7411	5.5007	18.5938	0.2741	31.1438	0.1437	0.1957	1.3512	33.1085	51.7023
CSA	0.5652	9.0090	2.7764	0.7403	5.5096	18.6005	13.275	56.1291	0.1403	0.1948	1.3455	71.0847	89.6852

Figures 4.77 and 4.78 show the percentage changes in the waiting time of strategy 3 in the morning and afternoon sessions, respectively. The negative numbers indicate that the waiting time decreased whereas the positive numbers indicate that the waiting time increased. For the morning session, the percentage changes of the check weight and height process for both of the schedule and constant systems increased sharply. Therefore, the percentage changes of the total waiting time in the two sub-strategies are increased. Nevertheless, the percentage change of the total waiting time of the schedule system is increased less than the constant system.

For the afternoon session, the schedule system can help decrease the waiting time in every process as the percentage changes are shown as the negative numbers in Figure 4.78. On the other hand, the constant system cannot decrease the waiting time of every process. Especially, the waiting time of check weight and height process is dramatically increased.

The simulation results revealed that the schedule system is more effective than the constant system. It can decrease the individual waiting time and the total waiting time in the system. This may indicate that if patients arrive at the department by an exponential pattern, patients will waste less time waiting than in the constant arrival pattern. Therefore, the department should keep using the present appointment system (schedule system) in their outpatient service.

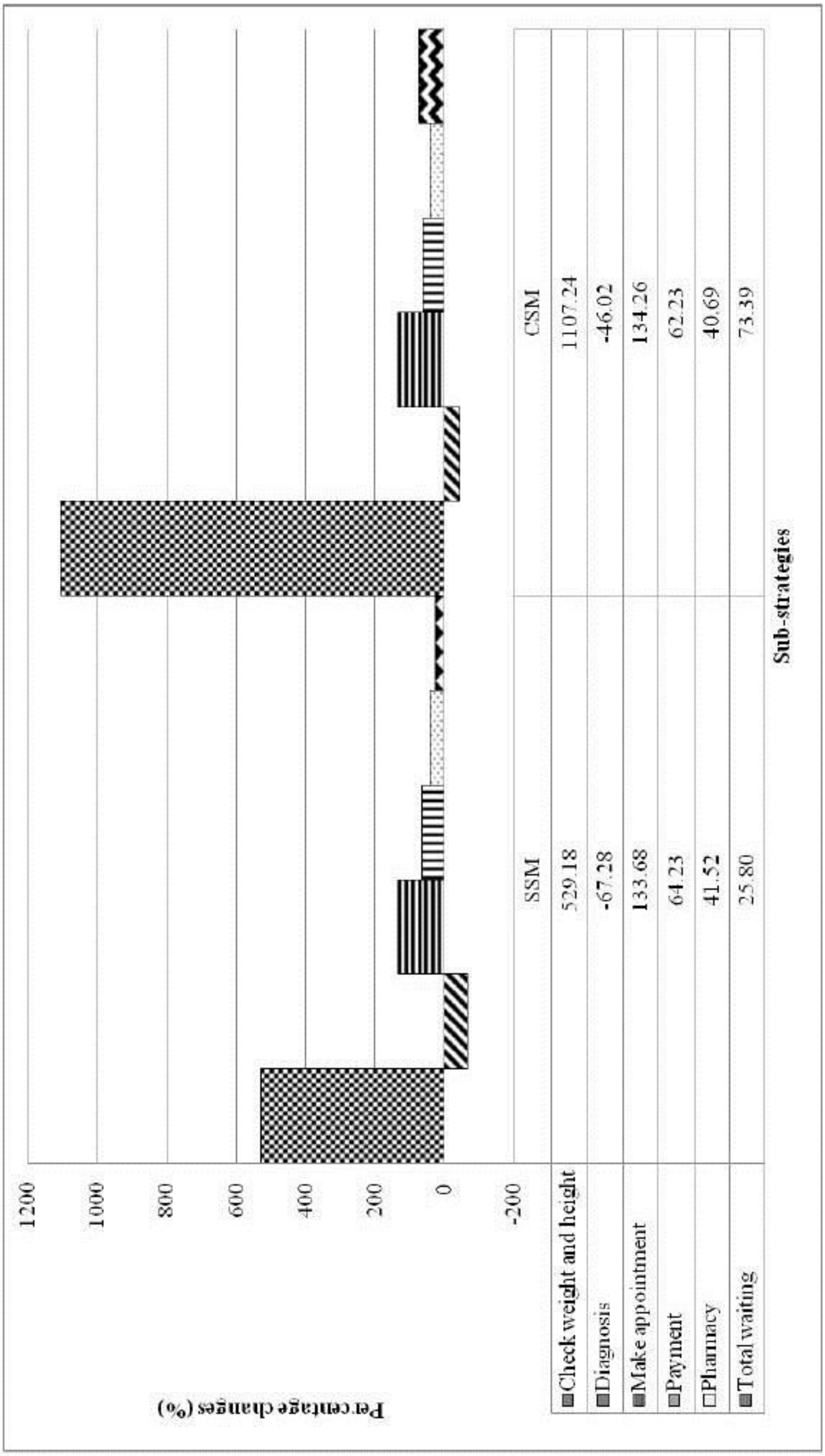


Figure 4.77 Percentage changes in waiting time by strategy 3 for the morning session

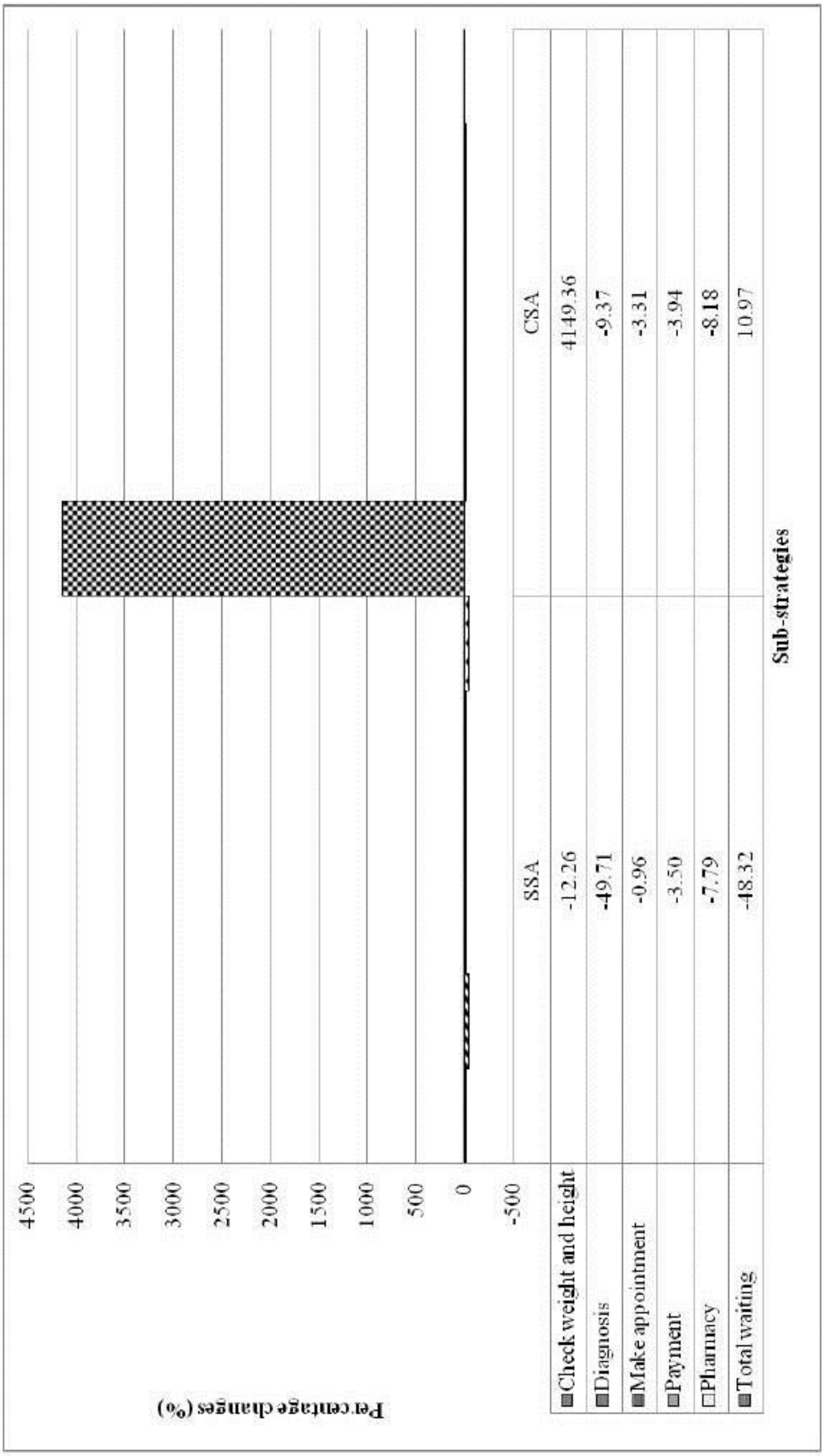
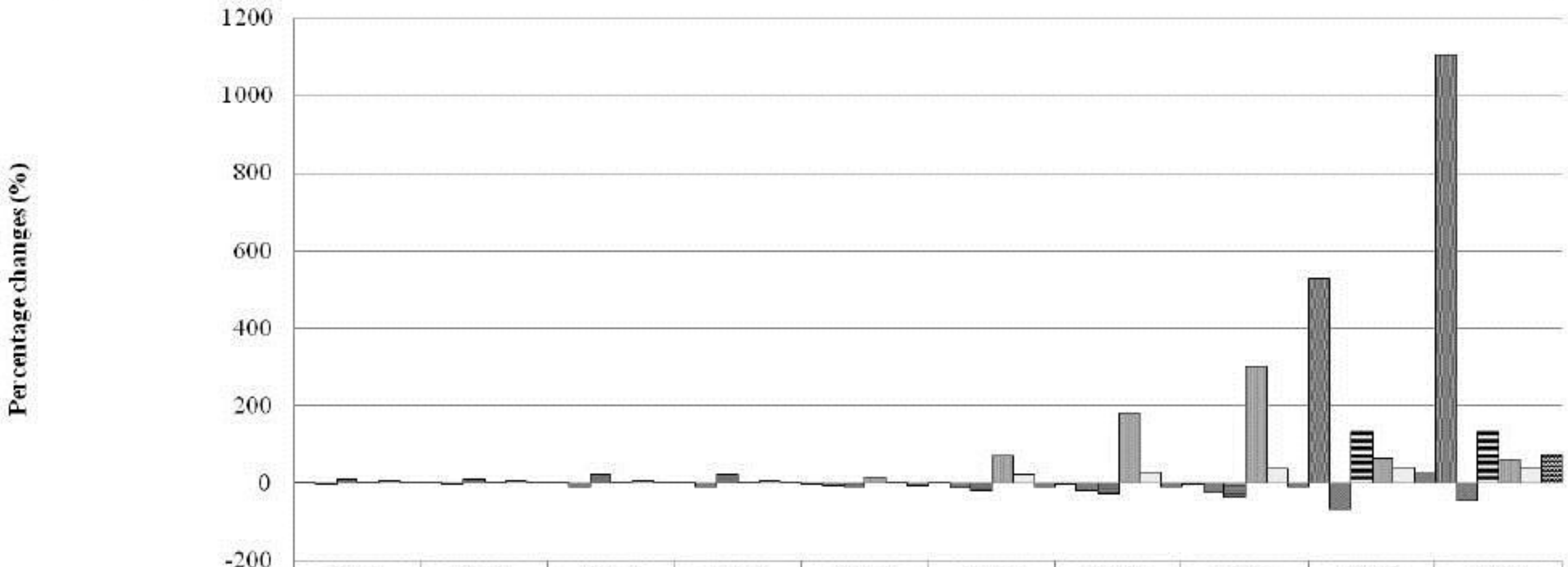


Figure 4.78 Percentage changes in waiting time by strategy 3 for the afternoon session

4.9 Strategy comparison

In order to identify the sub-strategies that could better decrease the waiting time in each strategy, the researcher compared their effectiveness in Figures 4.79 and 4.80. Table 4.31 shows the percentage changes in KPIs, which are the total waiting time and the total time in the system for the morning session. As described earlier, sub-strategy SM-3 is the best strategy for improving the outpatient flow in the morning session. It helps to decrease the total waiting time and the total time in the system more significantly than the other two sub-strategies. Meanwhile, the number out is the same as in the present system. In contrast, the number out of the sub-strategy SSM is 433 patients that are more than in the present system. Even though, there are more patients come out of the system, the total waiting time and the total time in the system are not decreased. Therefore, the strategy which should be implemented in the morning session is the staggering of physicians' working hours. The simulation results indicate that sub-strategy SM-3 may decrease the total waiting time and total time in the system by 9.19, and 7.70 percent respectively. Because of this, three physicians should change their working hours from 9.00 – 12.00 AM to be 8.00 – 11.00 AM.



	IM-1	IM-2	IM-3	IM-4	SM-1	SM-2	SM-3	SM-4	SSM	CSM
Check weight and height	0.20	0.20	0.13	0.13	-0.22	0.04	-0.13	-0.19	529.18	1107.24
Diagnosis	-4.00	-4.00	-7.75	-7.75	-6.73	-12.93	-19.41	-25.44	-67.28	-46.02
Make appointment	10.28	10.28	20.63	20.63	-10.16	-19.25	-27.18	-35.51	133.68	134.26
Payment	0.19	0.19	1.12	1.12	16.32	71.37	181.14	301.95	64.23	62.23
Pharmacy	5.47	5.47	6.02	6.02	0.62	21.45	27.82	38.50	41.52	40.69
Total waiting	0.14	0.14	0.35	0.35	-5.87	-8.73	-9.19	-8.82	25.80	73.39

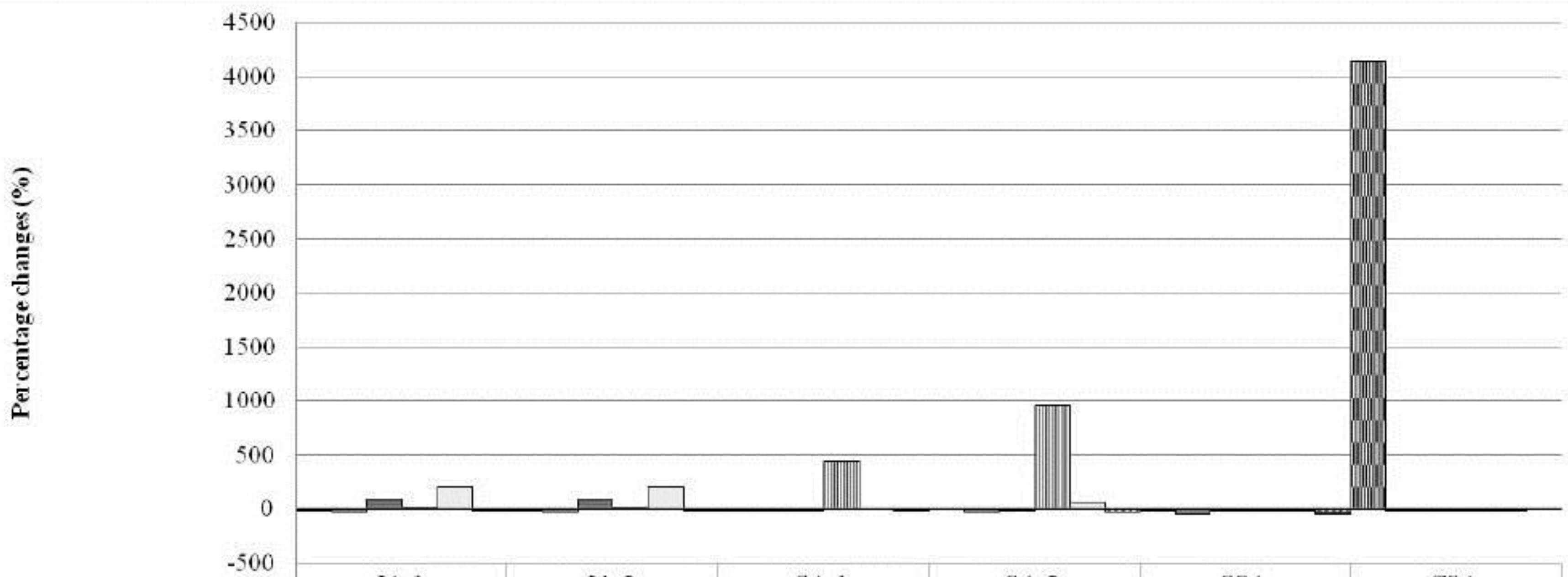
Sub-strategies

Figure 4.79 Percentage changes in waiting time for the morning session

Table 4.31 Comparison of percentage changes in KPIs among the best in each sub-strategies for the morning session

Sub-strategy	Percentage changes (%)		Number out
	Total waiting time	Total time in the system	
IM-1	0.14	0.13	206
SM-3	-9.19	-7.70	206
SSM	25.80	21.61	433

The percentage changes in KPIs of the afternoon session are shown in Table 4.32. Sub-strategy SSA is the sub-strategy which could decrease more waiting time than the other sub-strategies, but it has the least number out. Because of this, sub-strategy SA-2 may be the best strategy of the afternoon session. The output indicates that it may decrease the total waiting time and total time in the system by 22.97 and 17.80 percent, respectively. Meanwhile, the number out is the same as in the present system, so the sub-strategy is suitable for improving the system. For these reasons, the department should implement the sub-strategy SA-2 to improve the outpatient service in the afternoon session. Two physicians should change their working hours from 1.00 – 3.00 PM to be 12.00 – 2.00 PM.



	IA-1	IA-2	SA-1	SA-2	SSA	CSA
Check weight and height	-0.67	-0.67	-0.61	0.16	-12.26	4149.36
Diagnosis	-22.67	-22.67	-14.70	-28.25	-49.71	-9.37
Make appointment	93.11	93.11	-3.72	-10.75	-0.96	-3.31
Payment	23.62	23.62	451.58	961.09	-3.50	-3.94
Pharmacy	204.16	204.16	1.05	57.99	-7.79	-8.18
Total waiting	-16.97	-16.97	-12.77	-22.97	-48.32	10.97

Sub-strategies

Figure 4.80 Percentage changes in waiting time for the afternoon session

Table 4.32 Comparison of percentage changes in KPIs among the best in each sub-strategies for the afternoon session

Sub-strategy	Percentage changes (%)		Number out
	Total waiting time	Total time in the system	
IA-1	-16.97	-13.14	151
SA-2	-22.97	-17.80	150
SSA	-48.32	-37.45	96

As a result, the department implements the same strategy in both of the morning and afternoon sessions. It is uncomplicated to manage the department by using the same proposed strategy. Therefore, the researcher considered to implement the sub-strategy SM-3 to improve the outpatient service in the morning session. The output of this sub-strategy indicates that it may decrease the total waiting time and total time in the system by 9.19 and 7.70 percent, respectively. From the result, three physicians should change their working hours from 9.00 – 12.00 AM to 8.00 – 11.00 AM. As described earlier, the sub-strategy SA-2 is the best strategy in the afternoon session. It may decrease the total waiting time and total time in the system by 22.97 and 17.80 percent, respectively. Two physicians should change their working hours from 1.00 – 3.00 PM to be 12.00 – 2.00 PM.

4.10 Summary

This chapter reveals the details of the case study. The outpatient flow of the pediatrics department starts when patients show an appointment card or register at the registration counter and ends when they leave from the department after they receive medicine at the pharmacy. Besides, if the physician orders the patient to have the x-ray or blood testing, the patient will go to the diagnostic radiology or the OPD lab, respectively. From the data collection, the result shows that the patients always spend a lot of time for waiting. The waiting times are approximately 80.45 and 76.20 percent of the total time in the patient flow for the morning and afternoon sessions, respectively. The waiting time is non value-added which creates dissatisfaction in the service. Therefore, the patient flow is modeled and simulated by the discrete event simulation. The strategies are created to improve the outpatient service. There are three strategies which are 1) increasing the number of physicians 2) staggering of physicians' working hours and 3) improving the patient appointment system.

Based on the simulation results, the strategy of increasing number of physicians may not solve the problem in the morning session. The total waiting time and the total time in the system could not be decreased. Even though the total waiting time and the total time in the system of the afternoon session is less than that in the present, it may not be worthwhile to add more physicians to the system. In addition, it can be said that the waiting time is carried over to the next process.

On the contrary, the strategy of staggering physicians' working hours may decrease the total waiting time and total time in the system. This is based on the observation that patients usually come to see physicians before the working time, so staggering physicians' working hours may help to spread the number of patients over a longer period of time. This should reduce the congestion naturally. Therefore, this strategy is a better choice for decreasing the waiting time in the system.

Last, the strategy of improving patient appointment system revealed that the schedule system is better than the constant system. It can decrease the individual waiting time and total waiting time in the system. Most importantly, the number of patients should not be higher than the capacity of resources otherwise it will be overcrowded.

In conclusion, the strategy which can decrease the waiting time in both the morning and afternoon sessions is the staggering of physicians' working hours. For the morning session, three physicians should change their working hours from 9.00 – 12.00 AM to be 8.00 – 11.00 AM. For the afternoon session, two physicians should change their working hours from 1.00 – 3.00 PM to be 12.00 – 2.00 PM. In the next chapter, the researcher will conclude the research as well as provide suggestions and recommendations for the future research.

CHAPTER V
CONCLUSION

In Chapter 4, the researcher explained the characteristics of the case study. Then, the researcher analyzed the hospital's service system by using the simulation modeling and created three strategies for improving the patient flow. Afterward, the researcher reported the results and discussion of the strategies. Above all, the two main objectives of the research are reached. First, the researcher studied and understood the characteristics of the service and patient flow of outpatient in the pediatrics department of the studied hospital. Second, the researcher analyzed the problem and suggested possible strategies to increase the efficiency of the service. In this last chapter, the research is concluded.

5.1 Characteristics of the service and patient flow of the pediatrics department in the case study hospital

The pediatrics department is one of many departments in Ramathibodi Hospital. This department has its own payment and pharmacy rooms in the front of the department. In other words, this department provides the so-called "one – stop service". There are five stations (or processes) where a patient comes to obtain the medical service. First, the patient's weight and height is measured at the counter inside the department. Then the patient waits to see a physician. If the proceeding patient finishes the diagnosis process early, he/she is called to see the physician in an examination room. Next, the patient is diagnosed by the physician. Afterwards, the patient brings the medical record to the medical record counter, and receives an appointment card or a prescription/payment bill/counsel. Then the patient brings the prescription to the pharmacy room and makes a payment at the cashier's room. Finally, the patient receives medicine at the pharmacy room. Besides, if the physician orders the patient to get an x-ray or a blood test, the patient will go to the diagnostic radiology or the OPD lab respectively.

The department is located on the second floor of Building 1. It opens to provide medical services in two periods which are;

1) Morning session: 9.00 - 12.00 AM
2) Afternoon session: 1.00 - 3.00 PM

Visiting patients at the department are divided into three main groups; i.e., emergency patients, appointment patients, and walk in patients. The researcher found that these three types of patients may also obtain services at other departments. For examples, patients may have to go to the OPD lab for the blood test, or diagnostic radiology for an x-ray. Patients who obtain services at other departments may not have to come back to the pediatrics department if they do not need to see the physician again or are scheduled to see at another time.

5.2 Problems and possible solutions to increase the efficiency of the service

An observation is a methodology which is used to identify the problem of this department. The waiting time is approximately 80.45 percent of the total time in the patient flow in the morning session. Similarly, patients spend approximately 76.20 percent of the total time waiting in the afternoon session. The waiting time is non value-added which provokes dissatisfaction with the service. Especially, patients spend more than forty minutes in the diagnosis process which is the most important process in the system. Therefore, the administrators of the hospital need to improve the service in order to achieve an efficient operational system. The researcher imitated the behavior of the patient flow by using the simulation model and created strategies for improving the service of this department.

Table 5.1 summarizes three main strategies and their corresponding sub-strategies. For morning session, the first strategy is to increase the number of physicians which is subdivided into four sub-strategies, IM-1 to IM-4, varied by the number of additional physicians. The second strategy is staggering physicians' working hours, which consists of four sub-strategies, SM-1 to SM-4, varied by the number of physicians who change the working hours. The third strategy is the improvement of the patient appointment system which is subdivided into two sub-strategies, SSM and CSM. Sub-strategy SSM is for the schedule system such that the department appoints a group of patients during a time slot whereas sub-strategy CSM is the constant system such that the department appointed any individual patient at a specific time.

Table 5.1 Summary of the three improvement strategies and their corresponding sub-strategies

Strategy	Sub-strategy	
	Morning session	Afternoon session
Increasing the number of physicians	IM-1 to IM-4	IA-1 to IA-2
Staggering of physicians' working hours	SM-1 to SM-4	SA-1 to SA-2
Improve the patient appointment system	SSM and CSM	SSA and CSA

For afternoon session, the first strategy is to increase the number of physicians which is subdivided into two sub-strategies, IA-1 to IA-2, varied by the number of additional physicians. The second strategy is the staggering physicians' working hours, which consists of two sub-strategies, SA-1 to SA-2, varied by the number of physicians who change the working hours. The third strategy is the improvement of the patient appointment system which consists of two sub-strategies, SSA and CSA. Sub-strategy SSA is for the schedule system such that the department appoints a group of patients during a time slot whereas sub-strategy CSA is for the constant system such that the department appointed any individual patient at a specific time.

After the researcher tested the three strategies, the researcher identified the best result in each strategy for the morning and afternoon sessions, as shown in Table 5.2. Table 5.2 showed the percentage changes in KPIs, which are the total waiting time and total time in the system. As we can see, sub-strategy SM-3 is the most suitable for improving the outpatient flow in the morning session. It helps to decrease the total waiting time and total time in the system. For the afternoon session, sub-strategy SA-2 is the most suitable. The outputs indicate that it may decrease the total waiting time and total time in the system more than sub-strategy IA-3. Moreover, the number out is more than in sub-strategy SSA, and it is the same as in the present system. Therefore, the sub-strategy SA-2 is suitable for improving the system.

Table 5.2 Comparison of the percentage changes in KPIs of the best sub-strategy

Session	Sub-strategy	Percentage changes (%)		Number out
		Total waiting time	Total time in the system	
Morning	IM-1	0.14	0.13	206
	SM-3	-9.19	-7.70	206
	SSM	25.80	21.61	433
Afternoon	IA-1	-16.97	-13.14	151
	SA-2	-22.97	-17.80	150
	SSA	-48.32	-37.45	96

5.3 Suggestions and policy implication

5.3.1 Morning session

The research shows that the most suitable strategy for the morning session is the staggering working hours of three physicians. In effect, there will be three physicians changed their working hours from 9.00 – 12.00 AM to be 8.00 – 11.00 AM. Before using the strategy, the department needs to manage the working schedules of physicians. Moreover, the department should remind the physicians who must come to work an hour earlier in order to avoid the physicians’ confusion with their new working hours.

5.3.2 Afternoon session

The most suitable strategy for the afternoon session is the staggering working hours of two physicians. The new working hours of the two physicians is 12.00 – 2.00 PM instead of the present system during 1.00 – 3.00 PM. In the same way, the department will have to manage the working schedules of physicians before using the strategy, and should remind the physicians who must come to work an hour earlier in order to avoid the physicians' confusion with their new working hours.

5.4 Recommended future research

Overall, the patient flow is so complicated and has many details. Therefore, the patient flow analysis and improvement strategy must involve other related factors as much as possible in order to eliminate the unnecessary waiting time in the system. Then, the researcher recommends two subjects for future research.

1) The three existing strategies can be integrated into one new strategy. For instance, the second and the third strategies can be combined as a fourth strategy. For instance in the morning session, the department may use the schedule system in the appointment process along with staggering working hours of physicians in the system. The waiting time of this combination may be decreased more than using only one strategy.

2) Other important factors should be studied; for example, the payment system and the pharmacy system. Because the research focused on the diagnosis process, other factors were neglected. In addition, other factors are also important to the system. For this reason, other factors should be considered in the future research.

Future research can create other strategies and study other important factors in order for the hospital to efficiently provide service and meet patients' demand. Most importantly, it must be for patient's satisfaction and be beneficial to the hospital. From then on, the quality of service at public hospitals will be better.

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APPENDICES

APPENDIX A
PATIENT TRACKING FORM

The patient tracking form in Figure A.1 is an important hardware in this research. It was used to record the data about the outpatient service. A collector (researcher) collected data of patient who came to obtain the service throughout the flow although the patient went to other department. For example, when the patients finished the activities at the pediatrics department and had blood testing at the OPD Lab, the collector (researcher) also wrote process names, resources, and process time of both pediatrics department and the OPD Lab. As a result, the researcher can clearly understand the flow of patient along the service chain.

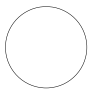
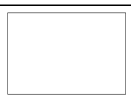
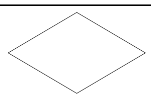
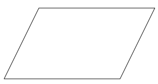
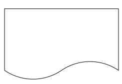
	ProcessName & Description	Resource (number of resource in each activity)													ProcessTime (min)	Special Trigger (Before starting this process)	
Process/ Activity ID	+ activity and scope of activity + document which use to continue the activity	Nurse Assistant (PN)	Nurse (RN)	Clerk	Doctor	Resident (1_2_3)	Officer	X-ray machine	CT scanner	Vital sign	Treatment Room			PatientType	+ DependsOn PatientType(P) + DependsOn Resource(R) + DependsOn ClockTime(T) + DependsOn TypeOfDisease(D) + DependsOn ClinicalProcedure(C)	mechanism which concern with a beginning of process such as waiting for a physician after register at registration counter	Note
Entity Flow Diagram (Patient)															ClinicalProcedure/ Queuing Discipline		patient's name/type

Figure A.1 Patient tracking form

APPENDIX B
FLOW OF PATIENT

Patients who come to obtain the healthcare service at the pediatrics department had activities like in a swim lane diagram in Figure B.1. Some types of patient might use resources of other department as seen in the first column of the swim lane diagram. The first column shows resources which work for activities in the second column. Moreover, there are many forms of module which use to draw the diagram as shown in Table B.1.

Table B.1 Module in swim lane diagram

Module	Description
	A representative of patients, and it is used to connect the flow between page to other page
	A process which patients and resources do in the hospital
	A decision point in the flow
	A process which use data for continue the flow
	A process which has documents

A beginning of every patient is at the first circle which has a word "Patient" in it. Patients obtain the service by following their own type. Finally, they finished their activity at the last circle which has a phrase "leave from hospital" in it. So the flow is completed when the patients leave from the system.

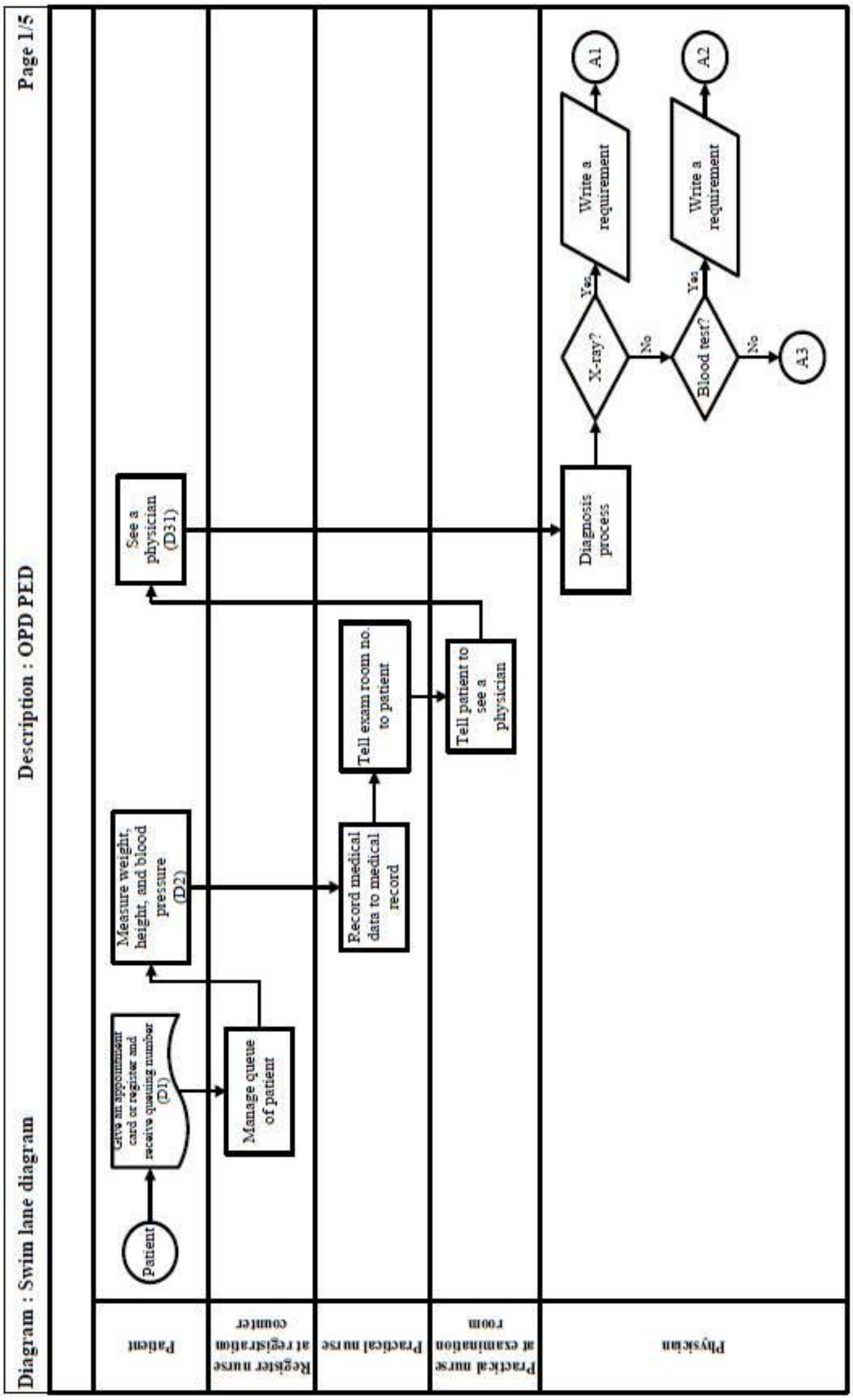


Figure B.1 Swim lane diagram of the patient flow

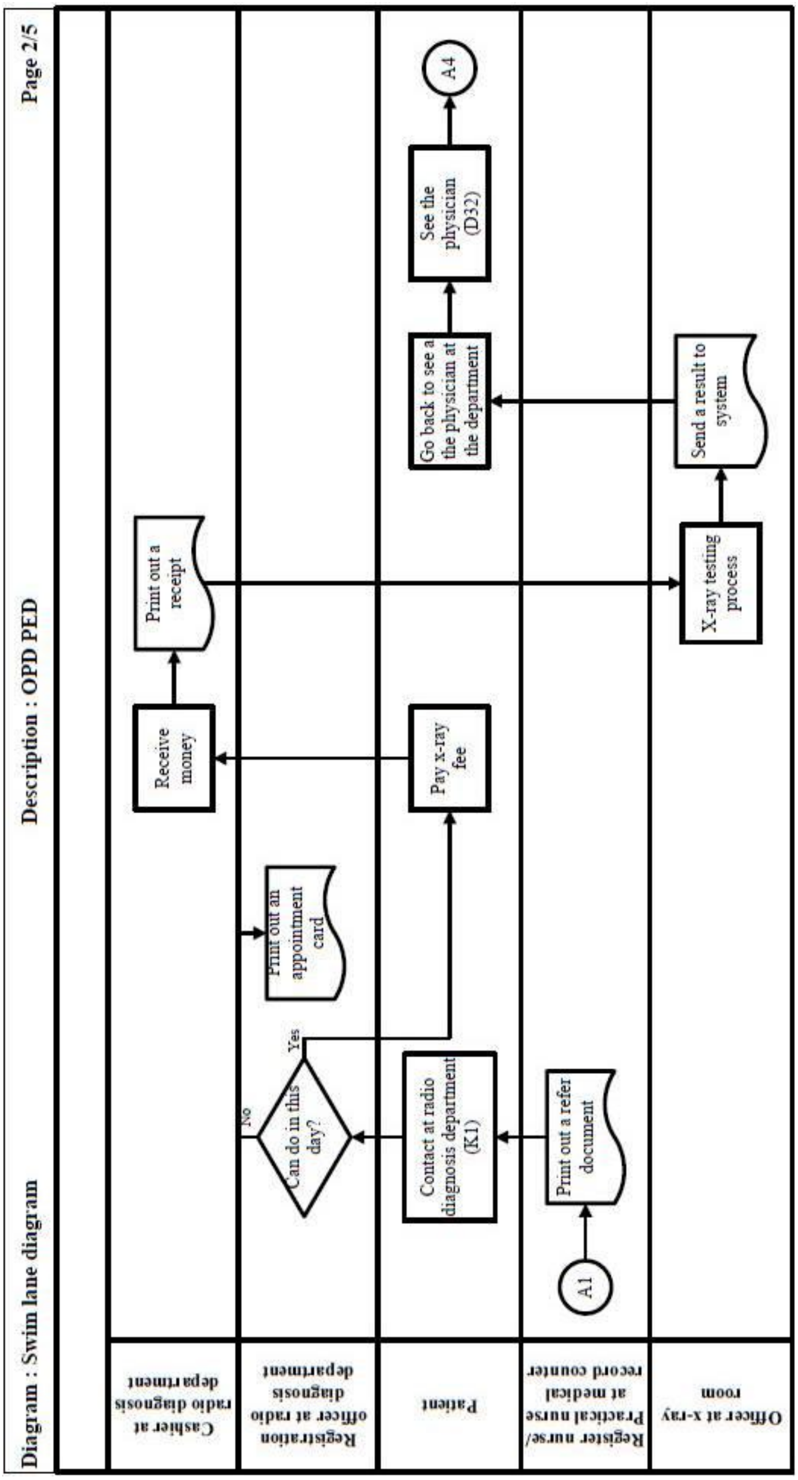


Figure B.1 Swim lane diagram of the patient flow (continued)

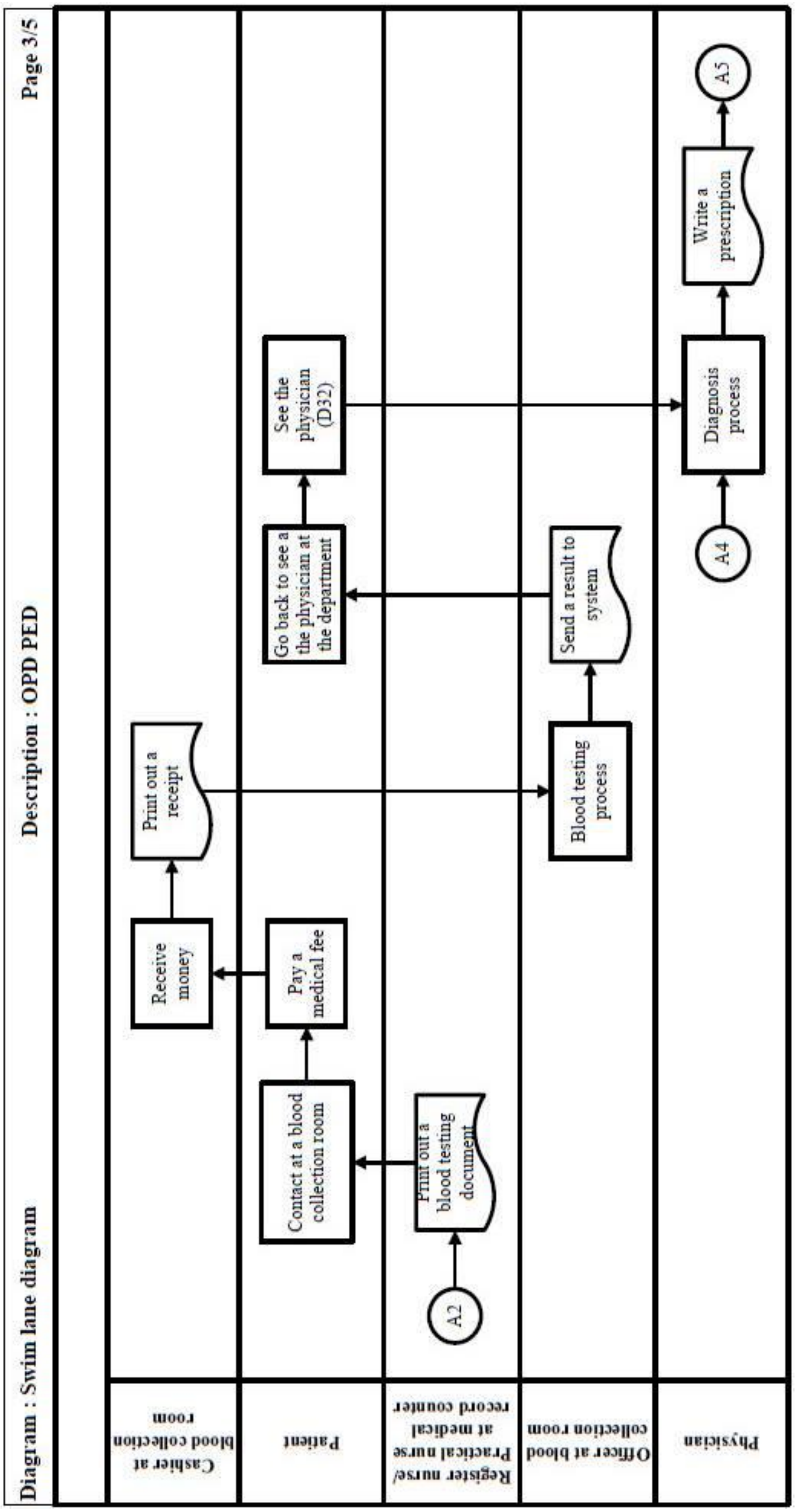


Figure B.1 Swim lane diagram of the patient flow (continued)

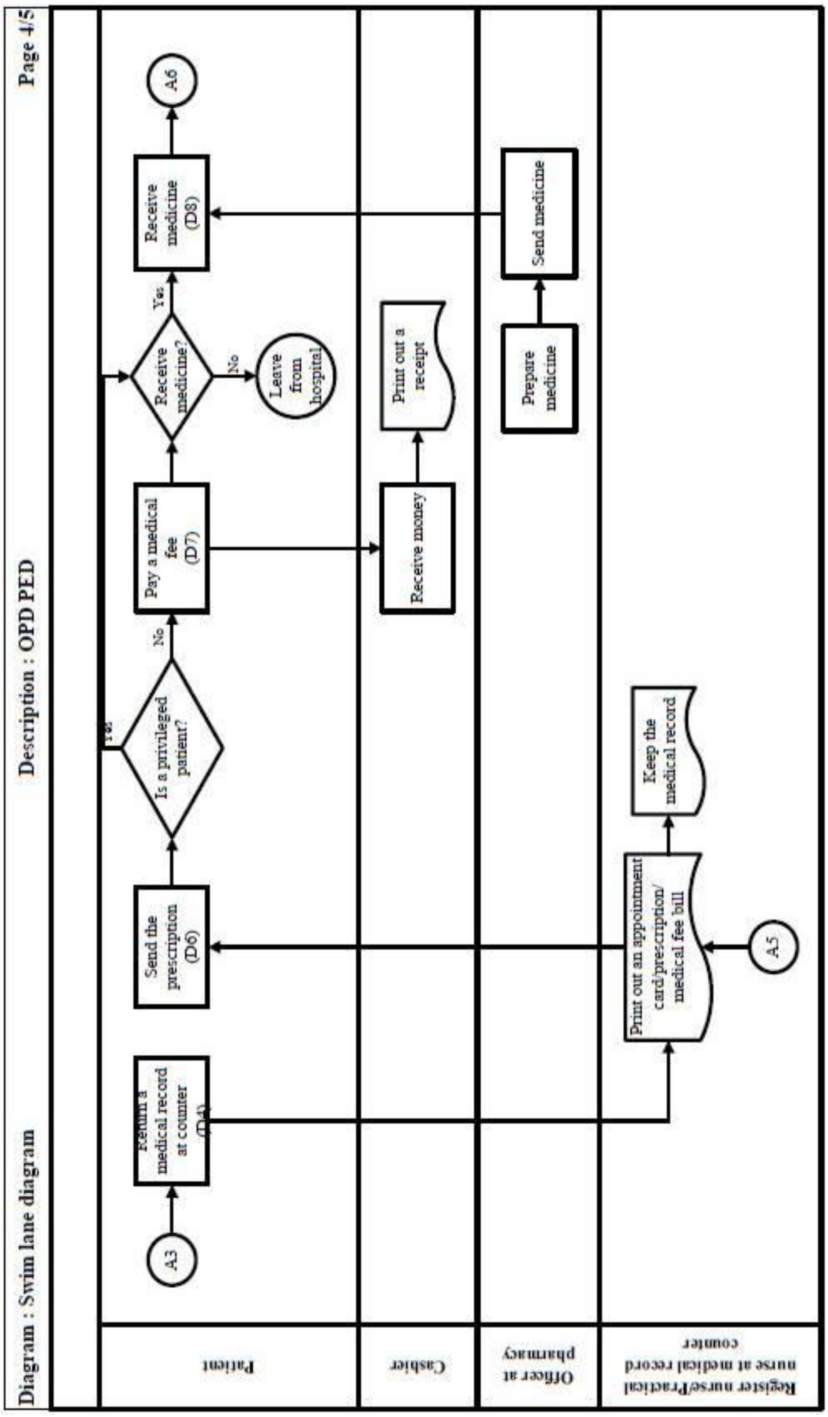


Figure B.1 Swim lane diagram of the patient flow (continued)

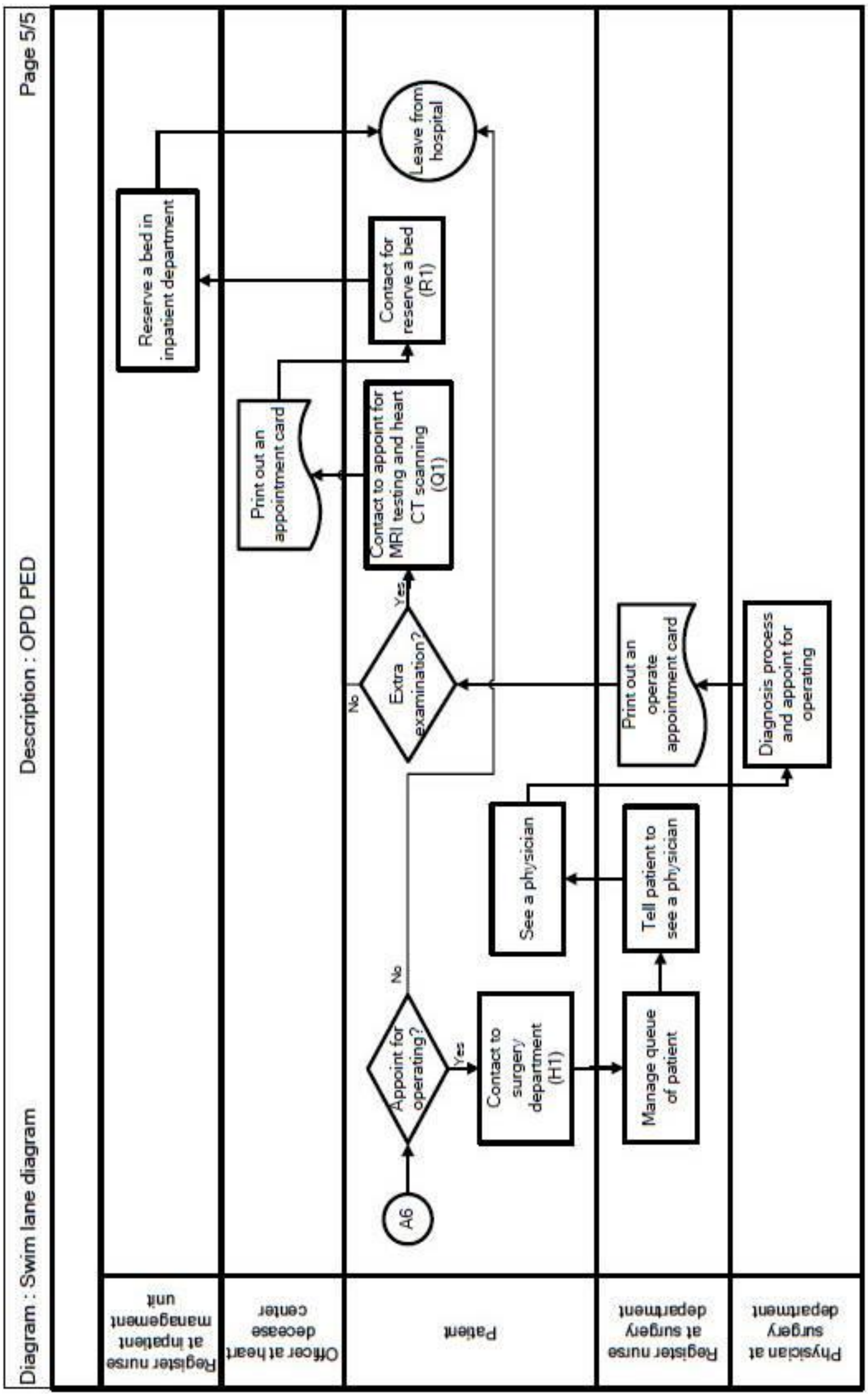


Figure B.1 Swim lane diagram of the patient flow (continued)

APPENDIX C
SIMULATION MODELING

The selection of distribution

Sections 4.5.3 described about the input analysis which the researcher must use the results to build the model. The researcher analyzed raw data to obtain the set of appropriate statistical distributions. However, there are many candidate forms. Thus, the researcher chose only one distribution which passed the goodness-of-fit test with higher corresponding p-value. Moreover, the lowest square error is preferable. In this appendix, the send prescription process is used as an example for showing a method of distribution's selection.

1) First, create the data set on the notepad as shown in Figure C.1. There are totally 50 data points on service time in the check weight and height process.

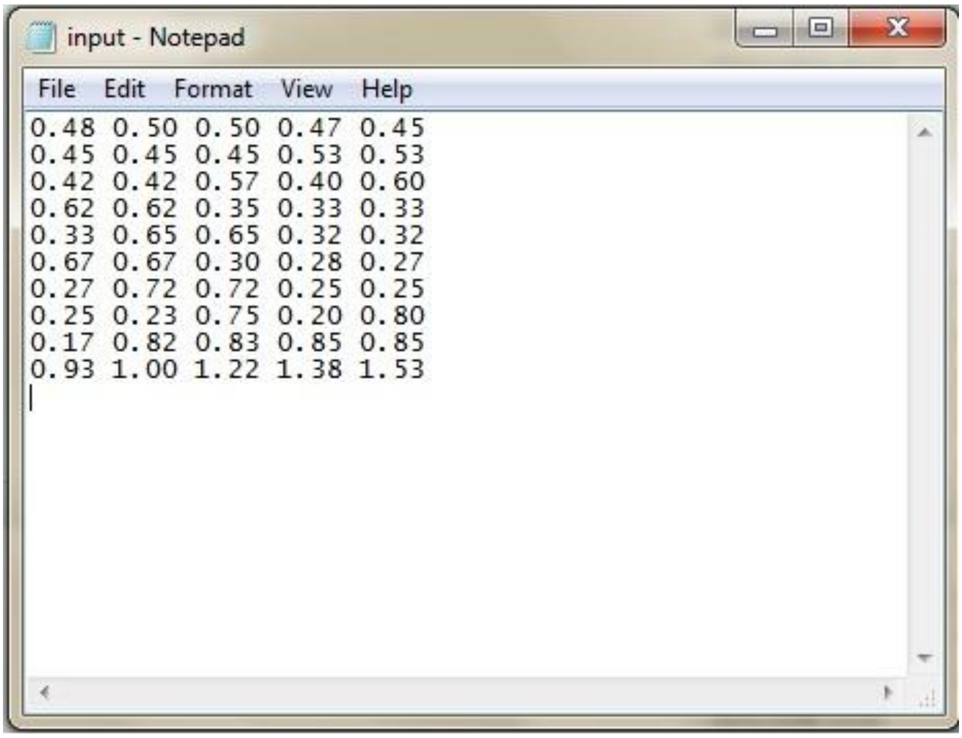


Figure C.1 Check weight and height notepad

2) Open an Input Analyzer program and click at the button "New". Then, the new Input1 is shown in the program window (Figure C.2).

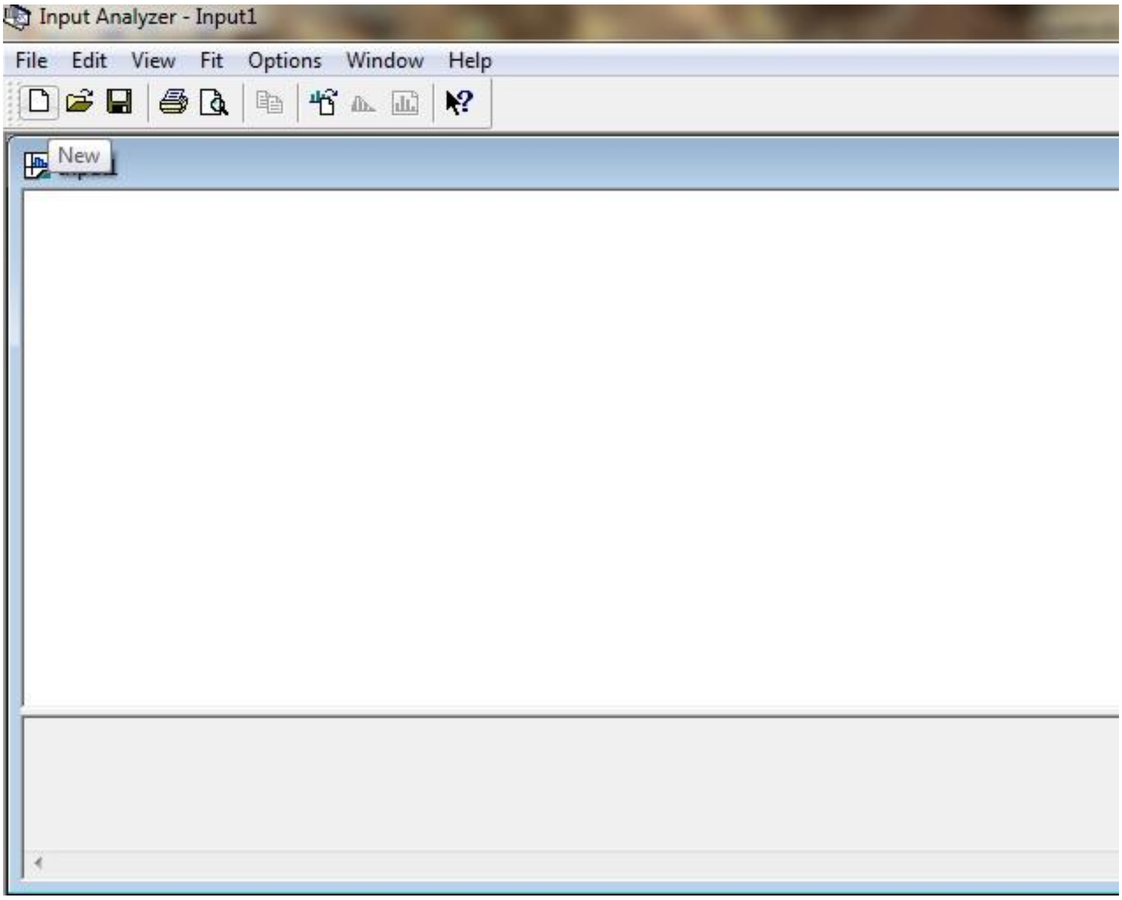


Figure C.2 New input in the program window

3) Click at the button “Use Existing Data File” as shown in Figure C.3. Next, select the notepad file which is created in step 1

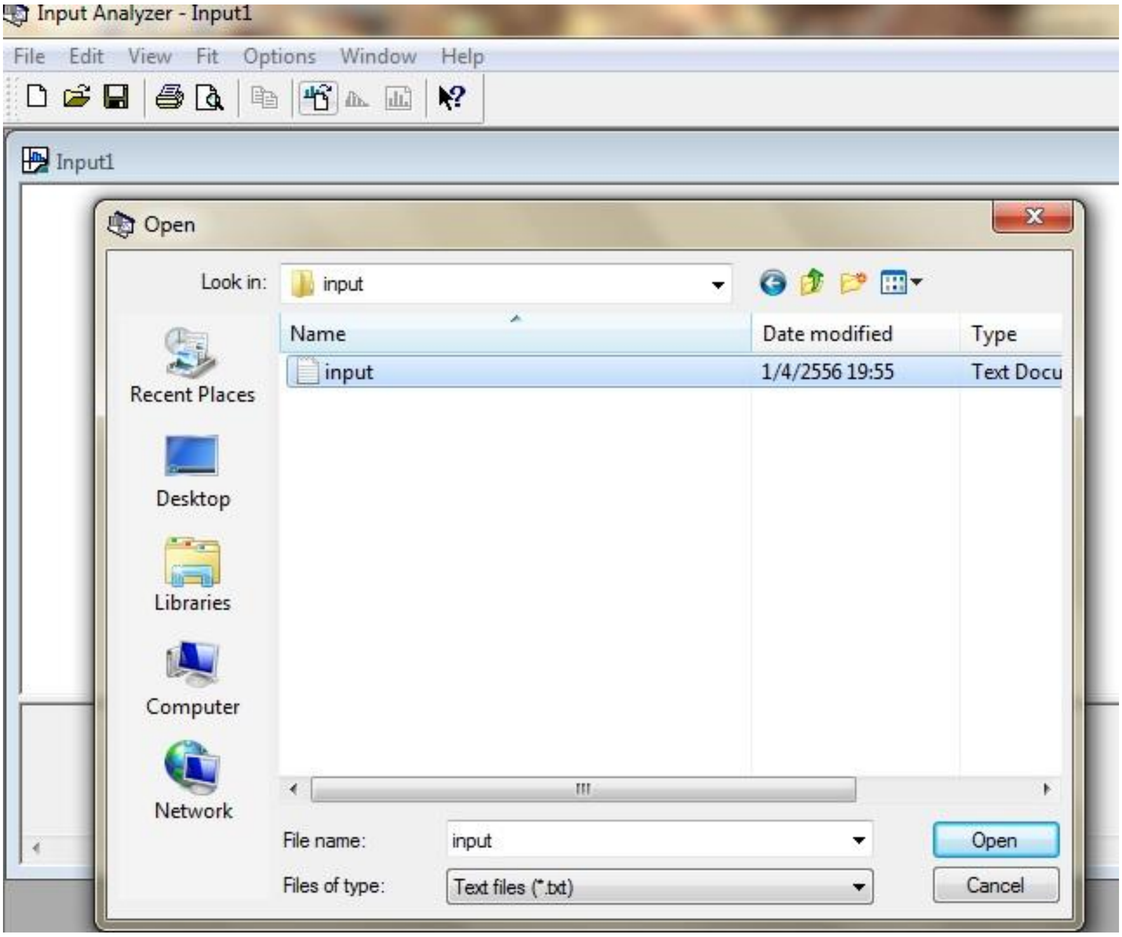


Figure C.3 Select the file

4) A histogram and statistical value of the data will be shown in the window (Figure C.4).

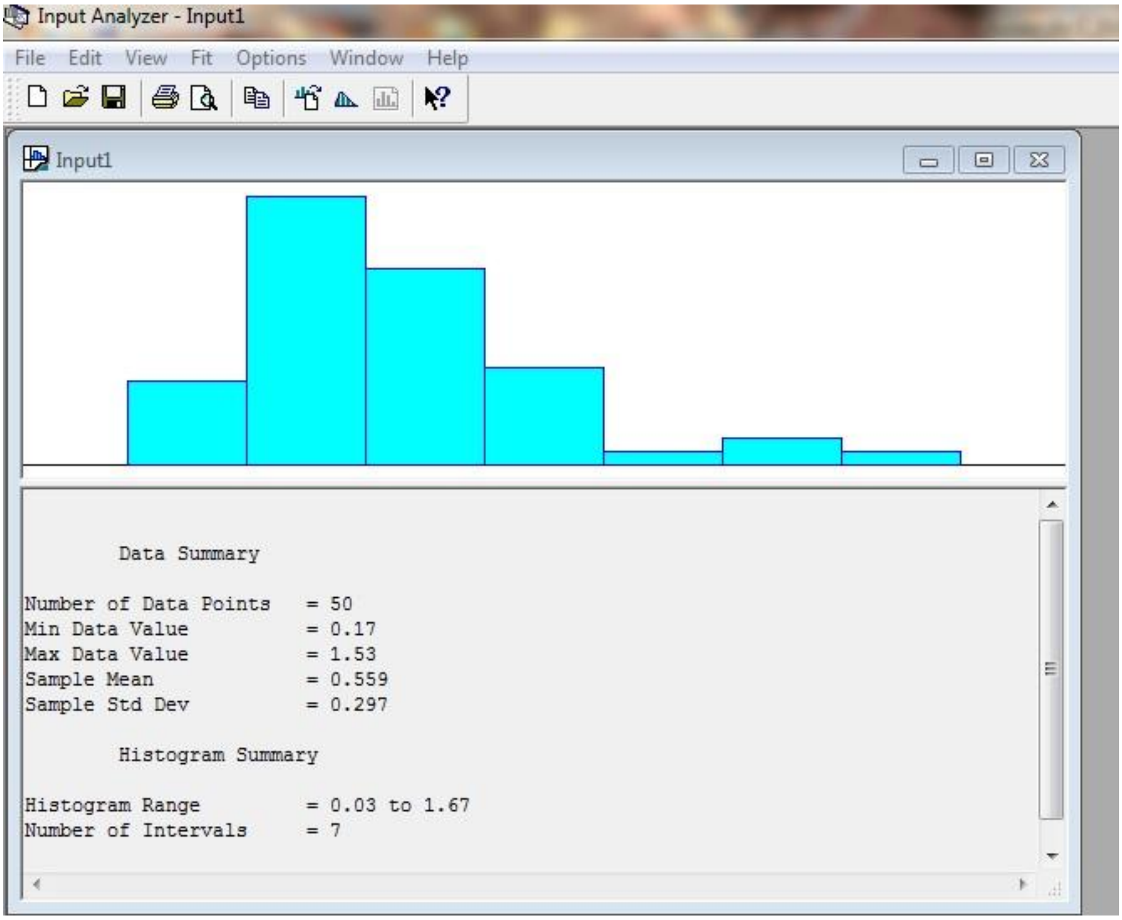


Figure C.4 Histogram of the data

5) Click at the button "Fit All" as shown in Figure C.5. The program will calculate the data and fit all distributions. Then, it shows the distribution, Gamma, which has the least square error as in Figure C.6.

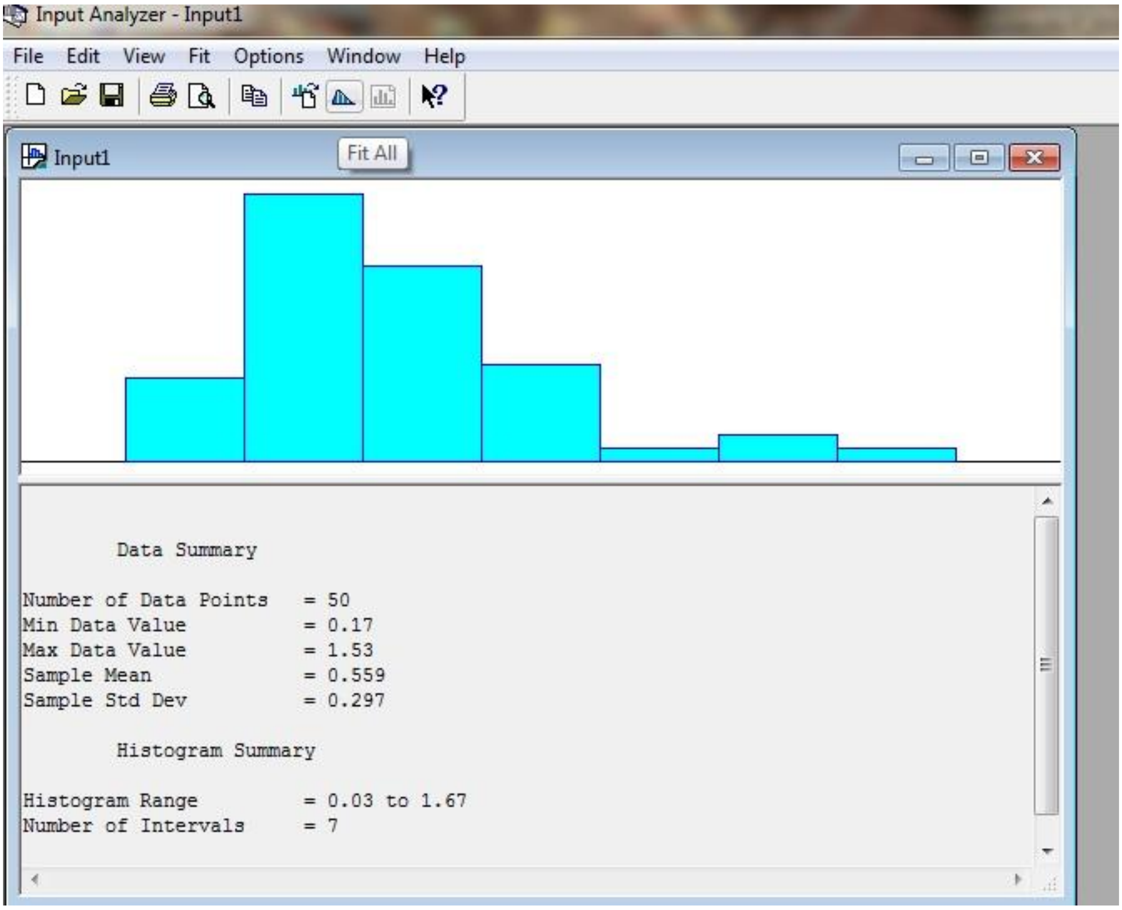


Figure C.5 Click the button Fit All

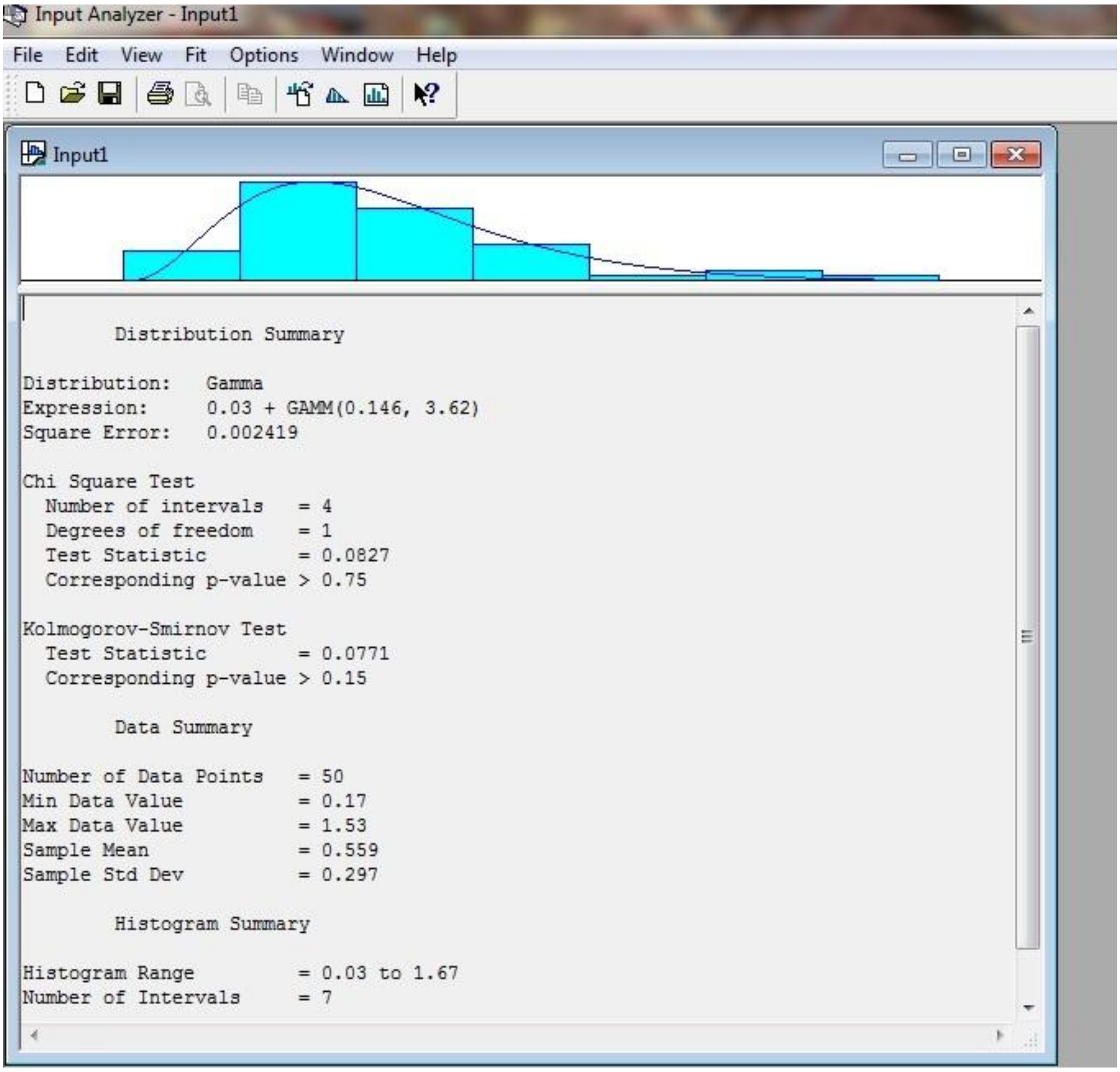


Figure C.6 Distribution of the data

6) A purpose of this step is to find a corresponding p-value. First, select Fit from the menu bar as shown in Figure C.7. Second, select any distribution, such as Beta distribution. Then, the Beta distribution will show in the window like in Figure C.8. The test statistics and corresponding p-value are shown in this window. The researcher also uses this method with other distributions. When the researcher obtained the p-values of all distributions, the researcher will consider them by using the criteria which is explained in the Section 4.5.3.

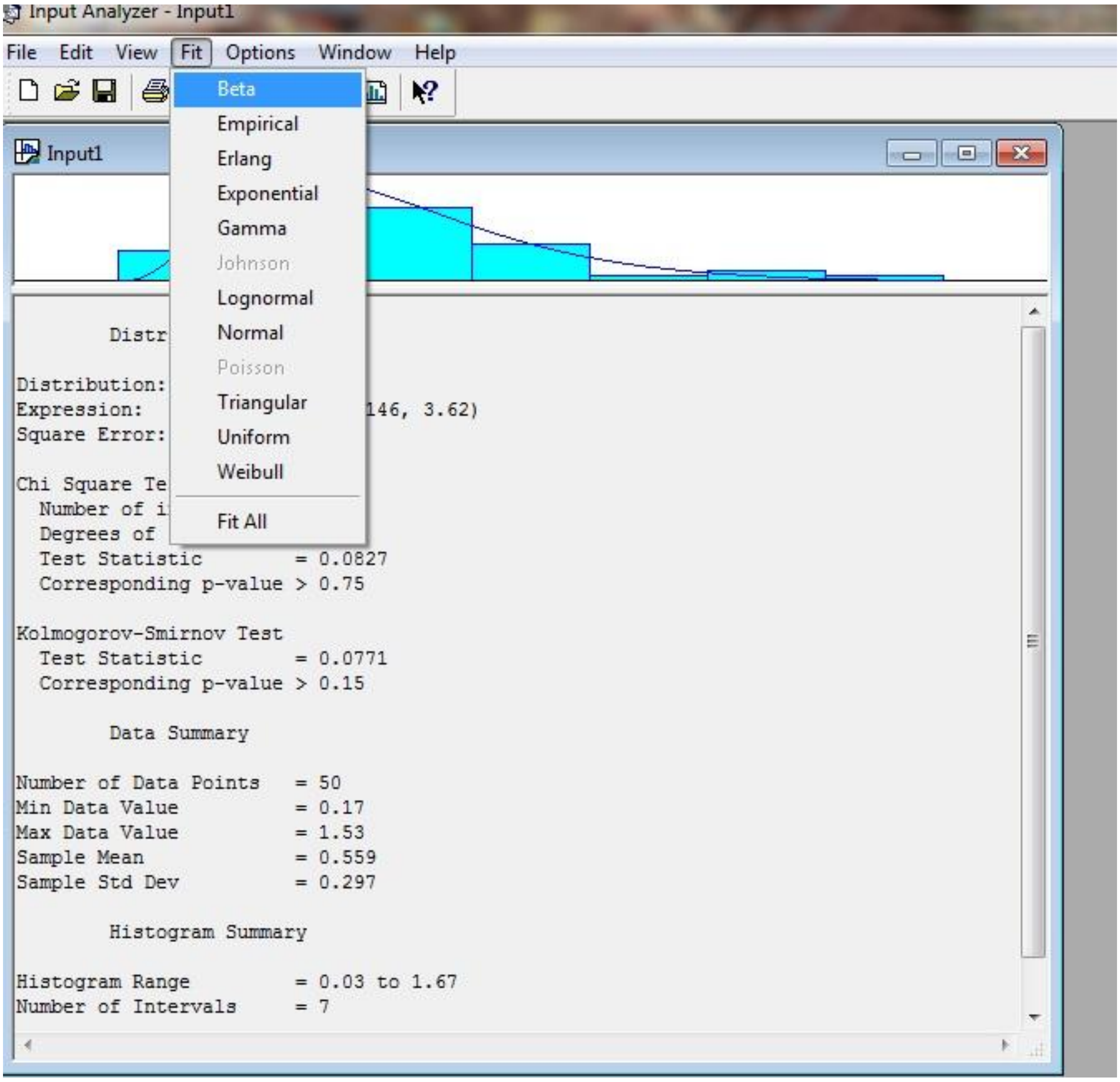


Figure C.7 Click Fit from the menu bar

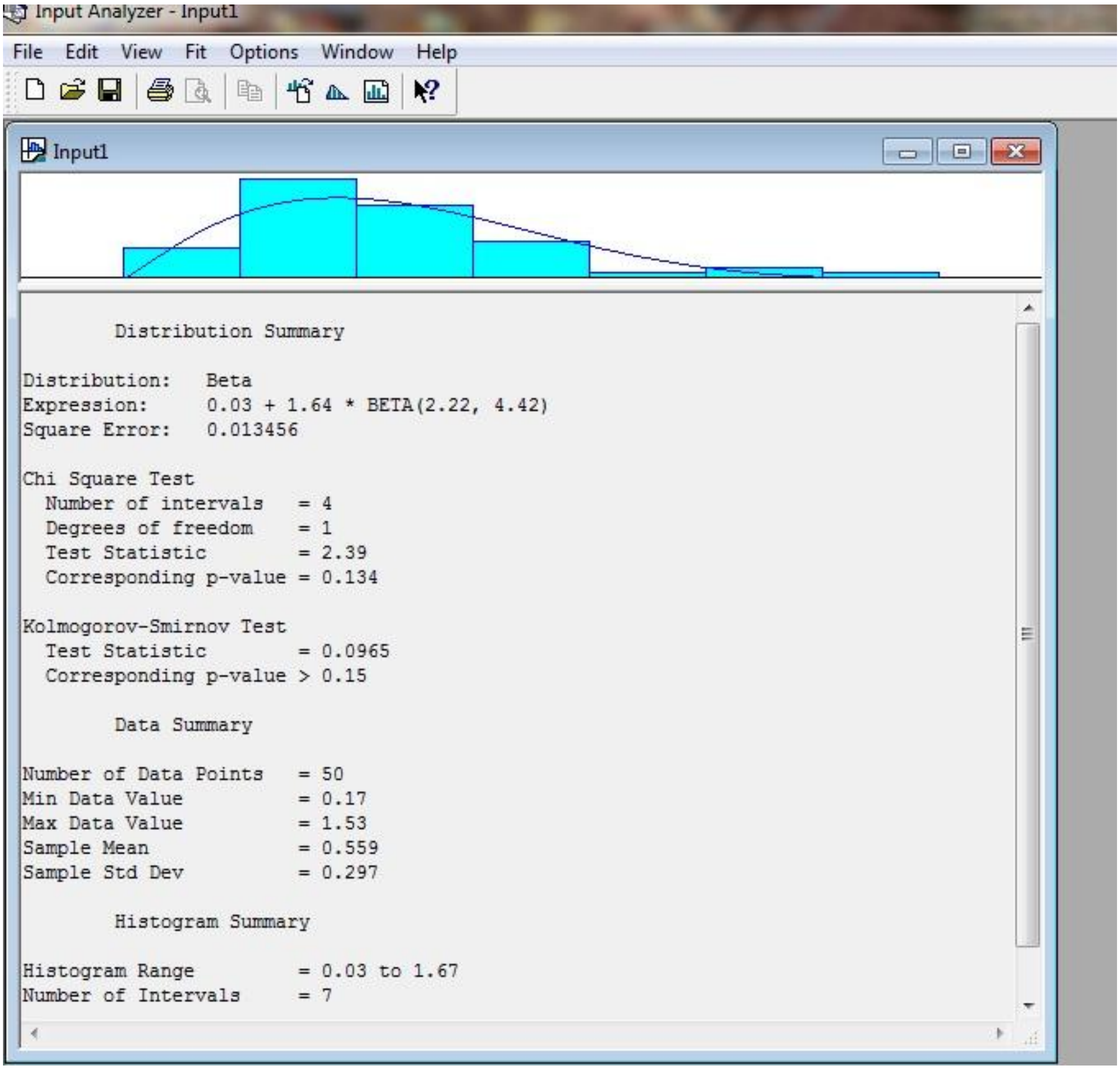


Figure C.8 Beta distribution

7) Click at the button "Fit All Summary" as shown in Figure C.9. Then, the square error of each distribution will be shown in the window like in Figure C.10. This square error is one criterion to consider for an appropriate distribution.

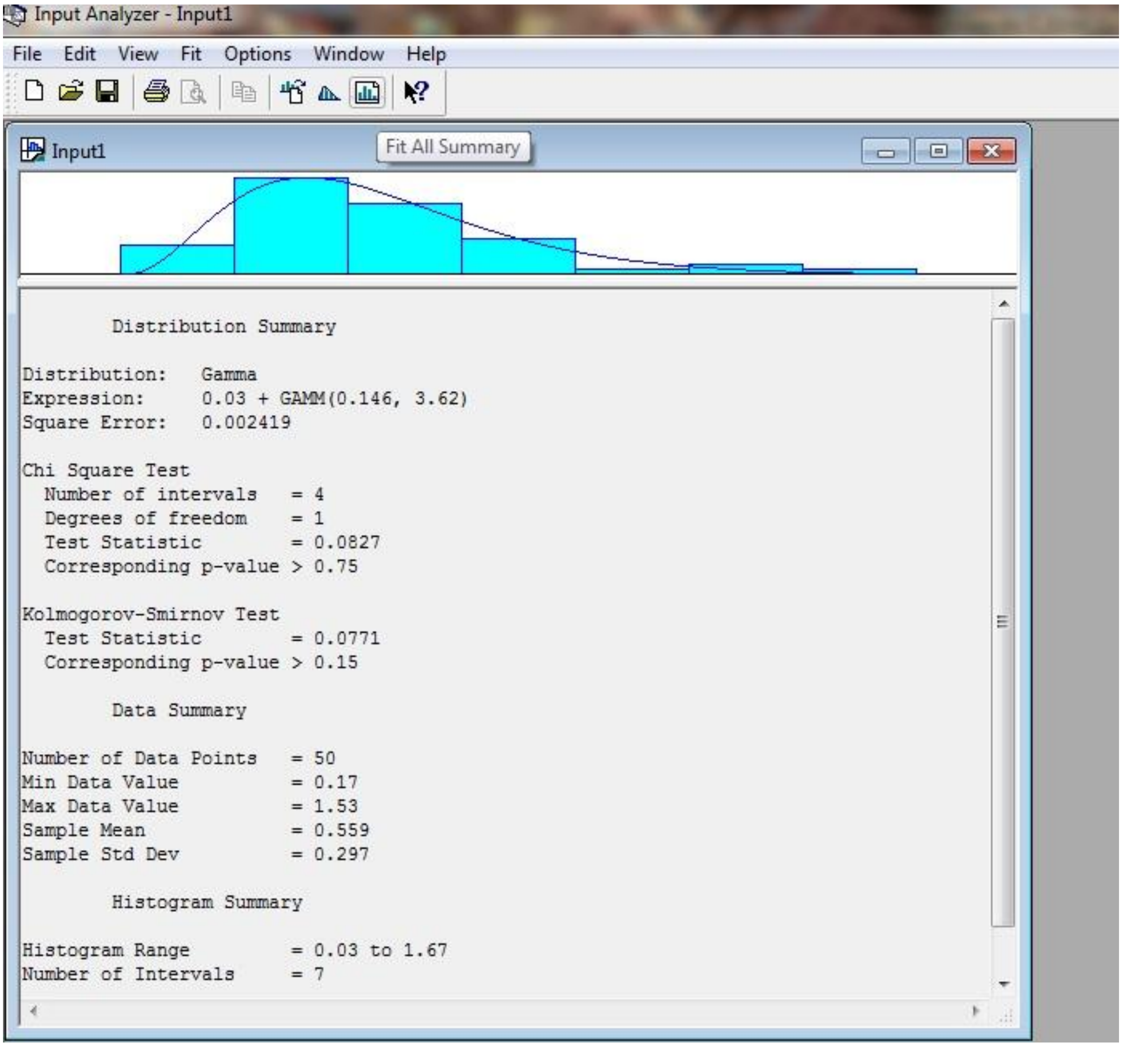


Figure C.9 Click the button Fit All Summary

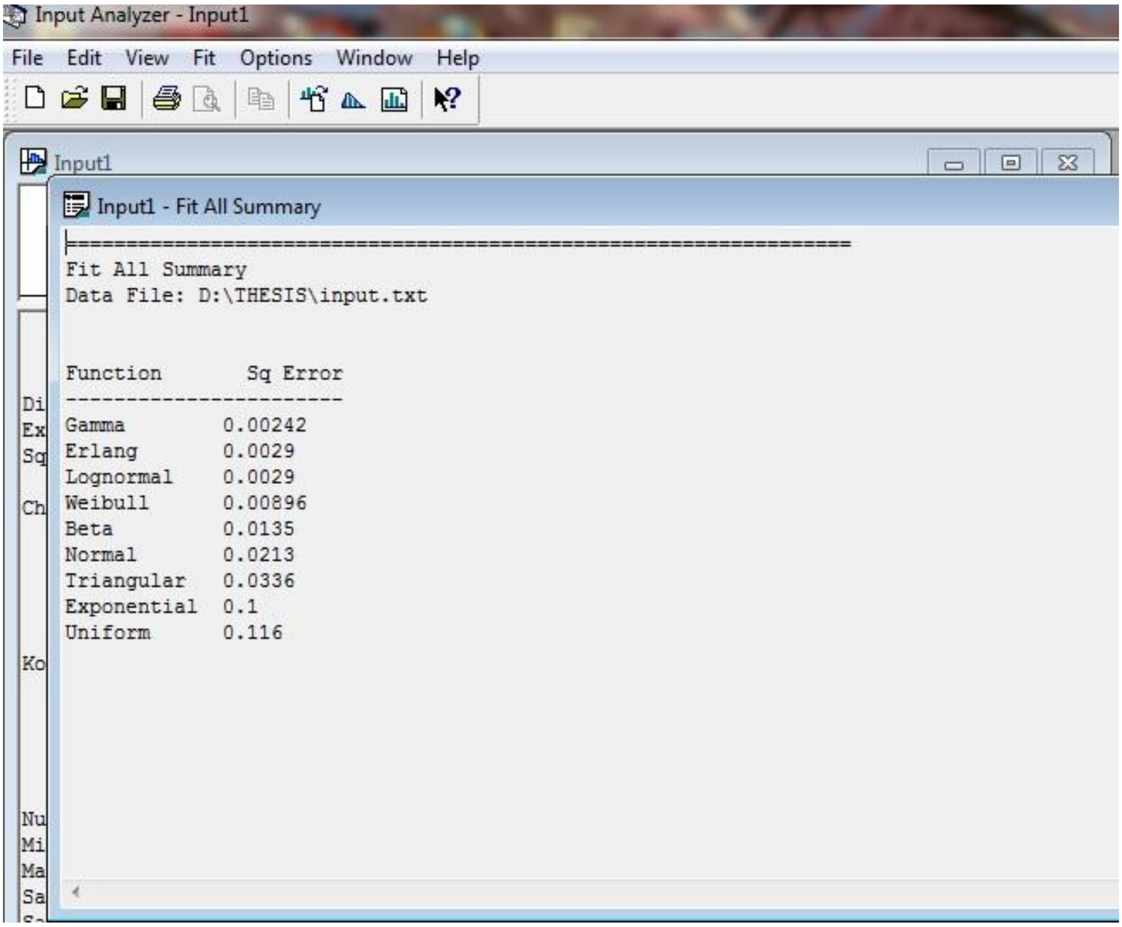


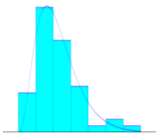
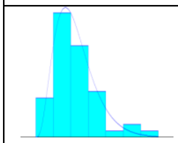
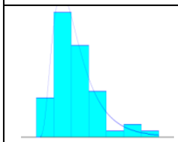
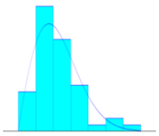
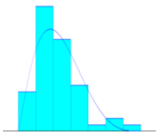
Figure C.10 Square error of distribution

8) Finally, select the appropriate distribution of the data based on the goodness-of-fit test with the highest corresponding p-value and the lowest square error. Therefore, the lognormal distribution is the appropriate distribution for explaining the service time of send prescription process.

Distribution of service time

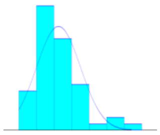
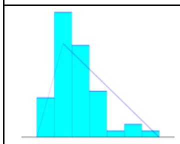
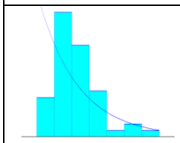
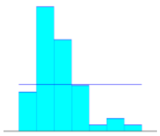
The researcher used Input Analyzer feature of Rockwell Arena software to list the candidate statistical distributions. Tables C.1-C.5 shows the distributions of process time for the morning session. Meanwhile, the distributions of process time for afternoon session are shown in Tables C.6-C.10. Only one distribution of individual process was chosen to be input in the simulation model by using the criteria which was explained in Section 4.5.3.

Table C.1 Distribution of check weight and height process for the morning session

Histogram	Distribution from Input Analyzer	Test Statistic		p-value		Accept H_0	Reject H_0	MSE
		Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test			
	0.03 + GAMM(0.146, 3.62)	0.0827	0.0771	> 0.75	> 0.15	✓		0.00242
	0.03 + ERLA(0.132, 4)	0.245	0.0946	0.649	> 0.15	✓		0.0029
	0.03 + LOGN(0.53, 0.309)	0.399	0.0663	0.539	> 0.15	✓		0.0029
	0.03 + WEIB(0.6, 1.93)	1.47	0.0746	0.234	> 0.15	✓		0.00896
	0.03 + 1.64 * BETA(2.22, 4.42)	2.39	0.0965	0.134	> 0.15	✓		0.0135

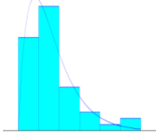
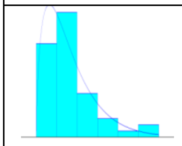
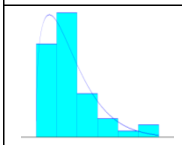
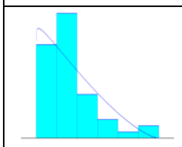
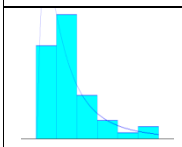
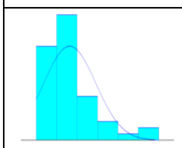
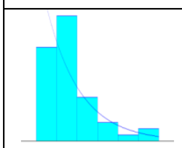
Note: The sample size is 50 patients. The descriptive statistics are 0.17, 1.53, 0.56, 0.30 minutes for the minimum, maximum, average and standard deviation, respectively.

Table C.1 Distribution of check weight and height process for the morning session (continued)

Histogram	Distribution from Input Analyzer	Test Statistic		p-value		Accept H_0	Reject H_0	MSE
		Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test			
	NORM(0.559, 0.294)	4.2	0.108	0.0423	> 0.15		✓	0.0213
	TRIA(0.03, 0.381, 1.67)	9.69	0.201	0.0224	0.0322		✓	0.0336
	0.03 + EXPO(0.529)	18.8	0.28	< 0.005	< 0.01		✓	0.1
	UNIF(0.03, 1.67)	40.7	0.38	< 0.005	< 0.01		✓	0.116

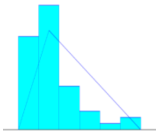
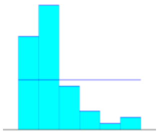
Note: The sample size is 50 patients. The descriptive statistics are 0.17, 1.53, 0.56, 0.30 minutes for the minimum, maximum, average and standard deviation, respectively.

Table C.2 Distribution of diagnosis process for the morning session

Histogram	Distribution from Input Analyzer	Test Statistic		p-value		Accept H_0	Reject H_0	MSE
		Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test			
	3 + ERLA(3.14, 2)	1.01	0.0752	0.341	> 0.15	✓		0.00713
	3 + GAMM(3.81, 1.65)	2.25	0.0834	0.149	> 0.15	✓		0.0144
	3 + WEIB(6.85, 1.34)	2.58	0.0859	0.113	> 0.15	✓		0.0152
	3 + 23 * BETA(1.03, 2.45)	6.81	0.166	0.00931	0.131		✓	0.0303
	3 + LOGN(7.01, 8.35)	4.82	0.137	0.0293	> 0.15		✓	0.0333
	NORM(9.28, 4.88)	7.55	0.173	0.00633	0.102		✓	0.0373
	3 + EXPO(6.28)	8.13	0.169	0.0188	0.119		✓	0.0502

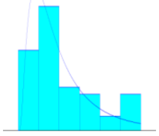
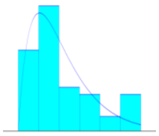
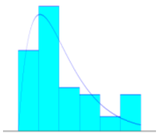
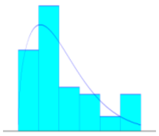
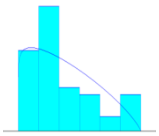
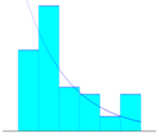
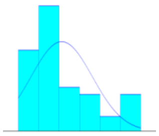
Note: The sample size is 48 patients. The descriptive statistics are 3.10, 122.00, 11.91, 16.82 minutes for the minimum, maximum, average and standard deviation, respectively.

Table C.2 Distribution of diagnosis process for the morning session (continued)

Histogram	Distribution from Input Analyzer	Test Statistic		p-value		Accept H_0	Reject H_0	MSE
		Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test			
	TRIA(3, 8.75, 26)	32	0.373	< 0.005	< 0.01		✓	0.0911
	UNIF(3, 26)	38	0.459	< 0.005	< 0.01		✓	0.132

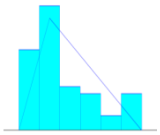
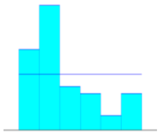
Note: The sample size is 48 patients. The descriptive statistics are 3.10, 122.00, 11.91, 16.82 minutes for the minimum, maximum, average and standard deviation, respectively.

Table C.3 Distribution of make appointment process for the morning session

Histogram	Distribution from Input Analyzer	Test Statistic		p-value		Accept H_0	Reject H_0	MSE
		Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test			
	1 + LOGN(1.48, 1.4)	3.32	0.106	0.0728	> 0.15	✓		0.0116
	1 + GAMM(0.724, 1.96)	2.52	0.103	0.12	> 0.15	✓		0.0159
	1 + ERLA(0.709, 2)	2.57	0.111	0.114	> 0.15	✓		0.016
	1 + WEIB(1.57, 1.47)	2.81	0.129	0.0953	> 0.15	✓		0.0196
	1 + 4 * BETA(1.09, 1.79)	5.54	0.206	0.0664	0.0357	✓		0.0343
	1 + EXPO(1.42)	7.4	0.167	0.0248	0.14		✓	0.0429
	NORM(2.42, 1.01)	9.7	0.224	< 0.005	0.0183		✓	0.0529

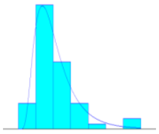
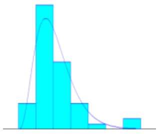
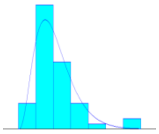
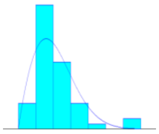
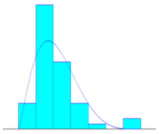
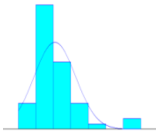
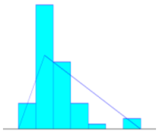
Note: The sample size is 46 patients. The descriptive statistics are 1.12, 5.63, 2.66, 1.28 minutes for the minimum, maximum, average and standard deviation, respectively.

Table C.3 Distribution of make appointment process for the morning session (continued)

Histogram	Distribution from Input Analyzer	Test Statistic		p-value		Accept H_0	Reject H_0	MSE
		Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test			
	TRIA(1, 2, 5)	13.9	0.259	< 0.005	< 0.01		✓	0.0539
	UNIF(1, 5)	19.2	0.359	< 0.005	< 0.01		✓	0.0696

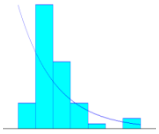
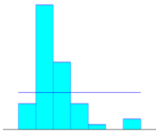
Note: The sample size is 46 patients. The descriptive statistics are 1.12, 5.63, 2.66, 1.28 minutes for the minimum, maximum, average and standard deviation, respectively.

Table C.4 Distribution of payment process for the morning session

Histogram	Distribution from Input Analyzer	Test Statistic		p-value		Accept H_0	Reject H_0	MSE
		Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test			
	LOGN(0.818, 0.465)	0.52	0.109	0.481	> 0.15	✓		0.00409
	ERLA(0.204, 4)	1.43	0.0845	0.239	> 0.15	✓		0.00975
	GAMM(0.217, 3.77)	1.75	0.0947	0.203	> 0.15	✓		0.0108
	WEIB(0.925, 1.89)	5.84	0.115	0.0174	> 0.15		✓	0.0304
	2.74 * BETA(2.37, 5.24)	6.51	0.156	0.0112	> 0.15		✓	0.0328
	NORM(0.817, 0.464)	9.29	0.197	< 0.005	0.038		✓	0.0465
	TRIA(0, 0.587, 2.74)	16.1	0.311	< 0.005	< 0.01		✓	0.0762

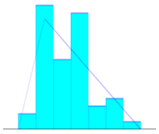
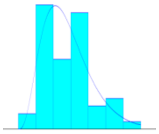
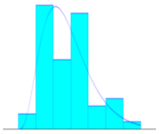
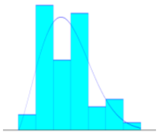
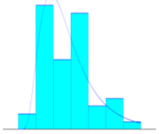
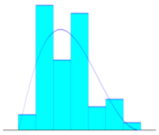
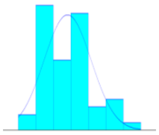
Note: The sample size is 50 patients. The descriptive statistics are 0.18, 2.50, 0.82, 0.47 minutes for the minimum, maximum, average and standard deviation, respectively.

Table C.4 Distribution of payment process for the morning session (continued)

Histogram	Distribution from Input Analyzer	Test Statistic		p-value		Accept H_0	Reject H_0	MSE
		Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test			
	EXPO(0.817)	28.1	0.309	< 0.005	< 0.01		✓	0.154
	UNIF(0, 2.74)	62	0.437	< 0.005	< 0.01		✓	0.177

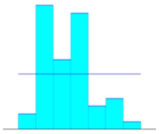
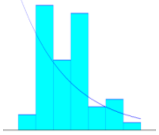
Note: The sample size is 50 patients. The descriptive statistics are 0.18, 2.50, 0.82, 0.47 minutes for the minimum, maximum, average and standard deviation, respectively.

Table C.5 Distribution of pharmacy process for the morning session

Histogram	Distribution from Input Analyzer	Test Statistic		p-value		Accept H_0	Reject H_0	MSE
		Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test			
	TRIA(1, 2.22, 6.68)	6.36	0.105	0.0966	> 0.15	✓		0.029
	1 + ERLA(0.571, 4)	6.02	0.0809	0.0157	> 0.15		✓	0.0305
	1 + GAMM(0.558, 4.09)	6.1	0.0775	0.015	> 0.15		✓	0.0309
	1 + WEIB(2.59, 2.23)	5.63	0.0834	0.0194	> 0.15		✓	0.0315
	1 + LOGN(2.32, 1.32)	6.73	0.105	0.0096	> 0.15		✓	0.0317
	1 + 5.68 * BETA(2.16, 3.21)	5.93	0.0902	0.0166	> 0.15		✓	0.032
	NORM(3.28, 1.09)	6.82	0.106	0.00925	> 0.15		✓	0.0393

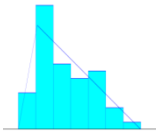
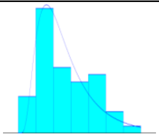
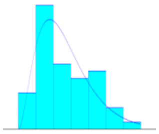
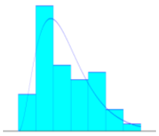
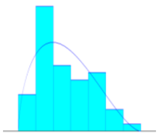
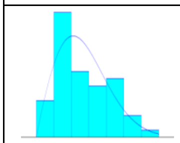
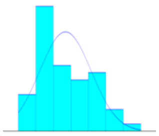
Note: The sample size is 50 patients. The descriptive statistics are 1.38, 6.19, 3.28, 1.10 minutes for the minimum, maximum, average and standard deviation, respectively.

Table C.5 Distribution of pharmacy process for the morning session (continued)

Histogram	Distribution from Input Analyzer	Test Statistic		p-value		Accept H_0	Reject H_0	MSE
		Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test			
	UNIF(1, 6.68)	32.9	0.277	< 0.005	< 0.01		✓	0.0939
	1 + EXPO(2.28)	33.5	0.314	< 0.005	< 0.01		✓	0.12

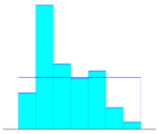
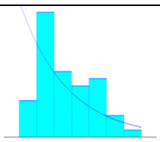
Note: The sample size is 50 patients. The descriptive statistics are 1.38, 6.19, 3.28, 1.10 minutes for the minimum, maximum, average and standard deviation, respectively.

Table C.6 Distribution of check weight and height process for the afternoon session

Histogram	Distribution from Input Analyzer	Test Statistic		p-value		Accept H_0	Reject H_0	MSE
		Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test			
	TRIA(0.12, 0.299, 1.28)	2.8	0.0921	0.438	> 0.15	✓		0.0107
	0.12 + LOGN(0.453, 0.294)	8.75	0.088	< 0.005	> 0.15		✓	0.0147
	0.12 + ERLA(0.149, 3)	6.28	0.0761	0.0447	> 0.15		✓	0.0159
	0.12 + GAMM(0.138, 3.23)	7.01	0.0761	0.00851	> 0.15		✓	0.0179
	0.12 + 1.16 * BETA(1.63, 2.61)	4.92	0.0839	0.0886	> 0.15	✓		0.0199
	0.12 + WEIB(0.506, 1.95)	6.1	0.0968	0.048	> 0.15		✓	0.0214
	NORM(0.566, 0.244)	8.46	0.144	< 0.005	> 0.15		✓	0.0378

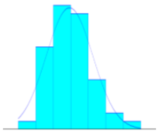
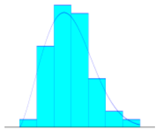
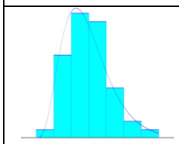
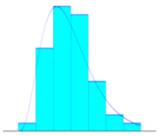
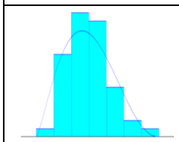
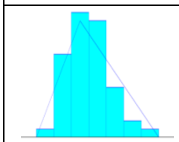
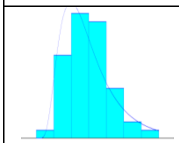
Note: The sample size is 50 patients. The descriptive statistics are 0.22, 1.18, 0.57, 0.25 minutes for the minimum, maximum, average and standard deviation, respectively.

Table C.6 Distribution of check weight and height process for the afternoon session (continued)

Histogram	Distribution from Input Analyzer	Test Statistic		p-value		Accept H_0	Reject H_0	MSE
		Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test			
	UNIF(0.12, 1.28)	22.5	0.243	< 0.005	< 0.01		✓	0.0643
	0.12 + EXPO(0.446)	18.8	0.249	< 0.005	< 0.01		✓	0.0709

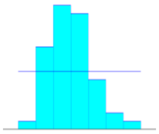
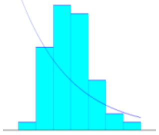
Note: The sample size is 50 patients. The descriptive statistics are 0.22, 1.18, 0.57, 0.25 minutes for the minimum, maximum, average and standard deviation, respectively.

Table C.7 Distribution of diagnosis process for the afternoon session

Histogram	Distribution from Input Analyzer	Test Statistic		p-value		Accept H_0	Reject H_0	MSE
		Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test			
	NORM(10.4, 3.79)	0.576	0.136	0.465	> 0.15	✓		0.00472
	2 + WEIB(9.43, 2.31)	1.13	0.104	0.306	> 0.15	✓		0.00493
	2 + GAMM(1.87, 4.47)	1.49	0.0993	0.231	> 0.15	✓		0.00604
	2 + ERLA(2.09, 4)	2.26	0.118	0.148	> 0.15	✓		0.00878
	2 + 20 * BETA(2.35, 3.27)	2.14	0.128	0.161	> 0.15	✓		0.00927
	TRIA(2, 9.14, 22)	3.31	0.168	0.365	0.115	✓		0.0127
	2 + LOGN(8.55, 4.84)	3.75	0.123	0.0539	> 0.15	✓		0.0155

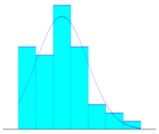
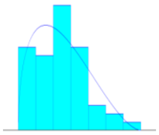
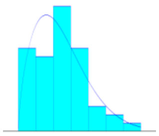
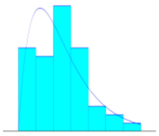
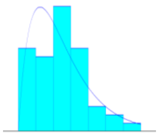
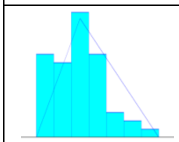
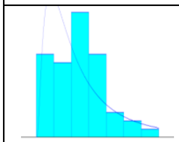
Note: The sample size is 49 patients. The descriptive statistics are 2.82, 36.00, 10.87, 5.25 minutes for the minimum, maximum, average and standard deviation, respectively.

Table C.7 Distribution of diagnosis process for the afternoon session (continued)

Histogram	Distribution from Input Analyzer	Test Statistic		p-value		Accept H_0	Reject H_0	MSE
		Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test			
	UNIF(2, 22)	31.4	0.254	< 0.005	< 0.01		✓	0.0916
	2 + EXPO(8.36)	37.1	0.348	< 0.005	< 0.01		✓	0.134

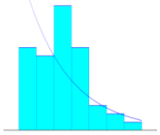
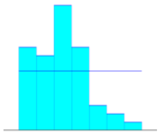
Note: The sample size is 49 patients. The descriptive statistics are 2.82, 36.00, 10.87, 5.25 minutes for the minimum, maximum, average and standard deviation, respectively.

Table C.8 Distribution of make appointment process for the afternoon session

Histogram	Distribution from Input Analyzer	Test Statistic		p-value		Accept H_0	Reject H_0	MSE
		Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test			
	NORM(2.78, 1.04)	5.64	0.0657	0.0627	> 0.15	✓		0.0131
	1 + 5 * BETA(1.49, 2.69)	4.55	0.0689	0.104	> 0.15	✓		0.0139
	1 + WEIB(1.98, 1.66)	3.79	0.0877	0.167	> 0.15	✓		0.0158
	1 + ERLA(0.891, 2)	5.44	0.116	0.0699	> 0.15	✓		0.0223
	1 + GAMM(0.891, 2)	5.38	0.123	0.072	> 0.15	✓		0.0224
	TRIA(1, 2.79, 6)	10.2	0.201	0.0185	0.0307		✓	0.0352
	1 + LOGN(2.05, 2.33)	12	0.163	< 0.005	0.127		✓	0.0387

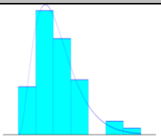
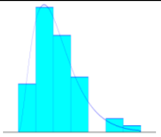
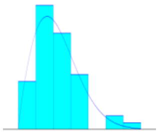
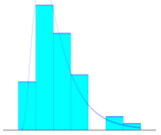
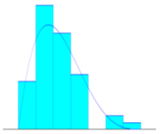
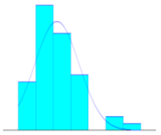
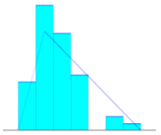
Note: The sample size is 50 patients. The descriptive statistics are 1.03, 5.83, 2.78, 1.05 minutes for the minimum, maximum, average and standard deviation, respectively.

Table C.8 Distribution of make appointment process for the afternoon session (continued)

Histogram	Distribution from Input Analyzer	Test Statistic		p-value		Accept H_0	Reject H_0	MSE
		Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test			
	1 + EXPO(1.78)	14.8	0.21	< 0.005	0.0219		✓	0.0521
	UNIF(1, 6)	22.8	0.314	< 0.005	< 0.01		✓	0.0651

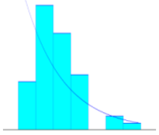
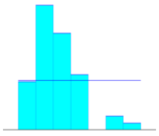
Note: The sample size is 50 patients. The descriptive statistics are 1.03, 5.83, 2.78, 1.05 minutes for the minimum, maximum, average and standard deviation, respectively.

Table C.9 Distribution of payment process for the afternoon session

Histogram	Distribution from Input Analyzer	Test Statistic		p-value		Accept H_0	Reject H_0	MSE
		Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test			
	0.18 + GAMM(0.168, 3.31)	0.219	0.0638	0.667	> 0.15	✓		0.00423
	0.18 + ERLA(0.186, 3)	0.395	0.0621	0.542	> 0.15	✓		0.00507
	0.18 + WEIB(0.632, 1.86)	0.645	0.0886	0.445	> 0.15	✓		0.0074
	0.18 + LOGN(0.562, 0.351)	1.51	0.0795	0.23	> 0.15	✓		0.00812
	0.18 + 1.77 * BETA(2.04, 4.18)	1.37	0.133	0.245	> 0.15	✓		0.0118
	NORM(0.738, 0.321)	2.44	0.131	0.129	> 0.15	✓		0.0157
	TRIA(0.18, 0.559, 1.95)	11.2	0.25	0.0112	< 0.01		✓	0.0339

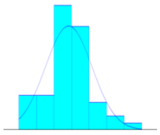
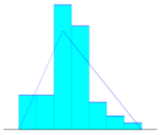
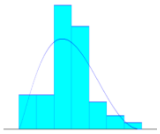
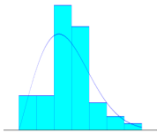
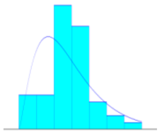
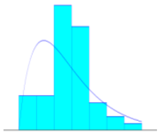
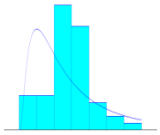
Note: The sample size is 50 patients. The descriptive statistics are 0.33, 1.80, 0.74, 0.32 minutes for the minimum, maximum, average and standard deviation, respectively.

Table C.9 Distribution of payment process for the afternoon session (continued)

Histogram	Distribution from Input Analyzer	Test Statistic		p-value		Accept H_0	Reject H_0	MSE
		Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test			
	0.18 + EXPO(0.558)	16.5	0.244	< 0.005	< 0.01		✓	0.0924
	UNIF(0.18, 1.95)	39.3	0.388	< 0.005	< 0.01		✓	0.112

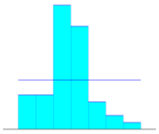
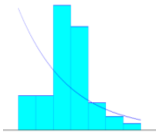
Note: The sample size is 50 patients. The descriptive statistics are 0.33, 1.80, 0.74, 0.32 minutes for the minimum, maximum, average and standard deviation, respectively.

Table C.10 Distribution of pharmacy process for the afternoon session

Histogram	Distribution from Input Analyzer	Test Statistic		p-value		Accept H_0	Reject H_0	MSE
		Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test			
	NORM(5.15, 1.47)	3.66	0.118	0.0579	> 0.15	✓		0.0185
	TRIA(2, 4.77, 9.76)	7.03	0.16	0.0752	0.143	✓		0.0317
	2 + 7.76 * BETA(2.26, 3.31)	7.24	0.136	0.00757	> 0.15		✓	0.034
	2 + WEIB(3.49, 2.06)	7.12	0.176	0.00806	0.0839		✓	0.0362
	2 + GAMM(1.29, 2.43)	15.3	0.209	< 0.005	0.022		✓	0.0616
	2 + ERLA(1.57, 2)	19.5	0.229	< 0.005	< 0.01		✓	0.0724
	2 + LOGN(3.79, 4.25)	31.5	0.258	< 0.005	< 0.01		✓	0.101

Note: The sample size is 50 patients. The descriptive statistics are 2.03, 9.05, 5.15, 1.49 minutes for the minimum, maximum, average and standard deviation, respectively.

Table C.10 Distribution of pharmacy process for the afternoon session (continued)

Histogram	Distribution from Input Analyzer	Test Statistic		p-value		Accept H_0	Reject H_0	MSE
		Based on Chi - square test	Based on K - S test	Based on Chi - square test	Based on K - S test			
	UNIF(2, 9.76)	36.8	0.304	< 0.005	< 0.01		✓	0.105
	2 + EXPO(3.15)	43.7	0.318	< 0.005	< 0.01		✓	0.135

Note: The sample size is 50 patients. The descriptive statistics are 2.03, 9.05, 5.15, 1.49 minutes for the minimum, maximum, average and standard deviation, respectively.

Z-test statistics

The z-test statistics is a hypothesis test which the researcher used to validate the simulation model of the pediatrics department. It uses to test a difference between the mean of the observe data and the simulation outputs. To illustrate, the mean of the total process time from the model is compared to the mean of the observed total process time. Also the mean of the total waiting time from the model is compared to the mean of the observed total waiting time. The researcher used two-tailed test with 95% confident level in this procedure. The parameters which are used in the procedure are the degree of freedom and the test statistic value. These parameters can be calculated as follows.

test statistic value (z)

$$z = \frac{\bar{x} - \bar{y} - \Delta_0}{\sqrt{\frac{s_1^2}{m} + \frac{s_2^2}{n}}}$$

where

$\bar{x}$	=	mean of observed values
$\bar{y}$	=	mean of model outputs
s_1	=	standard deviation of observed values
s_2	=	standard deviation of model outputs
m	=	number of observed values
n	=	number of model outputs
Δ_0	=	0

Above all, the null hypothesis and the rejection region of the z-test statistics are as follows;

the null hypothesis	$H_0: \mu_1 - \mu_2$	=	Δ_0
if $\Delta_0 = 0$ then	$H_0: \mu_1$	=	μ_2

μ_1 = mean of the observed population

μ_2 = mean of the model population

rejection region $z \geq 1.96$ or $z \leq -1.96$

First, the researcher calculated the test statistics (z value). Next, the test statistic value is compared with the rejection region. If the test statistic value is between -1.96 and 1.96, the null hypothesis is accepted. Tables C.11 and C.12 are the results of validated model for the morning and afternoon sessions, respectively. All of null hypothesis are accepted so the models can be the representative for the outpatient flow of the pediatrics department.

Table C.11 Results of the hypothesis testing on the difference between the two means of observed values and model outputs for the morning session

Time	$\overline{x}$	$\overline{y}$	s_1	s_2	m	Critical value	z	Accept H_0
Total process time	19.23	16.38	16.72	0.33	50	± 1.96	1.21	✓
Total waiting time	79.15	84.35	15.71	7.98	30	± 1.96	-1.81	✓

Table C.12 Results of the hypothesis testing on the difference between the two means of observed values and model outputs for the afternoon session

Time	$\overline{x}$	$\overline{y}$	s_1	s_2	m	Critical value	z	Accept H_0
Total process time	20.11	18.59	5.80	0.26	50	± 1.96	1.85	✓
Total waiting time	64.40	64.06	14.36	9.50	30	± 1.96	0.13	✓

APPENDIX D

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20-21 ตุลาคม 2554

การวิเคราะห์กลยุทธ์เพื่อปรับปรุงการไหลของผู้ป่วยนอกแผนกกุมารเวชศาสตร์ ด้วยการจำลองสถานการณ์

Analyzing Strategies to Improve Flow of Outpatients at the Pediatrics Department By Using Simulation

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บทคัดย่อ

งานวิจัยนี้เป็นการศึกษาการไหลของผู้ป่วยนอกแผนกกุมารเวชศาสตร์ของโรงพยาบาลรัฐขนาดใหญ่แห่งหนึ่ง เพื่อศึกษาและทำความเข้าใจลักษณะการให้บริการ รวมถึงวิเคราะห์ปัญหาและเสนอแนะแนวทางการปรับปรุงการให้บริการแก่ผู้ป่วยให้มีประสิทธิภาพ โดยพิจารณาการไหลตั้งแต่กิจกรรมแรกที่ผู้ป่วยต้องกระทำเมื่อเข้ามารับบริการไปจนถึงกิจกรรมสุดท้าย อันได้แก่ ชั่งน้ำหนัก และวัดส่วนสูง, วัดความดันโลหิต, พบแพทย์, รับบัตรนัด, ยื่นใบสั่งยา, ชำระเงิน, และรับยา โดยจากการเก็บข้อมูลและนำมาวิเคราะห์ด้วยการจำลองสถานการณ์ พบว่า โดยเฉลี่ยแล้วผู้ป่วยต้องเสียเวลาไปกับการรอคอยเพื่อเข้ารับบริการถึงร้อยละ 67.15 ของเวลาทั้งหมดที่ใช้ในระบบ และกิจกรรมที่มีผู้ป่วยรอเข้ารับบริการโดยเฉลี่ยสูงที่สุด คือ กิจกรรมการเข้าพบแพทย์ เป็นจำนวน 5.34 คน ซึ่งเวลาการรอคอยและจำนวนผู้ป่วยที่รอเข้ารับบริการดังกล่าวนี้ควรถูกทำให้ลดลง เพื่อให้ผู้ป่วยที่เข้ามารับบริการเกิดความพึงพอใจและไม่เสียเวลาไปกับกระบวนการที่ไม่ก่อให้เกิดมูลค่า ดังนั้น งานวิจัยนี้จึงเสนอแนะทางเลือกในการปรับปรุงด้วยการเพิ่มจำนวนแพทย์ โดยสร้างแผนดำเนินงานขึ้นจำนวน 9 แผนดำเนินงาน ซึ่งเป็นการเพิ่มจำนวนแพทย์เพิ่มขึ้นครั้งละ 1 คน จากเดิมที่มีแพทย์ลงตรวจเป็นจำนวน 36 คน จึงเพิ่มขึ้นเป็น 37 – 45 คน แล้วทำการวิเคราะห์ผลลัพธ์โดยพิจารณาเวลาทั้งหมดที่ผู้ป่วยใช้ในระบบ เวลาที่ผู้ป่วยรอคอย และการใช้ประโยชน์ของแพทย์ เพื่อแสดงให้เห็นถึงผลของทางเลือกที่สร้างขึ้นว่าสามารถตอบสนองต่อความต้องการของผู้ป่วยได้มากน้อยเพียงใด

คำหลัก ผู้ป่วยนอก, แผนกกุมารเวชศาสตร์, โรงพยาบาล, การจำลองสถานการณ์, การไหลของผู้ป่วย

1. บทนำ

จากสภาวการณ์ในปัจจุบันที่มนุษย์ต้องเผชิญกับอาการเจ็บป่วยมากมาย ส่งผลให้มีผู้ป่วยเข้ารับบริการจากสถานบริการสาธารณสุขเป็นจำนวนมาก อีกทั้งทางภาครัฐได้มีการให้หลักประกันสุขภาพถ้วนหน้าแก่ประชาชน จึงทำให้เกิดความแออัดในการเข้ารับบริการและก่อให้เกิดความลำบากแก่ประชาชนผู้เข้ารับบริการจากโรงพยาบาลรัฐเป็นอย่างยิ่ง ซึ่งแตกต่างกับในโรงพยาบาลเอกชนที่มีความสะดวกสบายมากกว่า แต่เนื่องจากค่ารักษาพยาบาลที่แพงกว่าโรงพยาบาลรัฐ ทำให้มีเฉพาะประชาชนบางส่วนเท่านั้นที่สามารถเข้ารับบริการของโรงพยาบาลเอกชนได้ ดังนั้น งานวิจัยนี้จึงทำการศึกษาการไหลของผู้ป่วยนอกภายในโรงพยาบาลรัฐแห่งหนึ่ง เพื่อช่วยให้โรงพยาบาลรัฐสามารถตอบสนองต่อความต้องการของผู้ป่วยได้เป็นอย่างดีและให้บริการได้อย่างมีประสิทธิภาพ โดยใช้การจำลองสถานการณ์เป็นเครื่องมือในการวิเคราะห์การไหลของผู้ป่วย

2. ทบทวนงานวิจัย

การจำลองสถานการณ์เป็นการเลียนแบบการทำงานของระบบจริงโดยอาจสร้างขึ้นด้วยมือหรือคอมพิวเตอร์ และใช้เพื่อศึกษาหรือวิเคราะห์ระบบที่สนใจก่อนลงมือปฏิบัติจริง [1] ซึ่งหากพิจารณาเฉพาะการจำลองระบบงานของโรงพยาบาลนั้น ได้เคยมีการศึกษามายาวนานมากกว่า 30 ปี [2] และมีการศึกษาในหลากหลายหน่วยงาน ตัวอย่างเช่น คลินิกผู้ป่วยนอก [3 - 4] คลินิกแมมโมแกรม [5] แผนกฉุกเฉิน [6 - 7] และแผนกโรคไต [8] เมื่อศึกษาและวิเคราะห์ปัญหาที่เกิดขึ้นภายในระบบที่สนใจแล้ว ผู้วิจัยจะทำการสร้างทางเลือกในการปรับปรุงระบบ โดยอาจสร้างทางเลือกเกี่ยวกับระบบการนัดผู้ป่วย [4] หรือ พิจารณาจำนวน

เจ้าหน้าที่ภายในหน่วยงาน [6 - 7] ซึ่งจะเห็นได้ว่างานวิจัยเหล่านี้ได้ให้ความสำคัญกับความพึงพอใจของผู้ป่วยเป็นอย่างมาก เช่นเดียวกับงานวิจัยนี้

เป็นที่ทราบกันดีว่าการเข้ารับบริการจากโรงพยาบาลรัฐในปัจจุบัน ผู้ป่วยต้องใช้เวลาอยู่ภายในโรงพยาบาลเป็นจำนวนหลายชั่วโมง และเวลาส่วนใหญ่นั้นจะสูญเสียไปกับการรอคอยเพื่อเข้ารับบริการ ดังนั้น ผู้วิจัยจึงมีแนวคิดในการหากลยุทธ์เพื่อปรับปรุงระบบการไหลของผู้ป่วยนอกด้วยการจำลองสถานการณ์ เพื่อให้สามารถลดเวลาการรอคอยของผู้ป่วยลงจากเดิม และเป็นการตอบสนองต่อความต้องการของผู้ป่วย

3. กรณีศึกษา

งานวิจัยนี้ใช้แผนกกุมารเวชศาสตร์ของโรงพยาบาลรัฐขนาดใหญ่แห่งหนึ่งเป็นกรณีศึกษา จากสถิติพบว่าปริมาณผู้ป่วยนอกรายวันเป็นไปตามตารางที่ 1

ตารางที่ 1 ปริมาณผู้ป่วยนอกรายวันของแผนกกุมารเวชศาสตร์

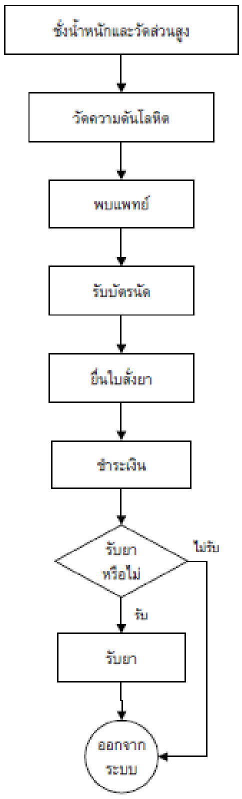
วัน	จำนวนผู้ป่วย (คน)
จันทร์	309
อังคาร	270
พุธ	443
พฤหัสบดี	262
ศุกร์	208
เสาร์	254
อาทิตย์	40

การไหลของผู้ป่วยนอกที่มาใช้บริการเป็นไปตามรูปที่ 1 กล่าวคือ เมื่อผู้ป่วยเข้ามาติดต่อกับทางหน่วยเรียบร้อยแล้วจะต้องมาทำการชั่งน้ำหนักและวัดส่วนสูงเป็นอันดับแรก ต่อไปเป็นการวัดความดันโลหิต เข้าพบแพทย์เพื่อทำการรักษา รับบัตรนัด ยื่นใบสั่งยาที่ห้องยา ชำระเงินที่ห้องการเงิน ตามลำดับ ซึ่งหากผู้ป่วยรายใดที่แพทย์ไม่ได้สั่งยาให้ ก็จะสามารถกลับบ้านได้ทันที ส่วนผู้ป่วยที่แพทย์สั่งยาให้นั้น จะต้องรับยาในขั้นตอนสุดท้ายก่อนออกจากระบบ แต่จะมีผู้ป่วยจำนวนหนึ่งที่ต้องถูกส่งไปตรวจเพิ่มเติมยังหน่วยรังสีวินิจฉัย และห้องเจาะเลือด แล้วกลับเข้ามาพบแพทย์ที่หน่วยกุมารเวชศาสตร์อีกครั้ง จากการสัมภาษณ์พยาบาลและแพทย์ สามารถแบ่งประเภทของผู้ป่วยตามประเภทของบริการออกเป็น 8 ประเภท ดังตารางที่ 2 จะเห็นว่าหน่วยตรวจโรคแห่งนี้ให้บริการผู้ป่วยที่มีการนัดหมายล่วงหน้าเป็นส่วนใหญ่ (57.88%) แต่จะมีผู้ป่วยไม่ได้นัดจำนวนมากพอสมควรในแต่ละวัน (24.22%) ผู้ป่วยทั้งที่นัดและไม่นัดอาจได้รับการรักษาด้วยวิธีการแตกต่างกัน เช่น ผู้ป่วยนัด อาจจะต้องไปเจาะเลือด (หรือเอกซเรย์) และต้องพบแพทย์ถึง 2 ครั้ง

ตารางที่ 2 ประเภทของผู้ป่วยและจำนวนผู้ป่วย

ประเภทของผู้ป่วย	จำนวน (ร้อยละ)
1. ผู้ป่วยฉุกเฉิน	2.00
2. ผู้ป่วยนัด	57.58
3. ผู้ป่วยนัดโรคพัฒนาการ	2.98
4. ผู้ป่วยนัด + เอกซเรย์ + พบแพทย์ 2 ครั้ง	3.15
5. ผู้ป่วยนัด + เจาะเลือด + พบแพทย์ 2 ครั้ง	6.30
6. ผู้ป่วยไม่นัด	24.22
7. ผู้ป่วยไม่นัด + เอกซเรย์ + พบแพทย์ 2 ครั้ง	1.26
8. ผู้ป่วยไม่นัด + เจาะเลือด + พบแพทย์ 2 ครั้ง	2.52

จำนวนของทรัพยากรที่ใช้ในแต่ละกิจกรรมจะมีจำนวนแตกต่างกันไป ตามตารางที่ 3 กล่าวคือ กิจกรรมนั้นๆจะมีทรัพยากรทั้งที่เป็นเครื่องมือและบุคลากรประจำอยู่ที่จุดนั้นเป็นจำนวนดังที่ปรากฏในตาราง ในการจำลองสถานการณ์ หากกิจกรรมใดมีจำนวนทรัพยากรในการทำงานมากกว่างานที่ต้องทำ จะใช้หลักการเลือกทรัพยากรจากสถานะของการทำงาน ถ้าทรัพยากรใดว่างงานอยู่ จะให้ทรัพยากรนั้นทำงาน



รูปที่ 1 การไหลของผู้ป่วยนอกภายในแผนกกุมารเวชศาสตร์

ตารางที่ 3 ทรัพยากรภายในแผนกกุมารเวชศาสตร์

กิจกรรม	ทรัพยากรและจำนวนของทรัพยากร
ชั่งน้ำหนักและวัดส่วนสูง	ผู้ช่วยพยาบาล 1 คน* เครื่องชั่งน้ำหนักและวัดส่วนสูง 1 เครื่อง
วัดความดันโลหิต	ผู้ช่วยพยาบาล 1 คน* เครื่องวัดความดันโลหิต 1 เครื่อง
พบแพทย์	แพทย์ 36 คน ผู้ช่วยพยาบาล 18 คน ห้องตรวจ 36 ห้อง
รับบัตรนัด	พยาบาล 1 คน ผู้ช่วยพยาบาล 1 คน เจ้าหน้าที่ธุรการ 1 คน
ยื่นใบสั่งยา	เจ้าหน้าที่ 1 คน
ชำระเงิน	เจ้าหน้าที่ 1 คน
รับยา	เจ้าหน้าที่จัดยา 1 คน เภสัชกร 1 คน

หมายเหตุ: * ผู้ช่วยพยาบาลคนเดียวกัน

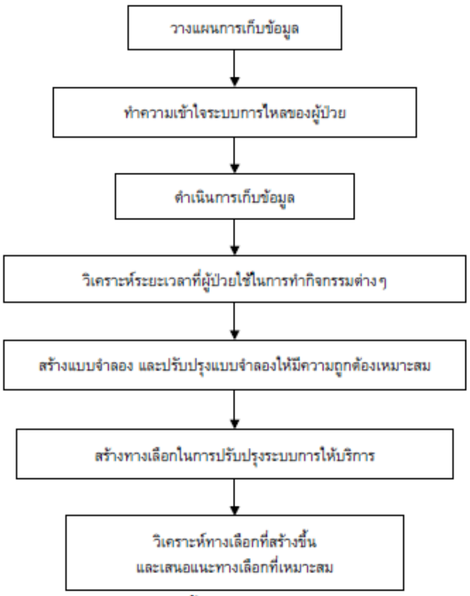
4. ข้อมูล

4.1 การสำรวจรวบรวมข้อมูลและวิเคราะห์ข้อมูล

ขั้นตอนแรกของการดำเนินงานวิจัยนี้ คือ การวางแผนเก็บข้อมูล ดังปรากฏในรูปที่ 2 จากนั้นผู้วิจัยจะต้องทำความเข้าใจกับระบบการไหลของผู้ป่วยนอกแผนกกุมารเวชศาสตร์ เพื่อให้สามารถดำเนินการเก็บข้อมูลได้อย่างถูกต้อง ซึ่งในการเก็บข้อมูลนี้ ผู้วิจัยได้เลือกตัวอย่างผู้ป่วยด้วยวิธีการสุ่มตัวอย่างผู้ป่วยจำนวน 30 คน และทำการเก็บรวบรวมข้อมูลโดยตรงจากระบบการให้บริการผู้ป่วย ซึ่งกระทำโดยใช้วิธีการสำรวจ สังเกตและการตามรอยผู้ป่วย (Patient Tracking) ซึ่งการตามรอยผู้ป่วยนั้น หมายถึง การติดตามผู้ป่วยตั้งแต่กิจกรรมแรกที่ผู้ป่วยเข้ามาติดต่อเพื่อรับบริการ ไปจนกระทั่งกิจกรรมสุดท้ายที่ผู้ป่วยสามารถออกจากโรงพยาบาลได้ โดยการตามรอยนี้ต้องไม่เป็นการรบกวนและแทรกแซงการทำกิจกรรมต่างๆ ของผู้ป่วย ข้อมูลที่สำรวจประกอบด้วย

- ขั้นตอนการให้บริการผู้ป่วย
- ประเภทของผู้ป่วย
- ระยะเวลาที่ผู้ป่วยใช้ทำกิจกรรมต่างๆ ในระบบการไหลภายในโรงพยาบาล
- ระยะทางและระยะเวลาที่ผู้ป่วยใช้เดินทางจากจุดให้บริการแต่ละจุดภายในโรงพยาบาล
- จำนวนทรัพยากรต่างๆ ภายในหน่วยกุมารเวชศาสตร์
- แผนผังแผนกกุมารเวชศาสตร์
- หน่วยงานต่างๆ ที่ผู้ป่วยเข้ารับบริการภายในโรงพยาบาล

หลังจากดำเนินการเก็บข้อมูลเป็นที่เรียบร้อยแล้ว ขั้นตอนต่อไป คือ การวิเคราะห์ระยะเวลาที่ผู้ป่วยใช้ในการทำกิจกรรม เพื่อให้ได้ระยะเวลาเฉลี่ย ระยะเวลาต่ำสุด และระยะเวลาสูงสุดที่ผู้ป่วยใช้ จากนั้นจะนำระยะเวลาของแต่ละกิจกรรมไปทำการหารูปแบบการกระจายตัวของข้อมูลด้วยโปรแกรม Input Analyzer เพื่อนำไปใช้สำหรับการสร้างแบบจำลองต่อไป



รูปที่ 2 ขั้นตอนการดำเนินงาน

4.2 การสร้างแบบจำลองสถานการณ์

การสร้างแบบจำลองสำหรับงานวิจัยนี้ มีขั้นตอนที่สำคัญ 2 ขั้นตอน ดังต่อไปนี้

1) สร้างแบบจำลองด้วยโปรแกรม Rockwell Arena โดยนำรูปแบบการกระจายตัวของข้อมูลที่ทำการวิเคราะห์แล้วข้างต้นมาใช้กับแบบจำลองนี้ ซึ่งแบบจำลองที่สร้างขึ้นจะมีลักษณะการไหลของผู้ป่วยเช่นเดียวกับที่เกิดขึ้นกับระบบจริง

2) ทำการตรวจสอบความสอดคล้องและความถูกต้องของแบบจำลอง ดังนี้

2.1 Verification เป็นการตรวจสอบแบบจำลองที่สร้างขึ้นว่าสามารถทำงานได้หรือไม่ โดยในงานวิจัยนี้ได้ทำการ verify แบบจำลองด้วยการตรวจสอบว่า entity (ผู้ป่วย) ที่เข้ามาในระบบของแบบจำลองนั้นได้ไหลถูกต้องตามการไหลของผู้ป่วยนอกของระบบจริง อีกทั้งตรวจสอบว่าแบบจำลองที่สร้างขึ้นนี้สามารถทำงานได้จริงโดยไม่เกิดความผิดพลาด (error) ขึ้นในแบบจำลอง

2.2 Validation เป็นการตรวจสอบว่าผลลัพธ์ที่ได้จากแบบจำลองมีความถูกต้องสอดคล้องกับระบบจริง ซึ่งผู้วิจัยได้ทำการ validate แบบจำลอง โดยการให้โปรแกรมทำงาน 500 รอบ และนำผลลัพธ์ (ระยะเวลาของแต่ละกิจกรรม) ที่ได้มาทำการเปรียบเทียบกับข้อมูลที่ได้จากการสำรวจและเก็บรวบรวม ซึ่งหากผลลัพธ์ของกิจกรรมใดไม่สอดคล้องกับข้อมูลจริง ผู้วิจัยจะทำการปรับค่า parameter ของรูปแบบการกระจายตัวของกิจกรรมนั้นๆ และให้โปรแกรมทำงาน

ใหม่ แล้วทำการเปรียบเทียบผลลัพธ์ใหม่อีกครั้ง หากผลลัพธ์ใหม่นี้สอดคล้องกับข้อมูลจริงแล้ว ถือว่าเป็นอันเสร็จสมบูรณ์ แต่หากยังไม่เกิดความถูกต้องสอดคล้อง ผู้วิจัยจะทำตามวิธีข้างต้นซ้ำจนกว่าจะได้ผลลัพธ์ที่ถูกต้องสอดคล้องครบทุกกิจกรรม

4.3 การพัฒนาทางเลือกในการปรับปรุงระบบ

ภายหลังจากการสร้างแบบจำลองของระบบการให้บริการและทราบถึงปัญหาที่เกิดขึ้นภายในระบบแล้ว ขั้นตอนต่อไป ผู้วิจัยจะทำการสร้างทางเลือกเพื่อปรับปรุงแก้ไขปัญหาดังกล่าว ทางเลือกที่พัฒนาขึ้นได้มาหลายแหล่ง ได้แก่ จากตัวอย่างที่เคยประยุกต์ใช้กันมาแล้วอย่างได้ผลทั้งในและต่างประเทศ จากประสบการณ์ของนักวิจัย จากข้อเสนอแนะของผู้บริหารโรงพยาบาล จากข้อเสนอของพยาบาลและเจ้าหน้าที่ผู้ปฏิบัติงานในแผนกกุมารเวชศาสตร์ จากนั้นจะเป็นการวิเคราะห์ผลกระทบหากปฏิบัติตามทางเลือกที่พัฒนาขึ้น โดยประเมินจากค่าดัชนีชี้วัดที่สนใจ และเสนอแนะทางเลือกที่เหมาะสมต่อผู้บริหารโรงพยาบาลสำหรับการปรับปรุงระบบการให้บริการผู้ป่วยนอกให้มีประสิทธิภาพ ซึ่งผู้บริหารจะเป็นผู้ตัดสินใจนำเอาทางเลือกเหล่านั้นไปใช้กับระบบจริงต่อไป

5. ผลการวิเคราะห์

5.1 ระบบการให้บริการในปัจจุบัน

เมื่อทำการสร้างแบบจำลองของแผนกกุมารเวชศาสตร์ด้วยโปรแกรมคอมพิวเตอร์ Rockwell Arena และกำหนดให้โปรแกรมทำงานทั้งหมด 500 รอบ พบว่าเวลาที่ผู้ป่วยใช้ในโรงพยาบาลนั้นจะสูญเสียไปกับการรอคอยเพื่อเข้ารับบริการ ซึ่งโดยเฉลี่ยแล้วเวลารอคอยจะคิดเป็นร้อยละ 67.15 ของเวลาทั้งหมดที่ผู้ป่วยใช้ในระบบ ดังจะเห็นได้จากตารางที่ 4 ซึ่งเวลาการรอคอยนี้ควรจะถูกทำให้ลดลง เนื่องจากเวลาการรอคอยเป็นเวลาที่ไม่ก่อให้เกิดมูลค่า จึงไม่ควรเสียเวลาอยู่ภายในโรงพยาบาลโดยที่ไม่ได้รับบริการใดๆ

ตารางที่ 4 ระยะเวลาที่ผู้ป่วยใช้เมื่อเข้ามารับบริการในโรงพยาบาล

ประเภทผู้ป่วย	ระยะเวลาทั้งหมดที่ใช้ (นาที)	ระยะเวลาเข้ารับบริการ (นาที)	ระยะเวลารอเข้ารับบริการ (นาที)
1	115.3	23.3	92.0 (79.82%)
2	115.3	23.3	92.0 (79.82%)
3	115.3	23.3	92.0 (79.82%)
4	193.4	67.4	125.9 (65.13%)
5	225.2	99.3	125.9 (55.92%)
6	115.3	23.3	92.0 (79.82%)
7	193.4	67.4	125.9 (65.13%)
8	225.2	99.3	125.9 (55.92%)
เฉลี่ย	162.3	53.3	109.0 (67.15%)

หมายเหตุ: ตัวเลขในวงเล็บ คือ ร้อยละของระยะเวลารอเข้ารับบริการต่อระยะเวลาทั้งหมดที่ใช้

ตารางที่ 5 จำนวนผู้ป่วยโดยเฉลี่ยที่รอเข้ารับบริการแยกตามประเภทกิจกรรม

กิจกรรม	จำนวนผู้ป่วยที่รอเข้ารับบริการ (คน)
ชั่งน้ำหนักและวัดส่วนสูง	4.76
วัดความดันโลหิต	0.00
พบแพทย์	5.34
รับบัตรนัด	1.16
ยื่นใบสั่งยา	0.00
ชำระเงิน	0.71
รับยา	0.86

และหากพิจารณาในแง่ของจำนวนผู้ป่วยที่รอคอยเพื่อเข้ารับบริการในแต่ละกิจกรรม จะพบว่า จำนวนผู้ป่วยที่รอคอยอยู่ในคิวโดยเฉลี่ย เป็นดังตารางที่ 5 ซึ่งแสดงให้เห็นได้ว่า กิจกรรมที่มีผู้ป่วยรอเข้ารับบริการมากที่สุด ได้แก่ กิจกรรมการพบแพทย์ ที่มีผู้ป่วยรอเข้ารับบริการโดยเฉลี่ย 5.34 คน

ดังนั้นผู้วิจัยจึงมีแนวคิดในการพัฒนาทางเลือกสำหรับแก้ไขปัญหาภายในระบบการไหลของหน่วยกุมารเวชศาสตร์แห่งนี้ ด้วยการเพิ่มจำนวนทรัพยากรบุคคลประจำจุดของกิจกรรมที่ถือว่าเป็นจุดคอขวดของระบบ ซึ่งคือ กิจกรรมการพบแพทย์ และบุคลากรที่มีความสำคัญมากที่สุดของกิจกรรมนี้ ก็คือ แพทย์ผู้ทำการตรวจรักษาผู้ป่วย โดยผู้วิจัยได้เสนอแผนดำเนินงานขึ้นมาทั้งหมด 9 แผนดำเนินงาน ได้แก่ แผนดำเนินงาน A-1 ถึง A-9 ซึ่งเป็นการเพิ่มจำนวนแพทย์ขึ้นจากระบบปัจจุบัน โดยจะเพิ่มจำนวนขึ้นตั้งแต่ 1 คน ไปจนถึง 9 คน เรียงตามลำดับแผนดำเนินงาน ดังปรากฏในตารางที่ 6 โดยที่แผนดำเนินงาน A-0 นั้น จะเป็นการดำเนินงานตามระบบปัจจุบัน

ตารางที่ 6 แผนดำเนินงานสำหรับการเพิ่มทรัพยากรแพทย์

แผนดำเนินงาน (scenario)	จำนวนแพทย์ทั้งหมด (คน)	จำนวนแพทย์ที่เพิ่มขึ้น (คน)
A-0	36	0
A-1	37	1
A-2	38	2
A-3	39	3
A-4	40	4
A-5	41	5
A-6	42	6
A-7	43	7
A-8	44	8
A-9	45	9

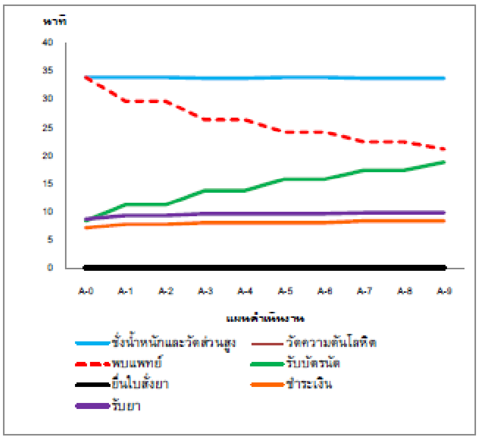
5.2 ผลกระทบจากการเพิ่มจำนวนแพทย์

จากการทดลองเพื่อหาผลลัพธ์ของแผนดำเนินงานที่ได้นำเสนอในข้างต้น พบว่า ระยะเวลาเข้ารับบริการที่ผู้ป่วยใช้ในแต่ละแผนดำเนินงาน มีแนวโน้มใกล้เคียงกับระบบปัจจุบัน กล่าวคือ ลดลงเพียงร้อยละ 0.19 – 0.39 เท่านั้น แสดงให้เห็นว่าการเพิ่มจำนวนแพทย์ไม่ส่งผลกระทบมากนักกับระยะเวลาเข้ารับบริการที่ผู้ป่วยใช้ในการทำกิจกรรมต่างๆ ดังจะเห็นได้จากคอลัมน์ที่ 3 ของตารางที่ 7

เมื่อพิจารณาในด้านระยะเวลาที่ผู้ป่วยรอเพื่อเข้ารับบริการ จะพบว่า การเพิ่มจำนวนแพทย์ทำให้เวลารอเข้ารับบริการมีแนวโน้มคงที่ หรืออาจเพิ่มขึ้นโดยแปรผันตามการเพิ่มขึ้นของจำนวนแพทย์ แต่หากพิจารณาเฉพาะกิจกรรมการพบแพทย์เพียงกิจกรรมเดียว พบว่า เวลารอเข้าพบแพทย์มีแนวโน้มลดลง ซึ่งแปรผกผันกับจำนวนแพทย์ที่เพิ่มขึ้น แสดงให้เห็นเป็นดังเส้นประที่ดิ่งลงตามการเพิ่มขึ้นของจำนวนแพทย์ ในรูปที่ 3

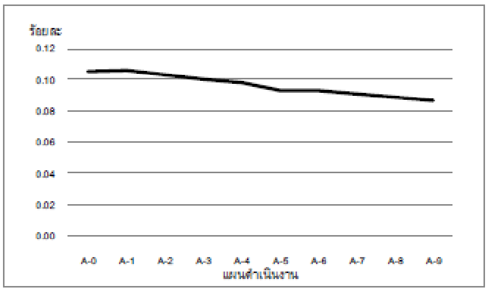
ตารางที่ 7 ระยะเวลาเข้ารับบริการที่ผู้ป่วยใช้ในการทำกิจกรรม แยกตามแผนดำเนินงาน

แผนดำเนินงาน	ระยะเวลาเข้ารับบริการ (นาที)	ระยะเวลาที่ลดลงจากระบบปัจจุบัน (ร้อยละ)
A-0	115.31	-
A-1	115.03	0.25
A-2	115.03	0.25
A-3	114.89	0.36
A-4	114.89	0.36
A-5	114.86	0.39
A-6	114.86	0.39
A-7	115.07	0.20
A-8	115.07	0.20
A-9	115.10	0.19



รูปที่ 3 แผนภูมิแสดงระยะเวลารอเข้ารับบริการในแต่ละกิจกรรม

ส่วนในด้านการใช้ประโยชน์จากทรัพยากรแพทย์ หรือสัดส่วนเวลาการทำงานจริงของแพทย์ต่อเวลาการทำงานทั้งหมดในระบบนั้น เป็นดังรูปที่ 4 นั่นคือ การเพิ่มแพทย์ในแต่ละแผนดำเนินงาน ไม่ได้ก่อให้เกิดความแตกต่างของการใช้ประโยชน์จากแพทย์เมื่อเปรียบเทียบจากระบบปัจจุบันมากนัก อีกทั้งการใช้ประโยชน์ยังมีค่าน้อยลดลงกว่าปัจจุบันอีกด้วย ซึ่งที่เป็นเช่นนี้อาจเนื่องมาจากจำนวนแพทย์ในระบบปัจจุบันของทางหน่วยมีมากอยู่แล้ว การเพิ่มจำนวนแพทย์ให้มากขึ้นกว่าเดิมนั้น จึงไปลดเวลาการทำงานของแพทย์กลุ่มเดิมที่ทำงานอยู่ เมื่อเฉลี่ยการทำงานออกมาจึงได้ผลลัพธ์ของการใช้ประโยชน์ของแพทย์แต่ละคนที่มีค่าน้อยลง



รูปที่ 4 แผนภูมิแสดงการใช้ประโยชน์ของทรัพยากรแพทย์

6. สรุปผลและข้อเสนอแนะ

การวิจัยนี้เป็นการศึกษาการไหลของผู้ป่วยนอกภายในแผนกกุมารเวชศาสตร์ ของโรงพยาบาลรัฐขนาดใหญ่แห่งหนึ่ง เพื่อวิเคราะห์ปัญหาและเสนอแนะแนวทางการปรับปรุงระบบการให้บริการผู้ป่วยนอกให้มีประสิทธิภาพสูงขึ้น โดยใช้การจำลองสถานการณ์เป็นเครื่องมือในการวิเคราะห์ และพัฒนาทางเลือกเพื่อนำมาใช้เป็นแนวทางในการปรับปรุงระบบ ซึ่งผลลัพธ์จากการวิเคราะห์ข้อมูลทำให้ทราบว่า ปัญหาที่เกิดขึ้น คือ ผู้ป่วยเสียเวลาส่วนใหญ่ไปกับการรอคอยเพื่อเข้ารับบริการ และกิจกรรมที่มีผู้ป่วยรอเข้ารับบริการมากที่สุด ได้แก่ กิจกรรมการพบแพทย์

ผู้วิจัยได้ทดลองเพิ่มจำนวนบุคลากรที่มีความสำคัญมากที่สุดของกิจกรรมการพบแพทย์ นั่นก็คือ แพทย์ โดยคาดว่าจะเป็นการแก้ปัญหาที่สาเหตุโดยตรง และวิเคราะห์ผลกระทบด้วยแบบจำลองสถานการณ์ โดยได้เสนอแผนดำเนินงานที่เป็นการเพิ่มทรัพยากรแพทย์ให้มากขึ้นเป็นลำดับ แต่ผลลัพธ์จากการวิเคราะห์กลับแสดงให้เห็นว่า การเพิ่มจำนวนแพทย์เข้าไปในระบบไม่ได้ทำให้ระยะเวลาที่ผู้ป่วยเข้ารับบริการลดลงมากนัก อีกทั้งระยะเวลาที่ผู้ป่วยรอเข้ารับบริการในแต่ละกิจกรรมยังเพิ่มสูงขึ้นด้วย มีเพียงแค่ระยะเวลาการรอเพื่อเข้าพบแพทย์เท่านั้นที่ลดลง และการใช้ประโยชน์โดยเฉลี่ยของแพทย์แต่ละคนก็ยังมีแนวโน้มลดลงแปรผกผันกับจำนวนแพทย์ที่เพิ่มขึ้นอีกด้วย

ผลลัพธ์จากการวิเคราะห์ดังกล่าว แสดงให้เห็นว่าการเพิ่มจำนวนแพทย์เข้าไปในระบบอาจจะไม่ใช่วิธีการแก้ปัญหาการไหลของผู้ป่วยอย่างมีประสิทธิผลอย่างที่คาดไว้ เนื่องจากโซ่อุปทาน

การให้บริการผู้ป่วยนอกมีความยาวและสลับซับซ้อน ประกอบด้วยกิจกรรมจำนวนมากซึ่งขึ้นอยู่แก่กันและกัน การเพิ่มจำนวนแพทย์จึงอาจเป็นเพียงการแก้ปัญหาเฉพาะหน้าหรือเลื่อนปัญหาความคับคั่งไปยังกิจกรรมอื่นๆ เช่น ไปแออัดกันที่แผนกการเงินหรือแผนกยา เป็นต้น ดังนั้นการแก้ปัญหาการไหลของผู้ป่วยซึ่งล่าช้าและแออัดคับคั่ง จึงจำเป็นต้องพิจารณาองค์ประกอบต่างๆ อย่างทั่วถึง อีกทั้งแผนดำเนินงานที่จะนำไปปฏิบัติควรต้องทำการศึกษาต่อไปถึงความคุ้มค่าในด้านต้นทุนและความพึงพอใจของผู้ป่วย การศึกษาต่อไปในอนาคตจึงควรวิเคราะห์แนวทางอื่นเป็นการเพิ่มเติม เช่น การเลื่อนเวลาลงตรวจรักษาของแพทย์ให้เร็วขึ้นกว่าปกติ เพื่อหวังว่าจะกระจายความแออัดของผู้ป่วยไปตามช่วงเวลาต่างๆ ของวันให้มากขึ้น หรือการนำระบบนัดหมายผู้ป่วย มาใช้อย่างจริงจัง ซึ่งจะเป็นการจำกัดจำนวนผู้ป่วยที่ควรจะอยู่ที่โรงพยาบาลไม่ให้แออัดเกินไปอย่างเช่นที่เป็นอยู่ในปัจจุบันนี้ ทั้งนี้เพื่อประโยชน์อันสูงสุดแก่โรงพยาบาลและผู้ป่วยที่เข้ามารับบริการ

กิตติกรรมประกาศ

ขอขอบพระคุณผู้บริหารของโรงพยาบาล แพทย์ พยาบาล และเจ้าหน้าที่ผู้ปฏิบัติงานของแผนกกุมารเวชศาสตร์ ณ โรงพยาบาลกรณีศึกษา รวมทั้งหน่วยงานต่างๆ ที่เกี่ยวข้อง ที่ให้ความร่วมมือเป็นอย่างดีระหว่างการสัมภาษณ์ สอบถาม และสำรวจรวบรวมข้อมูลจำนวนมากภายในโรงพยาบาล และที่จะขาดมิได้คือ ผู้ป่วยนอกทุกท่าน ซึ่งทีมงานวิจัยทำการตามรอยท่านไปตลอดโซ่อุปทานของการเข้ารับบริการ อีกทั้งความคิดเห็นต่างๆ ของทุกท่านที่มีต่อระบบการให้บริการ อันเป็นประโยชน์อย่างยิ่งต่อการทำงานวิจัยโครงการนี้รวมถึงผู้ช่วยศาสตราจารย์ ดร. ธนัญญา วสุศรี ที่กรุณาให้ความช่วยเหลือด้านการจำลองสถานการณ์อย่างเต็มที่

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APPENDIX E
A PUBLICATION IN THE EIGHTH NATIONAL TRANSPORT CONFERENCE (NTC8)

การประชุมวิชาการ การขนส่งแห่งชาติ ครั้งที่ 8
พัฒนาการขนส่งหลายรูปแบบสู่ความเป็นเลิศทางเศรษฐกิจระดับโลก

(NTC8-089)

ผลของการเลื่อนตารางลงตรวจของแพทย์ต่อประสิทธิภาพการไหลของผู้ป่วยนอก

Effects of Adjusting Physician Work Schedule on the Efficiency of Outpatient Flow

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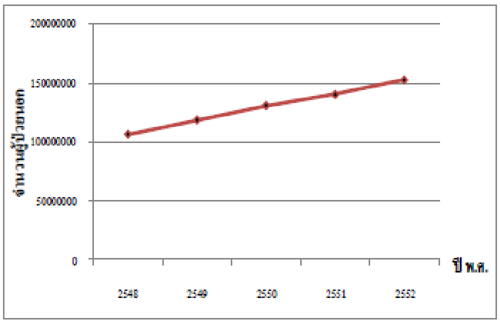
บทคัดย่อ:

บทความวิจัยนี้รายงานผลการศึกษาและวิเคราะห์ทางเลือกของแผนการดำเนินงานเพื่อเพิ่มประสิทธิภาพการไหลของผู้ป่วยนอกแผนกกุมารเวชศาสตร์ในโรงพยาบาลรัฐขนาดใหญ่มากแห่งหนึ่งของประเทศไทย การสำรวจรวบรวมข้อมูลเพื่อทำความเข้าใจการไหลใช้วิธีการตามรอยผู้ป่วย (Patient Tracking) ตลอดโซ่อุปทานของบริการสุขภาพตั้งแต่เริ่มเข้ามาในแผนกกระทั่งกลับบ้านไป กิจกรรมต่างๆ ที่ผู้ป่วยนอกต้องทำระหว่างเข้ารับบริการประกอบด้วย การยื่นบัตรนัด, ชั่งน้ำหนักและวัดส่วนสูง, วัดความดันโลหิต, พบแพทย์, รับบัตรนัด, ยื่นใบสั่งยา, ชำระเงิน, และรับยา โดยเฉลี่ยแล้วผู้ป่วยต้องเสียเวลาไปกับการรอคอย ณ สถานีต่างๆ ก่อนเข้ารับบริการถึงร้อยละ 67.15 ของเวลาทั้งหมดที่ใช้ในระบบ กิจกรรมที่มีผู้ป่วยนอกรอเข้ารับบริการโดยเฉลี่ยสูงที่สุด คือ กิจกรรมการเข้าพบแพทย์ ซึ่งเวลาการรอคอยและจำนวนผู้ป่วยที่รอเข้ารับบริการดังกล่าวนี้ควรถูกทำให้ลดลง เพื่อให้ผู้ป่วยและญาติเกิดความพึงพอใจและไม่เสียเวลาไปกับการรอคอยซึ่งไม่ก่อให้เกิดมูลค่าใดๆ ผู้บริหารจึงมีแนวคิดจะเลื่อนเวลาลงตรวจของแพทย์ให้เร็วขึ้นอีกหนึ่งชั่วโมงเพื่อกระจายปริมาณผู้ป่วยไปตามช่วงเวลาให้กว้างขึ้นลดความแออัดคับคั่ง จากการวิเคราะห์ผลกระทบด้วยแบบจำลองสถานการณ์พบว่าแนวคิดดังกล่าวไม่สามารถลดเวลาทั้งหมดที่ผู้ป่วยใช้ในระบบได้อย่างมีนัยสำคัญ แต่สามารถช่วยลดเวลารอคอยในกิจกรรมพบแพทย์และรับบัตรนัดได้ ดังนั้นก่อนนำแผนดำเนินงานไปปฏิบัติจริง ควรต้องศึกษาวิเคราะห์ถึงความคุ้มค่าในด้านต้นทุนและความพึงพอใจของผู้ป่วยด้วย

คำสำคัญ: ผู้ป่วยนอก, แผนกกุมารเวชศาสตร์, โรงพยาบาล, การจำลองสถานการณ์, การไหลของผู้ป่วย

1. บทนำ

การเข้ารับบริการทางด้านสุขภาพจากสถานพยาบาลของรัฐในปัจจุบันได้สร้างความยากลำบากให้กับประชาชนผู้เข้ารับบริการเป็นอย่างยิ่ง แนวโน้มการเพิ่มขึ้นอย่างต่อเนื่องของปริมาณผู้ป่วยนอกตามภาพที่ 1 [1] โดยเฉพาะอย่างยิ่งในโรงพยาบาลรัฐที่มีขนาดใหญ่นั้น เป็นสัญญาณบ่งบอกถึงความแออัดคับคั่งที่เพิ่มขึ้นในระบบการไหลของผู้ป่วยนอก หากว่าไม่มีแนวทางป้องกันหรือรองรับปัญหาตั้งแต่บัดนี้ ซึ่งแตกต่างจากโรงพยาบาลเอกชนที่มีความสะดวกสบายมากกว่า แต่ก็มาพร้อมกับค่ารักษาพยาบาลที่แพงกว่าด้วยเช่นกัน ดังนั้นเพื่อช่วยให้โรงพยาบาลรัฐสามารถให้บริการได้อย่างมีประสิทธิภาพ และตอบสนองต่อความต้องการของผู้ป่วยได้ดีขึ้น งานวิจัยนี้จึงได้ทำการศึกษาการไหลของผู้ป่วยนอกภายในโรงพยาบาลรัฐแห่งหนึ่ง โดยใช้แบบจำลองสถานการณ์ (Simulation) เป็นเครื่องมือในการวิเคราะห์



ภาพที่ 1 จำนวนผู้ป่วยนอกของสถานพยาบาลรัฐในประเทศไทยระหว่างปี พ.ศ. 2548 - 2552

2. งานวิจัยที่เกี่ยวข้อง

2.1 การไหลของผู้ป่วย

การไหลของผู้ป่วย เริ่มต้นเมื่อผู้ป่วยมาถึงสถานพยาบาล หรือเมื่อได้รับการวินิจฉัยโรค และสิ้นสุดเมื่อผู้ป่วยออกจากสถานพยาบาลนั้น [2] ซึ่งแต่ละแผนกหรือแต่ละสถานพยาบาลก็จะมีการไหลของผู้ป่วยแตกต่างกัน เนื่องจากการรักษาและระดับความซับซ้อนที่แตกต่างกัน นอกจากนี้ยังอาจแตกต่างกันตามประเภทของผู้ป่วยด้วย มีงานวิจัยมากมายทำการศึกษาเกี่ยวกับการไหลของผู้ป่วยในสถานพยาบาล เช่น การปรับปรุงการไหลของผู้ป่วยเพื่อลดเวลาการรอคอยในแผนกฉุกเฉิน [3] และการวิเคราะห์ปัจจัยหลักซึ่งบั่นทอนประสิทธิภาพการไหลของผู้ป่วยด้วยแบบจำลองสถานการณ์ [4] เป็นต้น การไหลของผู้ป่วยที่ไม่เป็นระบบนั้นจะเป็นการเพิ่มเวลาการรอคอย [4 - 5] ลดคุณภาพในการให้บริการ และเพิ่มต้นทุนการให้บริการ ดังนั้นการไหลของผู้ป่วยที่มีประสิทธิภาพนั้น จะหมายถึงการไหลที่สามารถให้บริการผู้ป่วยได้เป็นจำนวนมาก มีการให้บริการที่รวดเร็ว และมีระยะเวลาการรอคอยที่ต่ำ [4]

2.2 ดัชนีชี้วัดประสิทธิภาพ (KPIs) การไหลของผู้ป่วย

ดัชนีชี้วัดประสิทธิภาพ (Key Performance Indicators; KPIs) เป็นตัวแปรที่ใช้ในการบ่งชี้ถึงทางเลือกที่มีประสิทธิภาพ ซึ่งอาจนำไปประยุกต์ใช้ได้ในระบบจริง KPIs ที่นิยมใช้กันมากในงานวิเคราะห์ประสิทธิภาพการไหลของผู้ป่วย ประกอบด้วย

1) ระยะเวลาทั้งหมดในระบบ (Length of Stay; LOS) คือ เวลาทั้งหมดที่ผู้ป่วยใช้อยู่ภายในสถานพยาบาล เป็นระยะเวลาตั้งแต่เมื่อผู้ป่วยลงทะเบียนเพื่อเข้ารับบริการ กระทั่งผู้ป่วยออกจากสถานพยาบาล ระบบที่มี LOS ยาวนาน ความพึงพอใจของผู้ป่วยจะลดลง [6 - 7]

2) ระยะเวลาการรอคอย (Waiting Time) เป็นเวลาที่ไม่ก่อให้เกิดมูลค่า ซึ่งผู้ป่วยต้องเสียไปกับการรอคอยก่อนเข้ารับบริการ ระยะเวลาการรอคอยแสดงให้เห็นถึงการขาดแคลนขีดความสามารถในการให้บริการของระบบได้ [8]

3) การใช้ประโยชน์ของทรัพยากร (Resource Utilization) หมายถึง ปริมาณการทำงานของทรัพยากร [9] สามารถแสดงให้เห็นถึงจุดที่เป็นคอขวด (bottlenecks) และทรัพยากรที่ไม่จำเป็นในระบบได้ [10]

โดยสรุปแล้ว KPIs ทั้งสามตัวนี้มีความเกี่ยวข้องสัมพันธ์ซึ่งกันและกัน คือ เมื่อการใช้ประโยชน์ของทรัพยากรมีค่าสูงมาก จะทำให้เวลาการรอคอยนานขึ้น ในทางตรงกันข้าม หากทรัพยากรถูกใช้อย่างมีประสิทธิภาพ เวลาทั้งหมดในระบบของผู้ป่วยก็จะลดลง

2.3 การจำลองสถานการณ์

การจำลองสถานการณ์เป็นการเลียนแบบระบบการทำงานจริง ซึ่งมักถูกใช้ในการวิเคราะห์ผล ในกรณีที่ระบบถูกเปลี่ยนแปลงไปจากปัจจุบัน หรือใช้ในการศึกษาระบบที่สนใจก่อนที่ระบบนั้นจะถูกสร้างขึ้นจริง [11] ซึ่งการใช้การจำลองสถานการณ์นี้จะมีความรวดเร็วและมีค่าใช้จ่ายต่ำกว่าการลงมือปฏิบัติจริง [12] โดยซอฟท์แวร์ที่นำมาใช้ในการจำลองสถานการณ์มีอยู่มากมาย เช่น Extend, Rockwell Arena และ SIMUL8 เป็นต้น

3. ระเบียบวิธีวิจัย

3.1 ข้อมูล

งานวิจัยนี้ใช้แผนกกุมารเวชศาสตร์ของโรงพยาบาลรัฐขนาดใหญ่แห่งหนึ่งเป็นกรณีศึกษา ข้อมูลหลักที่ต้องใช้ประกอบด้วย

1) จำนวนผู้ป่วยที่เข้ารับบริการ
2) ขั้นตอนการให้บริการผู้ป่วย
3) ประเภทของผู้ป่วย
4) ระยะเวลาที่ผู้ป่วยใช้ทำกิจกรรมต่างๆ
5) ระยะทางและระยะเวลาที่ผู้ป่วยใช้เดินทางจากจุดให้บริการแต่ละจุดภายในโรงพยาบาล
6) จำนวนทรัพยากรต่างๆ ภายในแผนกกุมารเวชศาสตร์
7) แผนผังแผนกกุมารเวชศาสตร์
8) หน่วยงานต่างๆ ในโรงพยาบาลที่ผู้ป่วยเข้ารับบริการ

3.2 การรวบรวมข้อมูล

ก่อนที่จะเก็บรวบรวมข้อมูล ผู้วิจัยจะต้องทำความเข้าใจถึงการไหลของผู้ป่วยในแผนกกุมารเวชศาสตร์เสียก่อน เพื่อให้สามารถวางแผนการเก็บข้อมูลได้อย่างถูกต้อง ในการเก็บข้อมูลจริง ผู้วิจัยให้พยาบาลที่แผนกช่วยเลือกตัวอย่างผู้ป่วยโดยการสุ่มจำนวนทั้งสิ้น 30 คน และทำการเก็บรวบรวมข้อมูลโดยตรงจากระบบการให้บริการผู้ป่วย โดยใช้วิธีการสังเกต และการตามรอยผู้ป่วย (Patient Tracking) ซึ่งการตามรอยผู้ป่วยนั้น หมายถึง การติดตามผู้ป่วยพร้อมทั้งจดบันทึกข้อมูลที่ต้องการตั้งแต่กิจกรรมแรกที่ผู้ป่วยเข้ามาติดต่อเพื่อรับบริการ ไปจนกระทั่งกิจกรรมสุดท้ายที่ผู้ป่วยสามารถออกจากโรงพยาบาล โดยการตามรอยนี้ต้องไม่เป็นการรบกวนและแทรกแซงการทำกิจกรรมต่างๆ ของผู้ป่วย

3.3 การวิเคราะห์ข้อมูล

ผู้ป่วยนอกของแผนกกุมารเวชศาสตร์สามารถแบ่งออกได้เป็น 8 ประเภท ดังตารางที่ 1 และพบว่า การไหลของผู้ป่วยเป็นดังภาพที่ 2 กล่าวคือ ผู้ป่วยจะต้องทำการชั่งน้ำหนักและวัดส่วนสูงเป็นอันดับแรก ต่อไปเป็นการวัดความดันโลหิต เข้าพบแพทย์ รับบัตรนัด ยื่นใบสั่งยา ชำระเงิน ตามลำดับ ซึ่งหากผู้ป่วยรายใดที่แพทย์ไม่ได้สั่งยาให้ ก็จะสามารถกลับบ้านได้ทันที ส่วนผู้ป่วยที่แพทย์สั่งยาให้นั้น จะต้องรอรับยาในขั้นตอนสุดท้ายก่อนออกจากระบบ

ตารางที่ 1 ประเภทของผู้ป่วยนอกแผนกกุมารเวชศาสตร์

ประเภทผู้ป่วย	จำนวน (ร้อยละ)
1. ผู้ป่วยฉุกเฉิน	2.00
2. ผู้ป่วยนัด	57.58
3. ผู้ป่วยนัดโรคพัฒนาการ	2.98
4. ผู้ป่วยนัด + เอกซเรย์ + พบแพทย์ 2 ครั้ง	3.15
5. ผู้ป่วยนัด + เจาะเลือด + พบแพทย์ 2 ครั้ง	6.30
6. ผู้ป่วยไม่นัด	24.22
7. ผู้ป่วยไม่นัด + เอกซเรย์ + พบแพทย์ 2 ครั้ง	1.26
8. ผู้ป่วยไม่นัด + เจาะเลือด + พบแพทย์ 2 ครั้ง	2.52

ในส่วนการวิเคราะห์ระยะเวลาที่ผู้ป่วยใช้ในการทำกิจกรรม ต่างๆ นั้น ผู้วิจัยวิเคราะห์ค่าสถิติเชิงพรรณา (Descriptive Statistics) จากนั้นจะนำระยะเวลาของแต่ละกิจกรรมไปวิเคราะห์หารูปแบบการกระจายตัวของข้อมูล (Frequency Distribution) ด้วยโปรแกรม Input Analyzer (ซึ่งเป็นส่วนหนึ่งของโปรแกรมจำลองสถานการณ์ Arena) เพื่อนำไปใช้สำหรับการสร้างแบบจำลองต่อไป

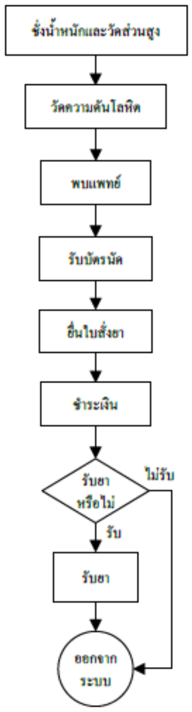
3.4 การสร้างแบบจำลองสถานการณ์

การสร้างแบบจำลองสถานการณ์ของแผนกกุมารเวชศาสตร์ประกอบด้วย 3 ขั้นตอนสำคัญ ดังต่อไปนี้

1) สร้างแบบจำลอง ด้วยโปรแกรม Arena โดยใช้รูปแบบการกระจายตัวของข้อมูลมาใช้กับแบบจำลองนี้ ซึ่งแบบจำลองที่สร้างขึ้นจะมีลักษณะการไหลของผู้ป่วยเช่นเดียวกับที่เกิดขึ้นกับระบบจริง

2) Model Verification เป็นการตรวจสอบแบบจำลองว่า Entity (ผู้ป่วย) ที่เข้ามาในระบบของแบบจำลองนั้นไหลอย่างถูกต้องตามการไหลของผู้ป่วยนอกในระบบจริงหรือไม่ อีกทั้งยังตรวจสอบด้วยว่าแบบจำลองนี้สามารถทำงานได้จริงโดยไม่เกิดความผิดพลาด (Error) ขึ้นในแบบจำลอง

3) Model Validation เป็นการตรวจสอบว่าผลลัพธ์ที่ได้จากแบบจำลองมีความถูกต้องสอดคล้องกับระบบจริงหรือไม่ โดยทำการเปรียบเทียบระหว่างผลลัพธ์ของระยะเวลาการรอคอยจากแบบจำลองในแต่ละกิจกรรมกับระยะเวลาการรอคอยที่ได้จากการเก็บรวบรวมข้อมูล ซึ่งหากผลลัพธ์ของกิจกรรมใดไม่สอดคล้องกับข้อมูลจริง ผู้วิจัยจะทำการปรับค่าพารามิเตอร์ของรูปแบบการกระจายตัวของกิจกรรมนั้นๆ จนกว่าจะได้ผลลัพธ์ที่ถูกต้องสอดคล้องครบทุกกิจกรรม



ภาพที่ 2 การไหลของผู้ป่วยนอกแผนกกุมารเวชศาสตร์

4. ผลลัพธ์และอภิปราย

4.1 ระบบการให้บริการปัจจุบัน

เมื่อให้โปรแกรมคอมพิวเตอร์ Arena ทำงานสิ้น 500 รอบ พบว่าเวลาที่ผู้ป่วยใช้ในโรงพยาบาลนั้นสูญเสียไปกับการรอคอยเพื่อเข้ารับบริการค่อนข้างมาก ดังแสดงในตารางที่ 2 โดยเฉลี่ยเวลารอคอยคิดเป็นร้อยละ 67.15 ของเวลาทั้งหมดที่ผู้ป่วยใช้ในระบบ นับเป็นความสูญเสียโดยเปล่าประโยชน์ที่เกิดขึ้นทุกวัน

ตารางที่ 2 ระยะเวลาที่ผู้ป่วยใช้ในการเข้ารับบริการ

ประเภทผู้ป่วย	ระยะเวลาทั้งหมดที่ใช้ (นาที)	ระยะเวลาเข้ารับบริการ (นาที)	ระยะเวลารอเข้ารับบริการ (นาที)	% ของระยะเวลารอต่อระยะเวลาทั้งหมดที่ใช้
1	115.3	23.3	92.0	79.82
2	115.3	23.3	92.0	79.82
3	115.3	23.3	92.0	79.82
4	193.4	67.4	125.9	65.13
5	225.2	99.3	125.9	55.92
6	115.3	23.3	92.0	79.82
7	193.4	67.4	125.9	65.13
8	225.2	99.3	125.9	55.92
เฉลี่ย	162.3	53.3	109.0	67.15

ตารางที่ 3 จำนวนผู้ป่วยโดยเฉลี่ยที่รอเข้ารับบริการแบ่งตามประเภทกิจกรรม

กิจกรรม	จำนวนผู้ป่วยที่รอเข้ารับบริการ (คน)
ชั่งน้ำหนักและวัดส่วนสูง	4.76
วัดความดันโลหิต	0.00
พบแพทย์	5.34
รับบัตรนัด	1.16
ยื่นใบสั่งยา	0.00
ชำระเงิน	0.71
รับยา	0.86

เมื่อพิจารณาจำนวนผู้ป่วยที่รอคอยเพื่อเข้ารับบริการในแต่ละกิจกรรม จะพบว่า กิจกรรมที่มีผู้ป่วยรอเข้ารับบริการมากที่สุด ได้แก่ กิจกรรมการพบแพทย์ ที่มีผู้ป่วยรอเข้ารับบริการ โดยเฉลี่ย 5.34 คน ดังแสดงรายละเอียดในตารางที่ 3

4.2 พัฒนาแผนดำเนินงาน

การสร้างแบบจำลองช่วยให้ทราบถึงปัญหาที่เกิดขึ้นภายในระบบ ผู้บริหารของโรงพยาบาลมีแนวคิดที่จะนำแผนการเลื่อนตารางลงตรวจของแพทย์ให้เร็วขึ้นมาใช้ เนื่องจากมีความเชื่อว่าจะช่วยกระจายปริมาณคนไข้ออกไปตามช่วงเวลาต่างๆ ให้กว้างขึ้น ซึ่งอาจจะทำให้การไหลของผู้ป่วยดีขึ้น ลดความคับคั่งในแผนก ผู้วิจัยจึงได้พัฒนาแผนดำเนินงานดังกล่าวในแบบจำลองสถานการณ์ ทั้งนี้ผู้วิจัยเสนอแผนการเลื่อนเวลาลงตรวจทั้งสิ้น 9 แผน ได้แก่ แผน M-1 ถึง M-9 ซึ่งเป็นการเลื่อนตารางเวลาลงตรวจของแพทย์ให้เร็วกว่าในระบบปัจจุบันเป็นเวลา 1 ชั่วโมง จากเวลา 8.30 น. เป็นเวลา 7.30 น. ดังปรากฏในตารางที่ 4 ซึ่งอธิบายได้ว่าแผนดำเนินงาน M-1 จะมีแพทย์ลงตรวจเร็วขึ้นเป็นจำนวน 1 คน และเพิ่มขึ้นครั้งละ 1 คน จนกระทั่งเป็นจำนวน 9 คนในแผน M-9

ตารางที่ 4แผนดำเนินงานสำหรับการเลื่อนตารางเวลาแพทย์

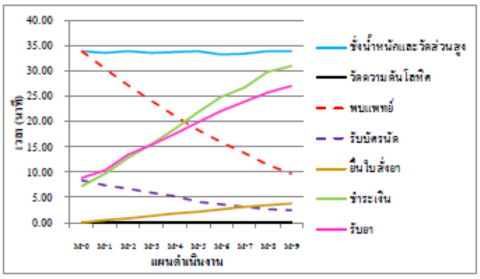
แผนดำเนินงาน	จำนวนแพทย์ที่ลงตรวจ (คน)		
	7.30 – 8.30	8.30 – 11.00	11.00 – 12.00
M-0	0	36	36
M-1	1	36	35
M-2	2	36	34
M-3	3	36	33
M-4	4	36	32
M-5	5	36	31
M-6	6	36	30
M-7	7	36	29
M-8	8	36	28
M-9	9	36	27

ผลในตารางที่ 5 แสดงให้เห็นว่าการเลื่อนตารางการลงตรวจของแพทย์ ทำให้สัดส่วนของเวลาที่ผู้ป่วยใช้ในระบบมีแนวโน้มเพิ่มขึ้นตามการเพิ่มขึ้นของจำนวนแพทย์ที่เลื่อนตารางการลงตรวจ ซึ่งมีเพียงแผน M-1 เท่านั้น ที่สัดส่วนของเวลาลดลง

ตารางที่ 5 สัดส่วนของเวลารอและเวลาที่ใช้ทั้งหมดในระบบ

แผนดำเนินงาน	สัดส่วนของเวลารอที่เพิ่มขึ้น (ร้อยละ)	สัดส่วนของเวลาที่ใช้ในระบบที่เพิ่มขึ้น (ร้อยละ)
M-1	-0.32	-0.27
M-2	3.06	2.43
M-3	4.04	3.24
M-4	6.32	5.02
M-5	9.05	7.23
M-6	11.33	9.06
M-7	12.98	10.41
M-8	16.11	12.85
M-9	17.11	13.63

นอกจากนี้ยังพบอีกว่า เวลารอคอยเพื่อทำแต่ละกิจกรรมของผู้ป่วยมีแนวโน้มคงที่ หรือเพิ่มขึ้น ตามการเพิ่มของจำนวนแพทย์ที่เลื่อนตารางเวลา เช่นเดียวกับเวลาทั้งหมดที่ใช้ในระบบของแต่ละแผนดำเนินงานสำหรับการเลื่อนตารางแพทย์ แต่เมื่อพิจารณากิจกรรมเข้าพบแพทย์และรับบัตรนัด จะพบว่าเวลารอคอยของทั้งสองกิจกรรมนั้นมีแนวโน้มลดลง แปรผกผันกับจำนวนแพทย์ที่เลื่อนตารางการลงตรวจ ซึ่งเห็นได้ชัดเจนดังในภาพที่ 3



ภาพที่ 3 เวลาที่ผู้ป่วยรอรับบริการ

หากสนใจเฉพาะเวลารอคอยพบแพทย์ เมื่อเลื่อนตารางแพทย์เพียง 1 คน พบว่า เวลารอคอยแพทย์ลดลงร้อยละ 10.31 และหากเลื่อนตารางเวลาแพทย์เป็นจำนวนร้อยละ 50 ของระบบปัจจุบัน จะสามารถลดเวลารอคอยได้มากถึงร้อยละ 71.48 ส่วนเวลารอคอยของกิจกรรมรับบัตรนัด พบว่าลดลงจากระบบปัจจุบันร้อยละ 10.84 ถึง ร้อยละ 70.84 ซึ่งแม้จะมีการเลื่อนตารางการลงตรวจของแพทย์เพียง 6 คน ก็สามารถลดเวลาการรอคอยของทั้งสองกิจกรรมดังกล่าวได้มากกว่าร้อยละ 50 ถือว่าช่วยลดเวลาในการรอคอยได้มาก แต่เมื่อพิจารณาถึงกิจกรรมถัดไป จะเห็นว่า เวลารอคอยกลับเพิ่มขึ้นในทุกกิจกรรม สรุปได้ว่ายิ่งเพิ่มจำนวนแพทย์ที่เลื่อนเวลาการลงตรวจจะยิ่งลดเวลารอคอยในการเข้าพบแพทย์ แต่จะมีผลให้เวลารอคอยรวมทั้งหมดมีค่าเพิ่มมากขึ้น ดังนั้นควรจะมีการเพิ่มจำนวนแพทย์ที่เลื่อนเวลาลงตรวจให้พอเหมาะ และไม่กระทบถึงเวลารอคอยรวม ไม่เช่นนั้นอาจเป็นการเพิ่มเวลารอคอยให้แก่ผู้ป่วยขึ้นกว่าเดิมได้

ตารางที่ 6 เวลารอคอยของกิจกรรมพบแพทย์และรับบัตรนัด

แผนดำเนินงาน	สัดส่วนของเวลารอคอยที่ลดลง (ร้อยละ)	
	กิจกรรมพบแพทย์	กิจกรรมรับบัตรนัด
M-1	10.31	10.84
M-2	19.75	19.89
M-3	28.75	29.81
M-4	37.81	37.43
M-5	45.71	50.40
M-6	52.97	56.75
M-7	59.47	62.97
M-8	66.11	68.14
M-9	71.48	70.84

5. สรุปผลและข้อเสนอแนะ

ผลลัพธ์จากการวิเคราะห์ดังกล่าว แสดงให้เห็นว่าการเลื่อนตารางเวลาแพทย์ในระบบไม่สามารถช่วยลดเวลาทั้งหมดที่ผู้ป่วยใช้ในระบบได้ แต่จะสามารถลดเวลารอคอยของกิจกรรมพบแพทย์และรับบัตรนัดได้ค่อนข้างมาก สาเหตุอาจเป็นเพราะว่าโซ่อุปทานการให้บริการผู้ป่วยนอกนั้นมีความสลับซับซ้อน ประกอบด้วยกิจกรรมจำนวนมากซึ่งขึ้นอยู่แก่กันและกัน ดังนั้นแผนดำเนินงานที่จะนำไปปฏิบัติควรต้อง

ทำการศึกษาต่อไปถึงความคุ้มค่าในด้านต้นทุนและความพึงพอใจของผู้ป่วย การศึกษาต่อไปในอนาคตอาจทำการวิเคราะห์แนวทางอื่นเป็นการเพิ่มเติม เช่น การเปลี่ยนแปลงระบบนัดหมายผู้ป่วย ซึ่งจะเป็นการจำกัดจำนวนผู้ป่วยที่ควรจะอยู่ที่โรงพยาบาลไม่ให้แออัดเกินไปอย่างเช่นที่เป็นอยู่ในปัจจุบันนี้ ทั้งนี้เพื่อประโยชน์อันสูงสุดแก่โรงพยาบาลและผู้ป่วยที่เข้ามารับบริการ

กิตติกรรมประกาศ

งานวิจัยนี้ได้รับความร่วมมือเป็นอย่างดีเยี่ยมจากผู้บริหารของโรงพยาบาล แพทย์ พยาบาลและเจ้าหน้าที่ผู้ปฏิบัติงานของแผนกกุมารเวชศาสตร์ ณ โรงพยาบาลกรณีศึกษา รวมทั้งหน่วยงานต่างๆ ที่เกี่ยวข้อง ที่ให้ความร่วมมือเป็นอย่างดีระหว่างการสัมภาษณ์ สอบถาม และสำรวจรวบรวมข้อมูลจำนวนมากภายในโรงพยาบาล และที่จะขาดมิได้คือผู้ป่วยนอกทุกท่าน ซึ่งทีมงานวิจัยทำการตามรอยท่านไปตลอดโซ่อุปทานของการเข้ารับบริการ อีกทั้งความคิดเห็นต่างๆ ของทุกท่านที่มีต่อระบบการให้บริการ อันเป็นประโยชน์อย่างยิ่งต่อการทำงานวิจัยโครงการนี้ สถานที่และเครื่องมือในการงานทำวิจัยได้รับความอนุเคราะห์จากศูนย์ผู้เชี่ยวชาญด้านระบบขนส่ง การจราจรและโลจิสติกส์ (T - LEX Center) ภาควิชาวิศวกรรมโยธาและสิ่งแวดล้อม คณะวิศวกรรมศาสตร์ มหาวิทยาลัยมหิดล

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เกี่ยวกับผู้เขียน

	**นางสาวอัธยา ช่อฉาย** ประวัติการศึกษา ปริญญาตรี : สำเร็จการศึกษา สาขาเทคโนโลยีอาหาร คณะวิศวกรรมศาสตร์และเทคโนโลยีอุตสาหกรรม มหาวิทยาลัยศิลปากร ปริญญาโท : กำลังศึกษา สาขาวิศวกรรมอุตสาหการ (การจัดการโลจิสติกส์) คณะวิศวกรรมศาสตร์ มหาวิทยาลัยมหิดล งานวิจัยที่สนใจ Logistics และ Supply Chain Management โดยเฉพาะอย่างยิ่งเรื่องการไหลของผู้ป่วยภายในโรงพยาบาล
	**ผู้ช่วยศาสตราจารย์ ดร. สมชาย ปฐมศิริ** วุฒิสมาชิกของ วสท. และสมาชิกสภาวิศวกรระดับสามัญ สำเร็จการศึกษา วศบ. โยธา (เกียรตินิยม), วศม. (ขนส่งและจราจร) จากจุฬาลงกรณ์มหาวิทยาลัย, MBA (หลักสูตรผู้บริหารระดับสูง) จาก มหาวิทยาลัยธรรมศาสตร์ และ PhD. (Transportation Systems Engineering and Planning) จาก University of Maryland, USA
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APPENDIX F
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Outpatient Flow Analysis and Simulation Study to Improve the Health Care Service of the Pediatrics Department at a Major Public University Hospital in Thailand

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ABSTRACT
Nowadays, there are so many patients waiting in line to receive treatment service that several Thai health centers and hospitals become crowded. This happens, especially, at all major public hospitals where people trust. In order for the public hospitals to efficiently provide service and meet the patients' demand, we should take patient flow into consideration seriously. As a case study, this research studies the characteristic of patient flow and analyzes the service problems of the pediatric department at the very large public university hospital. A number of outpatients were tracked to understand the flow. The results show that the outpatients spend the longest total time in the diagnosis process. The very long waiting time leads to patient dissatisfaction. The research then modeled the patient flow and used discrete event simulation to analyze the effectiveness of two improvement strategies; i.e., increasing the number of physicians and staggering of physicians' working hours. The simulation results revealed that the staggering strategy is likely the better choice to improve the system efficiency. In particular, staggering three physicians to start working an hour earlier may decrease the total process time, total waiting time, and total time in the system by 0.18, 8.11, and 6.76 percent, respectively.

Keywords: Outpatient, Pediatrics, Simulation, Patient Flow Analysis, Health Care

1 INTRODUCTION

In Thailand, it is not uncommon to see crowded outpatients at most, if not all, public hospitals. It is observed that patients easily spend half a day at the hospital where most of their time may be idle with waiting to receive services at various stages such as diagnosis, making appointment and receiving medicine. Nonetheless, patients are still coming to the public hospitals. This is because the medical fees at private hospitals are so expensive for most patients. The quality of service at public hospitals is therefore worsening. Such situation is so notorious that deserve serious attention in this study.

This paper reports results from the analysis of outpatients flow at a major public university hospital in Bangkok, the capital city of Thailand. The case study is the pediatric department. The purpose of the study is to understand the current service problem and propose the strategies to improve the service. The discrete event simulation is employed as an analytical tool to test the alternative strategies. The rest of the paper is outlined as follows. In section 2, the brief of literature is presented to show that the analysis of patient flow has been a major research topic across the world. Section 3 explains the research methodology and alternative strategies. The simulation results are reported in Section 4. Last but not least, Chapter 5 concludes the study.

2 LITERATURE REVIEW

Patient flow analysis is one of the most studied problems in healthcare research. There are a good number of publications from researchers around the globe. Swisher, Jacobson, Jun, & Balci (2001) stated that patient flow modeling has been studied for more than 30 years in the operation system of hospitals. Previous researches were conducted in many different units of a hospital such as outpatient clinic (Côte, 1999; Su & Shih, 2003), mammography clinic (Coelli, Ferreira, Almeida, & Pereira, 2007), ambulatory care unit (ACU) (Santibáñez, Chow, French, Puterman, & Tyldesley, 2009), emergency department (Ahmed & Alkhamis, 2009; Brenner, Zeng, Liu, Wang, Li, & Howard, 2010), and nephrology outpatient department (Jerbi & Kamoun, 2011). The discrete event simulation is a common analytical tool for analyzing the effectiveness of improvement strategies. These researches have common objectives; i.e., to test whether the proposed strategies are likely to be effective before the real implementation. The similar research approach is also adopted in this paper.

3 METHOD

3.1 Case study

The case study is a pediatric department at the major public university hospital. This hospital is located in the heart of Bangkok, Thailand. By its size measured by the number of annual outpatients, it is the second largest hospital in Bangkok. Daily, the pediatric department serves about 400 outpatients.

3.2 Data collection

There are two main types of required data for the study; i.e., characteristics of service and characteristics of patient flow. The data on characteristics of service is collected directly from personal interview, series of meetings with the nurses and administrators. In addition, the observation is made while the service is offered. For collecting characteristics of flow, the patient tracking is used. It is a follow-up process, which tracks a patient from the beginning activity (registration at the department) until the final activity after which patient can leave hospital. In this research, 30 - 50 outpatients in the pediatric department are the samples. In particular, service process, type of outpatient, process time, traveling time, number of resources, and layout of the department are the basic data.

3.3 Research plan

The research plan is outlined as follows;

1) Study theories and related literature regarding patient flow analysis and discrete event simulation
2) Data collection
3) Data analysis to understand the current flow of outpatients at the pediatric department
4) Simulation modeling which consists of three main steps:
- Build the simulation model by using the Rockwell Arena software
- Model verification in order to check the correctness of the flow
- Model validation by comparing the resulting key performance indices (KPIs) from the simulation with the observed data
5) Strategy design for improving the flow of the system
6) Analyze the strategies by using the simulation model in 4)
7) Propose the most efficient strategy to be implemented in the real-world system

4 RESULTS AND DISCUSSION

4.1 The present system

There are five processes; i.e., checking weight and height, diagnosis, making appointment, payment, and receiving medicine in the outpatient flow of the pediatric department. The flow is modeled for the simulation model by using the Rockwell Arena software. To validate the model, 1,400 replications were run. The results show that the outpatients spend the longest total time at the diagnosis process, as shown in Table 1. This long total time undoubtedly leads to patient dissatisfaction.

Table 1: Model validation results

Process	Process time (min.)	Waiting time (min.)	Total time (min.)
Checking weight and height	1.00	30.50	31.50
Diagnosis	9.26	31.13	40.39
Making appointment	1.80	3.04	4.84
Payment	0.64	3.89	4.53
Receiving medicine	3.20	9.04	12.24

Based on the personal interview and suggestions from the administrator, two important strategies for improving flow of outpatients are emerged. Their effectiveness are tested by using the simulation. The two important strategies consist of:
1) Increasing the number of physicians and
2) Staggering of physicians' working hours

4.2 Testing improvement strategies

4.2.1 Increasing the number of physicians

As the simulation indicated, the patients spent the longest total time at the diagnosis process. This result may point out about manpower shortage problem in the diagnosis process. Therefore, it may be intuitive to increase the number of physicians. In order to test such strategy, the number of physician is increased from one to nine (one fourth of the number in present system). Table 2 shows nine sub-strategies, I1 to I9, to be tested by the simulation model.

Table 2: Sub-strategies for increasing the number of physician

Strategy	Numbers of physicians
I1	37
I2	38
I3	39
I4	40
I5	41
I6	42
I7	43
I8	44
I9	45

Then, the simulation model was run for 1,400 replications. The outputs are shown in Table 3. The outputs revealed that increasing the number of physicians cannot significantly decrease total waiting time and total time in the system of the patients while the total process time is hardly decreased.

Table 3: Output of increasing the number of physicians' strategy

Strategy	Total process time (min.)	Total waiting time (min.)	Total time in the system (min.)
Present	15.90	77.60	93.50
I1	15.89	77.65	93.54
I2	15.89	77.65	93.54
I3	15.90	77.84	93.74
I4	15.90	77.84	93.74
I5	15.89	77.63	93.52
I6	15.89	77.63	93.52
I7	15.90	77.91	93.81
I8	15.90	77.91	93.81
I9	15.88	77.86	93.74

4.2.2 Staggering of physicians' working hours

The pediatrics department opens to provide medical services from 9.00AM to 12.00AM in the morning. However, many patients usually came to the department before 9.00AM. The administrator feels that if service starts earlier than 9.00AM, it might help spread the number of patients over longer period; hence, reduce the congestion at the department. Thus, this strategy changes the working time of physicians. The researcher tried to stagger one to nine physicians to start working an hour earlier. In sum, there are nine sub-strategies, represented by strategies S1 to S9, as shown in Table 4.

Table 4: Sub-strategies of staggering of physician's working hours

Strategy	Number of physicians		
	8 – 9AM	9 – 11AM	11 – 12AM
S1	1	36	35
S2	2	36	34
S3	3	36	33
S4	4	36	32
S5	5	36	31
S6	6	36	30
S7	7	36	29
S8	8	36	28
S9	9	36	27

The simulation outputs are shown in Table 5. It revealed that this strategy may be able to decrease the total process time, total waiting time, and total time in the system of the outpatients. Compared to the results in Table 3, it shows that the staggering of physicians' working hours is a more effective strategy than increasing the number of physicians. It has the potential to save more of the total waiting time and total time in the system.

Table 5: Output of staggering of physician's working hours strategy

Strategy	Total process time (min.)	Total waiting time (min.)	Total time in the system (min.)
Present	15.90	77.60	93.50
S1	15.89	73.44	89.33
S2	15.89	71.56	87.45
S3	15.87	71.30	87.17
S4	15.89	71.67	87.56
S5	15.88	71.95	87.83
S6	15.89	72.46	88.35
S7	15.89	72.82	88.71
S8	15.88	72.94	88.82
S9	15.88	73.26	89.14

4.2.3 Strategy comparison

Table 6 compares the effectiveness of the two tested strategies in terms of percentage change in the three key performance indices (KPIs). Obviously, the staggering strategy may be able to decrease the total waiting time and total time in the system better than the increment of physician numbers. From the plot in Figure 1, it clearly sees that the staggering strategy helps to decrease the total waiting time and total time in the system plentifully. Especially, the best strategy in this research is a strategy which staggering three physicians to start working an hour earlier. The simulation results indicate that it may decrease the total process time, total waiting time, and total time in the system by 0.18, 8.11, and 6.76 percent, respectively.

Table 6: Percentage changes in KPIs by sub-strategy

Strategy	% change		
	Total process time	Total waiting time	Total time in the system
Present	0.00	0.00	0.00
I1	-0.10	+0.06	+0.04
I2	-0.10	+0.06	+0.04
I3	-0.02	+0.31	+0.25
I4	-0.02	+0.31	+0.25
I5	-0.06	+0.04	+0.02
I6	-0.06	+0.04	+0.02
I7	-0.01	+0.40	+0.33
I8	-0.01	+0.40	+0.33
I9	-0.11	+0.33	+0.25
S1	-0.09	-5.36	-4.46
S2	-0.08	-7.79	-6.48
S3	-0.18	-8.11	-6.76
S4	-0.07	-7.64	-6.35
S5	-0.12	-7.28	-6.06
S6	-0.05	-6.62	-5.50
S7	-0.08	-6.16	-5.12
S8	-0.11	-6.01	-5.01
S9	-0.15	-5.60	-4.67

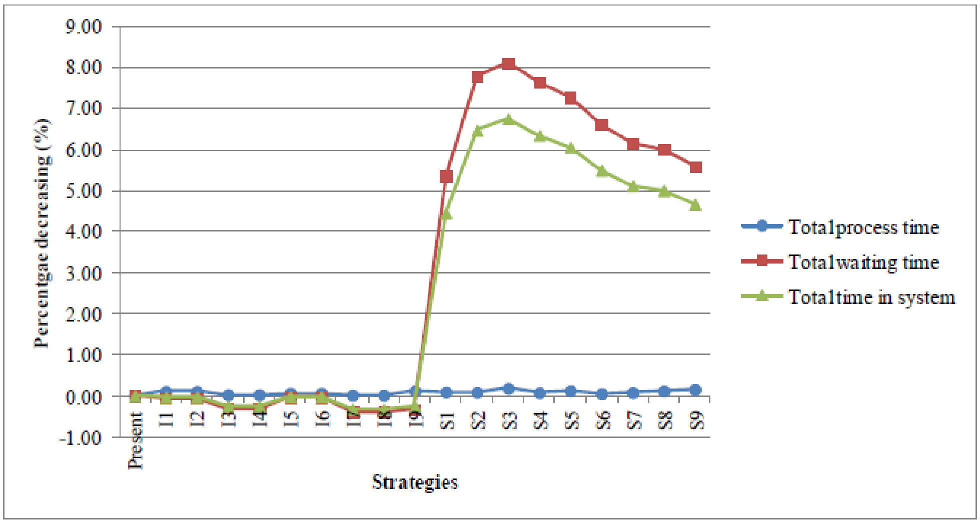

Fig. 1: Comparison of decreasing times

5. CONCLUSION

This research studied the flow of outpatients at the pediatric department in a large public university hospital in Bangkok, Thailand. The analysis points out that the outpatients spend the longest total time in the diagnosis process. The two strategies; i.e., increasing the number of physicians and staggering of physicians' working hours are designed to improve the efficiency of the system. The patient flow is modeled and simulated by using the discrete event simulation. It was found that increasing the number of physicians in the diagnosis process may not be able to solve the problem. The total waiting time and total time in the system which the patients must spend are not decreased. On the contrary, by staggering the physicians' working hours, it may be able to decrease the total waiting time and total time in the system plentifully. This is based on the intuition that the patients usually come to meet the physicians before the working time anyway, so staggering of physicians' working hours may help to spread the number of patients over wider period of time. Therefore, this strategy is a better choice to improve the system efficiency. Overall, the patient flow is so complicated, and there are many details. Thus, the patient flow analysis and improvement strategy must consider other related factors as much as possible in order to eliminate the unnecessary waiting time in the system. In the future, other important factors should be studied, including the appointment system, and payment system. Most importantly, the strategy must be for patient satisfaction, and a profit of the hospital.

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