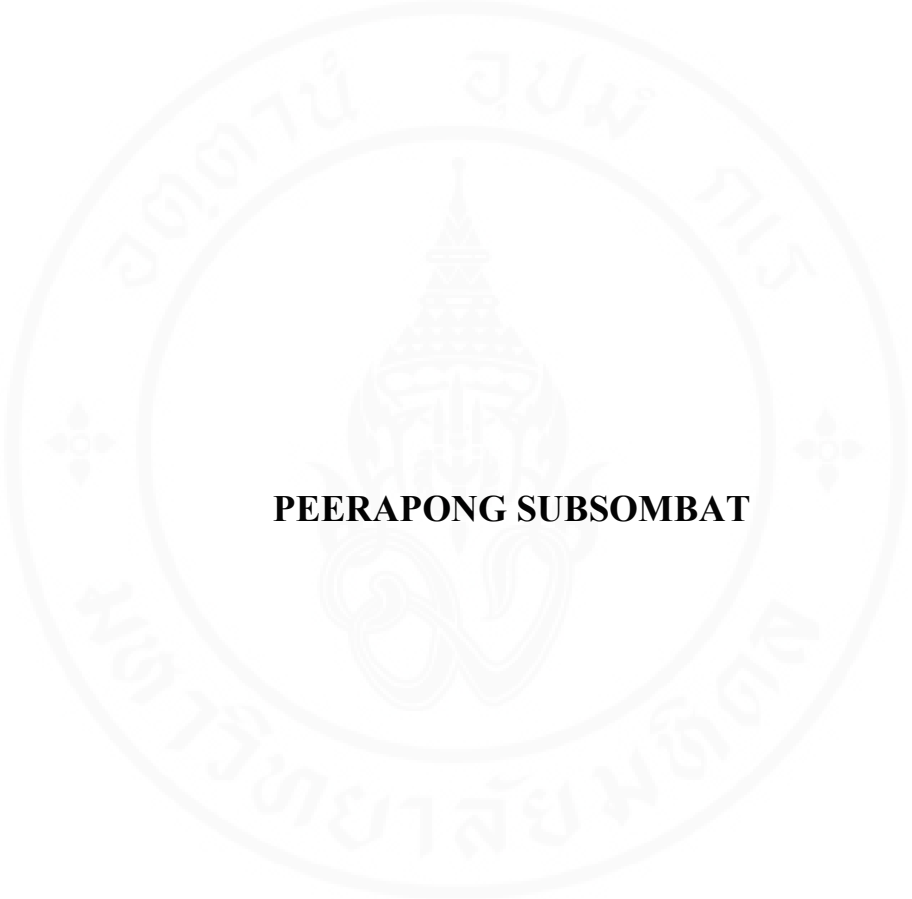


**A COMPARISON OF PROCESS-BASED AND OBJECT-BASED
SIMULATION: A CASE STUDY OF HOSPITAL SERVICE**

The seal of Mahidol University is a large, faint circular emblem in the background. It features a central five-tiered umbrella (parasol) with a flame-like base, surrounded by a circular border containing Thai script.

PEERAPONG SUBSOMBAT

**A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF ENGINEERING
(INDUSTRIAL ENGINEERING)
FACULTY OF GRADUATE STUDIES
MAHIDOL UNIVERSITY**

2013

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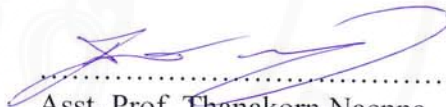
Thesis
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**A COMPARISON OF PROCESS-BASED AND OBJECT-BASED SIMULATION:
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ABSTRACT

Nowadays, simulation modeling has become an effective tool that is used to simulate real operations and analyze the results that can be used as guidelines for planning, decision making, and changing the strategies in the hospital. The objective of this research was to compare process-based orientation and object-based orientation simulations in the hospital service by a case study of a public hospital in Thailand, in order to discuss the advantages and disadvantages of each simulation modeling paradigm. As a result, both a process-based simulation (Arena) and an object-based simulation (Simio) were considered suitable tools for measuring the various key performance indicators in the hospital, such as total time in system and doctor utilization. However, Arena had more a greater of an advantage because it could call up attributes, variables, and time functions easier than Simio. Moreover, Arena could address the complexity of a hospital simulation model that has more variation in patient characteristics and the differing nature of clinics.

**KEY WORDS: PROCESS-BASED AND OBJECT-BASED SIMULATION/
HOSPITAL SIMULATION MODEL**

70 pages

การเปรียบเทียบแบบจำลองสถานการณ์ประเภท Process-based และ Object-based กรณีศึกษาการให้บริการในโรงพยาบาล

A COMPARISON OF PROCESS-BASED AND OBJECT-BASED SIMULATION: A CASE STUDY OF HOSPITAL SERVICE

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บทคัดย่อ

ในปัจจุบันแบบจำลองสถานการณ์ได้กลายเป็นเครื่องมือที่มีประสิทธิภาพในการใช้จำลองและวิเคราะห์ผลจากการดำเนินงานจริง เพื่อที่จะใช้เป็นแนวทางในการวางแผน การตัดสินใจ และการกำหนดกลยุทธ์ให้กับโรงพยาบาล โดยงานวิจัยนี้ต้องการเปรียบเทียบวิธีการจำลองสถานการณ์โดยใช้แนวคิดของ process-based และ object-based ในอุตสาหกรรมการให้บริการทางด้านสุขภาพ ซึ่งจะใช้การจำลองสถานการณ์การให้บริการของแผนกออร์ปิดิกส์ของโรงพยาบาลรัฐแห่งหนึ่งในประเทศไทยเป็นกรณีศึกษา โดยใช้แบบจำลองสถานการณ์ด้วยโปรแกรม Arena เป็นตัวแทนของการจำลองสถานการณ์แบบ process-based และแบบจำลองสถานการณ์ด้วยโปรแกรม Simio เป็นตัวแทนของการจำลองสถานการณ์แบบ object-based เพื่อวิเคราะห์วิจารณ์และสรุปให้เห็นถึงข้อดีและข้อเสียของแบบจำลองสถานการณ์ด้วยแนวคิดแบบ process-based และ object-based ในอุตสาหกรรมการให้บริการทางด้านสุขภาพ ซึ่งผลจากการศึกษาพบว่า Process-based simulation (Arena) และ Object-based simulation (Simio) ถือเป็นเครื่องมือที่มีประสิทธิภาพเพียงพอต่อการวัดประสิทธิภาพทางด้านระยะเวลาของการให้บริการหรือด้านอัตราประโยชน์การทำงานของแพทย์ แต่ Arena จะได้เปรียบกว่าในด้านการสร้างแบบจำลองสถานการณ์ที่มีความซับซ้อน เนื่องจากสามารถเรียกใช้ attribute, variable และ time function ได้ง่ายกว่า

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CHAPTER I

INTRODUCTION

This chapter will discuss about the background and problem statement of hospital service and the reason why simulation modeling is an excellent tool for evaluating decision and improving processes in the hospital. Then, we will briefly describe about process-based and object-based simulation modeling. Finally, we will clarify about the objective, scope, and expected result of this research.

1.1 Background and problem statement

Healthcare systems have the main function of deliver care to people in both developed and developing countries around the world. Most governments consider the delivering of healthcare to be one of their primary duties, along with providing an educational and defending their citizens. The performance of healthcare systems is literally a life and death matter which related to evaluate average lifespan and infant mortality. For example, the delay in emergency room access and treatment, or delay in cancer diagnosis is translated to the reduction in lifespan and increase in mortality of patient. In term of healthcare system, hospital is the one of a vital component because it is directly responsible for treatment, prevention, and rehabilitation of illness and diseases to the patients both physically and mentally. Due to the variation of disease and the complexity of illness in the present, these reasons result in the growing of patient demand in receives counseling and medical care. Figure 1.1 show the number of outpatients in Thailand increased of approximately 61% from 2000 to 2009, or about 58 million persons.

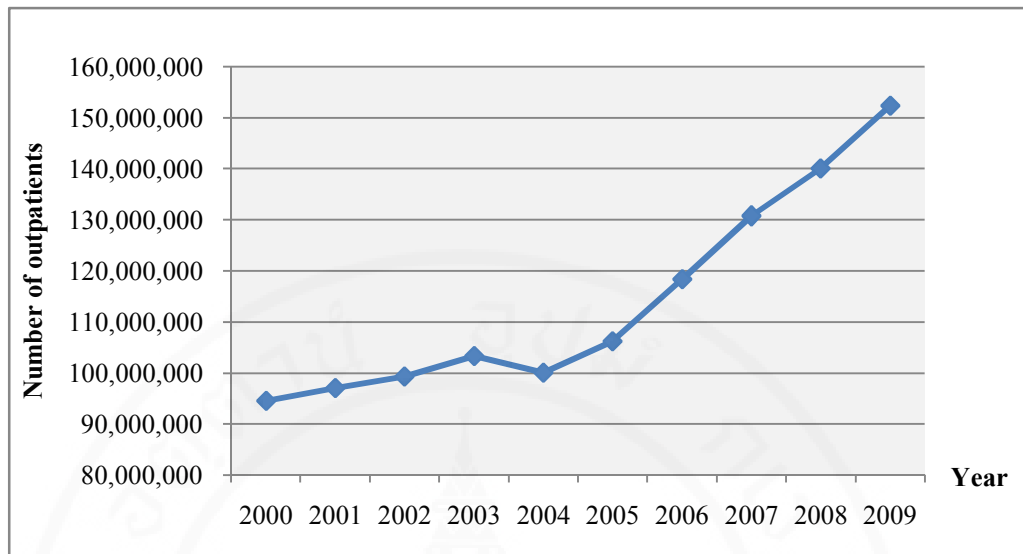


Figure 1.1 Number of outpatients in Thailand

(<http://service.nso.go.th/nso/nsopublish/BaseStat/basestat.html>)

The nature characteristic of hospital service is uniqueness and differs from another industry. First of all, hospital service is stochastic because the patient demand is unpredictable. The pattern of disease and individual patient behavior are vary and may change unpredictably. Moreover, the urgent patient may affect to the sequence of treatments. Second, the hospital clinical specialists are very limited. With these factors, the hospital service and response time can vary greatly.

As mentioned characteristics, a decision making tool that used to allocate the limited resource and improve the service of hospital is required. In this context, discrete event simulation, DES, modeling is considered as an excellent tool for evaluating decisions, analyzing and solving the various problems in the hospital. Many DES models have the stochastic framework, and queuing network structure that can address the unique characteristic of hospital service. Moreover, there are some difficulty to change the strategies in real operation in the hospital because of the experimentation is either impossible or expensive and risky. Over the last few decades, the process-based simulation software, such as Arena, have made DES modeling not only affordable but relatively easy to initiate simulation studies of a variety of situation. Furthermore, Arena software has been widely using for the modeling approach to study and solve the problem in hospital. For example, Weng and Houshmand (1999) model an outpatient clinic using Arena software which is one of

the DES commercial packages. Their goal is to compare different resident staffing scenarios in terms of cost, patient throughput and the total time in system. Ballard and Kuhl (2006) model the surgical suite operating room using the DES commercial software Arena to determine its daily maximum capacity, defined as the number of patients treated. They show that the capacity estimated by simulation is higher than what the management had calculated through considering only the ratio of available times and the required treatment time, and thus higher efficiency of the operating rooms can be realized.

Due to hospital operate in a fast pace, they need a rapid modeling to get a quick identifying and solving the problem in succession. Furthermore, the hospital operation is lack of standardization that might involve the presence or absence of a particular resource such as clinical staff and machine. As a result of these differences, it is very hard to develop a generic model that can just be configured and applied for the common operation in hospital (Seila and Brailsford, 2009). For this reason, object-based simulation software was created to address this challenge because they are able to simulate a rapid modeling by agent coding and also can be used a common coding for a generic model. Moreover, object-based simulation can address the stochastic and queuing network problem that is a unique characteristic in hospital service likely to DES.

The purpose of this research is to compare and contrast the advantages and disadvantages between process-based orientation and object-based orientation simulations in the hospital service by using Arena software to represent a DES model and Simio software to represent an object-based model. Furthermore, this research will also recommend and advice on which simulation paradigm will be more suitable and adaptable for the hospital service.

1.2 Objective of the study

The objectives of this research are following:

1.2.1 To study and compare the simulation modeling paradigm of DES in Arena and object-based in Simio by a case study of public hospital in Thailand.

1.2.2 To discuss on the advantages and disadvantages of both simulation modeling framework in hospital service.

1.3 Scope of the study

This research will compare and discuss on the difference between process-based and object-based simulation modeling by emulate the operation of Orthopedic department in public hospital of Thailand as shown in Figure 1.2.

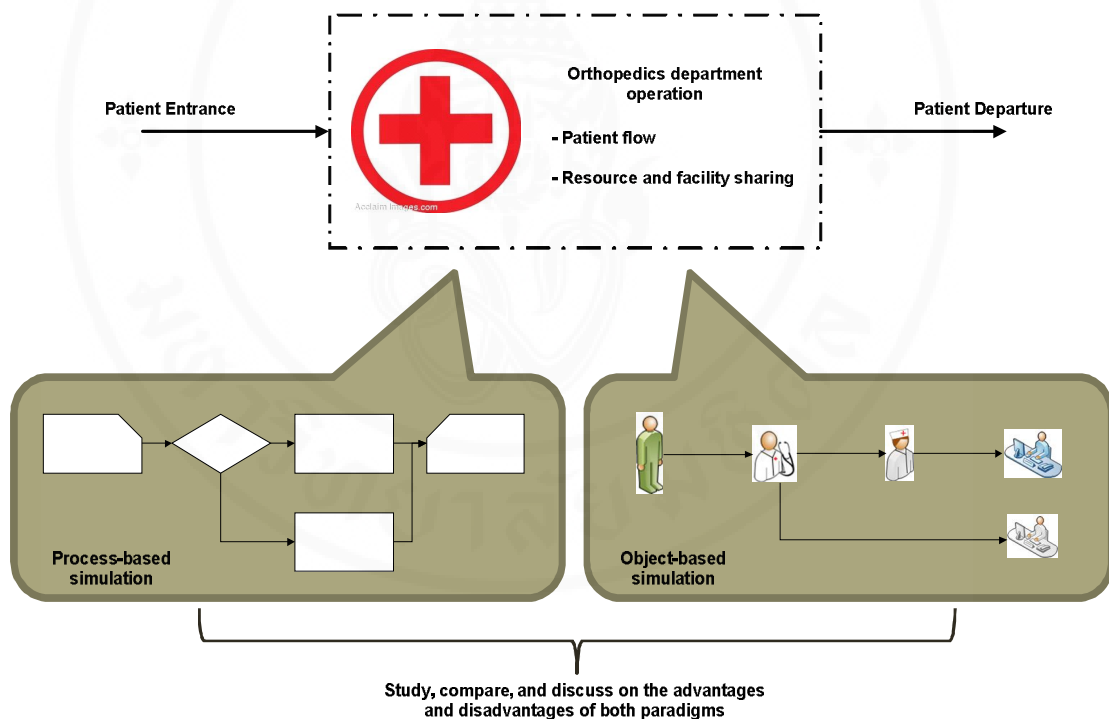


Figure 1.2 Scope of the research

1.4 Expected results

1.4.1 This research will summarize the advantages and disadvantages between process-based and object-based simulation paradigm.

1.4.2 This research will recommend the some understanding when commence on hospital simulation project.

CHAPTER II

BACKGROUND THEORY AND LITERATURE REVIEW

This chapter will show the summary of discussion about background theory and literature review of this research.

2.1 Background theory of simulation modeling

This section will discuss on the background theory that composes of 4 main subsection as following, an overview of simulation model, classification of simulation model, the description of DES and object-orientation model and process to construct the simulation model.

2.1.1 An overview of simulation model

Simulation refers to a broad collection of methods and applications that used to imitate the behavior of real systems, usually on a computer with appropriate software. Due to the complexity of actual work that cannot be tested or modified until the benefits of process will be received, the simulation is an effective tool that use to analyze the current state of the system and find an optimal solution before applied to the actual work (Coelli, et al., 2007). The main objective that applied the simulation is to study the flow of system in various points of view by collect data and analyze to find the optimal solution in the computer programs that used as the guidelines to improve the operation as shown in figure 2.1. With the development of more powerful computers and software, simulation technique has become a very powerful tool that has been applied to many industries including manufacturing, banking, transportation, and hospitality, as well as natural systems in physics, chemistry, biology, and economics.

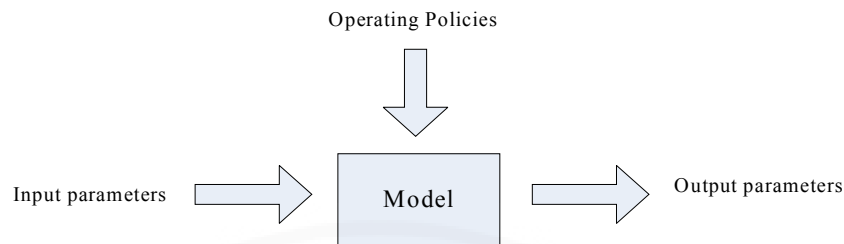


Figure 2.1 Relationship between input and output parameters of simulation model

2.1.2 Classification of simulation model

There are a lot of ways to classify simulation models, but one useful way is along these three dimensions:

2.1.2.1 Static vs. Dynamics

In static simulation models time is not explicit and the analysis can be done in Excel spreadsheets, whereas, the events can occur sequentially over time and it uses specialized software in dynamic simulation models.

2.1.2.2 Continuous vs. Discrete

In continuous models, the state variables change in a continuous way, and not abruptly from one state to another. This type of simulations are most appropriate if the material or information that is being simulated can be described as evolving or moving smoothly and continuously, rather than in infrequent discrete steps or packets. For example, the movement of water through a series of reservoirs and pipes can most appropriately be represented using a continuous simulator. Continuous simulators can also be used to simulate systems consisting of discrete entities if the number of entities is large so that the movement can be treated as a flow. In contrast, discrete models that the state variables change only at a countable number of points in time. These points in time are the ones at which the event occurs/change in state, such as call centers, factory operations, and shipping facilities in which the material or information that is being simulated can be described as moving in discrete steps or packets. Furthermore, the elements of both continuous and discrete change in the same model, which called mixed continuous-discrete models.

2.1.2.3 Deterministic vs. Stochastic

A model can have both deterministic and stochastic in the same model. Deterministic models that have no random input and outcomes are precisely determined through known relationships among states and events, without any room for random variation. In such models, a given input will always produce the same output, such as in a known chemical reaction. In comparison, stochastic models use ranges of values for variables in the form of probability distributions.

In conclusion, most operation models in real world situation are dynamic, discrete, and stochastic pattern that called discrete-event simulation (DES) models. This model has been represented as a chronological sequence of events that occur at an instant in time and marks a change of state in the system.

2.1.3 The description of DES and object-orientation model

2.1.3.1 Discrete-event simulation (DES)

The DES view hinges on the concept of process, sequence of events and activities through which a specific object moves that based on viewing the simulation in terms of the experience of entities that flow through the system. It enables the modeler to clearly grasp a model structure, since each object can be represented through a single, coherent process rather than multiple event routing.

2.1.3.2 Object-orientation simulation

Most elementary treatments of programming introduce the separate concepts of code and data. Code refers to the computer instructions used to carry out a task, and data is the information used, created, or calculated as part of the task. Strommen (1998) described that the under object-oriented paradigm, code and data are combined into the concept of an object. An object is a representation of real-world entity. Every object has a set of properties, which are descriptive characteristics of the data, and also has certain actions that it can perform, which are referred to as coding.

2.1.4 Process to construct the simulation model

Baldwin, et al. (2004) described the process of simulation that will take all 10 steps, as shown in Figure 2.2. The first step is problem formulation that is setting the objectives of the study and the specific issues to be considered. The second step is data collection that based on the objectives of study and defined the conceptual model. Step 3 is the verification which refers to whether the conceptual model is performing properly. After the verification then step 4 is constructing a computer model, which is based on the conceptual model. After that a pilot run is done in step 5. Then, the validation, that is performs in step 6, refers to whether the model is an accurate representation by comparing the operational model with the real system. Steps 7 through 10 are design of experiments for defining the different alternatives for experimentation, production runs for providing performance data on systems designs of interest, output analysis which consists of statistical techniques for analyzing output from production runs, and implementation of model.

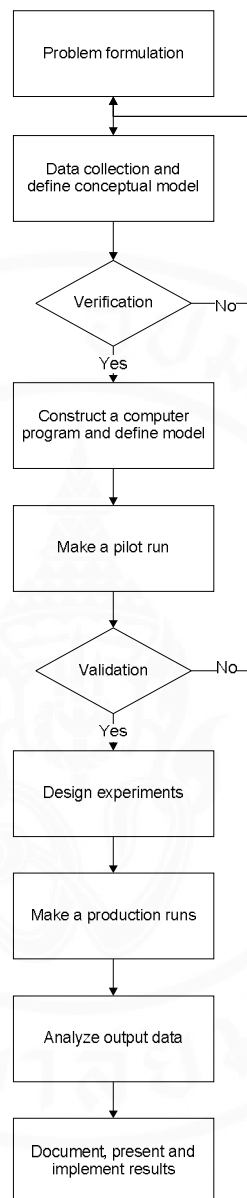


Figure 2.2 Step in a simulation study [4]

2.2 Related literature reviews

This section will discuss on the application of discrete-event simulation model in service and manufacturing industry. The related literature will focus on hospital and automotive. The literatures which related to this aim will be summarized in table 2.1.

Table 2.1 Application of DES model in the hospital

No.	First author	Year	Objective	Method	The main of KPIs	Software
1	Cote	1999	- Determine the optimal resource allocation to enhance the patient flow management	DES	- Resource utilization - Total time of patient	Arena
2	Harper	2003	- Cost-effectiveness evaluation of various prevention in diabetic retinopathy.	DES CART analysis	- Cost - Number of blind patient	JAVA
3	Su	2003	- Analyze several scheduling solutions for preregistered patients.	DES	- Waiting time of patient - Resource utilization	ProModel
4	Hunter	2004	- Demonstrated the development and used of a decision support tool based on simulation technique to assess the policy of health service	DES	- Cost	MARCA
5	Duguay	2007	- Determine the optimal resource allocation to enhance the patient flow management	DES	- Resource utilization - Total time of patient - Waiting time of patient - Patient throughput	Arena
6	Coelli	2007	- Analyzed and defined optimal operating conditions in the mammography clinic	DES	- Waiting time of patient - Resource utilization	ProModel

Table 2.1 Application of DES model in the hospital (cont.)

No.	First author	Year	Objective	Method	The main of KPIs	Software
7	Yeh	2007	- Determine the optimal resource allocation to enhance the patient flow management	DES Genetic algorithm	- Waiting time of patient	eM-Plant
8	Hoot	2008	- Forecasting near-future operating conditions in emergency department	DES	- Resource utilization - Total time of patient - Waiting time of patient	C program
9	Ahmed	2009	- Determine the optimal resource allocation to enhance the patient flow management	DES Stochastic optimization	- Waiting time of patient - Patient throughput	GoldSim
10	Brenner	2009	- Determine the optimal resource allocation to enhance the patient flow management	DES	- Resource utilization - Total time of patient - Waiting time of patient	SIMUL8
11	Werker	2009	- Improvement to the RT planning process in order to enhance the patient flow	DES	- Total time of patient	Arena

Table 2.1 Application of DES model in the hospital (cont.)

No.	First author	Year	Objective	Method	The main of KPIs	Software
13	Persson	2009	- Determine the optimal resource allocation to enhance the patient flow management and minimize hospital cost	DES Optimization algorithm	- Waiting time of patient - Cost	JAVA
14	Troy	2009	- Study on the impact of ICU bed capacity on the ICU performance	DES	- Waiting time of patient - Resource utilization	GoldSim
15	Oddoye	2009	- Determine the optimal resource allocation to enhance the patient flow management	DES Goal programming	- Waiting time of patient	Micro saint
16	Villamizar	2010	- Determine the optimal resource allocation to enhance the patient flow management	DES	- Resource utilization	ProModel
17	Jin	2010	- Identify the best performing by several scenarios of the number and the location of CT scanners	DES	- Waiting time of patient - Resource utilization	JAVA
18	Perez	2010	- Determine the optimal resource allocation to enhance the patient flow management	DES	- Waiting time of patient - Resource utilization - Patient satisfaction	JAVA

Table 2.2 Application of DES model in automotive industry

No.	First author	Year	Objective	Method
1	Arici	1999	- Simulate the dynamic operation of climate control system for a generic automobile	DES
2	Heilala	2008	- Maximize production efficiency and balance environmental	DES Lean manufacturing
3	Mtaawa	2005	- Present the framework for integrating DES into manufacturing system	DES Lean manufacturing
4	Spieckermann	2000	- Planning problem in new body shop of automotive industry	DES Genetic algorithm

Over the last decade, many research has been applied a DES model to study and analyze the operation in the department of hospital. For example, Cote (1999) used discrete-event simulation model to represent the physician's activities in outpatient clinic which is part of a health maintenance organization (HMO) in USA. The objective of this research was to evaluate the effect of different examining room capacity to their patient flow. For this purposes, DES model was used to analyze the performance variables such as examining room utilization, examining room queue length, and total time of patient that spent in the clinic.

Harper, et al. (2003) created the level of individual diabetic patients by using classification and regression tree (CART) analysis, which has been fed into a DES model. The objective of this research was to cost-effectiveness evaluation of various prevention and patient care in diabetic retinopathy. The results demonstrated how the DES model can be used to evaluate different interventions and patient care option.

Su and Shih (2003) applied simulation methodology to analyze several scheduling solutions and setting the appropriate arrival time interval for preregistered patients in Su-Ten Urology Hospital, Taiwan. These factors were significantly impact with patient waiting time for registration in outpatient services. This research utilized the advantages of appointment in clinic operation and found that mixed-registration scheduling (walk-in and scheduled) could be a better scheduling by reduce waiting time for registration to all patients.

Hunter, et al. (2004) proposed the simulation modeling of breast cancer screening to cost-effectiveness evaluation of impacts on the extending routine radiographic detection to women in the 40-49 age groups. The objective of this research was to demonstrated the development and used of a decision support tool based on simulation technique to assess the policy for the health services. The model predicted that changes to eligibility would result in the detection of an additional 6610 women with breast cancer, costing an additional \$795 per case.

Duguay and Chetouane (2007) proposed a DES model that used to improve the quality of care in an emergency department by adjust several alternatives of the scheduling in physicians, nurses, and examining rooms in order to reduce patient waiting time in ED. The results indicated that the alternative with one physician and nurse added would be reduced waiting time from registration to available exam room. In contrast, the number of examining room had no effect on waiting time if added without matching to the increased staff.

Coelli, et al. (2007) developed a DES model for the assessment of patient flow, equipment utilization, and personnel needs under the standard working routine of the mammography clinic in The National Cancer Institute of Brazil. The objective of this research was to analyzed and defined optimal operating conditions by change in patient arrival rates, number of equipment units, available personnel, equipment maintenance scheduling, and exam repeat rates. These results indicated that the exam repeat rate and equipment maintenance scheduling would be a large impact to patient waiting time.

Yeh and Lin (2007) proposed a DES model that combined with genetic algorithm (GA) to improve the quality care of emergency department at Show-Chwan Memorial Hospital in Taiwan. The objective of this research was to appropriately adjust nurse scheduling with the current existing staff. The advantage of applied the GA was to find a near-optimal nurse schedule based on minimizing the patient waiting time. As a result, the integration of simulation technique and GA could be reduced the patient waiting time that improve the quality of healthcare and patient satisfaction.

Hoot, et al. (2008) developed a DES model of patient flow in emergency department for the objective to forecasting near-future operating conditions, that is 2, 4, 6, and 8 hours into the future, and to validate the forecast with several measures of

the ED. The results indicated that the waiting time, length of stay, and bed occupancy level were started high and decreased gradually up to 8 hours into the future. In the conclusion, the simulation forecast showed good calibration and could be used to forecast the near-future operating condition in ED.

Ahmed and Alkhamis (2009) proposed the integration of DES model with stochastic optimization technique to address the operation of an emergency department at a government hospital in Kuwait. The objective of this research was to determine the optimal number of doctors, lab technicians, and nurses in order to maximize patient throughput and reduce waiting time of patients. These results indicated that the optimization simulation model would allowed 28% increase in patient throughput and an average of 40% reduction in patient's waiting time due to the optimal staffing allocation.

Brenner, et al. (2009) developed a DES model for the emergency department at University of Kentucky Chandler Hospital (UKCH). The objective of this research was to determine the optimal staffing, such as doctors and nurses, as well as testing equipment, such as X-ray and CT scan by using what-if analyses at different scenarios. In summary, the recommended number of resources in ED would enhance patient flow and resource allocation by considering in patient throughput, patient's waiting time, and resource utilization.

Werker, et al. (2009) used a DES model to represent the radiation therapy (RT) planning process at the British Columbia Cancer Agency. The objective of this research was to test various scenarios that could be identify and quantify potential improvement to the RT planning process in order to reduce waiting time of patients. These results indicated that decreasing the number of radiation therapists would be negatively impact to the RT planning time and ultimately to the patient's waiting time.

Ramwadhoebe, et al. (2009) introduced a DES model to describe a clinical example: pediatric ultrasound screening for hip dysplasia. The objective of this research was to explain where and why DES is used into the 4 steps, such as conceptual model and problem narrative, framing of the question, building the DES model, and statistical analysis. These result indicated that a policy using centralized screening center could be increase travel time and reduce parental attendance.

Persson (2009) proposed a DES model that combined with optimization algorithm for surgery management decision. The aim of this research was to minimize the hospital related costs, such as the cost of using extra beds at the surgery ward and the cost of staff working overtime in order to reduce the queue length and waiting time of patients. The results indicated that the combining DES and optimization algorithm could be applied to allocate the available resources in surgery department.

Troy and Rosenberg (2009) proposed a DES model to analyze patient and surgeon flows in an ICU of The Jewish General Hospital in Canada. This research was to study on the impact of ICU bed capacity on the ICU performance because of the increasing demand for critical care led to long waiting time and the cancellation in patients. The study found that 10 beds could be reduced the number of cancellation and have the best utilization. In conclusion, these results would be the important factors to increase the avenues of the hospital by reducing the cancellation of operative procedures in patients.

Oddoye, et al. (2009) applied a combining DES and goal programming (GP) for healthcare planning in a medical assessment unit (MAU). A comprehensive simulation model was developed to determine optimal staffing for the MAU and to define bottlenecks in the system. Afterward, GP model was constructed to evaluate the results of the simulation with the multi-objective perspective of the hospital management. The aim of the GP model was to minimize the queues lengths, waiting times, and number of beds. In summary, this research indicated that the combining DES and GP model had effective to determine the optimal resource level which can be eliminate bottlenecks in order to enhance the clinical workflow.

Villamizar, et al. (2010) developed a DES model to analyze the performance of a standard physiotherapy clinic in Brazil. The model was used to emulate the clinic's operational routine in order to change in the number of patients, human resources, and the scheduling of patient arrivals. The objective of this research was to analyze the optimal number of patient who attending to the clinic and their waiting times by the different in scheduling of patient arrivals, and the capacity of humans and treatment rooms in the clinic. In conclusion, this research indicated that the best scheduling of patient arrivals and the optimized resources could be

accommodate the increasing in the number of patients that result in the operational improvement in healthcare system.

Jin, et al. (2010) used a DES model to evaluate the patient flow management strategies of trauma center in Netherland which present ATW-concept of a sliding gantry CT scanner that serving two trauma rooms. The objective of this research was to identify the best performing of this concept by several scenarios of the number and the location of CT scanners, and different patient groups. Each scenario was assessed for patient waiting times, idle time of CT scanner, and overtime due to scheduling. The result indicated that the ATW concept could be reduced waiting time and overtime in urgent and trauma patients, but increased the idle time of CT scanner.

Perez, et al. (2010) presented a discrete event system specification (DEVS) simulation model for nuclear medicine patient service management that considers both patient and management perspectives. The results provide useful insights into patient service management in nuclear medicine. For example, a higher demand for service can negatively affect the level of service provided to the patient if resources are not managed efficiently. Thus it is up to the nuclear medicine clinic to alter their resource capacity for a given demand and patient preferences in order to maintain a high level of service.

Over the last decade, many research has been applied a DES model to study and analyze in the automotive industry. For example, Arici and Yang (1999) were developed software to simulate the dynamic operation of climate control system for a generic automobile. The transient nature of passenger cabin temperature and relative humidity are predicted using the principles of thermodynamics. Analysis is including detailed simulations of every component of the automobile air conditioning network. The methodology is validated by comparing the simulation results with the experimental results.

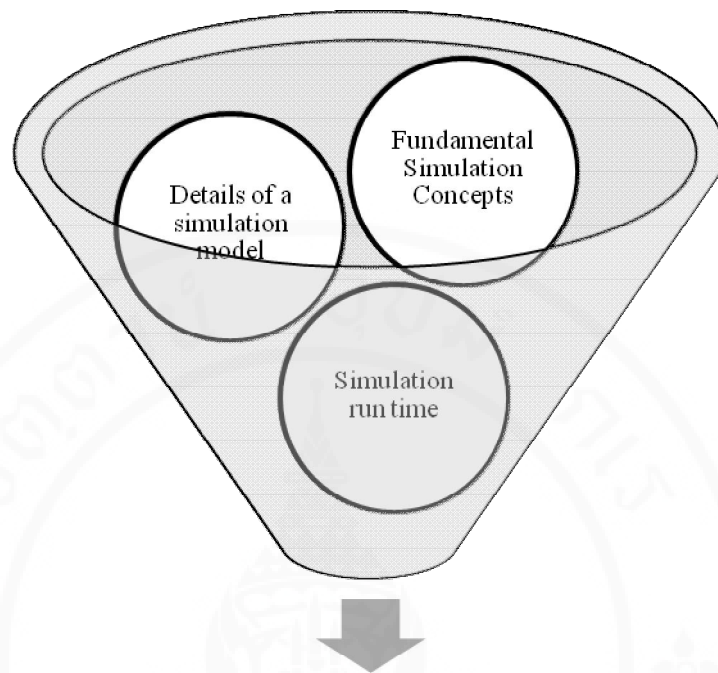
Heilala, et al. (2008) proposed an integrated simulation tool helping to maximize production efficiency and balance environmental constraints already in the system design phase. Lean manufacturing, identification and elimination of waste and production losses, and environmental considerations are all needed during development of a sustainable manufacturing system.

Basher and Mtaawa (2005) presented the framework a methodology for integrating discrete-event simulation into manufacturing system development.

Spieckermann, et al. (2000) presented a mathematical formulation and an automated optimization approach for the planning problem in new body shop of automotive industry. The optimization modules, which have a direct interface to the underlying simulation model, are based on metaheuristics, such as genetic algorithms and simulated annealing.

2.3 The analysis of literature

In a previous study, several literatures are mainly focused on the details of simulation model in any approach thus we investigated of the comparison point on which simulation approach is more applicable in several literatures. For example, Kritchanhai and MacCarthy (2000) reviewed the applicability between discrete-event-simulation and system dynamics in supply chain management in order to conclude the difference in term of results and level of details. Borshchev and Filippov (2004) compared the modeling paradigm and level of details by illustrating system dynamics, discrete event and agent based simulation. Seila and Brailsford (2009) discussed opportunities and challenges in applying discrete-event simulation and system dynamics simulation to healthcare. DES and SD simulations are described and compared on the level of details and simulation run time. For this reason, we selected this issue to be a comparison point in the research and also the simulation run time as shown in Figure 2.3.



The comparison points of process-oriented and object-oriented simulation

Figure 2.3 The comparison points in this research

Key performance indicator (KPI) that is a crucial instruments for the application of DES model has been used to measures and evaluates the performance depend on the various aspects of each research. Form the mentioned literature, the main of KPIs that used to evaluate the performance in the hospital has two indicators as following; total time in system of patient, and resource utilization as shown in Figure 2.4. Thus, there can be a guideline which use to select the appropriate KPI for evaluate the performance in the case study of hospital.

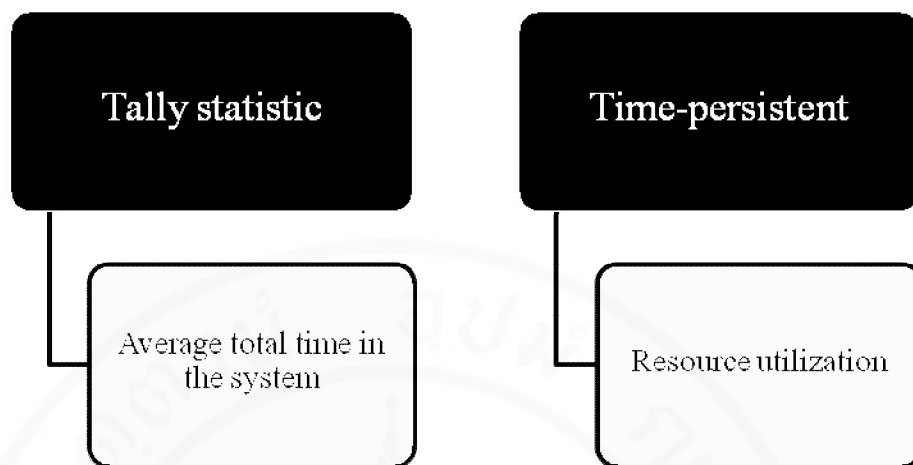


Figure 2.4 The KPI that regularly proposed for healthcare simulation

In summary, this research will develop DES model of the orthopedics department in public hospital of Thailand by using DES and object-oriented software. Then, we will compare the result of proposed KPI and discuss on the advantages and disadvantages between two type simulation modeling in hospital service.

CHAPTER III

RESEARCH METHODOLOGY

This chapter will discuss on the methodology of this research from the beginning to the ending. There are composes of 8 steps in this research.

3.1 Step of Research methodology

In this section, we will describe about the methodology in this research that has been concluded into 8 steps as shown in figure 3.1.

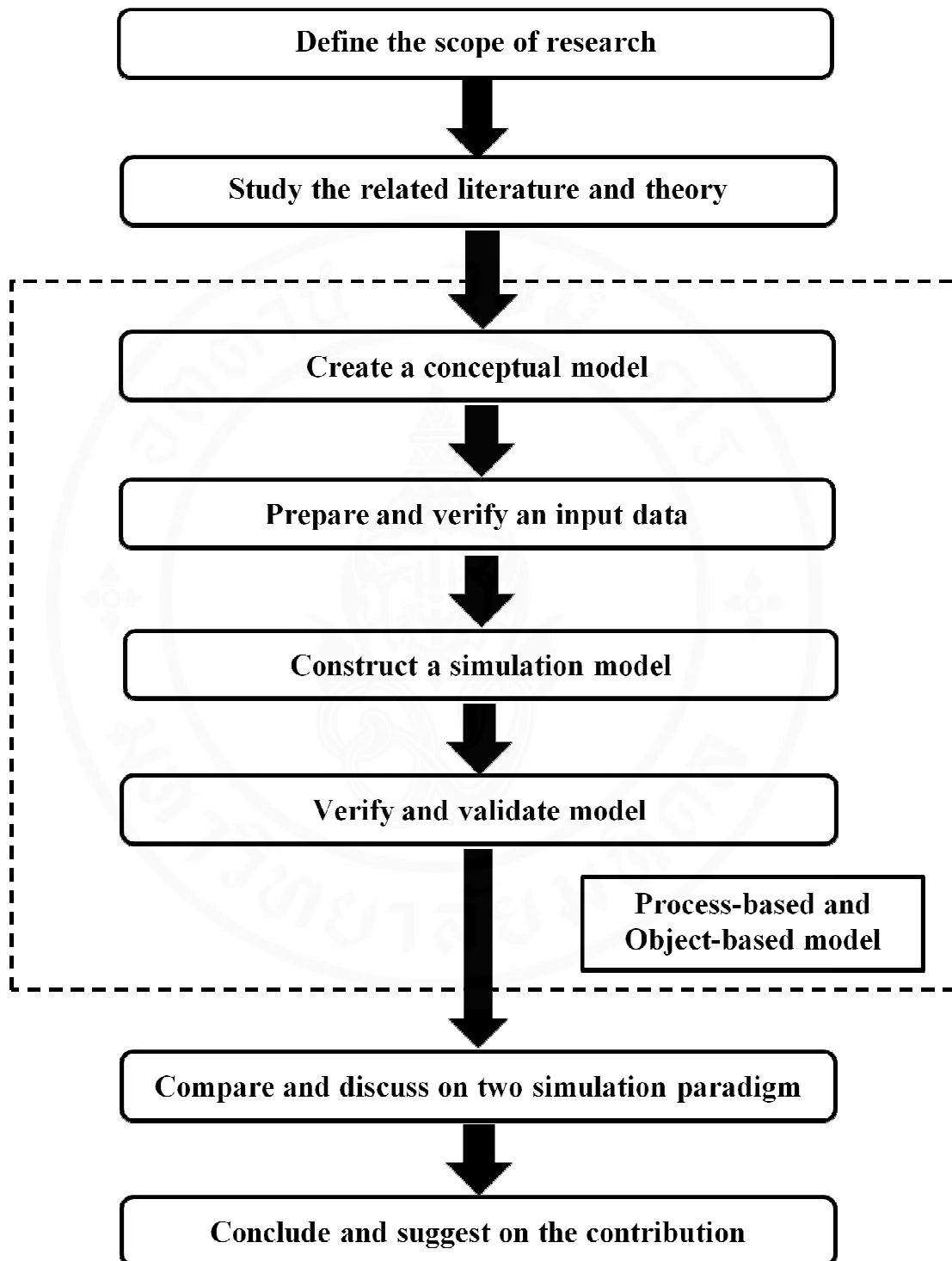


Figure 3.1 Step in research methodology

3.1.1 Define the scope of research

This research presents a case study of simulation modeling in public hospital of Thailand. The scope of this study is to compare between process-based simulation and object-based simulation paradigm in healthcare industry and also to discuss on the advantages and disadvantages between these two simulation frameworks.

3.1.2 Study the related literature and theory

This step is to collect and study of relevant literature on the application of simulation modeling in healthcare industry and especially the comparison in different types of simulation modeling. The main objective is identifying key issues that used to be compared the difference between each simulation types and also find out the key performance indicators that used to reflect the problems of the healthcare industry. This information is useful to identify a comparison issues, and key performance indicators of this research.

3.1.3 Create a conceptual model

Through on-site observations and interviews with the nursing staff at orthopedics department, we will create a conceptual flow that used to be a framework for constructing the models both process-based and object-based simulation. Furthermore, the conceptual flow will illustrate what input data that has prepare for using in the simulation model.

3.1.4 Prepare and verify an input data

Due to the different of format in some data that are redundant and unnecessary for this research. Therefore, the collected data must be through the data processing step to set a standard form that used as the input parameters for a DES model. For example, the actual arrival time of patients will have to fitting to determine the appropriate time interval of patient arrival. This step is the collecting and verifying an input data from various clinical processes that are associated with conceptual flow in the previous step.

3.1.5 Construct a simulation model

After we created a conceptual model, prepared and verified an input data, the simulation model has been constructed by using Arena that used to represent the process-based paradigm and Simio that used to represent the object-based paradigm.

3.1.6 Verify and validate model

Evaluation is regarded as a crucial step which used to analyze the performance measurement of the DES model. This step will verify that the results from Arena and Simio are not significant different and appropriate enough to simulate the actual clinical operation based on the proposed KPIs including total time in system, waiting time, the congestion, average treatment time in term of patient, and doctor utilization.

3.1.7 Compare and discuss on two simulation paradigm

After constructed and verified the simulation model, the issues that were identified from literature and other will be used to compare between Arena and Simio model. Then, we will discuss on the advantage and the disadvantage of two simulation paradigm.

Regarding the related literature of simulation modeling in hospital service and automotive industry, we can summarized the characteristic of hospital model that differ from automotive model and it make a challenge for hospital simulation modeling as shown in Table 3.1.

Table 3.1 The differentiation between automotive and hospital simulation model

Topic	Manufacturing (Automotive)	Service (Hospital)	Differentiation in hospital simulation modeling
1.) Entity arrival	- Entity type: Material/Part - Entity variation: Low	- Entity type: Patient - Entity variation: High (depend on severity, patient condition etc.)	- Patient entity enters to the transformation process, and changes his state and status.
2.) Process	- Process time: Constant - Queuing pattern: FIFO	- Process time: Vary and high distribution - Queuing pattern: Normally is FIFO but can be prioritized by severity and patient condition	- Process time for hospital model has high distribution from the variation of patient severity and condition. - Due to this variation, it make an abnormal sequence for treatment in hospital model.
3.) Resource	- Resource: Man/Machine	- Resource: Physician/Pharmacist/Nurs	- Hospital resources are clinical professional specialist
4.) Entity routing	- Routing: Simple direction	- Routing: Dynamic direction	- Entity routing in simulation model is more complicated because of the variation of patient behavior.

3.1.8 Conclude and suggest on a contribution

Finally, the contribution of this research will be concluded and the suggestion on which simulation modeling paradigm that is more suitable for healthcare industry will be described.

3.2 Research time

Table 3.2 Research time

Activities	Month							
	2	4	6	8	10	12	14	16
1. Define the scope of research								
2. Study the related literature and theory								
3. Create a conceptual model								
4. Prepare and verify an input data								
5. Construct a simulation model								
6. Verify and validate model								
7. Compare and discuss on two simulation paradigm								
8. Conclude and suggest on a contribution								

CHAPTER IV

CASE STUDY ON INFORMATION GATHERING

In this chapter, an overview of the case study will be described in the section 4.1. Next, an input data that is used for develop the DES model will be summarized in the section 4.2. Then, we will propose the list of KPIs which used for evaluation the performance of simulation model in the section 4.3. Finally, a general perspective of simulation modeling in Arena and Simio software will be described in the section 4.4.

4.1 An overview of the case study

The case study in this research is a public hospital of Thailand which has primary function for providing health service to people, teaching and researching for the medical students. The approximately resource of the case study consists of 528 doctors, 2,837 staffs (nurse, lab technician etc.), and 959 beds. In each day, the hospital is faced with the unpredictable problem of patient demand that lead to the congestion within the hospital area and also put the pressure to the hospital personnel to serve a quality of care in patients. Therefore, the hospital was planning to launch a new outpatient building which can accommodate with patient demand problem and enhance the quality in healthcare service to patients.

After the survey, interview, and data collection, we will be discussed about some information that associated to the operation in orthopedics department. These data are important for the construction of the DES model, which composed of conceptual workflow, patient arrival rate, clinical operation, resources, and service time parameter.

4.2 An input data for simulation modeling

This section will describe about the input data that required for developing the DES model as following; conceptual workflow, patient arrival rate, clinical operation, resource and service time parameter.

4.2.1 Conceptual flow

Besides interviews, the numerical data is collected from a stop-watch time study during June 2010 to develop a conceptual flow of patients. Each process in the flow is then further examined to identify information needed to implement a simulation model.

By an interview with the staff, we can classify patient in Orthopedics department into three groups as following by-appointment, walk-in, and transferred patient. The first process was starting from patients who entrance to the Orthopedics department will present an appointment card to register staff (C01). In the registration process, nurse will check the patient data and medical history before inform the patients who have a future order, i.e. lab and x-ray testing (C09/C10), go receive the test and back to orthopedics department. Then, the patients will measure weight and blood pressure (C02) and wait for nurse completed checking all patient documents including medical record, blood result and x-ray result. After nurse completed documentation process, the patient will receive a queue card (C03) that was ranking by two criterions as following: by-appointment patient will be ranked with higher priority than walk-in and transferred patient, and the first-in, first-out logic. Next, the patient was called into the examination room to receive the diagnosis and treatment by doctor (C04). After diagnosis and treatment process, the patient will return the medical record (C05) according to prepare an appointment card and prescription. Then, the patient receives a prescription and makes an appointment (C06) before leaving from orthopedic department and going to the pharmacy station. At the pharmacy station, patients will make a payment with cashier (C07) before receive a medicine from the pharmacist (C08) and then patient will be leaved from the hospital.

As a previous detail, we can created a conceptual workflow for develop a DES and an object-based model of orthopedics operation in the figure 4.1 and 4.2.

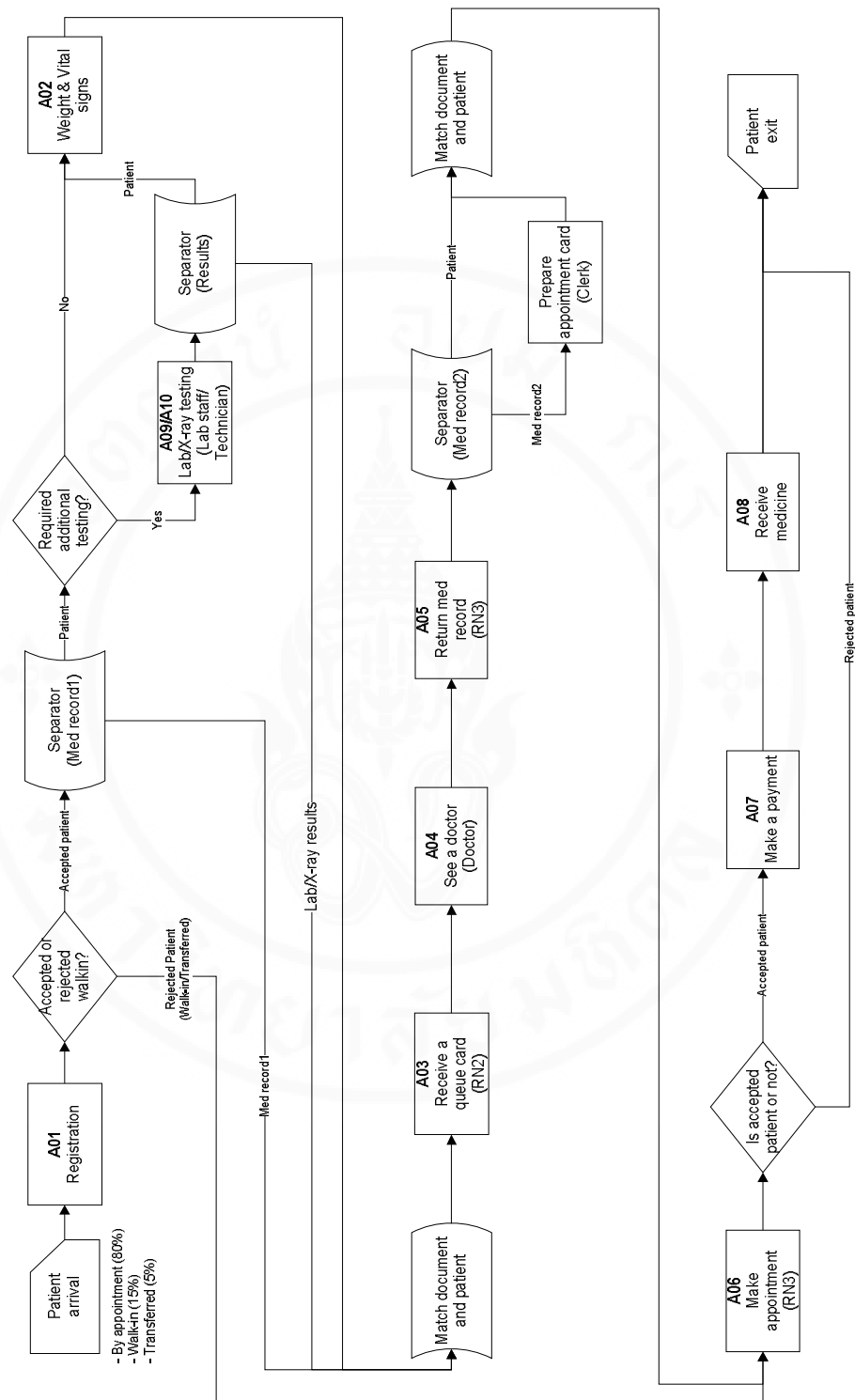


Figure 4.1 Conceptual workflow for DES model construction

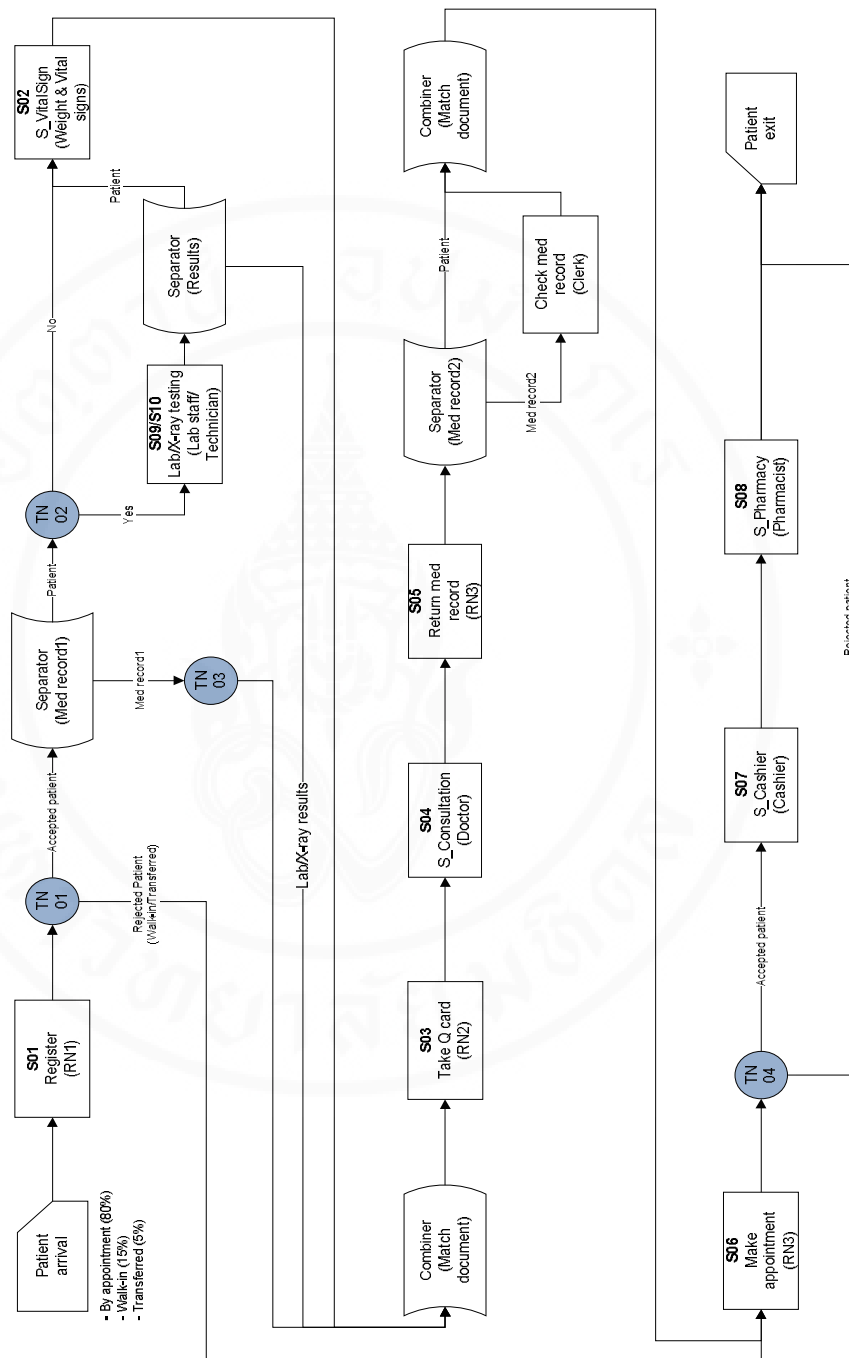


Figure 4.2 Conceptual workflow for object-based model construction

4.2.2 Patient arrival rate

In this section, we will summary about the patient arrival in Orthopedics department that has been separated into two categories as following; a daily demand, and an hourly demand.

4.2.2.1 A daily demand

Table 4.1 shows the treatment provided to patients on a daily basis is quite a variation because the clinical treatment of specific offices that have a specific day. Combined with walk-in and transferred patients who difficulty predict whether to use the services and how much of them. Figure 4.3 will show a daily demand for all patient type of Orthopedics department.

Table 4.1 Daily demand of Orthopedics department

Daily Arrival	Mon	Tue	Wed	Thu	Fri	Sat	Sun
By-appointment	308	385	406	290	444	308	78
Walk-in	43	48	49	35	56	51	19
Transferred	11	10	15	9	14	7	0
Grand Total	362	443	470	334	514	366	97

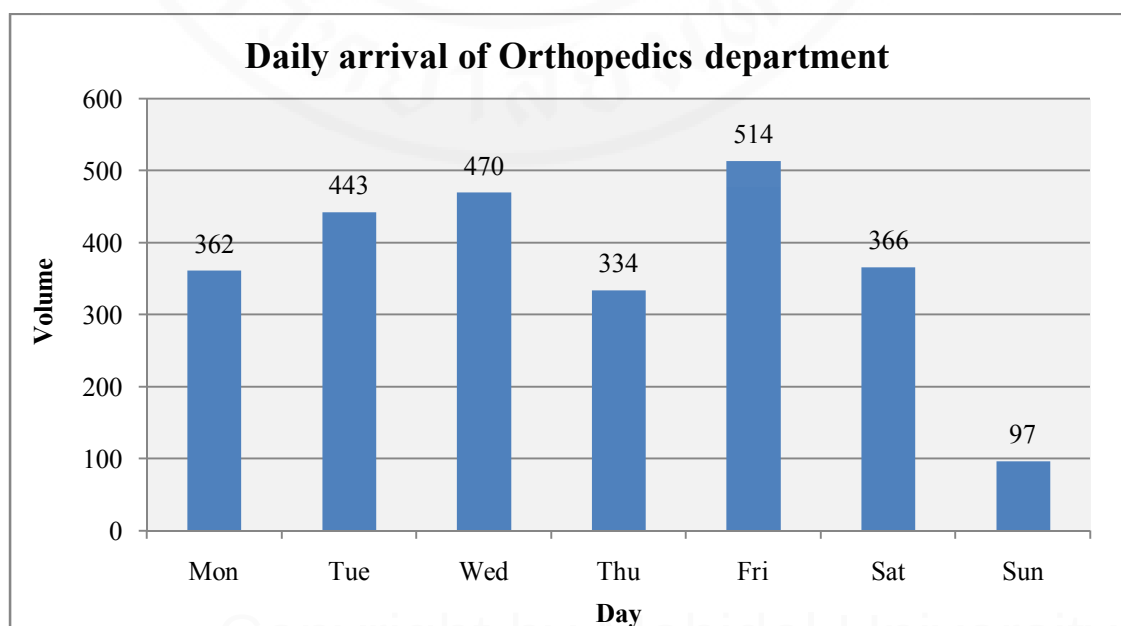


Figure 4.3 Daily arrival of Orthopedics department

4.2.2.2 An hourly demand

In addition to daily demand, we will also show a variation of patient demand in each hour because of a specification of clinical treatment in Orthopedics department. Table 4.2-4.4 will provides the summary of hourly demand in each period separated by patient type.

Table 4.2 Hourly arrival of by-appointment patient

Period	Mon	Tue	Wed	Thu	Fri	Sat	Sun
7.01 - 8.00	20	30	28	19	32	44	17
8.01 - 9.00	35	46	41	26	60	73	30
9.01 - 10.00	75	70	72	63	78	64	23
10.01 - 11.00	58	62	68	53	70	38	8
11.01 - 12.00	48	47	51	40	55	32	0
12.01 - 13.00	1	2	4	2	5	46	0
13.01 - 14.00	20	27	35	25	36	11	0
14.01 - 15.00	18	44	51	31	39	0	0
15.01 - 16.00	7	5	4	4	5	0	0
16.01 - 17.00	26	30	32	18	41	0	0
17.01 - 18.00	18	22	20	9	23	0	0

Table 4.3 Hourly arrival of walk-in patient

Period	Mon	Tue	Wed	Thu	Fri	Sat	Sun
7.01 - 8.00	18	17	19	14	20	17	8
8.01 - 9.00	8	10	6	7	11	15	7
9.01 - 10.00	5	6	6	5	7	7	4
10.01 - 11.00	0	0	0	0	0	0	0
11.01 - 12.00	0	0	0	0	0	0	0
12.01 - 13.00	0	0	1	0	1	9	0
13.01 - 14.00	4	5	7	4	7	3	0
14.01 - 15.00	0	0	0	0	0	0	0
15.01 - 16.00	0	0	0	0	0	0	0
16.01 - 17.00	5	6	6	3	7	0	0
17.01 - 18.00	3	4	4	2	3	0	0

Table 4.4 Hourly arrival of transferred patient

Period	Mon	Tue	Wed	Thu	Fri	Sat	Sun
7.01 - 8.00	0	0	0	0	0	0	0
8.01 - 9.00	0	0	0	0	0	0	0
9.01 - 10.00	0	0	0	0	0	0	0
10.01 - 11.00	4	3	4	3	4	2	0
11.01 - 12.00	3	2	3	2	3	2	0
12.01 - 13.00	0	0	0	0	0	2	0
13.01 - 14.00	1	1	2	1	2	1	0
14.01 - 15.00	1	2	3	2	2	0	0
15.01 - 16.00	0	0	0	0	0	0	0
16.01 - 17.00	1	1	2	1	2	0	0
17.01 - 18.00	1	1	1	0	1	0	0

4.2.3 Clinical operation

The schedule of the orthopedic ward is divided into ten types of specialized clinics: general practice (A), children (B), tumor (C), off-hour (D), sport injuries (E), osteoporosis (F), hands (G), backs (H), hips and knees (I), and special consultation (J). Table 4.5 shows the office hours of each ward. Some clinics are only open for some time during the week, e.g., the children clinic is only open on Monday afternoons. Many clinics may be available simultaneously, e.g., both the sports injuries and osteoporosis clinics are scheduled on Tuesday afternoons. The office hours of clinics affect the patient arrival rates. Patients arrival rates depend on operating shifts (morning, afternoon and evening), days of the week, and time of the day.

Table 4.5 Orthopedics department operation schedule

Shift	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1 (Morning)	A	A	A	A	A	D	D
2 (Afternoon)	B (64%), C (36%)	E (93%), F (7%)	G (73%), H (27%)	J	I	D	-
3 (Evening)	D	D	D	D	D	-	-

4.2.4 Resource and service time parameter

Our numerical data is collected from a stop-watch time study during June 2010. Details of the service time parameters and their associated resources of some service processes are shown in Table 4.6.

Table 4.6 Resource and service time parameters (ID is correspond to Figure 4.4)

ID	Process	Resource	Service time parameters (Average value)
C01	Present an appointment card	Nurse	5 sec.
C02	Weigh and check vital signs	Weight M/C	60 sec.
C03	Receive a queue card	Nurse	10 sec.
C04	See a doctor	Doctor	7 min.
C05	Return a medical record	Clerk	5 sec.
C06	Make an appointment	Doctor	30 sec.
C07	Make a payment	Cashier	60 sec.
C08	Receive medicine	Pharmacist	4 min.
C09	Receive a blood test	Technician	2 min.
C10	Receive an X-ray test	Technician	10 min.

4.3 The proposed of Key performance indicators (KPIs)

This section will summarize the KPI that used to measures the operational performance in orthopedics departments and also used to evaluate the simulation results from Arena and Simio. Because of the characteristics of hospital service that related with life and death and also focus on the allocation of the limited clinical staff. The KPIs including an average total time in system, an average time to receive queue card, an average time since take queue card to make next appointment, an average time to make payment and receive medicine, and doctor utilization are described in Table 4.7.

Table 4.7 List of proposed KPIs in this research

No.	KPI	Definition	Unit
1	Average total time in system	A period of overall process of patient since registration to receive medicine	Minute
2	Average time to receive queue card	A period of time since registration until received queue card	Minute
3	Average time since take queue card to make next appointment	A period of time since take queue card until make next appointment	Minute
4	Average time to make payment and receive medicine	A period of time since starting payment until received medicine	Minute
5	Doctor Utilization	The proportion between working time and total time of doctor	Percentage

4.4 An overview of Arena and Simio model

4.4.1 Arena perspectives

Arena models were built by using a single modeling paradigm referred to as a process-based orientation. We define elements that hold the state of the system, and build process flows using block modules. The block modules are passive and were activated by the arrival of entity. Entities move from block to block and change the state of the model over time. The elements, blocks, and entities define the process model as shown in Figure 4.4.

Arena model can animate the model in 2D as a 2-step process. First, we draw process flows for the model, and then we draw the animation for the facility in a separate area of the same drawing space. This is sometimes done by first importing an AutoCAD drawing as a static background for the animation. Then we add levels, animated routes, etc. that are linked back to the process model. The tasks of modeling and animating the model are typically done separately. We can employ Arena template panels to place hierarchical modules in your process flow. These modules are used in the same way as the standard blocks; however they represent a user-defined sequence

of blocks. For example, we can create a process module that is comprised of Seize-Delay-Release. The process module can have properties such as processing time that are passed to the Seize-Delay-Release blocks.

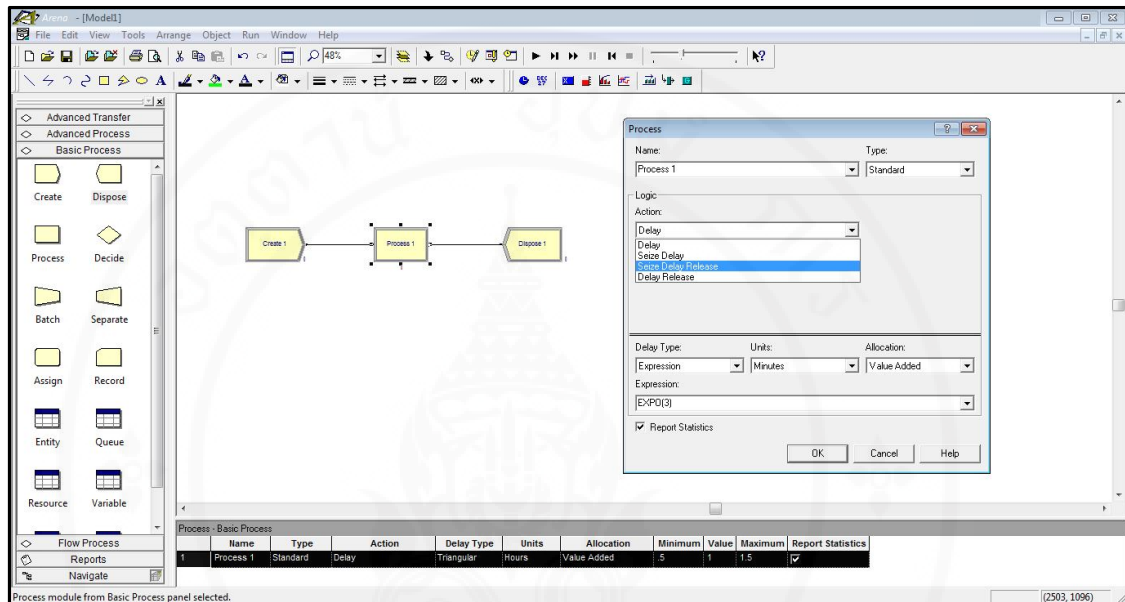


Figure 4.4 Process modeling paradigm in Arena

4.4.2 Simio perspectives

When we refer to “model” in Arena, we are referring to the process model that is the only modeling approach supported in Arena. However, Simio is a multi-paradigm modeling tool that supports both an object-based orientation and process-based orientation. We can build an object-based model in the facility window as shown in Figure 4.5, and/or a process based model in the process window as shown in Figure 4.6. The facility window is a 3-D drawing space in which we place objects that represent the physical components of system. The process window is a 2-D drawing window in which we construct Arena-like process flows. Although the object paradigm is the primary modeling approach in Simio, we can freely mix the two modeling approaches together in the same overall model. We will sometimes refer to these two separate components of the overall model as the facility model and the process model.

It is important to note that the classes in Simio define a generic behavior, but not the specific behavior of an object. The specific behavior of an object is defined

by an object definition which gives the object its own intelligent behavior. For example we have a Link class for defining a pathway between two nodes, and we can have a Conveyor object definition that is created from the Link class, but has specific logic added to represent the behavior of a conveyor. An object definition begins with some generic behavior defined by its class, and then refines that by modeling the specific behavior desired for that object. Object definitions can also have properties that further customize the behavior. Once you have created an object definition you can then place objects with the defined behavior into your facility model. An object is a specific instance of an object definition that has been placed within a model.

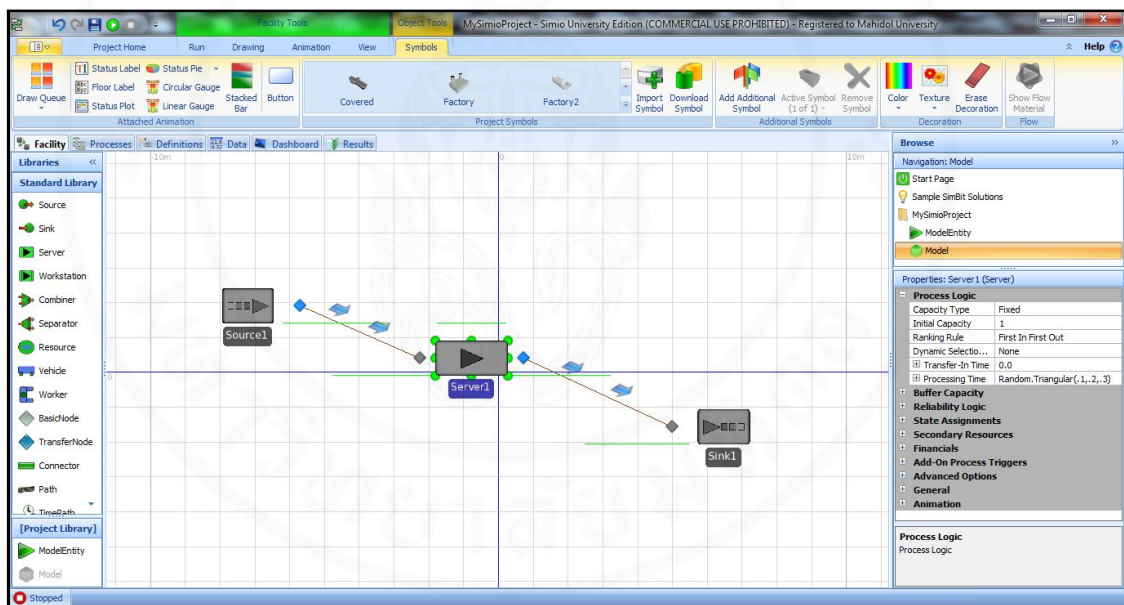


Figure 4.5 Facility window to built the object-based model in Simio

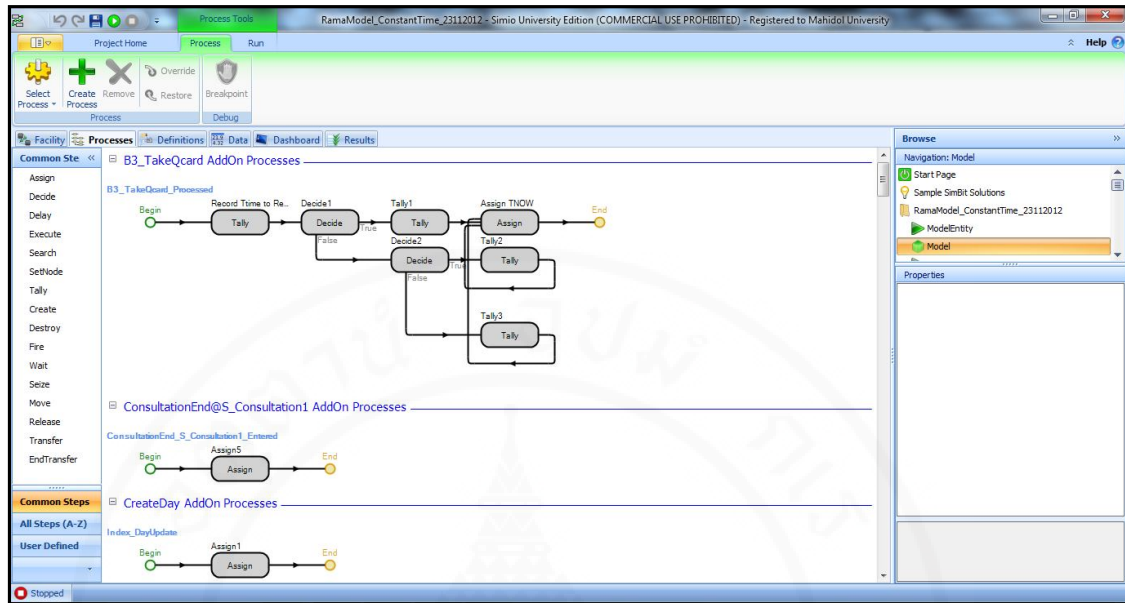


Figure 4.6 Process window to build the process-based model in Simio (cont.)

After we described on the perspective of both simulation model, we can build the case study model by transforming the conceptual workflow that was shown in section 4.2 to Arena and Simio model.

Process-based paradigm in Arena uses all the elements that are related to the process to build a model and allow the entity run through the series of process. This reason makes the detail of Arena model very large and complicate as shown in Figure 4.7. For object-based paradigm like Simio, the model will represent by object elements such as doctor, nurse, and pharmacist and then let the entity run through these objects. In additional, it can also support process-based paradigms by using add-on process trigger, which makes the detail of model for Simio smaller than Arena when compared with the same operation as shown in Figure 4.8.

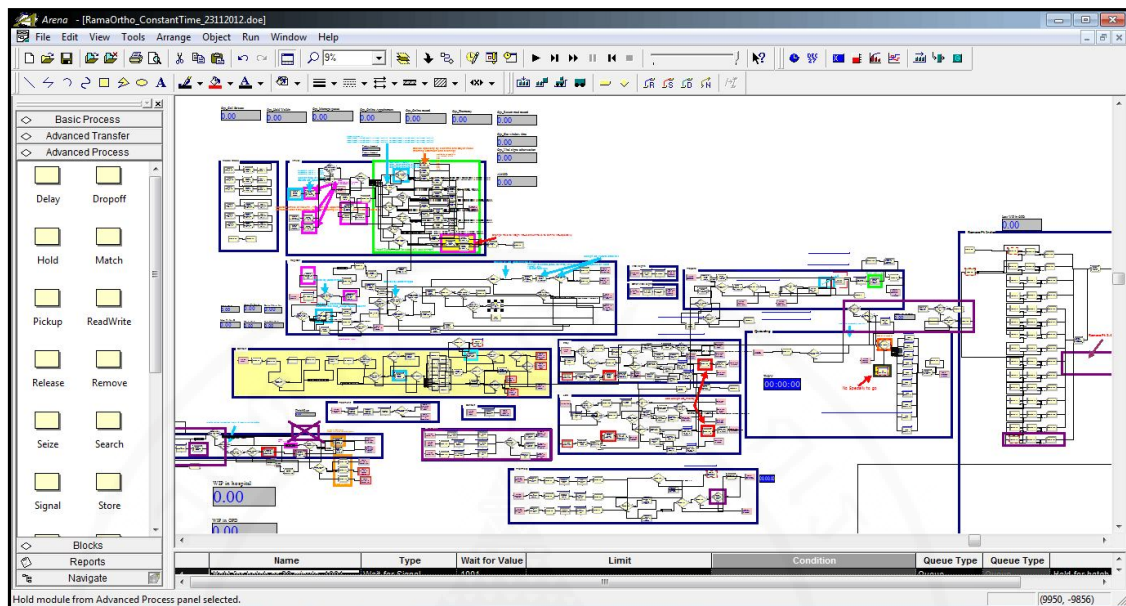


Figure 4.7 Arena model of this research

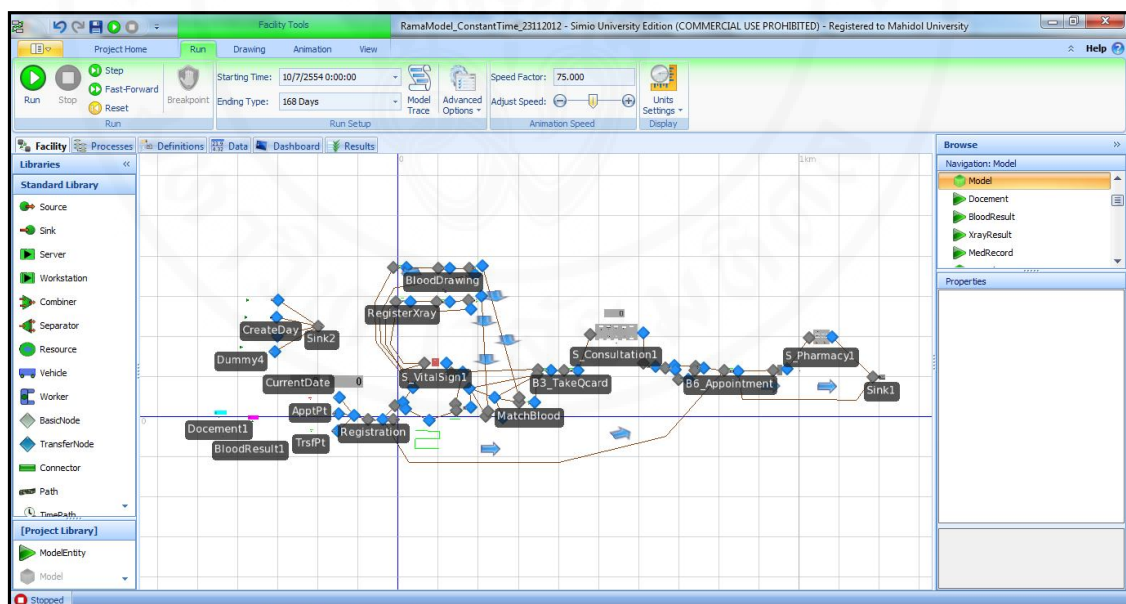


Figure 4.8 Simio model of this research

CHAPTER V

RESULTS AND DISCUSSION

This chapter presents the comparison between DES and objected-based simulation that based on fundamental simulation concepts and other points from literature review, and then describes about the advantage and disadvantage between two type of simulation modeling. Next, we will show the simulation results of the case study between Arena and Simio. Finally, we will discuss on the contribution of simulation modeling for hospital service.

5.1 The comparison between process-based and object-based simulation

This research studied the simulation modeling paradigm between process-orientation and object-orientation in order to compare the advantage and disadvantage on both paradigms in healthcare industry. For this purpose, we had to explored a several simulation modeling theory and also in the literature review to find out a comparison point that can be applied for this research. As a result, the key components of a simulation model that was described in fundamental simulation modeling such as entity, attribute, variable, resource, and routing logic. We applied the major points in literature review that used to compare simulation modeling paradigm are composed of the detail of a model and simulation run time. Furthermore, we are also notice the disparity between Arena and Simio that is how to create the trigger process and how to call and use time function.

5.1.1 Key components of a simulation model

5.1.1.1 Entity

Entity is the dynamic components in the simulation model that move around, change status, and affect the output performance measures. It was created when arrive, move through the process and change its status and state, was served by resource, and then disposed from system. From the mentioned, we will evaluate and compare the method that related to create and change status and state to entity with process-based and object-based simulation paradigm.

In this study, we will create patient entity that entered into Orthopedics department by schedule arrival. In Arena, we can input the patient arrival data into schedule spreadsheet that was appeared simultaneously after selected the arrival type as schedule. The patient arrival data that was input into schedule spreadsheet in Arena can be both numeric like “30, 46, 70, ...” or expression formula which composed of numeric value and variable, for examples “ $0.2148 * Var_Arrival_Appoint(1) * Fac_Arrival$ ” as shown in Figure 5.1. The method to create patient entity as schedule arrival into the Simio model is a bit difference from Arena because we first had to input the arrival rate by using numerical value only into rate table as shown in Figure 5.2. Then, we applied Source module for generating patient entity, chosen arrival mode as “*Time Varying Arrival Rate*” and call on the rate table which was defined before in Data window.

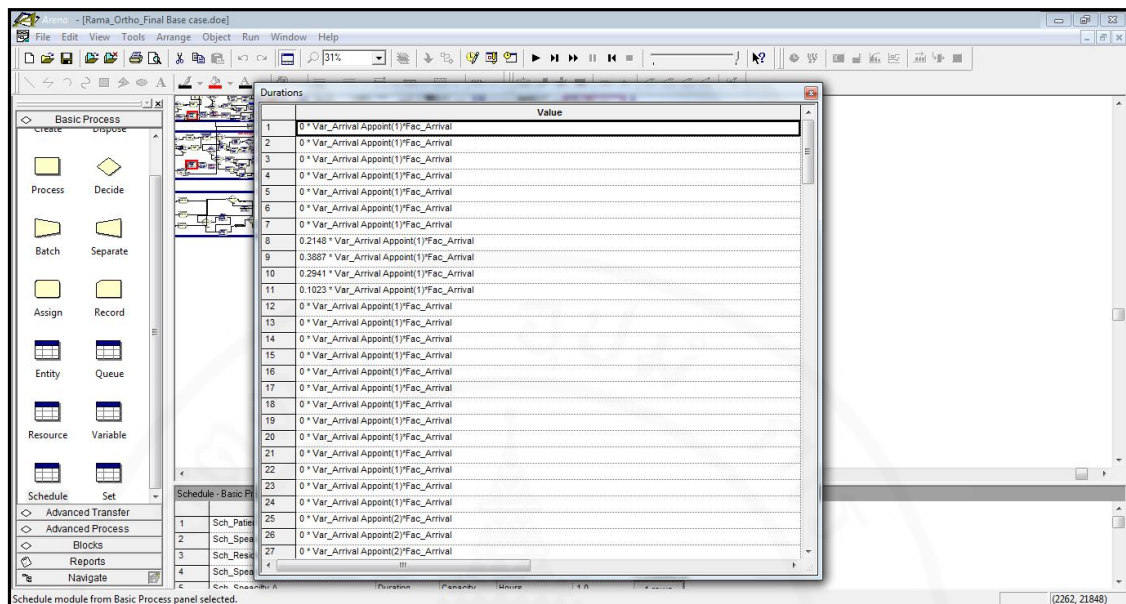


Figure 5.1 Schedule spreadsheet with expression formula in Arena

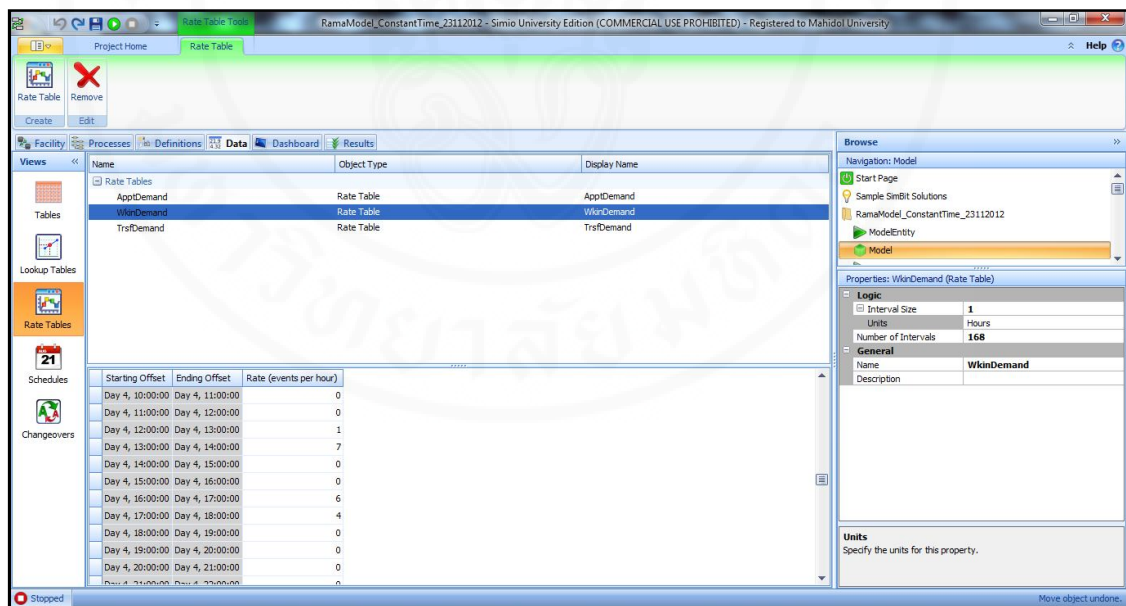


Figure 5.2 Definition of the arrival rate into rate table in Simio

In summary, both Arena and Simio have a similar method for generating the entry of the patient entity in an hourly rate by setting the input data into a schedule spreadsheet data. But to simulate the data after the entry to study the effect of future growth (for example, if the volume of patient was increased by 50%, how will this effects to the total time in system). For this purpose, Arena has more

flexibility than Simio because Arena allows the assign the arrival data as expression with numeric value and variable entry into the schedule spreadsheet, while Simio only allows for numeric value in the table that has to input the new value every time.

The main feature of DES in Arena is to construct model with many process elements for the changing status and state to entity. Every step that related to real operation was put to the model by several modules. For this reason, we will define state and status to patient entity in Arena by assign module which normally used to define attribute and variable in Arena. After that, we will set the specific value to indicate characteristic for each patient entity as shown in Figure 5.3. Meanwhile, the advantages of object-based simulation like Simio is to determine the state and status to the patient entity with the properties that attached to Source module and set the desired value in state assignment function. In contrast to Arena that need assign module to define the specific value to patient entity. This topic will be more described in the Attribute topic.

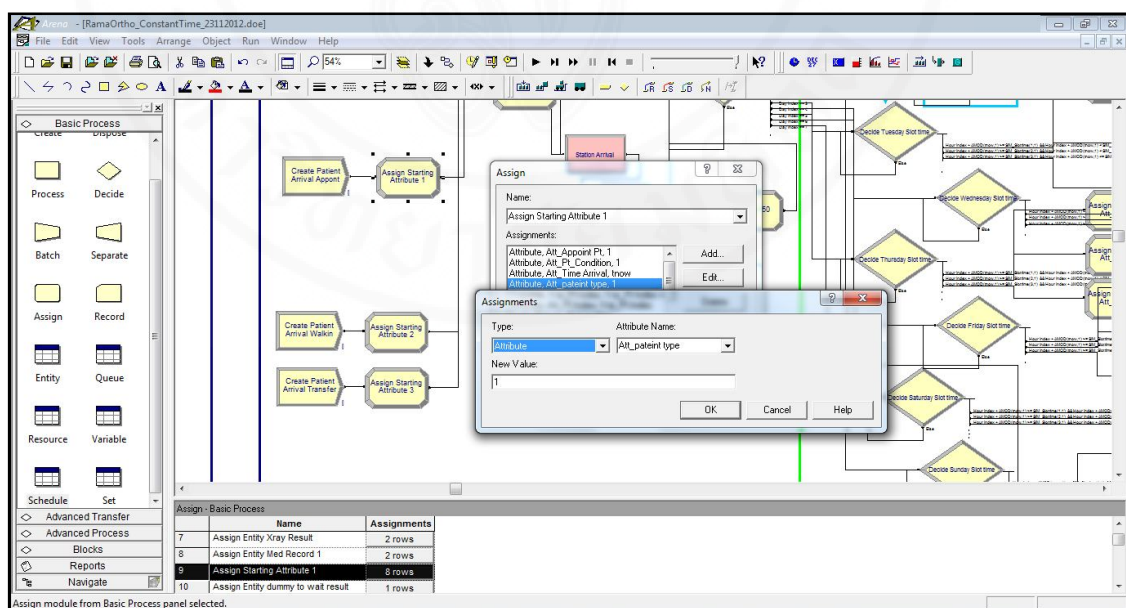


Figure 5.3 Assign module for define state and status in Arena

5.1.1.2 Attribute

An attribute is a common characteristic of all entities but with a specific value that can differ from one entity to another. For instance, patient entities could have attributes such as type, sex, arrival time that indicate to each patient entity. Therefore, we will compare and point out the differences of the attribute values in Arena and Simio.

According to the definition of state and status to patient entity that was described in the entity section, we had to apply the assign module to create and specify the attribute to the patient entity in process-based simulation like Arena by adding and specifying the attribute name without having to declare attribute before using. However, the disadvantage of Arena is difficult to check it how many attribute was used and what attribute name was defined in the model because there is no spreadsheet page for specifying attribute that was created in the Arena model. We will open each assign module to check all attribute in the model as shown in Figure 5.4.

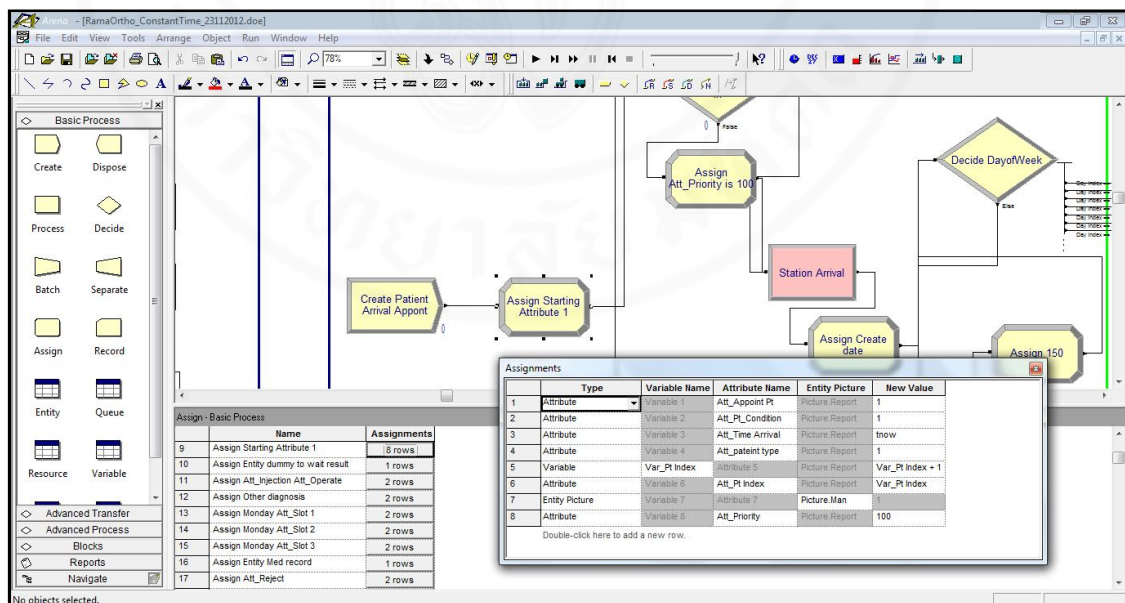


Figure 5.4 The disadvantage of Arena to check all attribute in the model

Due to object-based paradigm in Simio, the model cannot create the attribute by applying process elements. For this purpose, all attribute of patient entity that was used in the model had to declared in definition window of Navigation: ModelEntity and defined the initial value to each attribute as shown in

Figure 5.5. After that, the attribute will be used in the model through the state assignment or add-on process trigger by using assign step to adjust the attribute value for defining specific characteristic to patient entity as shown in Figure 5.6.

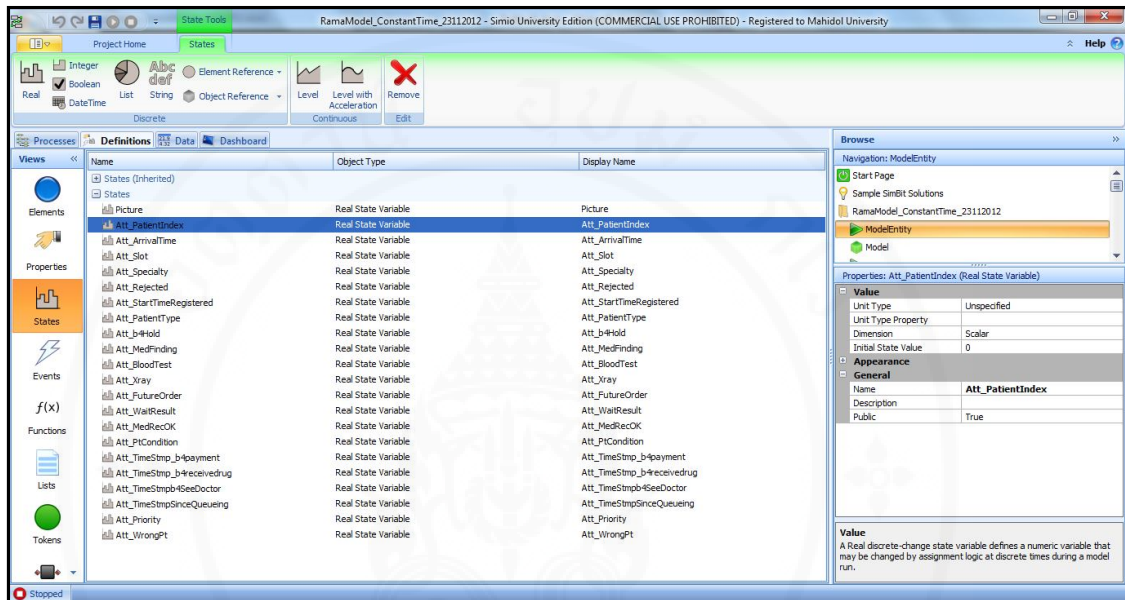


Figure 5.5 Attribute declaration in Simio

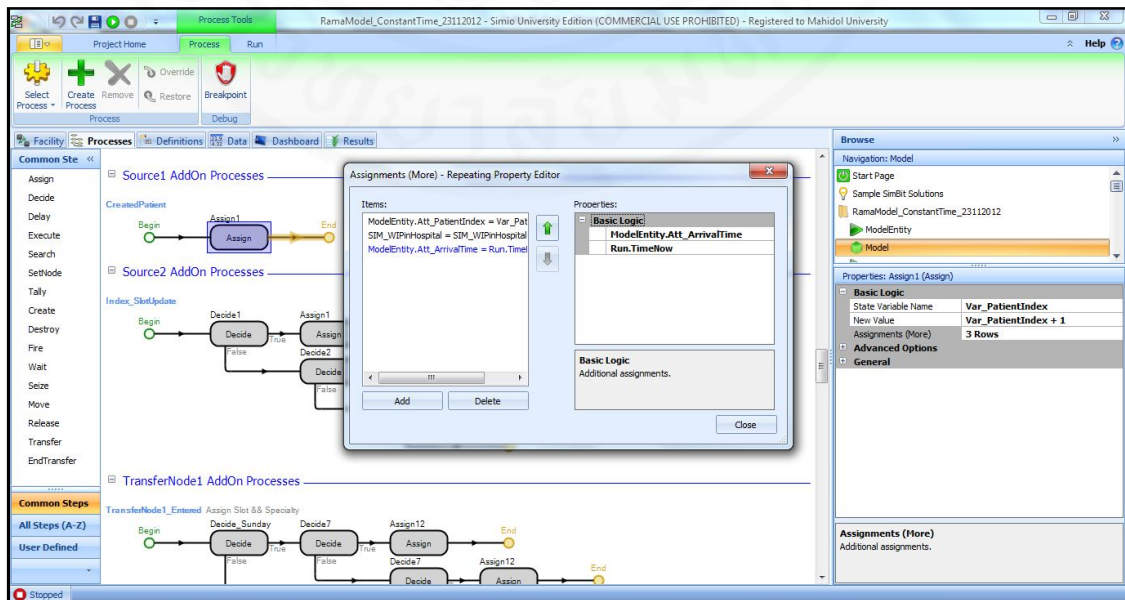


Figure 5.6 Add-on process to adjust attribute value in Simio

The method for creating an attribute in the model is quite different between Arena and Simio. Arena that can create and run attribute it easier and more convenient to assign module, but the Simio is first requiring the declaration of all attribute that is used in the model and changing the attribute value with the assign step through state assignment or add-on process trigger which is more complicated. But the advantage of Simio is enabling to check on which attribute that used in the model. Unlike the Arena may be easier to build and use it, but it is difficult to check of all attribute in the model.

5.1.1.3 Variable

A variable is a piece of information that reflects some feature of the system. Unlike to attributes, variables are not tied to any specific entity but pertain to the system at large scale. They are accessible by all entities, and many can be changed by any entity. In this subsection, we will compare and point out the difference and the value setting of variable in Arena and Simio.

The variable in Arena model will be first declare and set initial value in variable spreadsheet prior to adjust variable value by using assign module. For example, we will count the number of work-in-process patient in Orthopedics department. First, we will declare variable “SIM_WIP in OPD” in variable spreadsheet and set initial value is 0 as shown in Figure 5.7. Then, we used assign module to plus this variable by 1 when patient entity passed the starting of process and used assign module to minus this variable by 1 when patient entity passed the ending of process.

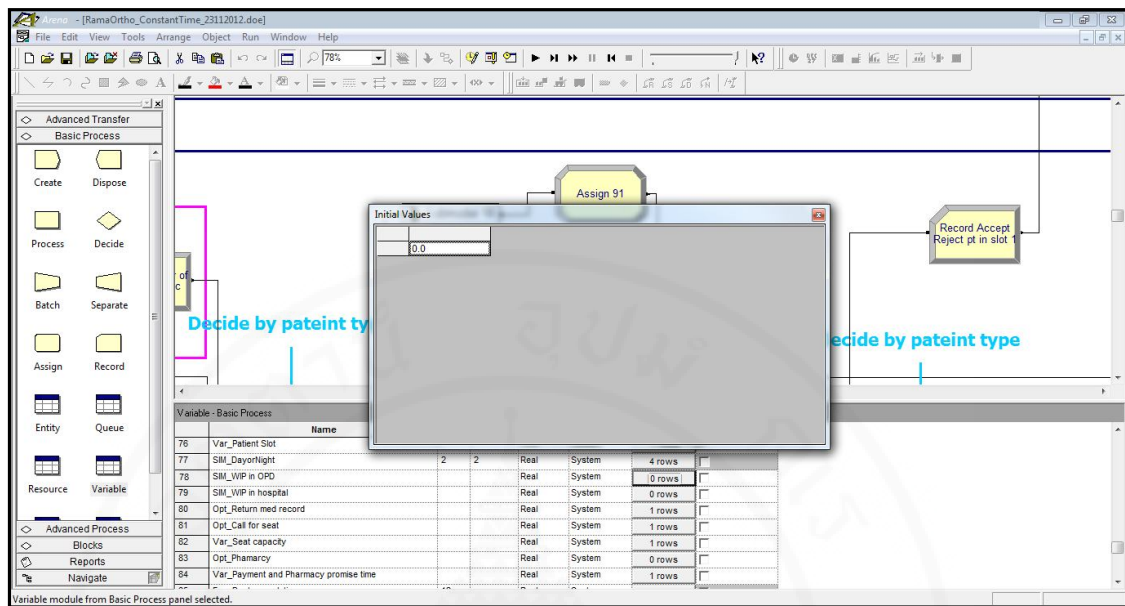


Figure 5.7 Variable declaration in Arena

In Simio model, we will first declare and set initial value of variable similarly to Arena in definition window of Navigation: Model. Because of the object-based modeling paradigm, we cannot create the variable by applying process elements like Arena. Therefore, the variable will be adjusting value by using assign step in add-on process window.

The construction of variable 2D in Simio is more complicated method than Arena. First, we will define specific row and column value by using table function in data window. For example, the variable 2D of the starting time and ending time of each treatment round as shown in Figure 5.8. After defined the table data, we will declare the variable and choose dimension as table prior to call the table data that was be defined before as shown in Figure 5.9. Finally, the variable will be adjusting value by using assign step in add-on process window such as the counting patient work-in-process of each Clinic can be done by using the variable, namely SIM_WIP by Clinic, plus or minus one as selected attribute row "Att_Clinic" which is determined Clinic attribute to patient entity earlier.

In terms of using the variable, Arena also has more flexibility to use the variable in 2D by assigning the variable through Assign Module. In Simio, the attribute that is needed to be used in ModelEntity Navigation must be assigned through the Assign Module before it can be adjusted. This is done in the Assign Step

in the Model. For the simulation of a hospital which has many differences between clinics (for example, operating hours in OPD, counting WIP of patients of different clinics, etc), using variable through Arena is thus much easier than Simio.

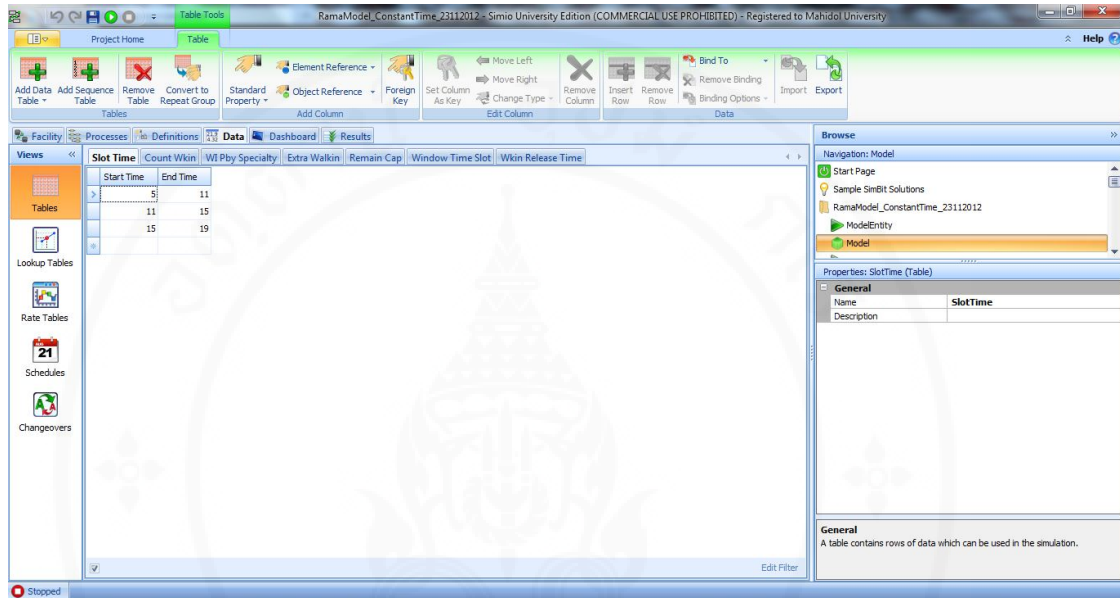


Figure 5.8 Defining row and column data in Table function

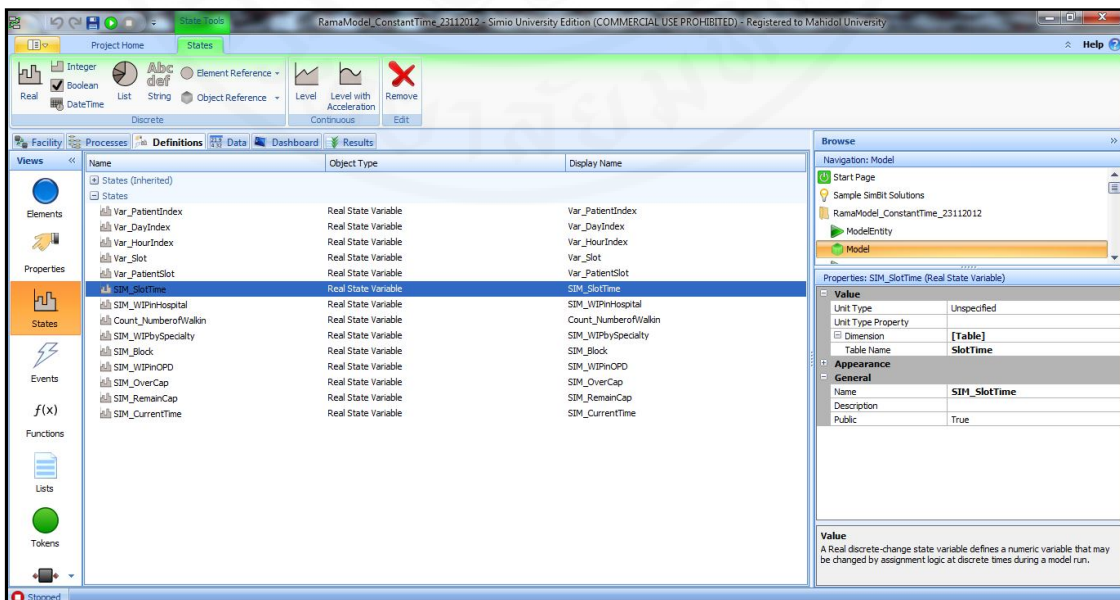


Figure 5.9 Variable 2D declarations in Simio

5.1.1.4 Resource

Entities often compete with each other for service from resources that represent things like personnel, equipment, or other facilities. An entity will seize resource when available to start a process and release when finished process. In the simulation modeling with process-based and object-based paradigm is rather difference in terms of resource that use associated with the process.

In process-based simulation like Arena, the model was built process flowchart by seizing a resource action. Therefore, we will define which resources are served to patient in each process as shown in Figure 5.10 and also set up the resource capacity in resource spreadsheet. Once we have defined resource to the process module, the model will generate queue of process with specific names simultaneously as shown in Figure 5.11. On the other hand, Simio model is an object-based paradigm that creates the model by using object element. For this reason, we have used server object to model a constrained service operation that has two attached nodes including input node and output node. The server object employ three stations, named *InputBuffer*, *Processing*, and *OutputBuffer*. An arriving entity enters from the network through the input node into the server's *Inputbuffer*, proceeds through *Processing*, and then waits in the *OutputBuffer* to move through the output node and into network as shown in Figure 5.12. The advantage of server object is more flexible for modeling because both the *InputBuffer* and *OutputBuffer* have their properties that can block entities to enter the server or define the destination to entities when they departed from the server. Furthermore, object in Simio is an intelligent that can be make 3D-animation easily and also display the state changing of resource during job as shown in Figure 5.13.

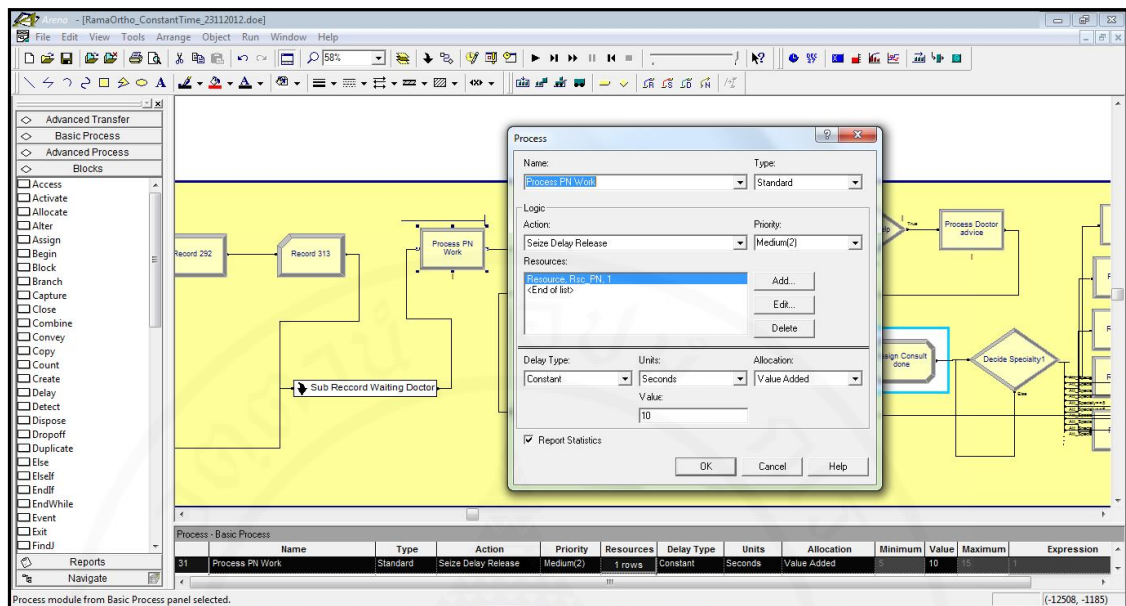


Figure 5.10 How to call the resource to process module in Arena

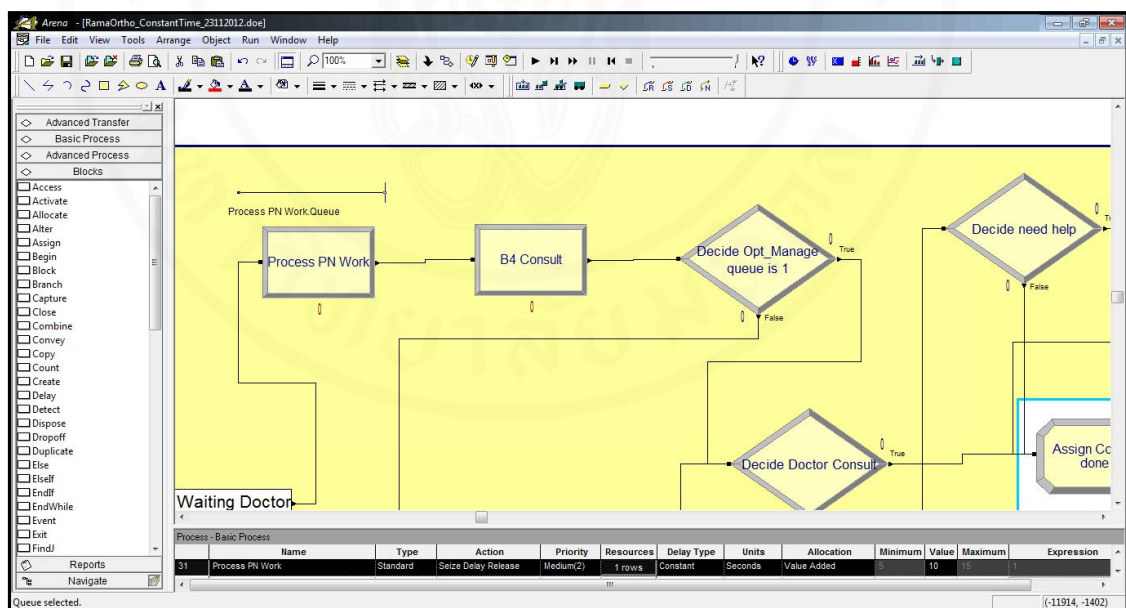


Figure 5.11 Process queueing in Arena

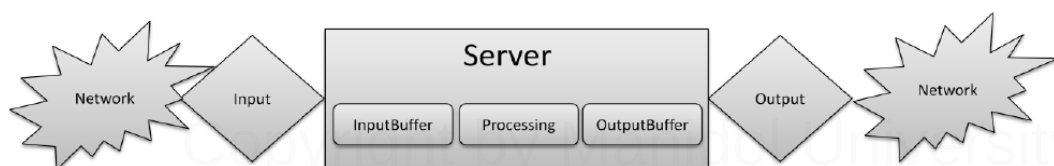


Figure 5.12 Server object framework in Simio

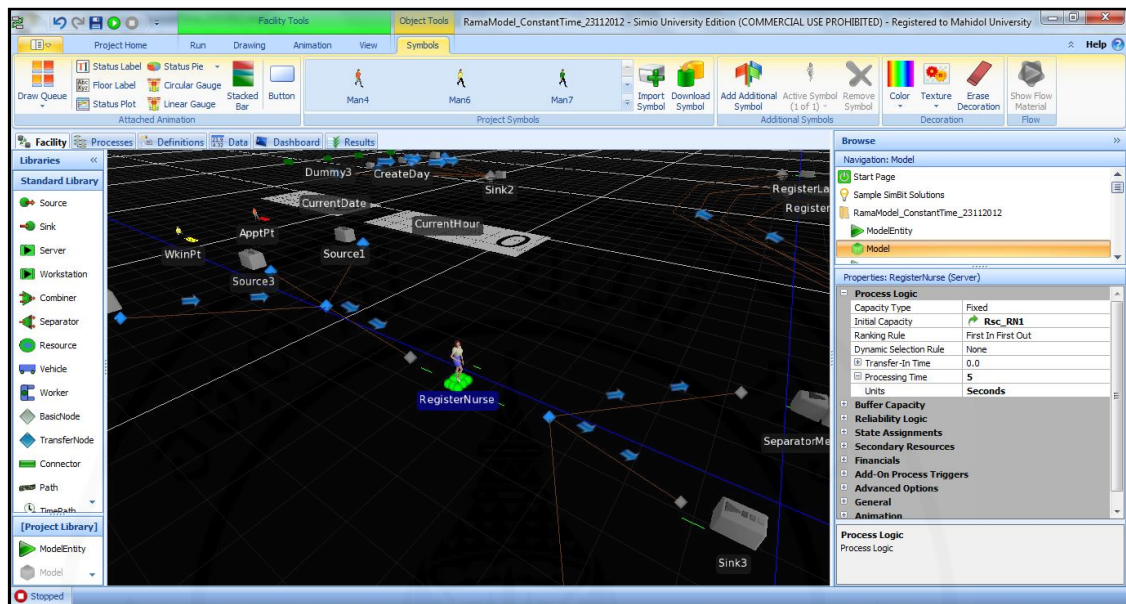


Figure 5.13 3D-animation of server in Simio

5.1.1.5 Routing logic

Whenever an entity departs from one process and then move through the other process based on routing with time travel, for example patient walked by taking average 5 minute from orthopedics department to Lab station, this logic can be created by the different way in Arena and Simio.

In Arena, the patient entities are moved through every process by the connecting without time travel. If we need to specify the time travel from one to other station, the route module will be selected, defined the routing time and destination as shown in Figure 5.14.

According to our mentioned with input node and output node that attached to the server object in Simio, this feature allows the flexibility to define the routing time to entities. Because the Simio can used TimePath to define the travel time that all entities will take from one station to other station. Moreover, routing logic in Simio can make 3D-animation easily because of the intelligent object feature in Simio as shown in Figure 5.15.

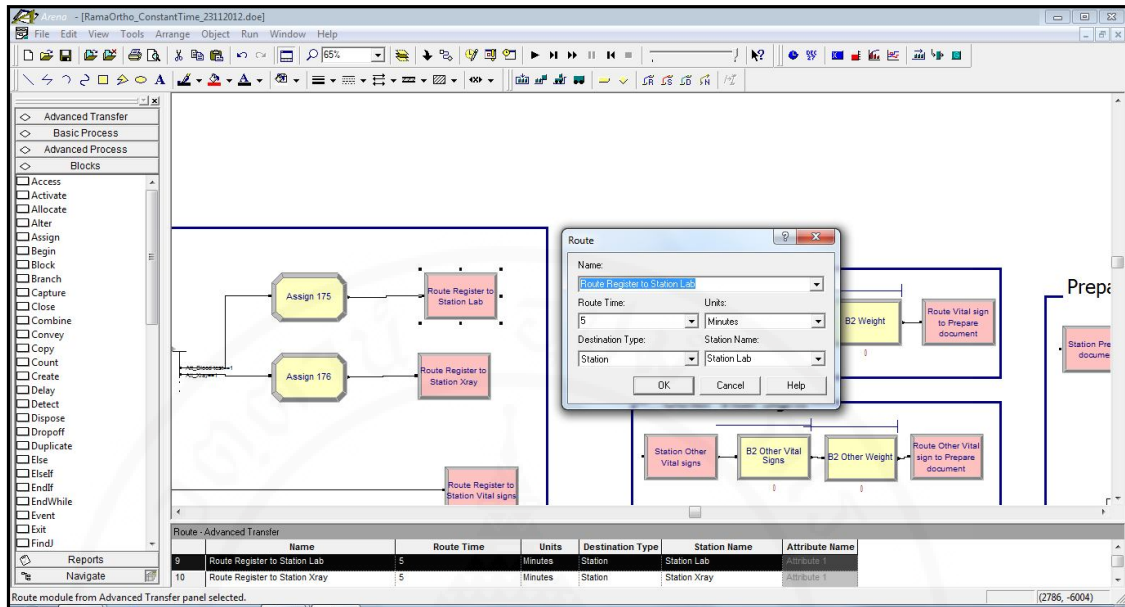


Figure 5.14 Route module in Arena

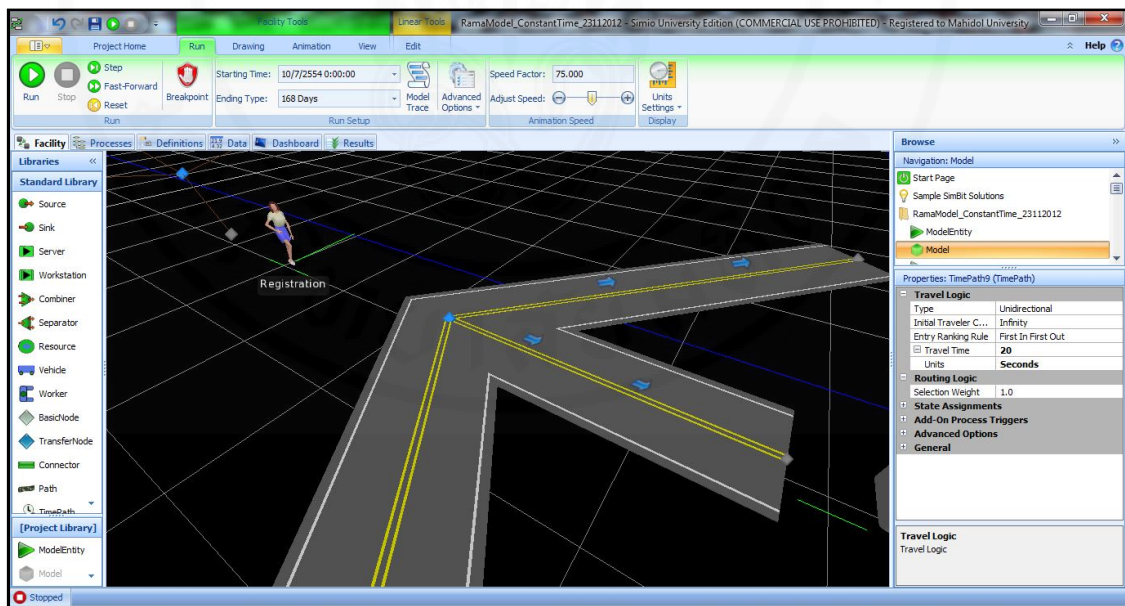


Figure 5.15 3D-animation of routing logic in Simio

5.1.2 The disparity between Arena and Simio

This subsection will describe on the other disparity of process-based and object-based simulation that we can be notice aside from the key element of simulation model in the reference book as following;

5.1.2.1 How to create the trigger process

A triggered process is a process that is incorporated into the model to create own custom process logic at specific points. In this case study, we created the custom process of medical record that was delivered from other location to orthopedics department. The criteria of medical record that will not deliver until accumulated 5 sets of medical record. The way to create this custom process is slightly difference in Arena and Simio model.

In process-based simulation like Arena, we applied three modules including hold, decide, and signal module to construct this criteria within the model window. The first is hold module that was used to entrap medical record entity into the holding queue and waited for signal to release it from holding queue. Then, we used decide module to make a decision when the holding queue of medical record is accumulated to 5 sets. Finally, we called signal module to activate medical record entity that accumulated 5 sets to the next process.

Object-based simulation paradigm like Simio will used object element for building the model. Therefore, we cannot construct the criteria into the model directly and need to use add-on process, namely MedRecord1_Logic, for creating this criterion. After that, we will build the custom process of medical record by using four elements including insert, decide, wait, and fire element. Similar to hold module in Arena, we applied insert element to entrap medical record entity into the holding queue and wait for signal to release it from holding queue. However, we had to declare holding queue in definition window that was called by insert step to storage medical record entity. After that, we used decide step to make a decision that the holding queue is accumulated to five sets and used wait step to hold medical record entity into the queue if it is not completed five sets of medical record. Finally, we used fire element to activate medical record entity leave from holding queue through the next process that is similar to signal module in Arena.

In conclusion, triggered process through process-based simulation like Arena can build process in the window by using the hold module to capture the entity in the queue and use the signal module to activate the entity out of the queue into the next process without declaring holding queue and signal first. For object-based simulation like Simio, Add-on process trigger must occur first to build

the logic in the process page by using insert step and wait step to input the entity into the queue in order to wait for the signal to activate the entity out of the queue by using the fire step to release the signal. Also, Simio must declare Holding queue first and signal in the Definition window before operating.

5.1.2.2 How to call and use time function

Time function is an important component in simulation model that used for defining, identifying, and making a decision to the operation processes at the specific date or time. These factors will affect to the changing of attribute of entity, variable of system, and statistical collection. In Arena, time function such as *TNOW* that indicated to current time of simulation run, *CalHour* that indicated to hourly period, and *CalDayOfWeek* that indicated to daily of week, is prompt to used because it was built-in the software as shown in Figure 5.16. On the other hand, we had to write an expression to identify time function manually in Simio. The built-in time function in Simio has only *Run.Timenow* that indicated to current time of simulation run like *TNOW* in Arena. If we would like to call and use time function that related to hourly and daily in Simio model, we had to write an expression formula as following:

- $Hourly = \text{Math.Floor}(\text{Math.Remainder}(\text{TimeNow}, 24)) + 1$
- $Daily = \text{Math.If}(\text{Math.Remainder}(\text{Math.Ceiling}(\text{TimeNow}/24), 7) == 0, 7, \text{Math.Remainder}(\text{Math.Ceiling}(\text{TimeNow}/24), 7))$

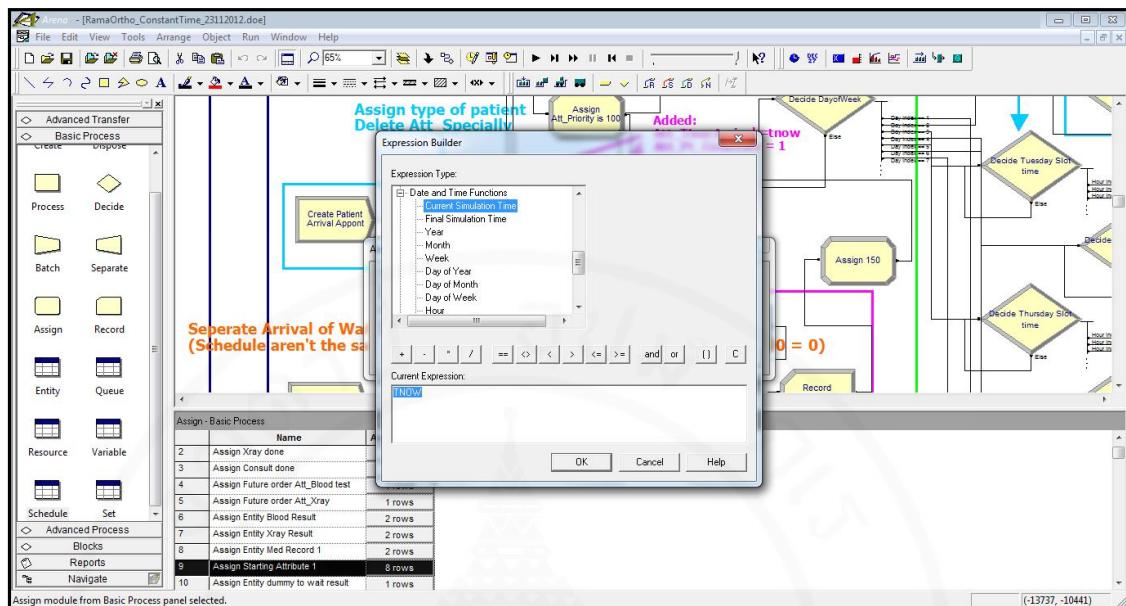


Figure 5.16 Date and Time function in Arena

In summary, an operation in the hospital generally has a different in the details of both daily and hourly such as patient arrival, resource capacity, and clinic working time. For this reason, simulation with Arena has the advantage over the Simio for running the time function which is set by default to the software already.

5.1.3 The comparison points from literature review

5.1.3.1 Simulation run time

When comparing in terms of time taken to run models with complex details, Arena takes longer time to run the model when run length and number of replications equal. This is because the framework of process-based simulation that the entity will run through the series of process and has to run through every element created. But Simio takes less time because it is based on object framework which relies on less detail of process. For our simulation model of orthopedics department, the simulation run setup is: simulation run length is 168 days, and the number of replications is 30, The Arena model is resulting in a run time of approximately one hour on a standard Intel Core i3 notebook PC with 4 GB installed memory (RAM). While, the Simio model is resulting in a run time less than ten minutes with the same computer spec.

5.2 Simulation results of the case study

This section will show the result comparison of a case study between process-based and object-based simulation. The main objective is to verify the model that was created by Arena will be not significant different from the Simio model. Therefore, we proposed some KPI that was used to verify the model including tally statistic and time-persistent statistic.

5.2.1 The results of tally statistic

Tally statistics are those that result from taking average, minimum, or maximum of a list of numbers. We will measure the performance the simulation model of a case study by the tally statistic KPIs as shown in Table 5.1.

Table 5.1 Tally statistic results from Arena and Simio

Index	Average time (min)		Number of entity	
	Arena	Simio	Arena	Simio
Total time in system	26.71	26.38	62390	62508
Ttime_ReceiveQcard	9.33	9.31	62390	62508
Ttime_ReceiveQcard_Appt	6.71	6.63	53504	53540
Ttime_ReceiveQcard_Wkin	30.18	30.18	7263	7372
Ttime_ReceiveQcard_Trsl	2.80	2.70	1623	1596
Ttime_TakeQcardtoAppointment	9.44	9.15	62390	62508
Ttime_TakeQcardtoAppointment_Appt	9.44	9.14	53504	53540
Ttime_TakeQcardtoAppointment_Wkin	9.49	9.22	7263	7372
Ttime_TakeQcardtoAppointment_Trsl	9.31	9.02	1623	1596
Ttime_PaymenttoReceiveDrug	7.74	7.75	62390	62508
Ttime_PaymenttoReceiveDrug_Appt	7.76	7.76	53504	53540
Ttime_PaymenttoReceiveDrug_Wkin	7.61	7.66	7263	7372
Ttime_PaymenttoReceiveDrug_Trsl	7.77	7.75	1623	1596

The simulation outputs quantify patients that they will spend total time in the hospital by Arena and Simio; the average total time in the system from Arena is 26.71 minutes, while the average total time in the system from Simio is 26.38 minutes as shown in Figure 5.19. The results indicated that tally statistic output from Arena is not different with Simio.

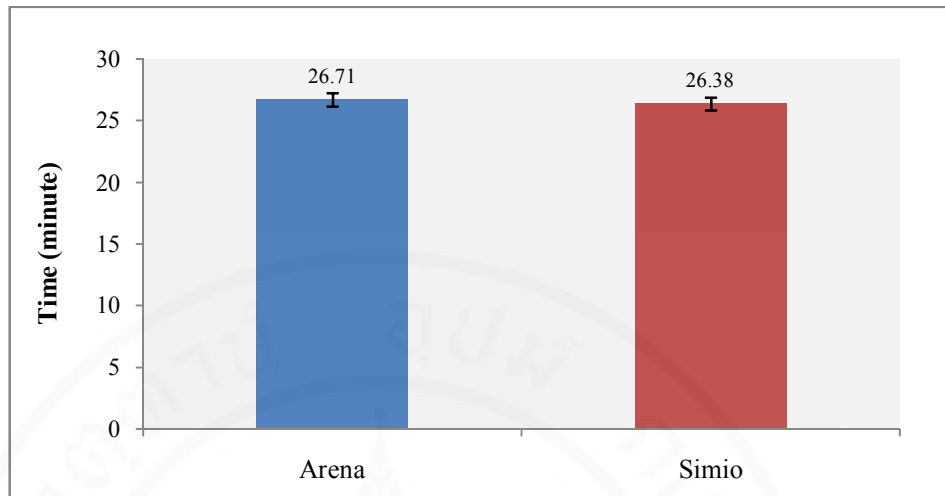


Figure 5.17 Average total time in system between Arena and Simio

5.2.2 The results of time-persistent statistic

Time-persistent statistics are those that result from taking the average, minimum, or maximum of a plot during the simulation. Table 5.2. shown the KPI performance the simulation model by the time-persistent statistic.

Table 5.2 Doctor utilization in each Clinic from Arena and Simio

Index	Average value	
	Arena	Simio
Clinic A	84.30%	84.31%
Clinic B	4.41%	4.44%
Clinic C	2.52%	2.55%
Clinic D	55.77%	55.53%
Clinic E	8.62%	8.64%
Clinic F	0.65%	0.62%
Clinic G	8.14%	8.14%
Clinic H	3.03%	3.01%
Clinic I	10.74%	10.46%
Clinic J	7.61%	7.52%

The time-persistent outputs quantify doctor workload that they provided a diagnosis and treatment to the patient. From above table, doctor utilization of clinic A is highest both Arena and Simio model (84.30% and 84.31%, respectively). This result indicated that the doctor workload of clinic A might be the bottleneck problem for

orthopedics department. Indeed, The results indicated that the doctor utilization from Arena is not different with Simio as shown in Figure 5.20.

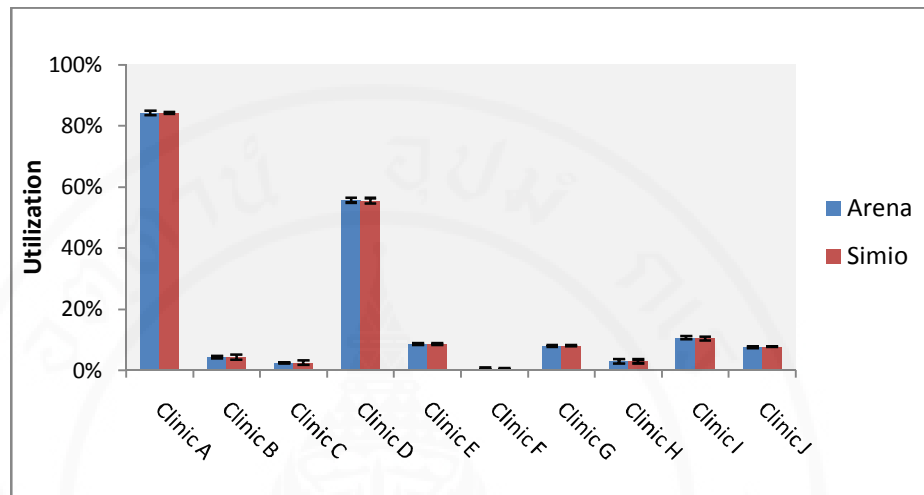


Figure 5.18 Doctor utilization by clinic between Arena and Simio

As a result, simulation models those were constructed by the process-based (Arena) and the object-based (Simio) framework can be use to represent the real operation of orthopedics department. Because the output from both simulation software is not different in term of tally statistic such as total time in the system of patient, and time-persistent statistic such as doctor utilization.

CHAPTER VI

CONCLUSION

In this chapter, we will describe on the advantages and disadvantages between DES and object-based model and also recommend the some understanding when commence on hospital simulation project.

6.1 Conclusions

This research illustrated the simulation modeling by case study of Orthopedics department by using Arena software that represents DES model and Simio software that represents object-based model. The main objective of this study is to compare the advantages and disadvantages between two types of simulation modeling in hospital operation.

As a healthcare provider, hospitals are giving responsibility to deliver care to patients and also planning a limited resource to serve the patients effectively. Both DES model and Object-based model are considered as suitable tools for KPI measuring. They yield similar results for the patient total time and the doctor utilization.

Arena would have some an advantage when compared on the basic simulation component because it can easily call up attribute, variables, and time function. All components are essential for operations in a hospital model that has many differences of patient behavior and also the characteristic of clinics in hourly or daily operation. While Simio which the detail of a model is smaller by using object framework and it uses less time to create the simulation and run the models. In this case study, the simulation run time of simio is 10 time faster than Areana. However, object-based simulation in this study was constructed by using Simio version 4.71 (sprint 71). However, Simio software changes the configurations up to 10 times within the past two years and the version 5.81 (sprint 81) has already been released. For this

reason, Simio might not have the functions that are required for creating such a complex simulation and properties.

6.2 Recommendation

This section will discuss on some aspect of simulation project in the hospital service and recommend for object-based simulation software.

In general, the simulation is not well-recognized in Thai hospital industry even it has been proven to be a very useful tool. This is due to the fact that the simulation project requires lots of data and process understanding. First of all, hospital operation is related with several stakeholders, such as physicians, nurses, and pharmacists, and it also be the human process that are quite complicated to simulation analyst who has no comprehension with the hospital operation. Therefore, the data collection involved lots of hospital staff who sometime are not pay attention because they might be not understand the important of the data collection process. Second, the process time is not standardizing due to the variation of disease and patient condition. This constraint makes a difficulty for time study and input analysis of simulation project even we can utilize the electronic timestamp data. Finally, electronic data is a crucial to business intelligent process due to its use for performance reviewing of hospital operation. Thus, hospital administrator and staff should be more perceive on the electronic data and the timestamp system.

Object-based simulation needs high modeling skill for coding the specific logic of hospital operation. This might cause the difficulty for applying object-based model to simulation in hospital service because it has a wide gap between process knowledge and simulation knowledge. Therefore, the improvement of object-based simulation software to friendly with user will reduce this gap and enhance the implementation of object-based model in hospital service.

REFERENCES

Available from: <http://service.nso.go.th/nso/nsopublish/BaseStat/basestat.html>

- Ahmed, M.A., Alkhamis, T.M., 2009, "Simulation optimization for an emergency department healthcare unit in Kuwait," *European Journal of Operational Research*, 198, 936-942.
- Arici, O., Yang, S.L., 1999, "Computer model for automobile climate control system simulation and application," *Int. J. Applied thermodynamic*, 2, 59-68.
- Baldwin, L.P., et al., 2004, "Simulation in healthcare management: a soft approach (MAPIU)," *Simulation Modelling Practice and Theory*, 12, 541-557.
- Ballard, S.M., Kuhl, M.E., 2006, "The use of simulation to determine maximum capacity in the surgical suit operating room," *Proceeding of the 2006 Winter Simulation Conference*, 433-438.
- Basher, Z., Mtaawa, J., 2005, "Integrating manufacturing system simulation development: A methodological framework, ", 234-241.
- Borshchev, A., Filippov, A., 2004, "From System Dynamics and Discrete Event to Practical Agent Based Modeling: Reasons, Techniques, Tools." *The 22nd International Conference of the System Dynamics Society*.
- Brenner, S., et al., 2009, "Modeling and Analysis of the Emergency Department at University of Kentucky Chandler Hospital using simulations," *Journal of Emergency Nursing*.
- Coelli, F.C., et al., 2007, "Computer simulation and discrete-event models in the analysis of a mammography clinic patient flow," *Computer Methods and Programs in Biomedicine*, 87, 201-207.
- Cote, M.J., 1999, "Patient flow and resource utilization in an outpatient clinic," *Socio-Economic Planning Sciences*, 33, 231-245.
- Duguay, C., Chetouane, F., 2007, "Modeling and Improving Emergency Department Systems using Discrete Event Simulation," *SIMULATION*, 83, 311-320.

- Harper, P.R., et al., 2003, "A system modeling approach for the prevention and treatment of diabetic retinopathy," *European Journal of Operational Research*, 150, 81-91.
- Heilala, J., S.M., et al., 2008, "Simulation-based sustainable manufacturing system design," *Proceeding of the 2008 Winter Simulation Conference*, 1922-1930.
- Hoot, N.R., et al., 2008, "Forecasting Emergency Department crowding: A discrete event simulation," *Annals of Emergency Medicine*, 52, 116-125.
- Hunter, D., et al., 2004, "Simulation modeling of change to breast cancer detection age eligibility recommendation in Ontario, 2002-2012," *Cancer Detection and Prevention*, 28, 453-460.
- Jin, F.K., et al., 2010, "Improving CT scan capabilities with a new trauma workflow concept: Simulation of hospital logistics using different CT scanner scenarios," *European Journal of Radiology*.
- Kelton, D.W., et al., 2003, "Simulation with Arena"- 3rd ed., International Edition, McGraw-Hill, The McGraw-Hill Company, Inc.
- Kritchanchai, D., MacCarthy, B.L., 2000, "Discrete or Continuous: Which is more appropriate for Supply Chain Simulation Modelling?," .
- Najmuddin, A.F., et al., 2010, "A Simulation Approach: Improving Patient Waiting Time for Multiphase Patient Flow of Obstetrics and Gynecology Department (O&G Department) in Local Specialist Centre," *ISSN*, 9, 778-790.
- Oddoye, J.P., et al., 2009, "Combining simulation and goal programming for healthcare planning in a medical assessment unit, *European Journal of Operational Research*, 193, 250-261.
- Perez, E., et al., 2010, "Modeling and Simulation of Nuclear Medicine Patient Service Management in DEVS," *SIMULATION*, 86, 481-501.
- Persson, M., Persson, J.A., 2009, "Health economic modeling to support surgery management at a Swedish hospital," *Omega*, 37, 853-863.
- Ramwadhoebe, S., et al., 2009, "A tutorial on discrete-event simulation for health policy design and decision making: Optimizing pediatric ultrasound screening for hip dysplasia as an illustration," *Health Policy*, 93, 143-150.

- Raouf, A., Ben-Daya, M., 1997, "Outpatient Clinic's Staffing: a Case Study." *International Journal of Health Care Quality*, 10, 229-232.
- Seila, A.F., Brailsford, S., 2009, "Opportunities and Challenges in Health Care Simulation." *International Series in Operations Research & Management Science*, 133, 195-229.
- Spieckermann, S., et al., 2000, "Simulation-based optimization in the automotive industry – A case study on body shop design." *Simulation*, 75, 276-286.
- Strommen, S.J., 1998, "An object-oriented design for dynamic simulation models." *North American Actuarial Journal*, 3, 38-49.
- Su, S., Shih, C., 2003, "Managing a mixed-registration-type appointment system in outpatient clinics, *International Journal of Medical Informatics*, 70, 31-40.
- Troy, P.M., Rosenberg, L., 2009, "Using simulation to determine the need for ICU beds for surgery patients," *Surgery*, 146, 608-620.
- Villamizar, J.R., et al., 2010, "Discrete-event computer simulation methods in the optimization of a physiotherapy clinic," *Physiotherapy*.
- Weng, M.L., Houshmand, A.A., 1999, "Healthcare simulation: a case study at a local clinic in Farrington," *Proceeding of the 1999 Winter Simulation Conference*, 1577-1584.
- Werker, G., et al., 2009, "The use of discrete-event simulation modeling to improve radiation therapy planning process," *Radiotherapy and Oncology*, 92, 76-82.
- Yeh, J., Lin, W., 2007, "Using simulation technique and genetic algorithm to improve the quality care of a hospital emergency department," *Expert Systems with Applications*, 32, 1073-1083.
- Zhu, Z.C., et al., 2009. "Simulation Study of the Optimal Appointment Number for Outpatient Clinics." *International Journal of Simulation Modelling*, 8, 156-165.



APPENDIX

ARENA AND SIMIO USER INTERFACE

Section I: The Arena User Interface

In this section, we will look around the Arena window to get familiar with where things are, and introduce some basic Arena terminology.

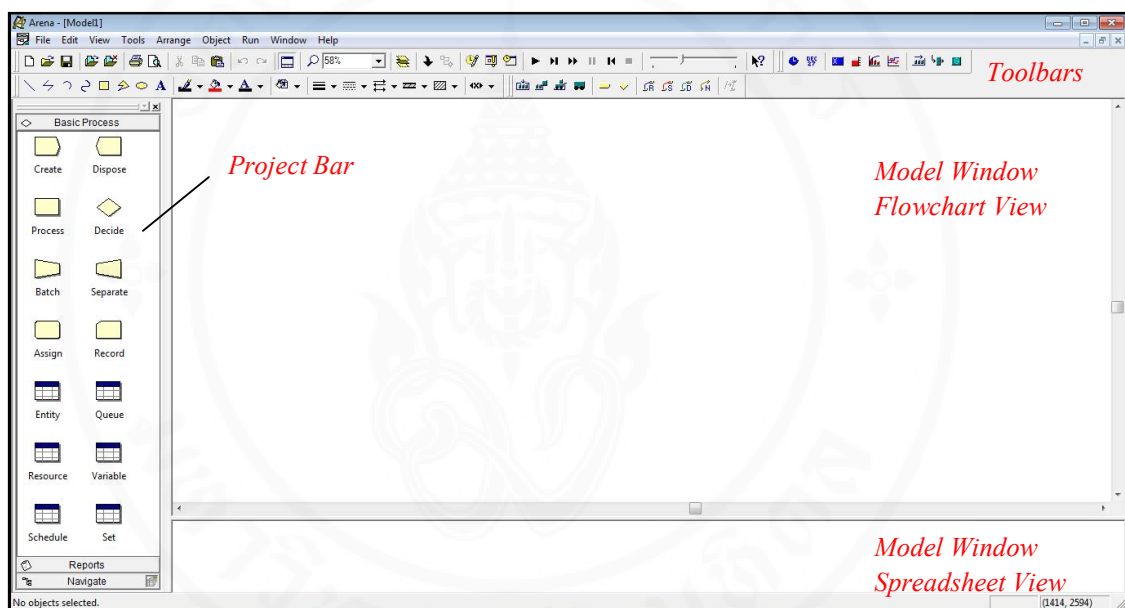


Figure A-1 Arena window for simple process modeling

As shown in Figure A-1, the Arena window is divided into several pieces including toolbars, model window flowchart view, model window spreadsheet view, and project bar.

The model window can be split into two regions: the flowchart view and the spreadsheet view. The flowchart view contains the model's graphics including the process flowchart, animation, and other drawing elements. The spreadsheet view can display model data such as resource capacity, arrival schedule, and other parameters that allows the user to enter or edit them. Many model parameters can be viewed and edited in either the flowchart view or the spreadsheet view, but the spreadsheet view gives the user access to lots of parameter at once, arranged in compact groups of similar parameters convenient for editing, especially in large models.

Down the left edge of the Arena window in Figure A-1 is the project bar, which contains the objects with will be working, displaying one panel at a time. Right now the project bar is displaying the Basic Process Panel that contains fundamental building blocks, called *modules* that are useful in a wide variety of simulation models. Below the Basic process panel on the project bar is a horizontal button labeled “Reports”, which will display another panel containing a road to the results of simulation after completed run. The navigation panel allows the user to display different views of a model including different submodels in a hierarchical model. There are several other panels that come with Arena that will be display in the model when the user attached them including: Advance Process (with different and smaller building blocks for more detailed modeling), and Advance Transfer (containing many options for moving entities around).

Process Modules

The basic building blocks for Arena models are called modules. These are the elements that define the process to be simulated and are chosen from panels in the Project bar. Modules come in two basic flavors as following: flowchart and data.

Flowchart modules describe the dynamic processes in the model. To put an instance of flowchart modules of a particular type into the model, drag it from the Project bar into the flowchart view of the model window. In the Basic Process Panel, the kind of flowchart modules available are Create, Dispose, Process, Decide, Batch, Separate, Assign, and Record.

Data modules define the characteristics of various process elements, like entities, resources, and queues. Icon for data modules in the Project bar look like little spreadsheets that are including Entity, Queue, Resource, Variable, Schedule, and Set.

Flowchart and data modules in Arena model are related to each other by the names for elements, like queues, resources, entity types, and variables, which have in common. Arena keeps internal lists of the names you give to these kinds of elements as you define them and then presents these names to you in drop-down lists in the appropriate places in both flowchart and data modules.

Section II: The Simio User Interface

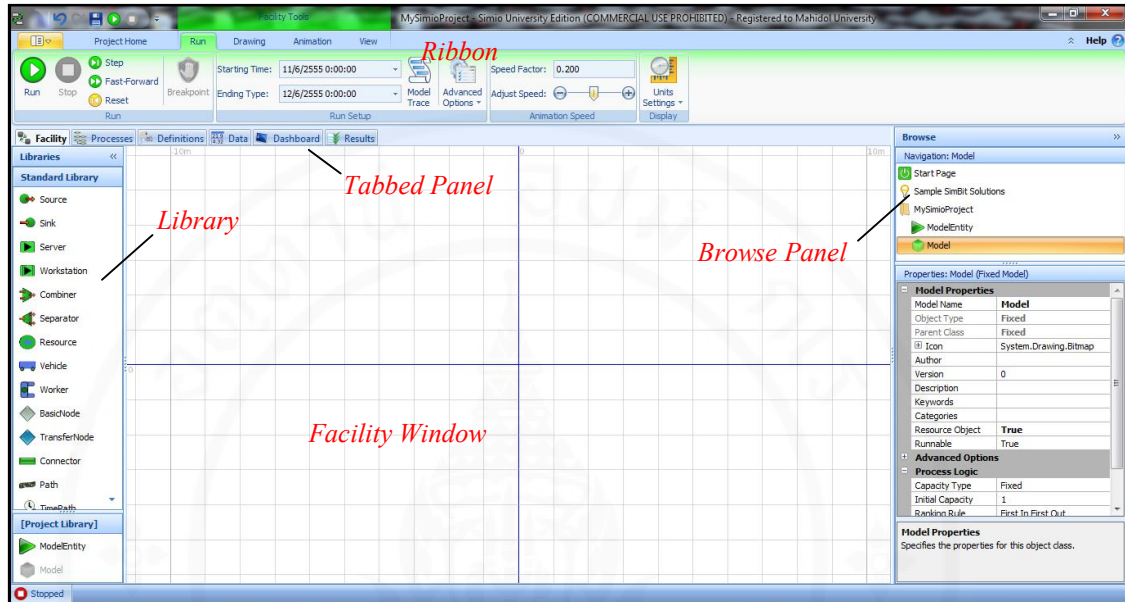


Figure A-2 Simio window for object-oriented modeling

The initial view of Simio window is shown in Figure A-2. The key areas include the ribbons across the top that currently showing the Run ribbon, the tabbed panel views the Facility highlighted, the libraries, the browse panel, and the Facility window.

The ribbons are providing a convenient way to access the many functions available to the model for building, animating, and running. The user can manually switch between ribbons by clicking on the ribbon tabs and also condense the ribbons to just the tabs by double-clicking on any tabs.

Whenever the Facility window of a model is selected the Libraries panel on the left displays the libraries that are open and available for modeling within the facility. The libraries will include the standard library, the project library, and any additional projects that have been loaded as libraries from the Project home ribbon. The standard library is a general purpose library of object that is provided with Simio for modeling a wide range of systems. The project library is a library of object corresponding to the current models. This feature lets the user use the project model as submodels that can be placed multiple times within a model.

The browse panel on the right provides for project navigation and property editing. The upper navigation window is used to switch between the start page, project view, and the associated models and experiments. The user can switch between models by simply clicking on the model in the navigation tree. For example clicking on the main model will make this active model and display the facility window for that model. Likewise clicking on the ModelEntity will make the default entity the active model, and display the initially empty set of processes that defines entities' behavior. The properties window that is located in the browse panel immediately below the navigation window is used for editing the properties of object.

The facility window that is shown in the center is drawing space for building both the object-based model and the animation for the model as a single step. The other panel views associated with a model include Process, Definition, Data, Dashboard, and Results. The process panel is used for defining custom process logic for Simio models. The definition panel is used to define different aspects of the model such as its external view and the properties, states, and events that are associated with the model. The data panel is used to define data that may be used by the model, and imported/exported to external data sources. The dashboard panel provides a 2D drawing space for placing buttons, dials, plots, etc., for real time viewing and interactions with the model. The results panel displays the output from the model in the form of both a pivot grid as well as traditional reports.

Objects and Libraries

The objects within a library are one of five basic types as following:

- **Fixed:** Has a single fixed location in the system such as a doctor
- **Link:** Provide a pathway over which entities move
- **Node:** Defines an intersection between one or more incoming/outgoing links. Nodes can also be associated with fixed objects to provide entry and exit points for the object.
- **Entity:** Define a dynamic object that can be created and destroyed, move over a network of links and nodes, and enter/exit fixed objects through their associated nodes.

- **Transporter:** Define a special type of entity that can also pickup and drop off other entities at nodes.

A library may contain objects of any these five types. The standard library includes objects of all types except for the entity type, since the entity is typically defined within the project library. The standard library contains the following object as shown in Table A-1.

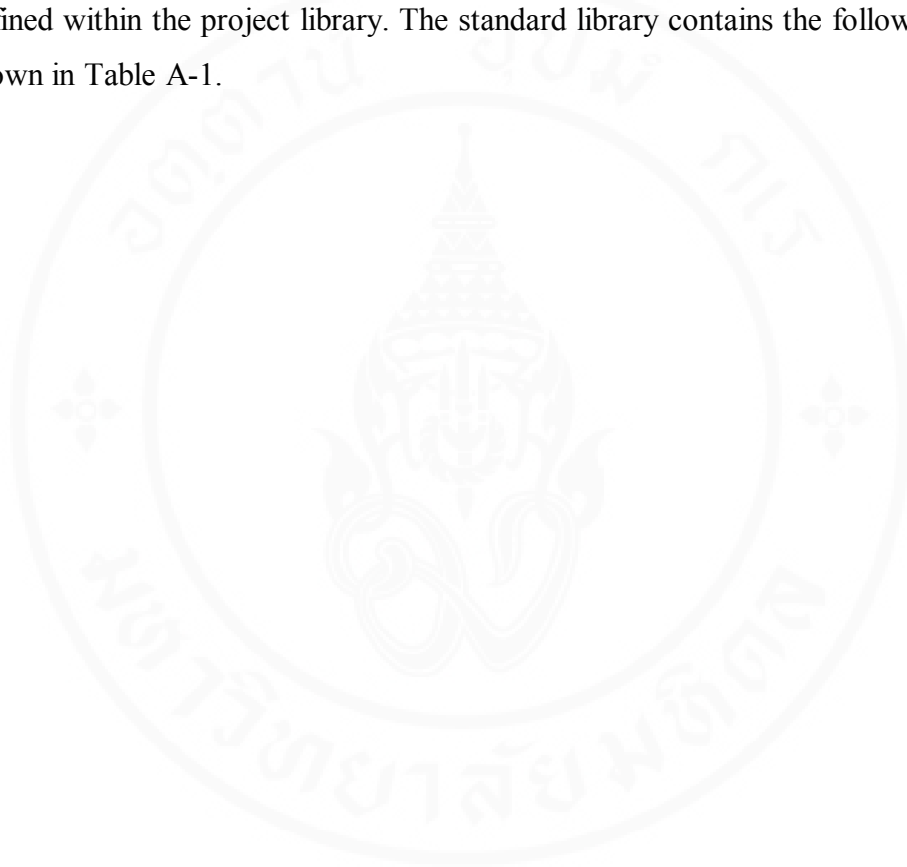


Table A-1 Standard library in Simio

Object	Description
Source	Generates entity object of a specified type and arrival pattern
Sink	Destroys entities that have completed processing in the model
Server	Represents a capacitated process such as a machine or service operation
WorkStation	Models a complex workstation with setup, processing, and teardown phases and secondary resource and material requirements.
Combiner	Combines multiple member entities together with a parent entity (e.g. patient and his lab result)
Seperator	Splits a batched group of entities or makes copies of a single entity
Resource	A generic object that can be seized and released by other objects
Vehicle	A transporter that can follow a fixed route or perform on demand transport pickups/drop offs.
Worker	A moveable resource that may be seized and released for task as well as used to transport entities between node locations
BasicNode	Models a simple intersection between multiple links
TransferNode	Models a complex intersection for changing destination and travel mode
Connector	A simple zero-time travel link between two nodes
Path	A link over which entities may independently move at their own speeds
TimePath	A link that has a specified travel time for all entities
Conveyor	A link that models both accumulating and non-accumulating conveyor devices

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