

PRODUCTIVITY IMPROVEMENT FOR PUSAT KESIHATAN PELAJAR (PKP)
BY USING WITNESS SIMULATION SOFTWARE

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BORANG PENGESAHAN STATUS TESIS♦

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**PRODUCTIVITY IMPROVEMENT FOR PUSAT
KESIHATAN PELAJAR (PKP) BY USING WITNESS
SIMULATION SOFTWARE**

SESI PENGAJIAN: 2009/2010

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PRODUCTIVITY IMPROVEMENT FOR PUSAT KESIHATAN PELAJAR (PKP)
BY USING WITNESS SIMULATION SOFTWARE

CHEN CHOY YUEN

Thesis submitted fulfilled of the requirements
for the award of the degree of
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We certify that the project entitled “*Productivity Improvement for Pusat Kesihatan Pelajar (PKP) by Using Witness Simulation Software*” is written by *Chen Choy Yuen*. We have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. We herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering.

Examiner

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I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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DEDICATION

Dedicated to my parents, grandparents, siblings and friends

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First of all, I would like to thanks to my supervisor, Mr. Hadi Bin Abdul Salaam for guiding me to complete this thesis and sharing his knowledge with me. In addition, to my friends and course-mates of Faculty of Mechanical Engineering who have been very supportive, thanks for your encouragements and helping hands through the time I spent on this project.

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ABSTRACT

As the world is improving rapidly, time is seems to be the most essential factor to decide the strength of competency of organization. In a short word, a company that can produce massive product or good services with high quality in a short timing is what efficiency means. With the respect of the project title, Productivity Improvement for *Pusat Kesihatan Pelajar* (PKP) By Simulation Software is meant to improve quality and the efficiency of the existing service process flow in PKP of Universiti Malaysia Pahang (UMP). The main project objectives are to design and improve service floor layout of this selected organization, analyzed the designed layout and select the best solution for PKP. The project is started by evaluating and identifying the problems existed in the service floor layout. Continue by data collection for the data analysis to choose the best goodness-of-fit test to proceed to the simulation modeling step. Meanwhile, there are three alternatives are suggested reducing the waiting area capacity, add-in a medical consultant and the last alternative is the combination of both alternatives. By running an experiment on the suggested alternatives to improve the output patient number, these alternatives are modeled in the WITNESS Simulation software and run for the experimental time of 4 hours. These results are analyzed by Kruskal-Wallis and one way ANOVA test for the best solution selection. The experimented results are then being compared with the Cost-effectiveness analysis to determine the most efficient layout that able to produce high output of patient number with lowest cost. From the findings, the most productivity improvement method is adding a medical officer in the service floor layout and reducing the waiting area capacity from 27 to 5 chairs. Furthermore, this approach is also minimized the lead time of giving medical consultant to patient. Hence, the objectives of this project have been achieved and the selected alternative will be proposed to the PKP for implementation.

ABSTRAK

Ketika dunia ini berkembang dengan pesat semakin hari, waktu yang tampaknya menjadi faktor yang paling penting untuk menentukan kekuatan kompetensi organisasi. Dalam kata singkat, sebuah syarikat yang mampu menghasilkan produk atau perkhidmatan yang baik dan berkualiti tinggi dalam waktu singkat adalah apa yang kecekapan bererti. Merujuk kepada tajuk projek iaitu Peningkatan Produktiviti Pusat Kesihatan Pelajar (PKP) melalui *WITNESS Simulasi Software* adalah untuk meningkatkan kualiti dan kecekapan aliran perkhidmatan yang sedia ada di PKP Universiti Malaysia Pahang (UMP). Objektif projek utama adalah untuk memperbaiki, mereka-bentuk, menganalisis tapak susun atur perkhidmatan dan memilih cadangan terbaik untuk PKP. Projek ini bermula dengan menilai dan mengenalpasti masalah terdapat di tapak susun atur perkhidmatan. Seterusnya, projek ini disambungkan dengan pengumpulan data dan menganalisiskannya dan mendapatkan kumpulan data terbaik dengan *goodness-of-fit test* yang bertujuan untuk meneruskan langkah yang seterusnya iaitu melakarkan model simulasi. Sementara itu, tiga alternatif yang disarankan dengan mengurangkan kapasiti ruangan tunggu, menambahkan seorang pakar perubatan dan alternatif terakhirnya adalah kombinasi dari kedua-dua alternatif. Dengan menjalankan ujian pada alternatif yang bertujuan untuk meningkatkan jumlah pesakit yang melawati PKP, kesemua model alternatif akan dieksperimen dengan *WITNESS Simulation Software* untuk tempoh 4 jam masa simulasi. Keputusan ini yang dihasilkan dalam *WITNESS Simulation Software* dianalisis dengan *Kruskal-Wallis* dan *one-way ANOVA test* untuk pilihan alternatif terbaik. Keputusan eksperimen ini kemudian dibandingkan dengan *Cost-effectiveness analysis* untuk menentukan tapak susun atur yang paling efisien yang mampu menghasilkan jumlah pesakit yang terbanyak dengan kos terendah. Dari penemuan, kaedah yang paling berkesan dalam peningkatan produktiviti merupakan kaedah ketiga yang mengurangkan kapasiti ruangan tunggu dari 27 kepada 5 kerusi. Manakala, kaedah ini juga mengurangkan jumlah waktu pesakit menerima rawatan perubatan. Justeru itu, tujuan projek ini telah dicapai dan alternatif yang dipilih akan dicadangkan kepada PKP untuk pelaksanaannya.

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LIST OF SYMBOLS

\bar{x}	Average of Total Observations
s	Standard Deviation
α	Desire Significant Level

LIST OF ABBREVIATIONS

FYP	Final Year Project
PKP	Pusat Kesihatan Pelajar
UMP	Universiti Malaysia Pahang
JHEPA	Jabatan Hal-Ehwal Pelajar dan Alumni
ID	Identity Card
PDGA	Panel Design Genetic Algorithm
CEA	Cost-effectiveness Analysis

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Time management can be describes as a crucial component for anybody that desires to get the most out of their daily life. Well planning of time can be described as the key of success in these days for all industries as it encourages better control and productivity as a catalyst to reach the company goal.

In order to increase profit of an organization, there are plenty of methods available for service industry to improve their time management system. The methods are including employ trained workers, utilization of high performance machine, applying material handling principles, designing non-adjacent plant layout etc. All of these mentioned ideas are generally can be describe as the tools which applied in Industrial Engineering. Yet, there is another method which is the most welcoming among these methods; it is productivity improvement by simulation method.

Simulation is recognized as the use of a model of a process, product or service to explore its characteristic before the process, product or service is created. Simulation provides wide range of flexibility in modeling and it allows detail examinations of the results before the manufacturing stage of product.

Simulation is now not only available for manufacturing industry use, but it is also widely implemented in others industry such as service industry, business field, food industry, hospitality industry, transportation industry and others. Not to mention that

this simulation implementation is benefits the industries far ahead beyond the industrial engineering tools that had been applied years before.

Besides of mentioning the implementation of simulation method, the design or planning for an industry floor layout also play an important role that directly affected time management control. In an existing service floor layout plant, the station from one to another can be adjusted or modified by shorten the travelling distance and time. This could be done by using simulation modeling and through this step, productivity improvement would definitely being improved and wastage will be deteriorated.

1.2 PROBLEM STATEMENT

The selected service organization is *Pusat Kesihatan Pelajar* (PKP) in Universiti Malaysia Pahang (UMP). The reason for selecting this healthcare center for research after some inspection is due to the unsatisfactory of existing service floor layout that causes the lead time of treatment process of a patient increased. Therefore, analysis and improvement for the service floor layout will be done in this project to get rid the existing root causes of low efficiency performance to improve the productivity of *Pusat Kesihatan Pelajar* (PKP).

1.3 PROJECT OBJECTIVES

The project objectives include:

- i. To evaluate the existing service floor layout.
- ii. To design and improve service floor layout by using Witness Simulation Software and also by observation during the collection data of cycle time.
- iii. To analyze and select the best solution to be suggested to *Pusat Kesihatan Pelajar* (PKP) of Universiti Malaysia Pahang (UMP).

1.4 PROJECT SCOPES

The scopes of this project are:

- i. Research is conducted in *Pusat Kesihatan Pelajar* (PKP) in Universiti Malaysia Pahang (UMP).
- ii. Only taking considerations of students and staffs of Universiti Malaysia Pahang (UMP) who visits *Pusat Kesihatan Pelajar* (PKP).
- iii. Service floor layout evaluation will be done with Witness Simulation Software and results analysis will be done by using Cost-effectiveness Analysis and Minitab software.
- iv. Treatment fees are given free to patients.

1.5 REPORT ARRANGEMENT

This thesis overall consist of 6 chapters where Chapter 1 is mainly included the introduction, problem statement, objectives and the scope of this project. Existing problem occurs in the service floor layout is clearly identified with objectives and scopes are set to concentrate on solving the particular problem.

Chapter 2 defines the title's keywords and some gathered information will be shown this relevant chapter. The definition of productivity, productivity improvement, introduction for service process and service industry, model verification and techniques, model validation with techniques used, simulation study, advantages and disadvantages of simulation will all be shown in this chapter. Nonetheless, there are ten similar previous researches included in here as the references.

Chapter 3 starts with introduction of the PKP organization background. The organization profile such as organization history of establishment, most visited customers, most common cases the organization faced; organization's objective and mission will be shown in the following topics. In additional, the organization chart and organization service floor layout will be attached for reference. Lastly, the conceptual model is also included in this chapter as to reflect the pre-model of service floor layout.

The chapter 4 will be presenting on how the methods that used to approach the demand of the title and achieve the objectives of the title. In this chapter, design of the project with flow chart and the planning for the next stage of the project will be discussed and number of replication will be determine before proceed to ANOVA analysis.

In Chapter 5, the previous results of the alternatives suggested in Chapter 4 will be further discussed in this chapter. There are three suggested alternatives to improve the productivity and satisfactory of the patients that visits PKP. The results from designed and actual layout systems that inserted in WITNESS simulation software are taken for 5 replications to continue for ANOVA test. Nevertheless, the cost effectiveness analysis will contribute to the most cost effective selection. The best approach will be decided and discussed here as the ultimate selection for PKP.

Chapter 6 generally summarizes the results that gained in along the previous chapters. By observing the output results from previous chapter, the most efficiency among those suggested alternatives will be proposed to the PKP. Further improvement and recommendations for this organization might also be included in this chapter.

1.6 CONCLUSIONS

An overview of this project is mentioned in this Chapter 1 where it introduces a brief concept of whole project. Introduction is mainly to develop the idea of the problems encountered by the service industry nowadays. Then, project scopes, objectives and problem statement of the project are defined clearly after identify the selected research institute. It is then continue with the report arrangement of the project. From here, we can understand more on the processes involve in order completing this project by achieving the project's objectives and setting the project scopes for project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter defines the title's keywords and some gathered information will be shown in here. The definition of productivity, productivity improvement, introduction for service process and service industry, model verification and techniques, model validation with techniques used, simulation study, advantages and disadvantages of simulation will all be shown in this chapter. Nonetheless, there are ten similar previous researches included in here as the references.

2.2 PRODUCTIVITY

Current economic realities which refers to liberalized and dynamic markets, constantly changing customer preferences, new structure of production and work, etc. are leading to a rethinking of the notion/concept of productivity. Whereas traditionally, productivity is viewed mainly as an efficiency concept which is amount of outputs in relation to efforts or resources used, productivity is now viewed increasingly as an efficiency and effectiveness concept, effectiveness being how the enterprise meets the dynamic needs and expectations of customers/buyers/users of products and services i.e. how the enterprise creates and offers customer value. Productivity is now seen to depend on the value of the products and services including utility, uniqueness, quality, convenience, availability and the efficiency with which they are produced and delivered to the customers. (Arturo L. Tolentino, 2004)

According to Tauno OTTO et al. (2007), productivity is one of the key factors affecting the overall competitiveness of a company. Productivity can be managed in different levels – on national, sector or enterprise level. In the enterprise level there are also different possibilities for productivity management, e.g. different measures of productivity can be used or different levels regarded.

In addition, the U.S. Department of Commerce defines competitiveness as “the degree to which a nation can produce goods and services that meet the test of international markets while simultaneously maintaining or expanding the real incomes of its citizens” (John A. Young, President and CEO of Hewlett-Packard, 1985).

According to Russell and Taylor (2006), productivity is known as a common measurement of competitiveness. Increases in productivity allow wages to grow without producing inflation, thus raising the standard of living. Productivity growth also represents how quickly an economy can expand its capacity to supply goods and services.

Productivity is calculated by dividing units of output by unit of input. Output can be expressed in units or dollars in variety of scenarios, such as sales made, products produced, customers served, meals delivered, or calls answered. Single factory productivity compares output to individual inputs, such as labour hours, investment in equipment, material usage, or square footage. Multi-factory productivity relates output to a combination of inputs, such as labour and capital or labour, capital, energy and materials. Capital can include the value of equipment, facilities, inventory, and land. Total factor productivity compares the total quantity of goods and services produced with all the inputs used to produce them.

Refers to Krajewski and P. Ritzman (2005), the surge of investment across national boundaries can stimulate productivity gains by exposing firms to greater competition. The increased investment in information technology by service providers will also increase productivity. Nonetheless, productivity improvement is a particular concern for service providers. If productivity growth stagnates, so does the overall standard of living regardless of which part of the world u live in.

As a conclusion, productivity is defined as the ratio of output to input. Thus, it is also can be described as the effectiveness of the company in matter of planning management and process. Besides that, it is also recognized as a measurement for the competitiveness among company by comparing the ratio of income/output to the input. Productivity improvement is the method or idea that applied on a system or a plant layout to obtain a greater gain of the output and decreasing the input. By doing so, this would save the resources that needed for the process and the most important is to achieve the target of saving the supply cost for the process.

2.3 SERVICE PROCESS AND SERVICE INDUSTRY

According to Krajewski and Ritzman (2005), there are two major types of processes: service and manufacturing pervade the business world. Judging on statistics from the major industrialized countries in the world, 80% of the jobs in business are in services. The criteria of service process are tending to produce intangible, perishable outputs that we refer to as a service. For example, the output from the auto finance department of a bank would be a car loan, and the output of the U.S. Postal Service is the delivery of your letter. The outputs from service processes typically cannot be held in a finished goods inventory to insulate the process from erratic customer demands.

Service processes tend to have a high degree of customer contact. Customers may take an active role in the process itself, as in the case of shopping in a supermarket, or they may be in the close contact with the service provider to communicate specific service needs, as in the case of medical clinic. Furthermore, while service processes do not use finished goods inventories, they do inventory their inputs. For example, hospitals need to keep inventories of their medical supplies and day-to-day materials needed for the operation of the hospitals processes.

According to the Quarterly Bulletin, Fourth Quarter (2008), service industry is known as one of the most income beneficial sectors/industries in Malaysia of the year 2007 and 2008. Therefore, it is very important to provide outstanding service to their customers to achieve an advantage in today's highly competitive marketplace.

Referring to Davis and Heineke (2005), good service begins when the customer first comes in contact with an organization and waits in some type of line or queue prior to being served. There are many factors that contribute to good service, such as the friendliness and knowledge of workers, but customer's experiences with waiting lines can significantly affect their overall level satisfaction with the organization.

Providing ever-faster service, with the ultimate goal of having zero customer waiting time, has recently received managerial attention for several reasons. First, in more highly developed countries where standards of living are rising, time becomes more valuable and customers, therefore, are less willing to wait for service. As a result, customers in many cases are willing to pay a premium price to firms that minimize their waiting time.

Another reason for this increased emphasis on providing fast and efficient service is the realization by organizations that how they treat their customers today significantly affects whether or not they will remain loyal customers tomorrow. This differs from the past when the treatment of customers in the present was viewed to be independent of any potential future sales. This antique perspective has persisted because the impact of future customer behavior does not appear anywhere on the firm's financial statements.

Finally, advances in technology, especially in information technology, have given firms the ability to provide faster service than was previously possible. Fax machines, computers, e-mail, and satellite communications enable firms to respond faster to the customer.

In providing fast service, however, the real goal of service managers should not be to ensure that customers are served within a specified time but rather to ensure that customers are sufficiently satisfied with the level of service provided that they will want to return in the future.

Therefore, service industry is a sector which is very difficult to define as it includes a number of ways to identify the division, industries and kind of works that

involve within it. This general category of service industry division includes a wide variety of sectors, yet it is usually can be describe as a primarily consumer-oriented sector. Which means service is provided directly to consumers. Thus, the output of service industry is mostly not a product but the result is to satisfaction of guest or customer by more communication contact way.

2.3.1 Characteristics of Services

According to Russell and Taylor (2006), service can be distinguished from manufacturing by the following eight characteristics. Although not all services process each of these characteristics, they do exhibit at least some of them to some degree.

- Service is intangible.
- Service output is variable.
- Services have higher customer contact.
- Services are perishable.
- The service and service delivery are inseparable.
- Services tend to be decentralized and geographically dispersed.
- Services are consumed more often than products.
- Services can be easily emulated.

2.4 SIMULATION

The Oxford American Dictionary (1980) defines simulation as a way “to reproduce the conditions of a situation, as by means of a model, for study or testing or training, etc.”

Harrell et al. (2004) describe the simulation as the imitation of a dynamic system using a computer model in order to evaluate and improve system performance. In practice, simulation is usually performed using commercial simulation software like ProModel® that has modeling constructs specially designed for capturing the dynamic behavior of systems. Performance statistics are gathered during the simulation and automatically summarized for analysis. Modern simulation software provides a realistic

graphical animation of the system being modeled. The power of simulation lies in the fact that it provides a method of analysis that is not formal and predictive, but it is capable of accurately predicting the performance of even the most complex system.

According to Krajewski and Ritzman (2005), the act of reproducing the behavior of a system using a model that describes the processes of the system is called simulation. Once the model has been developed, the analyst can manipulate certain variables to measure the effects of changes on the operating characteristics of interests such as response time, waiting lines, resource utilization, and the like. A simulation model cannot prescribe what should be done about a problem. Instead, it can be used to study alternative solutions to the problem. The alternatives are systematically used in the model, and the relevant operating characteristics are recorded. After all alternatives have been tried, the best one is selected.

In the market, there are many simulation software packages which are available such as SimQuick, ExtendTM, SIMPROCESS, ProModel[®] and WITNESSTM. These software packages can be used for more possible advanced capabilities in simulation process. As a conclusion, simulation is the tool to modeling a process, product or service which meant to explore its characteristic before the process, product or service is created and predicting the result of the designed floor or process layout.

2.4.1 Advantages and Disadvantages of Simulation

Simulation is a flexible tools or technique that is favorable among all similar techniques due to following advantages:

- Simulation can solve the complex and heavy system analytically.
- Simulation is easy and direct to be use.
- Excellent in experimental techniques, enabling systems to be tested within a laboratory setting.
- Can be used for analyzing random variables which related to the real-world situation.

Although simulation brings a lot of benefits and being an efficiency problem solver, but it is also having some disadvantages which shown as below:

- Impossible to validate the simulation results whether it is accurately reflect the system under analysis.
- Requires imagination and intuitiveness to construct the model.
- Simulation software package is usually costly.
- Model building time would be long.

2.5 SIMULATION STUDY

There are 14 steps that involved in performing a simulation study. These steps are shown as below and summarized in the flow chart.

2.5.1 Problem Formulation

The simulation is started by identifying the problem encountered by PKP and it is necessary for one to develop the problem clearly to prevent from misunderstood of the project purpose. Although it is not shown in the flow chart, there is a possibility of reformulation of the problem identified along the study progress.

2.5.2 Setting of Objectives and Overall Project Plan

Objectives play a role as the indicator by simulation for the problem stated in the previous stage. In here, simulation will be considered whether it is suitable method to be used in solving the problem that mentioned earlier. If there is a positive answer, a detailed planning for this undertaking project will be required. The planning includes a statement of alternative systems to be considered and a method for evaluating the effectiveness of these alternatives. It also includes the amount of people involved, project cost, required days to complete the tasks in each phase and others.

2.5.3 Model Conceptualization

This is referring to the construction of model of a system which can be best described as the abstract of essential features that characterized the system flow. Modeling art is enhanced by an ability to abstract the essential features of a problem, to select and modify basic assumptions that characterize the system, and then to improve and elaborate the model until a useful approximation results. Users are encouraged to starts with a simple model before build toward greater complexity. Involving the model users during model conceptualization will both enhance the quality of the resulting model and increase the confidence of model user while applying the model.

2.5.4 Data Collection

Referring to Shannon (1975), she mentioned that there is a constant interplay between the construction of the model and the collection of the needed input data. The required data elements are depend on the complexity of model changes. Data collecting normally takes a long time to complete it therefore it is necessary to start it as early as possible before the model building stages.

2.5.5 Model Translation

To convert a real-system into a computer-recognizable model, it required a great deal of information storage and computation works to insert as the input for computer. The term “program” is used although there are plenty ways to accomplish the desired result in many instances with minimal or no actual coding. There are many types of simulation software that available in the market such as AutoModTM, ExtendTM, ProModel[®] and WITNESSTM. These simulation languages are flexible and efficient. However, if the problem is amenable to solution with the simulation software, the model development time is greatly reduced. Thus, most of the simulation-software packages are enrich with features that strengthen their flexibility although the amount of flexibility varies greatly.

2.5.6 Verification

It is uneasy to verify a complex model, if not impossible, to translate a model successfully in its entirety without a good deal of debugging; as the input parameters and logical structures are represented in computer with error free, that indicates the verification has been complete.

2.5.7 Validation

Validation is achieved by calibration of the model; compare the model against the actual system behavior and using the discrepancies between the two, and insights gained, to improve the model. This process is repeated until the model accuracy is reasonable.

2.5.8 Experimental Design

The alternatives of simulation must be determined before this since it will be a function of runs that have been completed and analyzed. For each system design that is simulated, decisions need to be made regarding to the length of initialization period, the length of simulation runs, and the number of replication to be made of each run.

2.5.9 Production Run and Analysis

These mentioned processes are used to estimate measures of performance for the system designs that are being simulated.

2.5.10 More Runs?

Analyst should determine whether additional runs are needed and another options of experimental should follow as the given analysis of runs have been completed.

2.5.11 Documentation and Reporting

Program and progress are the most general types of documentation. Program documentation is indeed important for some reasons where it can be used as the operation manual for the same or different analyst to make them understand how the program works. This will increase confidence in the program as the model users can make better decision based on the analysis output. Documenting a program is also enabled the model users can change parameters at will in an effort to learn relationships between input parameters and output measures of performance or to discover the input parameters that “optimize” some output measure of performance.

Musselman (1998) suggested frequent report according to month or etc. so that even those not involved in the day-to-day operation can keep abreast. The awareness of these others can often enhance the successful completion of the project by posting the misunderstanding early, when the problem can be solved easily. Musselman also suggests maintaining a project log providing a comprehensive record of accomplishments, change request, key decision, and other important items.

On the reporting side, Musselman said that “it is better to work with many intermediate milestones than one absolute deadline.” Model specification, prototype demonstration, animation, training results, intermediate analyses, program documentation, progress reports, and presentations are prior to the final report. These should be timed judiciously over the project’s life.

Analysis result should be reported concisely and clearly in final report. This enabled the model users to review final formulation, the alternative systems that were addressed, the criterion by which the alternatives were compared, the output of experiments and recommended solution and problem. Final report should provide with a vehicle of certification for model users and add to the credibility of the model and the model-building process in the higher level of justification.

2.5.12 Implementation

Refers to Pritsker (1995), the success of implementation phase depends on how well the previous steps have been performed. It is also contingent upon how thoroughly the analyst has involved the ultimate model user during the entire simulation process. If the model user has been undergoing the model-building process, understands the model nature and its output, the likelihood of a vigorous implementation is enhanced.

Overall, the successful implementation depends on continual involvement of the model user and on the successful completion of every step in this whole process. Perhaps validation is the most essential step among this whole process, because an invalid model will lead to erroneous results, which, if implemented, negative result such as causing costly, hazardous or both results will gained.

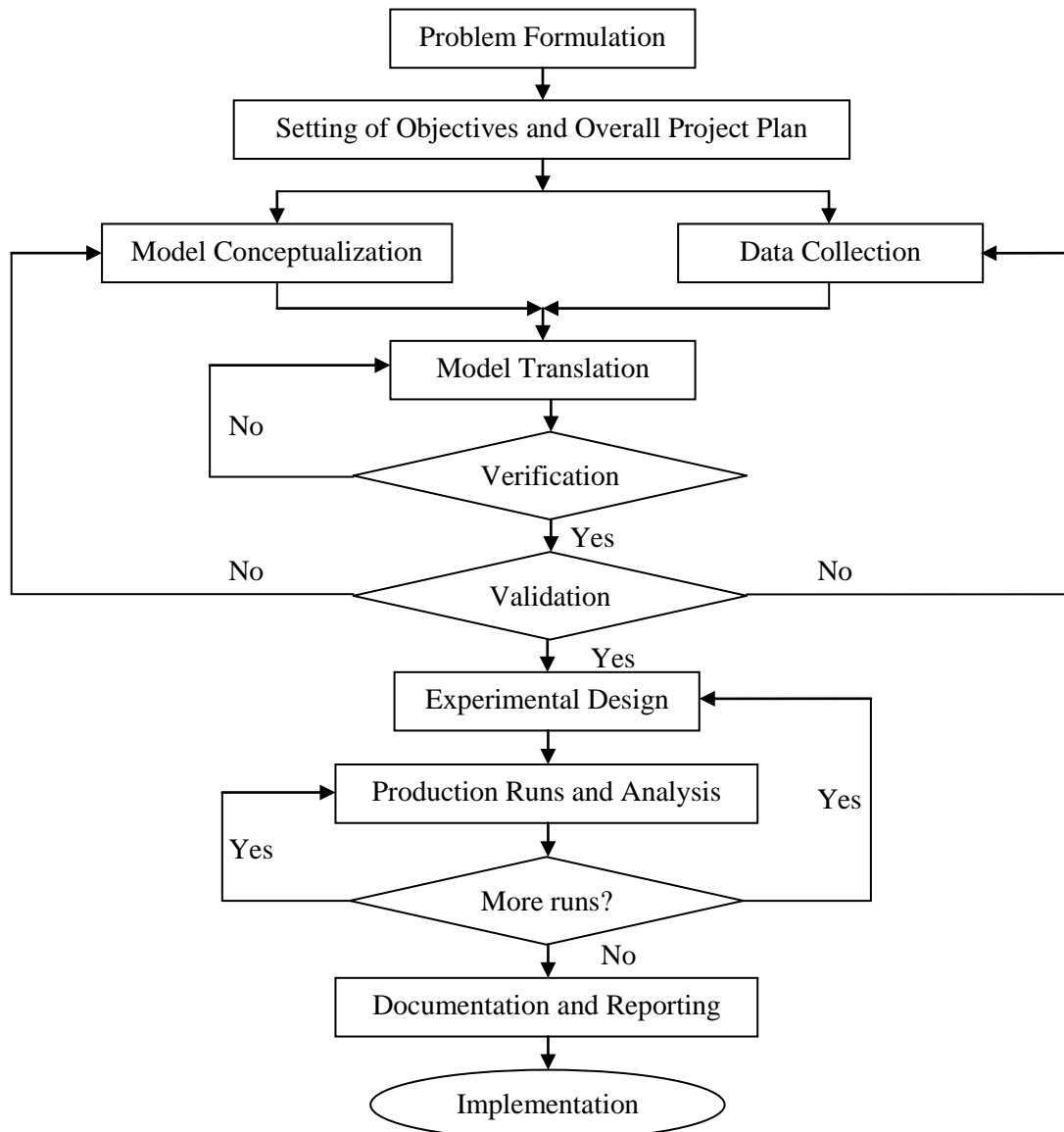


Figure 2.1: Steps of Simulation Study.

2.6 MODEL VERIFICATION

According to Banks et al. (2001), “Verification is concerned with the building the model right. It is utilized in the comparison of the conceptual model to the computer representation that implements the conception.”

Harrell et al. (2004) describes model verification as the process of determining whether the simulation model correctly reflects the conceptual model. It doesn’t necessarily mean that the model is valid, only that if it runs correctly. Model

verification involves the modeler more than customer. During the verification process, the modeler tries to detect unintended errors in the model data and logic and remove them. In essence, verification is the process of debugging the model. A verified model is a bug-free model.

2.6.1 Model Verification Technique

According to Harrell et al. (2004), once everything has been done at the outset to ensure that the model has been built correctly and a standard for comparison has been established, several techniques can be used to verify the model. Some of the more common ways include:

Conduct model code reviews can be performed either by the modeler or others that familiar to both the modeled system and modeling techniques. The objective of the model code review is to check for mistakes or inconsistencies. Simulation model can be test by either a bottom-up or top-down approaches. Bottom-up testing method is called unit testing where lowest modules are tested and verified first. Proceed with testing two or more modules until the model can be tested as a single system. As for the top-down method, verification begins with the main module to lower modules. The top level outputs are mostly same as expected with the given inputs while the discrepancies increase for lower-level code analysis.

Check the output for reasonableness since the operational relationships and quantitative values are predictable from simulation. For simple models, one way to help determine reasonableness of the output is to replace random times and probabilities into the entities to determine the outcomes in the model. This would allow analyst to predict precisely since the determined results should match the results of simulation.

Another model verification technique can be used is watching the animation to ensure the entities inserted by the modelers are exactly following the designed track. The animation can be adjusted to slow motion and enable the analyst to follow along visually. However, the amount of time required to observe a complete simulation run would be extremely long. If the animation is speed up, the run time will be smaller and

causing inconsistencies which led to difficulties in detecting this error. Therefore, the user can view the status of machines to see if the variables are correctly being set.

Use the trace and debug facilities provided with the software to find out what actually happens during simulation which usually hidden. Most simulation software comes with some sort of trace and debugging facility. Trace messages can be utilized to reveal the hidden information event by event and it can be turn on or off as analyst desire.

A typical trace message might be the time that an entity enters particular location or the time that a specific resource is feed. Debugger is a utility that displays and steps through the actual logic entered by users to define the model. Like trace messaging, debugging can be turned on either interactively or programmatically. By applying debugging and trace features, event occurrences and state variables can be examined and compared with hand calculations to see if the operating program is running as it should.

2.7 MODEL VALIDATION

From Hoover and Perry (1990), they mentioned that “Validation is the process of determining whether the model is meaningful and accurate representation of the real system.”

Harrell et al. (2004) defined model validation is the process of determining whether the conceptual model correctly reflects the real system. Because the process of validation can be very time-consuming and ultimately somewhat elusive, we are not interested in achieving absolute validity but only functional validity. As Neelamkavil (1987) explains, “True validation is a philosophical impossibility and all we can do is either invalidate or ‘fail to invalidate’.”

2.7.1 Model Validation Techniques

By Harrell et al. (2004), there is no simple test to determine the validity of model. Validation is an inductive process in which the modeler draws conclusions about the accuracy of the model based on the evidence available. Several techniques are given that described by Sargent (1998). Some of them tend to be rather subjective, while others lend themselves to statistical tests such as hypothesis tests and confidence intervals. Many of the techniques are the same as those used to verify a model, only now the customer and others who are acknowledgeable about the system need to be involved. As with model verification, it is common to use a combination of techniques when validating a model.

Watching the animation is one of the techniques to validate the model by comparing the visual animation with one's knowledge about the real system behaves. This could include dynamic plots and counters that provide dynamic visual feedback. Other available approaches are comparing with the actual system or other models. Users can run both of the actual and a designed model under similar conditions to observe if the results match. In case that the other valid model have been built of process such as analytic models, spreadsheet models and even other valid simulation models, the output of simulation can be compared to these known results.

Conducting degeneracy and extreme condition tests is known situation for which models model behavior degenerates, causing a particular response variable to grow infinitely large under extremely conditions.

Check for face validity by asking the acknowledgeable person about the system whether the model behavior appear reasonable. This technique is generally testing for the logical in conceptual model if it's correct and if the model's input-output relationships are reasonable.

Testing against historical data when there is an existing data for both performance and operation systems. The model can be tested by inserting the same

operating data and comparing the results of historical performance data. This process is an “as-once-saw” model.

Performing sensitivity analysis by varying the model input to determine the effect on model’s behavior and output. It is necessary for the modeler to have an intuitive idea of how the model will react for the changing of input as the direct relationship occurs in the model as in the real system.

An entity or sequence of event can be traced through the model processing logic to see if it follows the logical track as reflecting in the actual system. Thus, conducting a turing test by asking the experienced person to discriminate the model and actual outputs is another piece of evidence to use in favor of the model being valid.

2.8 PREVIOUS RESEARCHES IN SERVICE INDUSTRY

Weng and Houshmand (1999) written a journal entitled “Healthcare Simulation: A Case Study At Local Clinic” which regarding to simulation which been used in health care filed in comparison studies of alternative systems for resource or scheduling requirements (Lowery, 1998). In their study, they measured the standard performance measures of throughput, time in system, queue time and lengths in their system analysis. The clinic is modeled as a pulled system by using Arena as the simulation language. They concluded that the health care management group was only interesting in maximizing patient throughput and minimizing patient flowtime and performances measurement of Vexpenses and Revenues are used in their studies. In their conclusion, the expected number of 160 patients through the system daily will be difficult to achieve. Therefore, a proposed solution would be lower the expected number of patients at current level of staffing.

Miller et al. (2008) with their journal titled “Allocating Outpatient Clinic Services Using Simulation And Linear Programming”. Their research had been done in LAC+USC Medical Center which function as Los Angeles largest healthcare facility. With the staffing of over 6900 employees and 1395 beds available in this center, the researchers are going to determine ideal space assignments, schedule configurations and

throughput targets for numerous clinic services for the new hospital before it opened. They choose ExtendTM as their simulation tool. By integrating several distinct types of quantitative tool, the complexity and broad scope of this problem which required highly analytical expertise in service allocation methodologies and information technologies had being solved.

Spry and Lawley (2005) in their journal with title of “Evaluating Hospital Pharmacy Staffing And Work Scheduling Using Simulation”. This research is done by the Spry and Lawley in BroMenn Healthcare Medical Center to help this hospital in making decisions about staffing and work scheduling. A simulation model was created in AutoMod 11.1 Student Version (Banks 2004) to analyze the impact of alternate work schedules with the final goal of finding the best solution to get medications to the patients as quickly as possible by using pharmacy staff effectively. As the analysis output is published, they find that adding evening staffs improves the turn-around time in the evening and into the early morning and help BroMen in making decisions to add staff based on increasing hospital patient admissions.

Martin et al. (2003) with the journal entitled “Proposal To Reduce Over-Crowding, Length Stays And Improve Patient Care: Study Of The Geriatric Department In Norway’s Largest Hospital”. They aim to increase efficiency and rates of returns as well as improving the potential for geriatric patients re-convalescence and reducing the number of ‘corridor beds’ by using ProModel simulation software. Throughout the analysis, they found that the combination of filling up the ward to full capacity, reducing stay lengths and increase resources are the most effective method to use for increasing the number of admissions.

Atkins et al. (2003) with the article “Right on Queue” which the studies are done in Vancouver International Airport Authority which uses the queuing simulation to determine staffing level at security points. This study has been done for the objectives of reducing the queuing time the passengers spend in the security line to less than 10 minutes time among 90% of the passengers. In this part of study, if the 90-10 service criterion was exceeded over the length of the simulation, then the staffing level was induced and it works vice-versa in the opposite condition. Thus, they also convert the

staffing requirement for each ten-minute time period into minimum cost worker shift schedules for the security checkpoints.

Miller et al. (2003) in the journal with title “Simulating Six Sigma Improvement Ideas For A Hospital Emergency Department”. This project produced an ongoing, workable model from which to simulate potential process improvements in their Emergency Department (ED). Simulation software of ExtendTM is used in this project and in the result of their research, they found that the modeling and simulation enabled the client to better understand the patient experience, process performances and staffing inter-relationships for their proposed emergency department.

Form Balasubramanian et al. (2007) journal title “Improving Primary Case Access Using Simulation Optimization”, they proposed a multi-period metaheuristic simulation optimization model for determining the panel design of a set of physicians working in a primary care environment. This model is meant to maximize patient visits to their own providers, reducing waiting times, and minimize overage. In the end of the project, future works still needed to improves the accuracy of the model.

Brady (2003) with his journal entitled “Emergency Management: Capability Analysis of Critical Incident Response” that aim to treat the ever increasing number of patients in local county-level emergency management agencies to more quickly develop, test, and refine robust plans by utilization of ProModel simulation software. This simulation analysis had improve the emergency planners to faced with the potential scenarios that may severely test their capabilities and conventional process without using costly, time consuming physical drills.

Denton et al. (2006) in the journal with title “Simulation for A Multiple Operating Room Surgical Suite” is mainly describe on considering how to scheduling surgical procedures, aid to improve strategic and operational decision making relating to the delivery of surgical services. The writers demonstrated how the model can be used to evaluate multiple competing criteria for different staffing scenarios. They also mentioned about even the uses of simple scheduling heuristic based on scheduling of bottleneck (surgery) activity can lead to simultaneous improvements in expected patient

waiting time and overtime. Hence, further future investigation of scheduling decisions via simulation will be done in the future.

Morrison and Bird (2003) with the journal named “A Methodology For Modeling Front Office And Patient Care Process In Ambulatory Health Care” with the mission to assess the effectiveness and economics of simulation in free standing ambulatory health care settings. In their summary, they mentioned that attempting to have an impressive simulation up and running quickly would probably is the shortest road to disaster. They also found that validation is the most essential part for the whole project although it takes the longest time to be done.

Refers to all those previous studies above, we can conclude that simulation is an efficiency method which is widely used in service sector as a tool in model constructing for waiting lines solver, staffing scheduling and predicting the efficiency of a company. Yet, there are still many demands on simulation to provide better performance instead of solving these ordinary matters.

Table 2.1 below shows the summary of previous researches that have been done in service industry that mentioned as the above.

Table 2.1: Summary of previous researches of service industry.

Author(s)	Methodology	Industry	Results
Weng and Houshmand (1999)	Arena, Vexpenses and Revenues	Local Clinic	<p>Based on current standard of clinic, the desired goal for number of patients through the system, 160, would be very difficult if not near impossible to achieve. Therefore, a proposed solution would be to lower the expected number of patients at the current level of staffing.</p> <p>Using performance measures called Vexpenses and Revenues, which are the variable expenses and the patient revenues, respectively, this conclusion has been further solidified as the best among the alternatives.</p>
Miller et al. (2008)	Extend™	LAC+USC Medical Center	<p>Solution with both high-level and low-level model capabilities, enabled the hospital to better meet the community's needs while optimizing space utilization.</p> <p>The team provided key stakeholders the ability to make improved decisions with clinic assignments in the new hospital before it opened. The complexity and broad scope of this problem required highly</p>

			analytical expertise in service allocation methodologies and information technologies.
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Spry and Lawley (2005)	AutoMod 11.1 Student Version (Banks 2004)	BroMenn Healthcare Medical Center	This pharmacy management is using the results from this study. Since the results are based on some assumptions about the data, the effect of the changes may not be exact, but the direction and relative magnitude can be used to compare the effects of possible changes. As changes are made the model will be further verified, and if other options need to be explored the model can be modified to explore further changes.
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Martin et al. (2003)	ProModel	Norway Hospital Geriatric Department	Combination of filling up the ward to full capacity, reducing stay lengths and increase resources are the most effective method to use for increasing the number of admissions among 4 experiments.
Atkins et al. (2003)	Not mention	Vancouver International Airport	By using 90-10 service criterion, determining the staffing requirement for each ten-minute time period into minimum cost worker shift schedules for the security checkpoints.
Miller et al. (2003)	Extend TM	Emergency Department (ED)	It is important to regularly verify if client expectations are being met. An open and proactive communication is always the best way to ensure the success of a project by modeling and simulation.
Balasubramanian et al. (2007)	PDGA	Mayo Clinic at Rochester	Proposed a multi-period simulation-optimization model to optimize panel design and improve access to primary care. The objectives are to

			minimize the expected number of redirections, waiting time and overage is achieved.
Brady (2003)	ProModel	Emergency Management Agencies	The development of a simulation-based environment that allows emergency planners and professionals to prepare more robust emergency response plans without using costly, time consuming physical drills.
Denton et al. (2006)	C/C++	Mayo Clinic at Rochester	Demonstrated how the model can be used to evaluate multiple competing criteria for different staffing scenarios. Indicates that even a simple scheduling heuristic based on scheduling of the bottleneck (surgery) activity can lead to simultaneous improvements in expected patient waiting time and overtime.
Morrison and Bird (2003)	Not Specified	Healthcare center	The researchers found that attempting to have an impressive simulation up and running quickly would probably is the shortest road to disaster. They also found that validation is the most essential part

			for the whole project although it takes the longest time to be done.
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2.9 CONCLUSIONS

Literature reviews that regarding to this project title has been done in this chapter. In this chapter, details descriptions of the related subject in this topic and some case studies of the previous research are being reviewed. In additional, some techniques for using simulation software had been attached in this chapter. Nevertheless, the details of the selected organization for research will be presented in the next chapter.

CHAPTER 3

ORGANIZATION BACKGROUND

3.1 INTRODUCTION

This chapter starts with introduction of the organization background. The organization profile such as organization history of establishment, most visited customers, most common cases the organization faced, organization's objective and mission will be shown in the following topics. In additional, the organization chart and organization service floor layout will be attached for reference. Lastly, the conceptual model is also included in this chapter as to reflect the pre-model of service floor layout.

3.2 ORGANIZATION PROFILE

Pusat Kesihatan Pelajar (PKP) is known as a healthcare center for Universiti Malaysia Pahang. Before this, the *Pusat Kesihatan Pelajar (PKP)* is formerly operating under the authorization of *Jabatan Hal-Ehwal Pelajar dan Alumni (JHEPA)* Universiti Malaysia Pahang (UMP). The name of *Pusat Kesihatan Pelajar (PKP)* is had not been created during that time and the name of PKP is replaced by 'clinic'. The student or staff of university with physical disorder is all sent to JHEPA. After the preliminary inspection from the Treatment Assistant, the patient will be the sent to the nearest healthcare center by the On Duty-driver to get treatment.

This situation is maintained until the year of 2004 of 1st August. This clinic starts to operate as an independent unit and being established with the name of *Pusat Kesehatan Pelajar* (PKP). The total number of staff and medical officer that work in there are 15 peoples. This healthcare center is operating from 8am to 5pm every Monday to Friday. On Saturday and Sunday, the authorized person of PKP will scheduled a consultation assistant and a driver to standby for the emergency cases happened.

The majority of patients that visited PKP are the student of the university. However, cafeteria workers, staff of university and the vendors can also be found as the patients that visit PKP frequently. According to the forecasting report of the PKP, average numbers of patient that visit PKP per operating day are around 110 peoples and 1900 peoples per month. During the peak season of year 2009 due to the infection of H1N1 decease, the clinic was once visited by 2214 patients in July. These patients are mostly come to PKP for their medical consultation and treatment.

From the research, there is not much critical obstacle that faced by the PKP before and the common cases that PKP met are cough, flu and fever. On the other hand, there are also some critical cases that faced by the medical officers such as dengue, chicken pox and conjunctivitis. For these critical cases, patients may be sent to the hospital to get their treatment since the facilities in PKP is not as advanced to provide best treatment service to patients.

3.3 ORGANIZATION OBJECTIVE

Sebuah organisasi yang membangunkan siswa ke arah keperibadian unggul melalui pengurusan dan perkhidmatan professional.

3.4 ORGANIZATION MISSION

Untuk memebentuk insan yang kreatif, kompetitif dan berketampilan.

Kami komited dalam:

- i. Memupuk dan membangun sahsiah terpuji.*
- ii. Menyediakan perkhidmatan dan pengurusan yang efisien dan efektif.*
- iii. Mewujudkan persekitaran yang kondusif seiring dengan aspirasi.*

3.5 PKP ORGANIZATION CHART

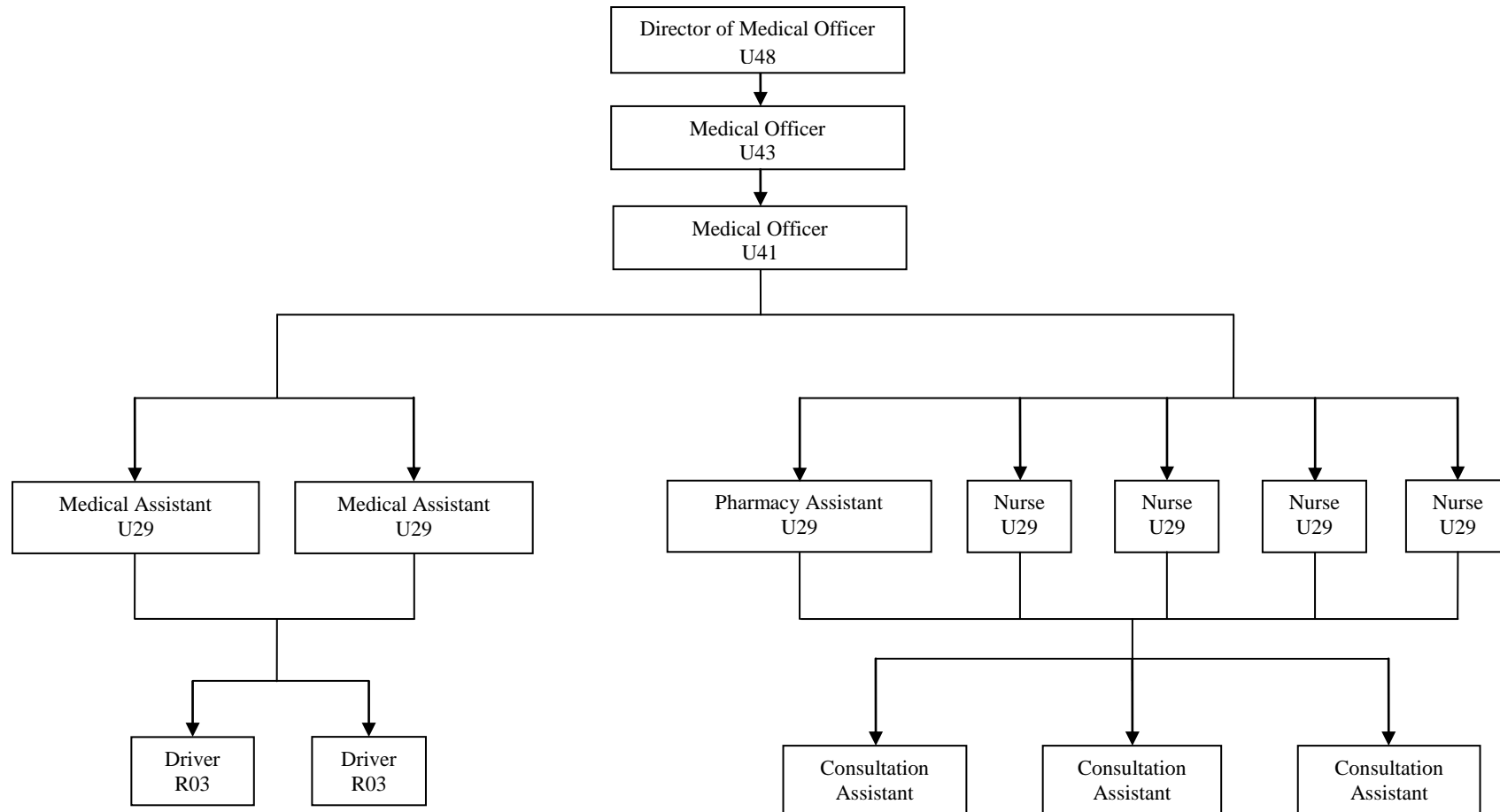


Figure 3.1: The organization chart of *Pusat Kesehatan Pelajar (PKP)* of year 2008.

3.6 PKP SERVICE FLOOR LAYOUT

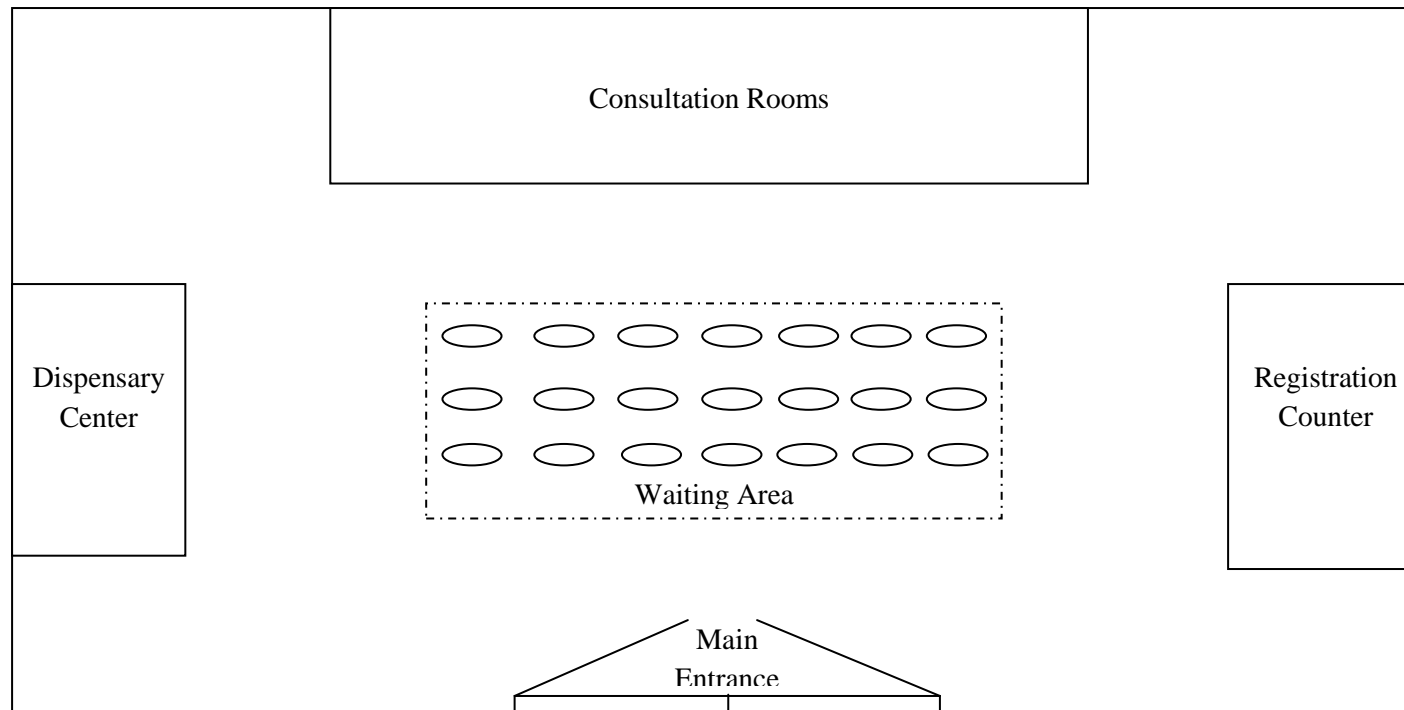


Figure 3.2: *Pusat Kesehatan Pelajar (PKP)* service floor layout.

3.7 CONCEPTUAL MODEL OF PKP SERVICE FLOOR LAYOUT

Harrell et al. (2004) describe the conceptual model as the result of the data-gathering effort and is a formulation in one's mind (Supplemented with notes and diagrams) of how a particular system operates. This conceptual model can be said as the pre-modeling before designing a model in simulation software as the simulation model is built by converting conceptual model into it. In this Figure 3.3, it shows 4 processes for a patient to complete a treatment cycle.

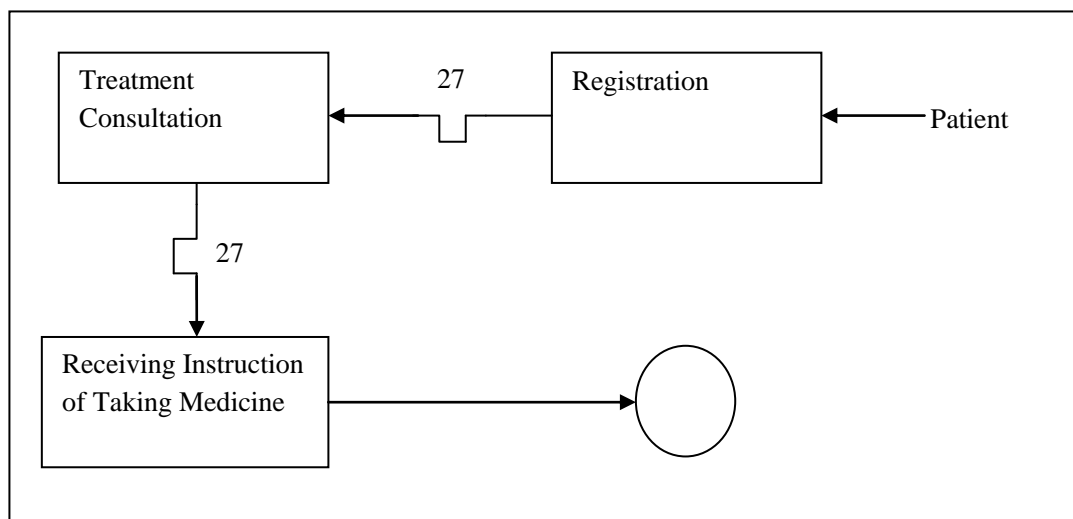


Figure 3.3: Conceptual model of a patient serving process.

3.8 SERVICE PROCESS FLOW

By referring to the PKP service floor layout in Figure 3.2, the process flow of the service will be described as below. Firstly, the patient will go in the PKP by the main entrance of PKP. Then they will turn to their right and approach to the registration counter. During the register time, they are required to show their ID card and fill their details in the registration list with name, matrix ID number and faculty.

As the registration process is complete, patient will walk to the waiting area to take a seat while waiting for the treatment assistance call. In this waiting time, patient can either spend their time on watching TV program or reading some healthcare magazine that available in the waiting area. After the medical card is taken by the nurse

from registration counter to medical officer's room, the nurse will call upon the patient's name and lead him/her the way to the consultation room after the medical officer is standby.

After enter the consultation room, patient will be seated in front of medical officer and receive treatment according to their sickness. After the diagnosis is complete, patient will walk out from the consultation room and approach to the waiting seat. During this waiting period, the nurse will bring the diagnosis report and patient's ID card from medical officer to dispensary center. Medicine is prepared according to the medical officer's instruction by pharmacy assistant in minutes.

The pharmacy assistant will call upon the corresponding patient's name as soon as the medicine is packed well and prepared. Patient approach the dispensary counter and will receive instruction from the pharmacy assistant for medicine taking or dose. After the patient took their medicine, they will proceed to the entrance and leave the *Pusat Kesehatan Pelajar (PKP)*. With completing all those steps mentioned from the above, there would be a complete cycle time observed for data collection.

3.9 CONCLUSIONS

As a summary, the organization background with introduction and the profile are discussed in detail in this chapter. The details that including the organization objectives, mission, conceptual model of service floor layout and organization chart are presented respectively in this chapter. These sketched service floor layout are implemented into the simulation software to estimate the required data for the next stage. In the next chapter, problems will be identified and the methodologies that used to solve the problem will be discussed.

CHAPTER 4

METHODOLOGY

4.1 INTRODUCTION

This chapter will be presenting on how the methods that used to approach the demand of the title and achieve the objectives of the title. In this chapter, design of the project with flow chart and the planning for the next stage of the project will be discussed and number of replication will be determine before proceed to ANOVA analysis.

4.2 PROJECT STUDY DESIGN

The project starts by finding an appropriate company which suits the project title. Gantt chart that needed for this project is created as in Appendix A and every step and time that taken to accomplish each task in this project is being stated in Gantt chart. On the other hand, journals and books which are needed for literature review is being search for the whole process of this project as the knowledge gain or need along this project will be increased.

After confirming the selected organization, this organization background will be studied for determining the project objectives and scopes. This will help us to clarify the target and range of research of this project. Then, the step of identifying the problems that occur on the existing floor layout is preceded and jot down these problems. By identify these occur problems in the floor layout, problem analysis of these problem are done and identify the main problem that we need to solve which is related to our project objectives and scope. This is the followed by constructing the

conceptual model which has been shown in previous chapter Figure 3.3 is constructed after identifying the process flow of the service floor layout.

In this period, data collection, data analysis and searching for journals and books are working simultaneously to get the preliminary results of the next procedure. During the data analysis process, the collected data are necessary to times with 1.15 due to the labour efficiency of 85%.

By completing calculation of the sample size, these values are being tabulated in Appendix B and Appendix C. As for the Appendix D, the data collected will be tested to see how good a fit has been obtained by using uniform distribution test, exponential distribution test and normal distribution test. The most appropriate distribution is selected as the input data to construct the desired model.

As the data analysis is done, model assumption are made before constructing the model in WITNESS simulation software. The assumptions are including the patients entering the PKP with 2.5 minutes during the busy operating time of 4 hours per operating day. Each counter and consultation room can only work on one patient at a time and there are no rejections of patients in the system. After completing the model assumption for the layout, model construction of actual layout plant and designed service floor layout by utilization of WITNESS software are the next steps to be estimate the output of patients visit the PKP per day by using different suggested alternatives.

In the mean time, model verification and model validation can be done as the actual and designed models have been inserted in the WITNESS Software. These steps are made to ensure the sketched models are accurately reflected the conceptual model. Model verification is done by observing the output for reasonableness and watching the animation simulated to ensure the icons are on the correct track. While model validation is carried out by watching the animation of the entities and comparing the output results with the actual system model.

As the number of patient visit the clinic per day from each alternative are predictable, these results will be bring forward for Kruskal-Wallis non-parameter test, ANOVA analysis and cost estimation analysis. Kruskal-Wallis non-parameter test is performed to compares the medians between inserted samples to determine if they come from different populations. ANOVA one way test is applied on the suggested approaches to test for differences among themselves with the highest value is the best alternatives. These results are then documented for the next cost effectiveness analysis by considering of the cost of running these alternatives.

By making a few necessary assumptions, calculation, graph plotting and tabulate the cost effectiveness analysis result, the most cost reducing alternatives can be observed and it will be proposed to PKP. The results that generated by all the test are documented in details in this report and presented to the panels at the final stage of this project. The project flow is summarized in the following Figure 4.1 and Figure 4.2.

4.2.1 Project Flow Chart for Final Year Project

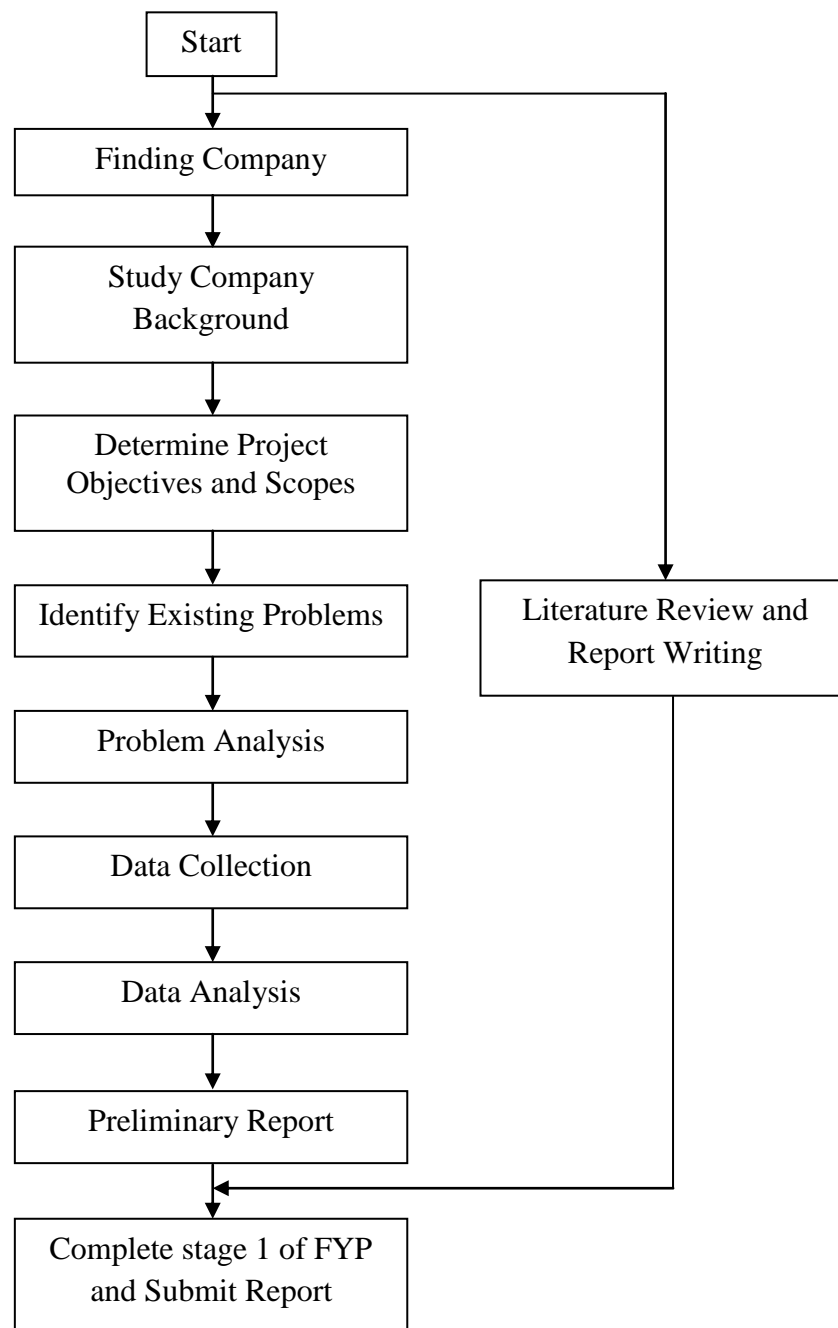


Figure 4.1: Designed project flow chart for FYP semester 1.

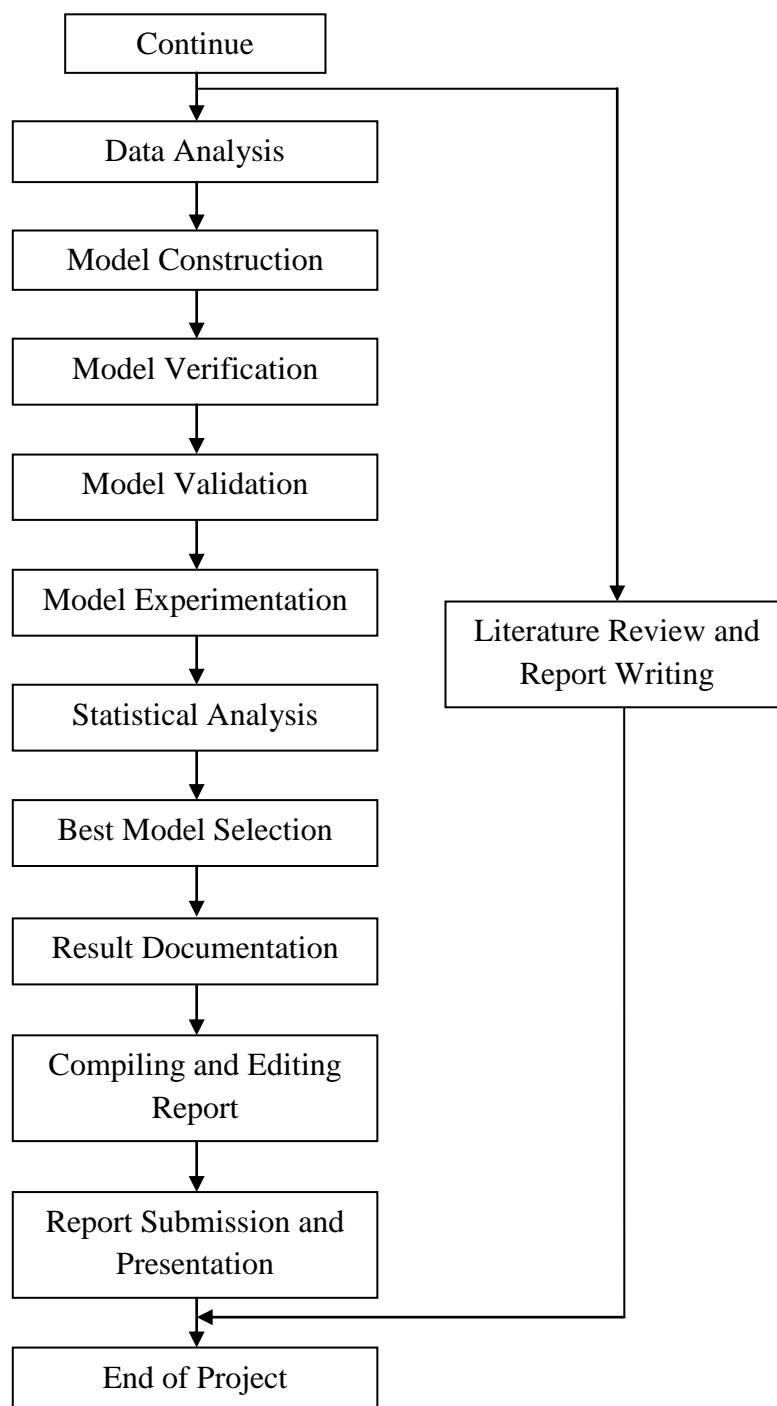


Figure 4.2: Designed project flow chart for FYP semester 2.

4.3 DETERMINING REQUIRED NUMBER OF REPLICATIONS

Terminating simulation has a fixed starting condition and a fixed ending condition which usually refers to the most of the service-oriented systems. The PKP begins their operating hours from 8.00 am with starting condition of zero patients in the system and terminates the service at 5.00 pm as the last patients is processed. This system returns to its starting condition after reaching a natural terminating event. The constructed simulation is run for 5 replications for each actual and experiment layout and determination of required number of replications are shown as below:

Table 4.1: Determination of required number of replications for actual layout.

Observations (n)	Output Patient, X_i	$X_i - X_{avg}$	$(X_i - X_{avg})^2$
1	93	12	154
2	70	-11	112
3	78	-3	7
4	80	-1	0
5	82	1	2
TOTAL	403		275

$$X_{avg} = 403/5 = 80.6 \text{ patients} \quad \text{Standard Deviation, } s = \sqrt{275/5 - 1} = 8.29$$

By using confidence level of 90%, $\alpha = 1 - 0.90 = 0.10$;

$$e = \text{half-width, } hw = [\text{High Interval} - \text{Average}]/2 = [93 - 80.6]/2 = 6.2 \approx 7 \text{ patients}$$

$$\text{Number of Replication, } n' = [(Z_{\alpha/2})s/e]^2 = [(1.6449)(8.29)/7]^2 = 3.79 \approx 4$$

From the calculation, we can determine the number of replication needed for this alternative is 4 and the observations tabulated at the above are enough to proceed to statistical and cost effectiveness analysis for the most efficient layout selection.

4.4 CONCLUSIONS

In conclusion, this chapter consists of the designed project flow from the beginning to the end. In a nutshell, the steps that taken from stage to stage are described in words and flow charts established as the above. Besides that, example of determination of required number of replication needed by the alternatives to continue ANOVA test is shown as the above. Results and discussions will be documented in the Chapter 5.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 INTRODUCTION

The previous results of the alternatives suggested in Chapter 4 will be further discussed in this chapter. There are three suggested alternatives to improve the productivity and satisfactory of the patients that visits PKP. The results from designed and actual layout systems that inserted in WITNESS simulation software are taken for 5 replications to continue for ANOVA test. Nevertheless, the cost effectiveness analysis will contribute to the most cost effective selection. The best approach will be decided and discussed here as the ultimate selection for PKP.

5.2 EXPERIMENTATIONS

Experimentations of each suggested alternatives in order to improve the PKP service productivity are conducted. These experiments are done by WITNESS simulation by inserting the data which has been analyzed earlier in the previous stage into the machine entity as labour. Terminating simulation is applied into these simulation models due to the characteristics of the system which returns to fixed starting condition after its operation hour. Simulation time with 14400 s running length is implemented of these experiments. The replications number needed for the statistical analysis are calculated and an adequate replications of the output results for each experiments generated are taken from the simulation statistics result.

5.3 EVALUATION FOR THE ACTUAL SERVICE FLOOR LAYOUT

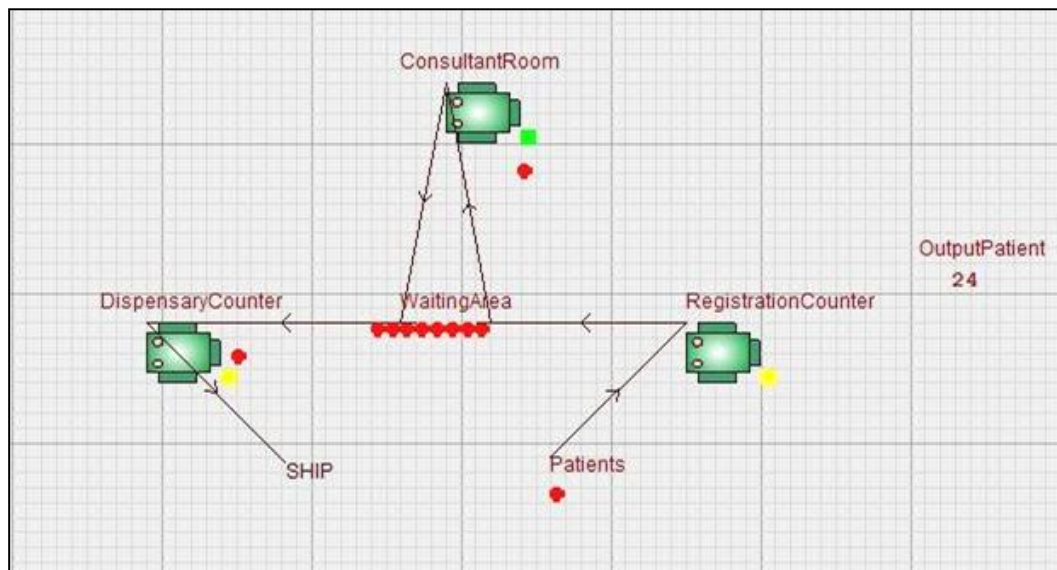


Figure 5.1: Simulation for existing service floor layout in PKP.

It is necessary to evaluating the actual system layout as the problem of the floor layout can be seen clearly and will be solved in the coming process. Referring to the Figure 5.1, the simulation layout shows that the waiting line are long in waiting area before the patients go to consultation room.

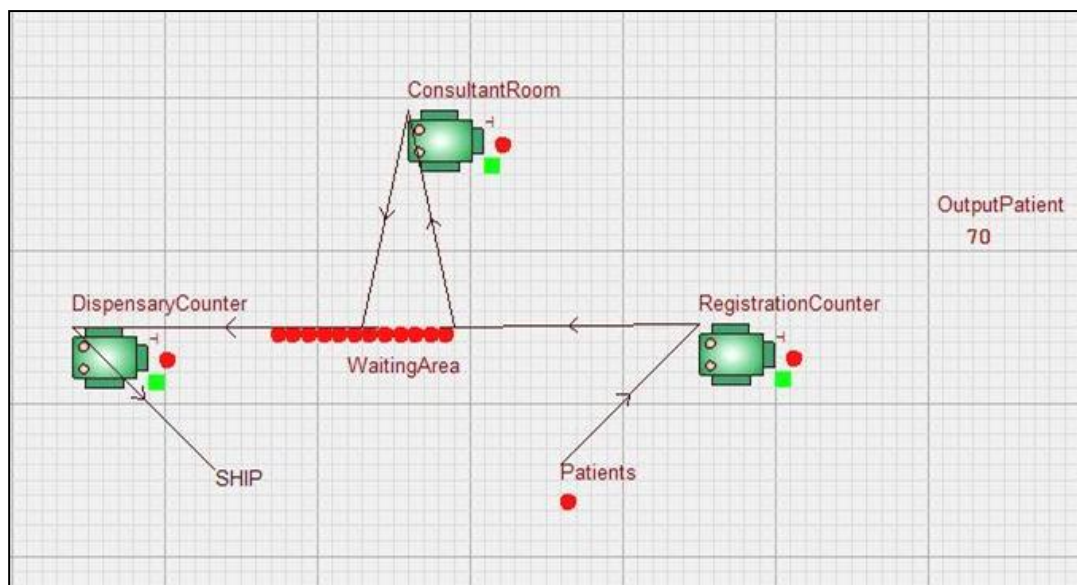
The actual numbers of output patients served in this existing service floor layout for duration of 14400s are tabulated as in Appendix E. The average output patients which processed in this actual layout is 78 patients while the simulation having its average patients number of 81 persons. The difference between this simulation and actual output system is 3.8% which is less than 5% of variation or error. Therefore, a confidence level of 95% is applied and this indicated the model is validated.

Simulation time length of 14400s is implemented into this system and the output patient which generated are 93, 70, 78, 80 and 82 patients. During this period, an average number of 81 patients are being served with an optimum time of 1334.62s. This shows that a patient needs to spend at least 22 minutes to complete their medical treatment and leaves the PKP. The simulated results of this layout are recorded as below.

Table 5.1: Results of output patients for the actual service floor layout.

Model		Replications					Average
		1	2	3	4	5	
Patient	Output	93	70	78	80	82	81
	Avg. Time	435.93	2106.85	1495.83	1378.35	1256.14	1334.62

5.4 EXPERIMENT 1: REDUCTION OF WAITING AREA CAPACITY

**Figure 5.2:** Simulation for Experiment 1 of reducing waiting area capacity.

The first experiment alternative that applied to this model is reducing the waiting area capacity. Before reduction of the waiting seat, there are total of 27 seats available for the patients to spending their waiting time before proceed to meet the doctor. The waiting seats are then deducted into 12 seats of waiting capacity due to the vacancy.

After running the simulation for this experiment few times, the output patients number are exactly same as the actual layout but with a lower average processing time

period. The average time for this alternative is 1295.21s for a patient to complete his/her

Model		Replications					Average
		1	2	3	4	5	
Patient	Output	93	70	78	80	82	81
	Avg. Time	435.93	1899.58	1489.20	1382.11	1269.23	1295.21

treatment in PKP.

Table 5.2: The experimental results for Experiment 1.

5.5 EXPERIMENT 2: ADDITIONAL OF A MEDICAL CONSULTANT

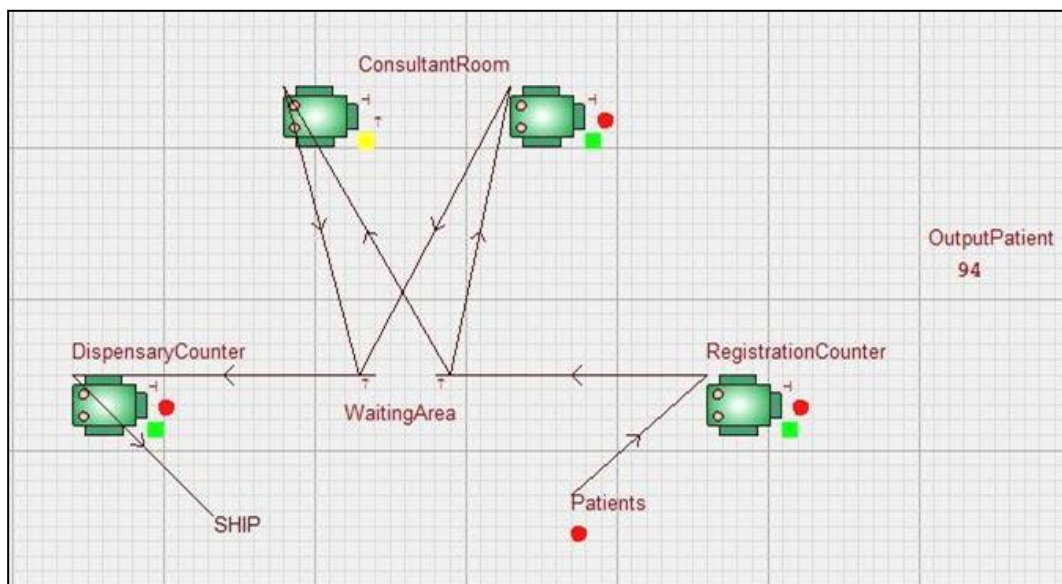


Figure 5.3: Simulation of Experiment 2 by adding one medical consultant on the layout.

This following Experiment 2 is the proposed as another approach to improve the productivity of the PKP service quality. Experiment 2 suggests to increases one medical consultant (Doctor) in another consultant room and from the Figure 5.3, the waiting queue which appeared in the actual system and Experiment 1 are now gone as a consultant room is added.

After repeating few simulation runs with 14400s of experimental time, a constant number output patients can be found to be 94 persons. From the replications, the maximum time taken to treat a patient is taking 396.53s whilst the minimum treatment time is 311.06s. Therefore, it indicates that the patients are having their average treatment time of 354.53s, this alternative shows the waiting line of the service floor could be reduced efficiently and having a lower patient treatment time compares to the previous Experiment 1.

Table 5.3: The experimental results for Experiment 2.

Model		Replications					Average
		1	2	3	4	5	
Patient	Output	94	94	94	94	94	94
	Avg. Time	311.06	396.53	358.16	355.06	351.86	354.53

5.6 EXPERIMENT 3: REDUCTION OF WAITING AREA CAPACITY AND ADDITIONAL OF A MEDICAL CONSULTANT

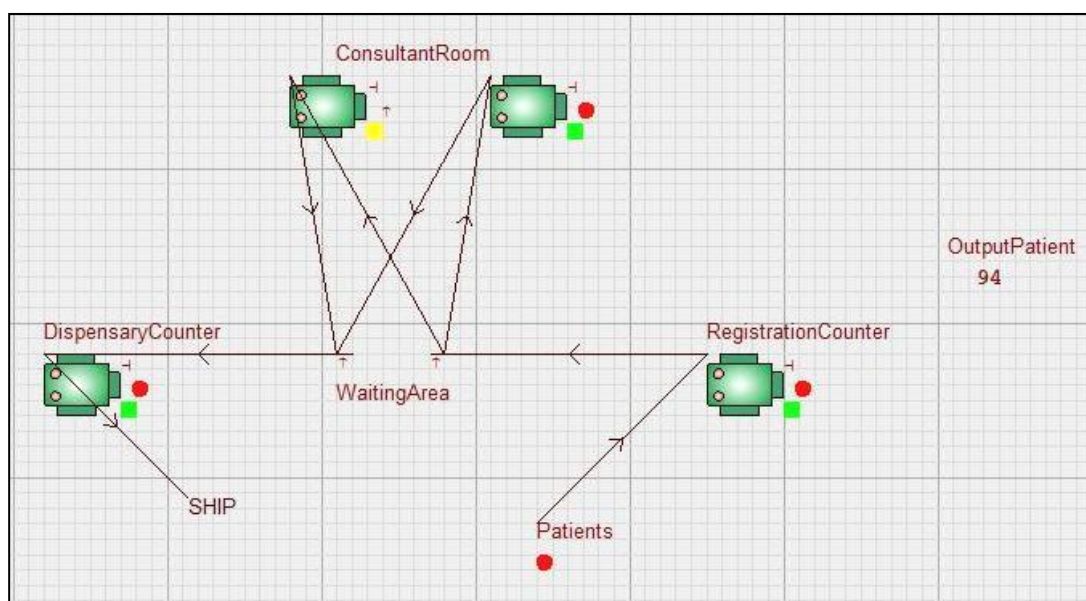


Figure 5.4: The simulation of Experiment 3.

This experiment can be describes as the combination of the both alternatives used in Experiment 1 and Experiment 2. The waiting area capacity has been reduced to 5 seats from its originally 27 seats and a consultant room is opened as one medical consultant is added in this layout.

As the simulation time is complete running, there are 5 results are being tabulated as in Table 5.4. Referring to the output patient number and the average treatment time of a patient, the readings are all similar to Table 5.3 from Experiment 2. The output patient number is 94 and the average time is 354.53s. This alternative is also another effective approach to minimize the waiting line in PKP.

Table 5.4: The experimental results for Experiment 3.

Model		Replications					Average
		1	2	3	4	5	
Patient	Output	94	94	94	94	94	94
	Avg. Time	311.06	396.53	358.16	355.06	351.86	354.53

5.7 RESULTS ANALYSIS

The statistical analysis for the actual and experimental output patients are being done by utilization of Minitab software. Kruskal-Wallis test is a type test under the non-parametric family to determine the group of output patients if the differences between the tested experimental groups are large. The H-value and P-value from the Figure 5.5 shows that the differences are significant among the groups with P-value of 0.003 and 0.001 where it indicates that hypothesis will not be rejected since P-value is smaller than 0.5.

Kruskal-Wallis Test on OutputPatient				
Alternatives	N	Median	Ave Rank	Z
Actual	5	80.00	5.5	-2.18
Experiment1	5	80.00	5.5	-2.18
Experiment2	5	94.00	15.5	2.18
Experiment3	5	94.00	15.5	2.18
Overall	20		10.5	
H = 14.29 DF = 3 P = 0.003				
H = 16.38 DF = 3 P = 0.001 (adjusted for ties)				

Figure 5.5: Concluded results in Kruskal-Wallis test on output patients.

After performing the Kruskal-Wallis test, one way ANOVA analysis is carried out with Hsu's MCB (Multiple Comparison with the Best) with family error of 10% and confidence level of 90%. From the results posted in the Figure 5.6, Experiment 1 has the upper value of 0.000 which indicates the efficiency on improving the output patients are less than Experiment 2 and experiment 3. Therefore, the best approach among the group are the Experiment 2 and Experiment 3 where they both sharing the same upper level value of 6.801.

Hsu's MCB (Multiple Comparisons with the Best)				
Family error rate = 0.1				
Critical value = 1.83				
Intervals for level mean minus largest of other level means				
Level	Lower	Center	Upper	
Actual	-20.201	-13.400	0.000	{-----*-----}
Experiment1	-20.201	-13.400	0.000	{-----*-----}
Experiment2	-6.801	0.000	6.801	{-----*-----}
Experiment3	-6.801	0.000	6.801	{-----*-----}
				-----+-----+-----+-----+
				-14.0 -7.0 0.0 7.0

Figure 5.6: The summary of one way ANOVA test.

5.8 ASSUMPTIONS FOR COST-EFFECTIVENESS ANALYSIS

Refers to Gold et al. (1996), Cost-effectiveness analysis (CEA) is considered the most appropriate method of comparing preventative health services from an economic point of view.

According to Tafazzoli et al. (2005), the basic purpose of CEA is to access the cost of healthcare resources dedicated to a healthcare intervention relative to the healthcare benefits that are produced by the same intervention. In this project, CEA is chosen as an appropriate tool that performs well in circumstances where the intervention is more costly and more effective than the suggested alternative. CEA can also show tradeoffs involved in choosing among various interventions.

Before starting the CEA, there are a few assumptions have to be made before proceeding to calculation. The assumptions are stated as below:

1. Experimental time is four hours.
2. Cycle time is recorded in second.
3. Treatment fees are not considered due to the healthcare service is given free by government.
4. Patients are available all the time.
5. The simulation is using machine as labour efficiency is 85%.

The experimental time for each suggested layout is four hours as the simulation time. Four hours of simulation running time is used because it is the busy time period for PKP out of its eight hours of operating hours where patients available all the time in these four hours of busy time.

Cycle time to run an experiment in WITNESS Simulation software are inserted in second as the data taken from the PKP are recorded in second. These data must be in the same unit when key in the machine parameter to avoid from standardizing error.

Besides that, treatments fees are not considered in this analysis due to the reason of medical services are supported by the government to the students and staff of UMP.

The simulation is using machine as labour efficiency is 85% which defining that a human is not able to operate as a machine as down time is a must. The mentioned down time refers to the possibility for an employee to excuse himself for wash room and having a short break during the fatigue condition.

5.8.1 Cost-effectiveness Analysis

Simulation Assumptions:

1. The experimental time is four hours.
2. Cycle time is recorded in second.
3. Treatment fees are not considered due to the healthcare service is given free by government.
4. Patients are available all the time.
5. The simulation is using machine as labour efficiency is 85%.

The calculation is made on this basis:

1. Doctor's salary per month = RM 8,000
2. Nurse's salary per month = RM 2,500
3. Driver's salary per month = RM 1,800
4. Waiting area capacity = 27 seats
5. Total patients per hour = 20 patients are served in an hour
6. Operating hour = 8 hours, 5 days per week

Table 5.5: Cost Estimation for Actual Service Floor Layout.

Cost Element	Cost per Month (RM)	Total Hours per Month	Cost per Hour (RM)
<u>Direct Equipment and Material Cost</u>			
Medical Tools	5,000	171.4	29.17
Medicine/Dose	25,800	171.4	150.53
<u>Direct Labour Cost</u>			
Doctor	8,000	171.4	46.68
Nurse	2,500	171.4	14.59
<u>Indirect Labour Cost</u>			
Driver	1,800	171.4	10.50
<u>Overhead Cost</u>			
Building Rental	600	171.4	3.50
Petrol	650	150.5	4.31
Furniture Cost	1600	171.4	9.33
Electricity	270	171.4	1.58
Water	140	171.4	0.82
Maintenance	1000	107.5	9.30
Cleaner	800	171.4	4.67
Total cost per hour			284.98
Cost for per patient			14.25

The calculation is made on this basis:

1. Doctor's salary per month = RM 8,000
2. Nurse's salary per month = RM 2,500
3. Driver's salary per month = RM 1,800
4. Waiting area capacity = 12 seats
5. Total patients per hour = 20 patients are served in an hour
6. Operating hour = 8 hours, 5 days per week

Table 5.6: Cost Estimation for Experiment 1.

Cost Element	Cost per Month (RM)	Total Hours per Month	Cost per Hour (RM)
<u>Direct Equipment and Material Cost</u>			
Medical Tools	5,000	171.4	29.17
Medicine/Dose	25,800	171.4	150.53
<u>Direct Labour Cost</u>			
Doctor	8,000	171.4	46.68
Nurse	2,500	171.4	14.59
<u>Indirect Labour Cost</u>			
Driver	1,800	171.4	10.50
<u>Overhead Cost</u>			

Building Rental	600	171.4	3.50
Petrol	650	150.5	4.31
Furniture Cost	711	171.4	4.15
Electricity	270	171.4	1.58
Water	140	171.4	0.82
Maintenance	1000	107.5	9.30
Cleaner	800	171.4	4.67
Total cost per hour			279.8
Cost for per patient			13.99

The calculation is made on this basis:

1. Doctor's salary per month = RM 8,000
2. Nurse's salary per month = RM 2,500
3. Driver's salary per month = RM 1,800
4. Waiting area capacity = 27 seats
5. Total patients per hour = 24 patients are served in an hour
6. Operating hour = 8 hours, 5 days per week

Table 5.7: Cost Estimation for Experiment 2.

Cost Element	Cost per Month (RM)	Total Hours per Month	Cost per Hour (RM)
<i><u>Direct Equipment and Material Cost</u></i>			
Medical Tools	5,000	171.4	29.17
Medicine/Dose	25,800	171.4	150.53
<i><u>Direct Labour Cost</u></i>			
Doctor	16,000	171.4	93.34
Nurse	2,500	171.4	14.59
<i><u>Indirect Labour Cost</u></i>			
Driver	1,800	171.4	10.50

<u>Overhead Cost</u>			
Building Rental	600	171.4	3.50
Petrol	650	150.5	4.31
Furniture Cost	1600	171.4	9.33
Electricity	270	171.4	1.58
Water	140	171.4	0.82
Maintenance	1000	107.5	9.30
Cleaner	800	171.4	4.67
Total cost per hour			331.64
Cost for per patient			13.82

The calculation is made on this basis:

1. Doctor's salary per month = RM 8,000
2. Nurse's salary per month = RM 2,500
3. Driver's salary per month = RM 1,800
4. Waiting area capacity = 5 seats
5. Total patients per hour = 24 patients are served in an hour
6. Operating hour = 8 hours, 5 days per week

Table 5.8: Cost Estimation for Experiment 3.

Cost Element	Cost per Month (RM)	Total Hours per Month	Cost per Hour (RM)
<u>Direct Equipment and Material Cost</u>			
Medical Tools	5,000	171.4	29.17
Medicine/Dose	25,800	171.4	150.53
<u>Direct Labour Cost</u>			
Doctor	16,000	171.4	93.34
Nurse	2,500	171.4	14.59
<u>Indirect Labour Cost</u>			

Driver	1,800	171.4	10.50
<u>Overhead Cost</u>			
Building Rental	600	171.4	3.50
Petrol	650	150.5	4.31
Furniture Cost	296	171.4	1.73
Electricity	270	171.4	1.58
Water	140	171.4	0.82
Maintenance	1000	107.5	9.30
Cleaner	800	171.4	4.67
Total cost per hour			324.04
Cost for per patient			13.50

From the cost-effectiveness analysis above, the actual layout cost estimation for treatment a patient is RM 14.25. For the Experiment 1 cost estimation table, RM 13.99 as treatment fee is needed to spend on a patient follow by Experiment 2 with RM 13.82. Lastly from the Experiment 3, RM 13.50 is the cost that needs to afford by government to treat a patient. These results are summarized in this following table:

Table 5.9: Summary of Output Patient per Hour and Treatment Cost per Patient.

Layout	Output patient/Hour (Patients)	Treatment Cost/Patient (RM)
<i>Actual</i>	20	14.25
<i>Experiment 1</i>	20	13.99
<i>Experiment 2</i>	24	13.82
<i>Experiment 3</i>	24	13.50

5.9 DISCUSSION

From the Table 5.9, we can observe that the actual service floor layout is producing the lowest output patient in an hour with highest treatment cost, this can be describes as the most in-efficiency layout comparing to other alternatives.

Meanwhile, the Experiment 1 which reducing the waiting area capacity from 27 seats to 12 seats does not performed well in increasing the output of patients number although it's reducing the average time if comparing to the actual layout which a patient needed to a complete cycle in receiving a medical treatment. However, the waiting line for this experiment does not showing any reduction from the simulation figure in Figure 5.2.

For Experiment 2, the output patient number has been increasing from 20 patients per hour to 24 patients per hour by adding one medical consultant in this experiment. In additional, the treatment cost that given to a single patient is lower than actual service floor layout by reduction of 3.11% and 1.23% compares to the Experiment 1.

The Experiment 3 which able to produce the result of 24 patients in an hour with average treatment time is 354.53s and lowest treatment cost of RM 13.50. This would be the best alternative suggested among the experimental layouts. Therefore, Experiment 3 can be identified as the most productivity efficiency service floor layout that had been suggested among the groups.

The summary of the output patients per hour and treatment cost that need to support a patient by government are plotted in the graphs below.

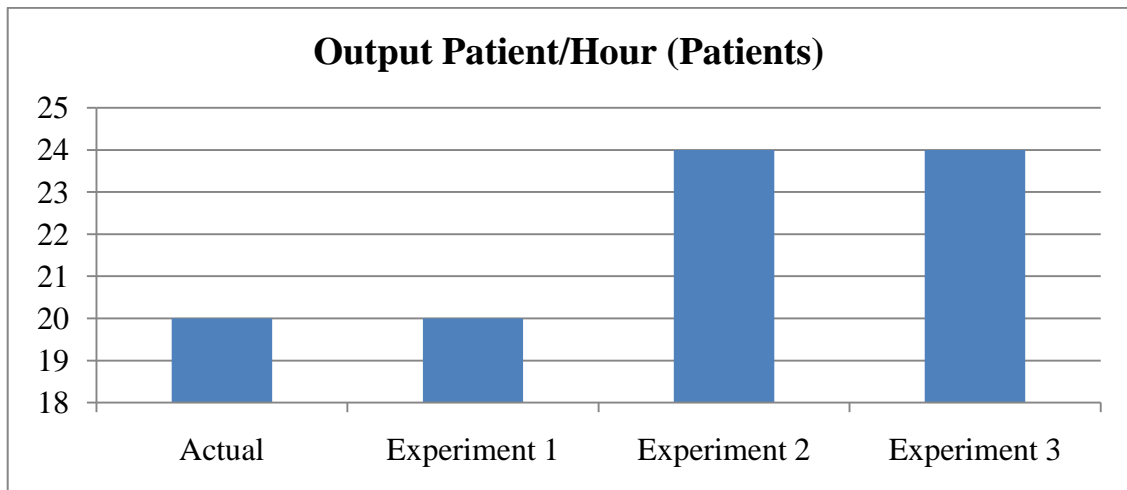


Figure 5.7: Graph of Output Patient per Hour.

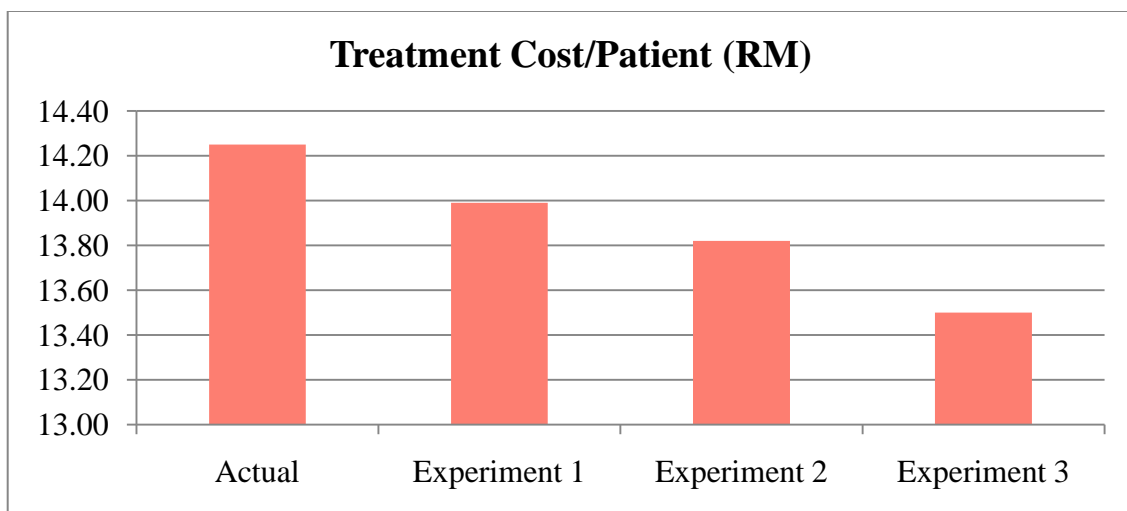


Figure 5.8: Graph of Treatment Cost per Patient.

5.10 CONCLUSIONS

Overall, this chapter has discussed the results of experiments run for each alternatives suggested in the earlier in the project. Thus, ANOVA test and cost-effectiveness analysis have also been done in order to select the most productivity excel service floor layout. The findings of this project will be concluded in the coming chapter.

CHAPTER 6

CONCLUSIONS

6.1 INTRODUCTION

The title for this chapter is conclusion as it generally summarizes the results that gained in along the previous chapters. By observing the output results from previous chapter, the most efficiency among those suggested alternatives will be proposed to the PKP. Further improvement and recommendations for this organization might also be included in this chapter.

6.2 PROJECT SUMMARY

This project started with searching for a suitable service floor layout to be study. The service floor layout might be a healthcare center, hotel reception counter or others. In this project, the PKP in UMP has been chosen for the purpose of conducting these experiments due to its lower productivity efficiency in producing a high output patient rate.

After selection of organization, evaluation of the existing service floor layout for PKP is carried out and existing problems are identified. These problems are included long queue line and time taken for treating a patient. Therefore, scopes and objectives are created in order to solve these problems.

In previous chapter, three approaches have been suggested to improve the output patient number for this service layout. These proposed methods are including reducing

the waiting area capacity, additional of one medical consultant and the last method is the combination of the earlier both methods.

6.3 FINDINGS

As the results being observed in chapter 5, the most productivity improvement method would definitely be the third alternative which suggests to combine the principle of Experiment 1 and Experiment 2. This alternative reduces the waiting area capacity and adding a medical consultant in the service floor layout that helps a lot in reducing the waiting line. The result of this alternative shows an incredible decrease of average treatment time of 73.5%, increases the output of patient served in an hour and most cost reduction.

Another two alternatives from Experiment 1 and Experiment 2 are rejected due to the low productivity performance which suggested by these alternatives. Experiment 1 that suggested reducing the waiting area capacity is the weakest alternative among these approaches where it only reduces the lead time of patient receiving treatment for 2.95%. This number of lead time reduction does not resulted significant changes of output patient produces in the service floor layout.

6.4 FUTURE RECOMMENDATIONS

This alternative from the Experiment 3 is applicable to other healthcare center which facing such similar problem. There are some approaches that available in order to increase productivity besides those suggested alternatives, which are rearranging the of the waiting area to shorten patient's walking distance from one to another destination and combining the dispensary and registration counter.

This method is practically reduces the time taken for a patient to move from a counter to another and increasing the satisfactory of patient from preventing them to stay longer in service floor. On the other hand, reduces the area space occupied by both dispensary and registration counter and make it into one is a method to reduce the cost

of building renovation and shorten the lead time for a patient that benefits both organization and customer demand.

6.5 CONCLUSIONS

As the result of the project is gained by running the design experiment, the objectives of this project have been achieved. The best alternative that selected has also proved to increase the productivity in the healthcare organization by utilization of WITNESS simulation software. As the project comes to an end, the selected alternative will be suggested to PKP for implementation.

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APPENDIX A: PROJECT GANTT CHART

[illegible]

APPENDIX B
EXAMPLE OF CALCULATING SAMPLE SIZE

Interval Time for Patient Entering Clinic (Process A)

Observations (n)	Time, s (x_i)	$(x_i - \bar{x})^2$
1	448.5	2277.7
2	462.3	1150.9
3	549.7	2859.6
4	531.3	1230.3
5	510.6	206.6
6	494.5	3.0
7	445.1	2618.9
8	496.8	0.3
9	547.4	2618.9
10	476.1	405.0
Total	4962.3	13371.1

By using 95% of confidence interval with $\pm 5\%$ of error, $t_{0.05} = 1.833$

Mean, $\bar{x} = x_i/10 = 4962.3/10 = 496.2$ s

Standard Deviation, $s = \sqrt{(x_i - \bar{x})^2 / n - 1} = \sqrt{13371.1 / 10 - 1} = 38.5$

Calculation for Sample Size needed, $n = (ts/k\bar{x})^2 = (1.833 \times 38.5 / 0.05 \times 496.2)^2$
 $= 8.1 \approx 9$

For the sample size, n calculated as above, at least 8 data are required to proceed to the next step of calculation. Since 10 data are collected and more than the required sample size. Therefore, data analysis will be proceed for this process A.

APPENDIX C
SUMMARY OF CYCLE TIME DATA AND SAMPLE SIZE

Observations (n)	Process Cycle Time (s)			
	A	BCD	EFGH	IJKL
1	448.5	51.2	179.9	131.5
2	462.3	47.4	178.6	140.1
3	549.7	51.3	197.5	117.0
4	531.3	51.2	195.6	147.5
5	510.6	49.0	174.8	138.6
6	494.5	52.9	201.1	135.5
7	445.1	46.4	173.1	123.4
8	496.8	48.7	181.8	145.2
9	547.4	54.7	182.0	146.0
10	476.1	51.8	152.8	133.3
\bar{x}	496.2	50.4	181.7	135.8
s	38.5	2.6	14.1	9.9
n	9	4	9	8

Process Cycle

A : Patients inter-arrival time

BCD : Waiting time for patients before receiving medical treatment/consultation

EFGH : Time taken for patients to receive medical treatment from doctor

IJKL : Time taken for patients to receive medical/dose instruction from dispensary counter

APPENDIX D: DATA ANALYSIS WITH CHI-SQUARE TEST

Process A: Patients inter-arrival time

X_i	$X_i - X_{avg}$	$(X_i - X_{avg})^2$	$(X_i - X_{avg})^2 / n - 1$
448.5	-46.0	2118.1	43.2
462.3	-32.2	1038.3	21.2
549.7	55.2	3044.5	62.1
531.3	36.8	1352.5	27.6
510.6	16.1	258.5	5.3
494.5	0.0	0.0	0.0
445.1	-49.5	2447.6	50.0
496.8	2.3	5.2	0.1
547.4	52.9	2796.0	57.1
476.1	-18.4	339.4	6.9
465.8	-28.8	827.9	16.9
508.3	13.8	189.8	3.9
484.2	-10.4	107.6	2.2
504.9	10.3	106.6	2.2
519.8	25.3	638.9	13.0
455.4	-39.1	1530.6	31.2
477.3	-17.3	298.4	6.1
519.8	25.3	638.9	13.0
452.0	-42.6	1812.5	37.0
531.3	36.8	1352.5	27.6
478.4	-16.1	260.0	5.3
525.6	31.0	962.7	19.6
424.4	-70.2	4924.2	100.5
547.4	52.9	2796.0	57.1
487.6	-6.9	47.9	1.0
475.0	-19.6	383.1	7.8
519.8	25.3	638.9	13.0
491.1	-3.5	12.1	0.2
458.9	-35.7	1272.6	26.0
465.8	-28.8	827.9	16.9
495.7	1.1	1.3	0.0
514.1	19.5	381.3	7.8
540.5	46.0	2113.9	43.1
489.9	-4.6	21.4	0.4
506.0	11.5	131.7	2.7
478.4	-16.1	260.0	5.3
492.2	-2.3	5.4	0.1
518.7	24.1	582.1	11.9

443.9	-50.6	2562.7	52.3
501.4	6.9	47.3	1.0
491.1	-3.5	12.1	0.2
480.7	-13.8	191.1	3.9
496.8	2.3	5.2	0.1
477.3	-17.3	298.4	6.1
487.6	-6.9	47.9	1.0
502.6	8.0	64.4	1.3
518.7	24.1	582.1	11.9
493.4	-1.2	1.4	0.0
529.0	34.5	1188.7	24.3
514.1	19.5	381.3	7.8
TOTAL			855.3

Number of data, $n = 50$; Average, $X_{\text{avg}} = 494.5$; Standard Deviation, $s = \sqrt{855.3} = 29.2$

Uniform Distribution

Cell (i)	Interval	Observed Frequency (X_1)	H_0 Probability	Expected Frequency (X_2)	$\frac{(X_2 - X_1)^2}{X_2}$
1	420.0-439.9	1	1/7	1.0	0.0
2	440.0-459.9	6	1/7	6.0	0.0
3	460.0-479.9	9	1/7	9.0	0.0
4	480.0-499.9	13	1/7	13.0	0.0
5	500.0-519.9	13	1/7	13.0	0.0
6	520.0-539.9	4	1/7	4.0	0.0
7	540.0-559.9	4	1/7	4.0	0.0
TOTAL		50			0.0

Degree of Freedom, $K-1 = 6$; Desired Significant Level, $\alpha = 0.05$

$$\chi^2_{6, 0.05} = 12.592$$

$$\chi^2_{6, \text{calc}} = 0.0$$

Since $\chi^2_{6, 0.05} > \chi^2_{6, \text{calc}}$; Accept

Exponential Distribution

Cell (i)	Interval	Observed Frequency (X_1)	$\alpha=1/\mu$	$(1-e^{-\alpha k})-(1-e^{-\alpha j})$	Expected Frequency (X_2)	$\frac{(X_2 - X_1)^2}{X_2}$
1	420.0-439.9	1	0.0020	0.0168	0.1179	6.6011
2	440.0-459.9	6	0.0020	0.0162	0.6796	41.6550
3	460.0-479.9	9	0.0020	0.0155	0.9777	65.8255
4	480.0-499.9	13	0.0020	0.0149	1.3588	99.7322
5	500.0-519.9	13	0.0020	0.0143	1.3058	104.7324
6	520.0-539.9	4	0.0020	0.0138	0.3858	33.8538
7	540.0-559.9	4	0.0020	0.0132	0.3709	35.5138
TOTAL		50				387.9137

j = class lower boundary; k = class upper boundary; $\mu = X_{\text{avg}}$

Degree of Freedom, $K-2 = 5$; Desired Significant Level, $\alpha = 0.05$

$$\chi^2_{5, 0.05} = 11.070$$

$$\chi^2_{5, \text{calc}} = 387.9137$$

Since $\chi^2_{5, \text{calc}} > \chi^2_{5, 0.05}$; Reject

Normal Distribution

Cell (i)	Interval	Observed Frequency (X_1)	Area (A_i)	Expected Frequency (X_2)	$\frac{(X_2 - X_1)^2}{X_2}$
1	420.0-439.9	1	0.0253	0.1771	3.8236
2	440.0-459.9	6	0.0883	3.7086	1.4158
3	460.0-479.9	9	0.1895	11.9385	0.7233
4	480.0-499.9	13	0.2629	23.9239	4.9880
5	500.0-519.9	13	0.2325	21.1575	3.1452
6	520.0-539.9	4	0.1316	3.6848	0.0270
7	540.0-559.9	4	0.0469	1.3132	5.4972
TOTAL		50			19.6200

Degree of Freedom, $K-3 = 4$; Desired Significant Level, $\alpha = 0.05$

$$\chi^2_{4, 0.05} = 9.488$$

$$\chi^2_{4, \text{calc}} = 19.6200$$

Since $\chi^2_{4, \text{calc}} > \chi^2_{4, 0.05}$; Reject

Process BCD: Waiting time for patients before receiving medical treatment or consultation

X_i	$X_i - X_{avg}$	$(X_i - X_{avg})^2$	$(X_i - X_{avg})^2 / n - 1$
51.2	-0.3	0.1	0.0
47.4	-4.1	16.9	0.3
51.3	-0.2	0.0	0.0
51.2	-0.3	0.1	0.0
49.0	-2.4	5.8	0.1
52.9	1.4	2.0	0.0
46.4	-5.1	25.6	0.5
48.7	-2.8	7.9	0.2
54.7	3.2	10.4	0.2
51.8	0.4	0.1	0.0
51.6	0.1	0.0	0.0
51.6	0.1	0.0	0.0
48.9	-2.6	6.5	0.1
53.3	1.8	3.4	0.1
50.7	-0.7	0.5	0.0
53.6	2.1	4.6	0.1
49.3	-2.2	4.8	0.1
49.6	-1.9	3.5	0.1
52.7	1.2	1.4	0.0
55.0	3.6	12.7	0.3
54.3	2.8	8.1	0.2
50.6	-0.8	0.7	0.0
53.3	1.8	3.2	0.1
48.6	-2.9	8.5	0.2
52.5	1.1	1.2	0.0
51.4	-0.1	0.0	0.0
48.3	-3.2	9.9	0.2
50.3	-1.2	1.3	0.0
51.6	0.1	0.0	0.0
54.5	3.1	9.4	0.2
54.0	2.6	6.5	0.1
47.1	-4.4	19.4	0.4
51.2	-0.2	0.1	0.0
53.7	2.3	5.1	0.1
53.4	2.0	3.9	0.1
54.3	2.8	7.8	0.2
50.3	-1.2	1.3	0.0
51.1	-0.3	0.1	0.0

52.7	1.3	1.6	0.0
50.2	-1.3	1.7	0.0
54.3	2.9	8.3	0.2
53.1	1.6	2.7	0.1
54.3	2.8	8.1	0.2
53.5	2.0	4.2	0.1
51.1	-0.4	0.2	0.0
52.2	0.8	0.6	0.0
49.4	-2.1	4.4	0.1
49.2	-2.3	5.2	0.1
50.2	-1.2	1.5	0.0
51.7	0.3	0.1	0.0
TOTAL			4.7

Number of data, $n = 50$; Average, $X_{\text{avg}} = 51.5$; Standard Deviation, $s = \sqrt{4.7} = 2.2$

Uniform Distribution

Cell (i)	Interval	Observed Frequency (X_1)	H_0 Probability	Expected Frequency (X_2)	$\frac{(X_2 - X_1)^2}{X_2}$
1	46.0-47.9	3	1/5	3.0	0.0
2	48.0-49.9	9	1/5	9.0	0.0
3	50.0-51.9	18	1/5	18.0	0.0
4	52.0-53.9	12	1/5	12.0	0.0
5	54.0-55.9	8	1/5	8.0	0.0
TOTAL		50			0.0

Degree of Freedom, $K-1 = 4$; Desired Significant Level, $\alpha = 0.05$

$$\chi^2_{4, 0.05} = 9.488$$

$$\chi^2_{4, \text{calc}} = 0.0$$

Since $\chi^2_{4, 0.05} > \chi^2_{4, \text{calc}}$; Accept

Exponential Distribution

Cell (i)	Interval	Observed Frequency (X_1)	$\alpha=1/\mu$	$(1-e^{-\alpha k})-(1-e^{-\alpha j})$	Expected Frequency (X_2)	$\frac{(X_2 - X_1)^2}{X_2}$
1	46.0-47.9	3	0.0194	0.0148	0.2223	34.7054
2	48.0-49.9	9	0.0194	0.0143	0.6417	108.8689
3	50.0-51.9	18	0.0194	0.0137	1.2342	227.7588
4	52.0-53.9	12	0.0194	0.0132	0.7918	158.6651
5	54.0-55.9	8	0.0194	0.0127	0.5075	110.6109
TOTAL		50				640.6091

j = class lower boundary; k = class upper boundary; $\mu = X_{\text{avg}}$

Degree of Freedom, $K-2 = 3$; Desired Significant Level, $\alpha = 0.05$

$$\chi^2_{3, 0.05} = 7.815$$

$$\chi^2_{3, \text{calc}} = 640.6091$$

Since $\chi^2_{3, \text{calc}} > \chi^2_{3, 0.05}$; Reject

Normal Distribution

Cell (i)	Interval	Observed Frequency (X_1)	Area (A_i)	Expected Frequency (X_2)	$\frac{(X_2 - X_1)^2}{X_2}$
1	46.0-47.9	3	0.0443	0.6645	8.2085
2	48.0-49.9	9	0.1768	7.956	0.1370
3	50.0-51.9	18	0.3231	29.079	4.2211
4	52.0-53.9	12	0.2711	16.266	1.1188
5	54.0-55.9	8	0.1043	4.172	3.5124
TOTAL		50			17.1978

Degree of Freedom, $K-3 = 2$; Desired Significant Level, $\alpha = 0.05$

$$\chi^2_{2, 0.05} = 5.991$$

$$\chi^2_{2, \text{calc}} = 17.1978$$

Since $\chi^2_{2, \text{calc}} > \chi^2_{2, 0.05}$; Reject

Process EFGH: Time taken for patients to receive medical treatment from doctor

X_i	$X_i - X_{avg}$	$(X_i - X_{avg})^2$	$(X_i - X_{avg})^2 / n - 1$
179.9	-0.4	0.2	0.0
178.6	-1.7	3.0	0.1
197.5	17.2	296.4	6.0
195.6	15.3	235.4	4.8
174.8	-5.5	30.1	0.6
201.1	20.9	434.8	8.9
173.1	-7.2	52.0	1.1
181.8	1.5	2.2	0.0
182.0	1.7	2.8	0.1
152.8	-27.5	756.0	15.4
180.8	0.5	0.3	0.0
173.6	-6.7	44.5	0.9
182.0	1.7	2.7	0.1
184.8	4.5	20.0	0.4
189.1	8.8	77.2	1.6
176.7	-3.6	13.0	0.3
182.6	2.3	5.5	0.1
169.2	-11.1	122.4	2.5
171.0	-9.3	86.1	1.8
185.6	5.3	28.1	0.6
166.1	-14.2	201.3	4.1
174.7	-5.6	31.5	0.6
182.3	2.0	4.1	0.1
175.6	-4.7	22.1	0.5
176.2	-4.1	16.9	0.3
182.4	2.1	4.3	0.1
185.3	5.0	25.5	0.5
185.4	5.1	25.7	0.5
169.2	-11.1	123.4	2.5
193.2	12.9	167.1	3.4
185.8	5.5	30.7	0.6
190.5	10.2	104.3	2.1
187.6	7.3	52.8	1.1
177.7	-2.6	6.7	0.1
187.5	7.2	52.5	1.1
173.6	-6.7	45.1	0.9
179.4	-0.9	0.9	0.0
170.6	-9.7	94.9	1.9

183.3	3.0	8.9	0.2
173.1	-7.2	52.3	1.1
177.5	-2.8	7.7	0.2
187.1	6.8	46.5	0.9
181.5	1.2	1.5	0.0
178.9	-1.4	1.9	0.0
180.7	0.4	0.2	0.0
175.8	-4.5	20.3	0.4
179.5	-0.8	0.6	0.0
182.1	1.8	3.3	0.1
174.5	-5.8	34.0	0.7
185.1	4.8	23.3	0.5
TOTAL			69.9

Number of data, $n = 50$; Average, $X_{\text{avg}} = 180.3$; Standard Deviation, $s = \sqrt{69.9} = 8.4$

Uniform Distribution

Cell (i)	Interval	Observed Frequency (X_1)	H_0 Probability	Expected Frequency (X_2)	$\frac{(X_2 - X_1)^2}{X_2}$
1	150.0-159.9	1	1/6	1.0	0.0
2	160.0-169.9	3	1/6	3.0	0.0
3	170.0-179.9	20	1/6	20.0	0.0
4	180.0-189.9	21	1/6	21.0	0.0
5	190.0-199.9	4	1/6	4.0	0.0
6	200.0-209.9	1	1/6	1.0	0.0
TOTAL		50			0.0

Degree of Freedom, $K-1 = 5$; Desired Significant Level, $\alpha = 0.05$

$$\chi^2_{5, 0.05} = 11.070$$

$$\chi^2_{5, \text{calc}} = 0.0$$

Since $\chi^2_{5, 0.05} > \chi^2_{5, \text{calc}}$; Accept

Exponential Distribution

Cell (i)	Interval	Observed Frequency (X_1)	$\alpha=1/\mu$	$(1-e^{-\alpha k})-(1-e^{-\alpha j})$	Expected Frequency (X_2)	$\frac{(X_2 - X_1)^2}{X_2}$
1	150.0-159.9	1	0.0055	0.0232	0.1393	5.3189
2	160.0-169.9	3	0.0055	0.0220	0.3955	17.1538
3	170.0-179.9	20	0.0055	0.0208	2.4948	122.8283
4	180.0-189.9	21	0.0055	0.0197	2.4804	138.2718
5	190.0-199.9	4	0.0055	0.0186	0.4471	28.2298
6	200.0-209.9	1	0.0055	0.0176	0.1058	7.5588
TOTAL		50				319.3613

j = class lower boundary; k = class upper boundary; $\mu = X_{\text{avg}}$

Degree of Freedom, $K-2 = 4$; Desired Significant Level, $\alpha = 0.05$

$$\chi^2_{4, 0.05} = 9.488$$

$$\chi^2_{4, \text{calc}} = 319.3613$$

Since $\chi^2_{4, \text{calc}} > \chi^2_{4, 0.05}$; Reject

Normal Distribution

Cell (i)	Interval	Observed Frequency (X_1)	Area (A_i)	Expected Frequency (X_2)	$\frac{(X_2 - X_1)^2}{X_2}$
1	150.0-159.9	1	0.0073	0.0438	20.8749
2	160.0-169.9	3	0.0997	1.7946	0.8096
3	170.0-179.9	20	0.3708	44.496	13.4856
4	180.0-189.9	21	0.3889	49.0014	16.0011
5	190.0-199.9	4	0.1152	2.7648	0.5518
6	200.0-209.9	1	0.0092	0.0552	16.1711
TOTAL		50			67.8942

Degree of Freedom, $K-3 = 3$; Desired Significant Level, $\alpha = 0.05$

$$\chi^2_{3, 0.05} = 7.815$$

$$\chi^2_{3, \text{calc}} = 67.8942$$

Since $\chi^2_{3, \text{calc}} > \chi^2_{3, 0.05}$; Reject

Process IJKL: Time taken for patients to receive medical/dose instruction from dispensary counter

X_i	$X_i - X_{avg}$	$(X_i - X_{avg})^2$	$(X_i - X_{avg})^2 / n - 1$
131.5	-1.5	2.4	0.0
140.1	7.1	50.3	1.0
117.0	-16.1	257.9	5.3
147.5	14.4	207.8	4.2
138.6	5.5	30.8	0.6
135.5	2.5	6.1	0.1
123.4	-9.6	92.8	1.9
145.2	12.2	148.2	3.0
146.0	13.0	167.8	3.4
133.3	0.2	0.1	0.0
130.0	-3.0	9.0	0.2
139.9	6.9	47.4	1.0
133.7	0.7	0.5	0.0
136.3	3.2	10.3	0.2
142.5	9.4	89.2	1.8
129.6	-3.5	12.0	0.2
119.3	-13.7	189.0	3.9
136.6	3.5	12.6	0.3
138.8	5.7	32.7	0.7
135.4	2.3	5.4	0.1
128.2	-4.8	23.3	0.5
140.8	7.7	59.6	1.2
148.3	15.3	233.7	4.8
119.6	-13.4	179.7	3.7
130.1	-2.9	8.4	0.2
128.4	-4.7	22.0	0.4
136.9	3.8	14.6	0.3
132.3	-0.7	0.5	0.0
130.0	-3.1	9.3	0.2
144.2	11.1	123.5	2.5
137.5	4.4	19.5	0.4
137.8	4.7	22.3	0.5
129.9	-3.1	9.8	0.2
130.4	-2.7	7.2	0.1
133.9	0.9	0.8	0.0
130.7	-2.3	5.4	0.1
117.7	-15.4	236.2	4.8
125.5	-7.5	56.8	1.2

129.0	-4.0	16.0	0.3
129.2	-3.9	15.0	0.3
139.5	6.5	42.0	0.9
121.8	-11.3	126.6	2.6
140.4	7.3	53.6	1.1
124.7	-8.4	69.8	1.4
128.4	-4.7	21.9	0.4
127.3	-5.7	32.6	0.7
139.9	6.8	46.7	1.0
138.8	5.8	33.5	0.7
121.4	-11.7	135.9	2.8
129.5	-3.6	12.8	0.3
TOTAL			61.5

Number of data, $n = 50$; Average, $X_{\text{avg}} = 133.0$; Standard Deviation, $s = \sqrt{61.5} = 7.8$

Uniform Distribution

Cell (i)	Interval	Observed Frequency (X_1)	H_0 Probability	Expected Frequency (X_2)	$\frac{(X_2 - X_1)^2}{X_2}$
1	115.0-119.9	4	1/7	4.0	0.0
2	120.0-124.9	4	1/7	4.0	0.0
3	125.0-129.9	10	1/7	10.0	0.0
4	130.0-134.9	10	1/7	10.0	0.0
5	135.0-139.9	13	1/7	13.0	0.0
6	140.0-144.9	5	1/7	5.0	0.0
7	145.0-149.9	4	1/7	4.0	0.0
TOTAL		50			0.0

Degree of Freedom, $K-1 = 6$; Desired Significant Level, $\alpha = 0.05$

$$\chi^2_{6, 0.05} = 12.592$$

$$\chi^2_{6, \text{calc}} = 0.0$$

Since $\chi^2_{6, 0.05} > \chi^2_{6, \text{calc}}$; Accept

Exponential Distribution

Cell (i)	Interval	Observed Frequency (X_1)	$\alpha=1/\mu$	$(1-e^{-\alpha k})-(1-e^{-\alpha j})$	Expected Frequency (X_2)	$\frac{(X_2 - X_1)^2}{X_2}$
1	115.0-119.9	4	0.0075	0.0152	0.4264	29.9464
2	120.0-124.9	4	0.0075	0.0147	0.4107	31.3656
3	125.0-129.9	10	0.0075	0.0141	0.9888	82.1266
4	130.0-134.9	10	0.0075	0.0136	0.9521	85.9787
5	135.0-139.9	13	0.0075	0.0131	1.1920	116.9695
6	140.0-144.9	5	0.0075	0.0126	0.4414	47.0857
7	145.0-149.9	4	0.0075	0.0122	0.3404	39.3406
TOTAL		50				432.8130

j = class lower boundary; k = class upper boundary; $\mu = X_{avg}$

Degree of Freedom, $K-2 = 5$; Desired Significant Level, $\alpha = 0.05$

$$\chi^2_{5, 0.05} = 11.070$$

$$\chi^2_{5, calc} = 432.8130$$

Since $\chi^2_{5, calc} > \chi^2_{5, 0.05}$; Reject

Normal Distribution

Cell (i)	Interval	Observed Frequency (X_1)	Area (A_i)	Expected Frequency (X_2)	$\frac{(X_2 - X_1)^2}{X_2}$
1	115.0-119.9	4	0.0361	1.0108	8.8398
2	120.0-124.9	4	0.1017	2.8476	0.4664
3	125.0-129.9	10	0.1931	13.517	0.9151
4	130.0-134.9	10	0.2428	16.996	2.8797
5	135.0-139.9	13	0.208	18.928	1.8566
6	140.0-144.9	5	0.1211	4.2385	0.1368
7	145.0-149.9	4	0.0468	1.3104	5.5204
TOTAL		50			20.6148

Degree of Freedom, $K-3 = 4$; Desired Significant Level, $\alpha = 0.05$

$$\chi^2_{4, 0.05} = 9.488$$

$$\chi^2_{4, calc} = 20.6148$$

Since $\chi^2_{4, calc} > \chi^2_{4, 0.05}$; Reject

APPENDIX E
ACTUAL OUTPUT PATIENT

Actual Daily Output Patient

74	77	76	84	78
78	75	81	82	79
68	80	80	79	81
72	73	78	77	69
81	81	74	75	79

Average, $\bar{x} = 1931/25$
= 77.24
 ≈ 78 patients