EVALUATING THE PERFORMANCE OF THE OPERATION AT THE SAWMILL PRODUCTION COMPANY

TENG LIK CHING

BACHELOR OF INDUSTRIAL TECHNOLOGY MANAGEMENT WITH HONS

UNIVERSITY MALAYSIA PAHANG

EVALUATING THE PERFORMANCE OF THE OPERATION AT THE SAWMILL PRODUCTION COMPANY

TENG LIK CHING (PC 10046)

Thesis submitted in fulfillment of the requirements for the award of the Bachelor of Industrial Technology Management with Hons

Faculty of Technology

UNIVERSITI MALAYSIA PAHANG

2013

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project report and in my opinion this report is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Industrial Technology Management with Honor.

Signature:
Name of Supervisor:
Position:
Date:

STUDENT'S DECLARATION

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

Signature:
Name:
ID Number:
Date:

DEDICATION

This thesis is dedicated to my parents and friends who support me all the way during my study.

I would like to dedicate this thesis to my supervisors, Professor Razman bin Mat Tahar who give me a lots of advice and suggestion throughout my study.

Finally, I want to dedicate this study to Principal Alliance Pallet as well.

ACKNOWLEDGEMENTS

I am thankful and would like to express my sincere gratitude to my supervisor Professor Razman bin Mat Tahar in providing his germinal ideas, invaluable guidance, continuous encouragement and constant support in succeeding this study. Professor has always impressed me with his professional in which it relates to this study and his belief that a PHD program is only a start of a life-long learning experience. I appreciate his advices during the time of my study. He advises me that this study's purpose is not only to fulfill the final year project but also for the future use which may relate to my career. I also sincerely thanks for Professor in spending him precious time in conducting discussion, guiding me, and correcting my mistakes.

My sincere thanks also go to all my course mates who share their knowledge with me in writing and conducting my study. There are many obstacles I faced during this study, but I manage to keep this on until I manage to finish the study. This is because of the advices given by a precious friend in UMP.

I acknowledge my sincere indebtedness and gratitude to my parents for the love, dream and sacrifice throughout my life. It is hard to express out all my appreciation for their devotion, faith and support in my ability to succeed my goals.

ABSTRACT

In this study, it discusses about evaluating the performance of the operation at the sawmill production company. The scope of this study is focusing on the production process in sawmill company. The time frame covered is one year it is in the year of 2013. This study is conducted by using the ARENA simulation software to simulate the modeled process in the simulation software. It is a quantitative study in which the performance is measured by the productivity for the whole system of sawmill. The reducing of the waiting time in the bottleneck station able to provide an improvement in the sawmill production process.

Keywords: Cycle Time, Average Waiting Time, Utilization, ARENA Software, Simulation.

ABSTRAK

Kajian ini membincangkan tentang penilaian prestasi operasi di syarikat kilang papan. Skop kajian ini memberi tumpuan pada process pengeluaran di kilang papan. Tempoh masa yang diliputi adalah satu tahun pada tahun 2013. Kajian ini menggunakan perisian simulasi ARENA untuk menjalankan proses simulation pada model yang telah dibina dalam perisian simulasi. Kajian ini adalah kajian kuantitatif di mana prestasi diukur dengan produktiviti dalam keseluruhan sistem pengilangan papan. Pengurangan masa menunggu di stesen kesesakan dapat membantu dalam peningkatan proses pengeluaran kilang papan

Kata kunci: Masa Kitaran, Purata Masa Menunggu, Pengunaan Sumber ,ARENA Perisian, Simulasi

TABLE OF CONTENTS

LIST OF Tables

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This chapter provides an overview of the study and outlines its scope. The background of study of this research is to evaluate the performance of the operation at the sawmill production company. This chapter will cover the problem statement, research objective, and research question. Moreover, scope of study, significance of study, and operational definition term also will be proposed through this chapter. The expected result also will be explained in the last part of the chpter1.

1.2 BACKGROUND OF STUDY

Wang, Zhao and Zheng(2005) descried the available of resources and the machines capacities in the system are affect the production system performance such as the circle time, average delay and throughput. Bottleneck is one of the constraint parts on production system, because it can make the whole operation chain become slow down. Wang, Zhao and Zheng also define the system bottleneck based of the Performance in Processing (PIP) as the measurement instrument of system performance to calculate the capacity of workload and average waiting time of the system. Therefore, to improve the performance of the system, it is important to improve the bottlenecks.

In operation management, bottleneck happen in continuously manufacturing when having a backup in one part of the sequence. Bottleneck can be detected by measuring the production level at each step and by searching at each sequence of the single process. The initial cause of the bottleneck is when certain sequence has a low production level. (Clark, n.d)

According to Krajewski, Ritzman, and Malhotra (2010), bottleneck generally will occur when the workstation in a process has the highest workload, or highest total time per unit processed. To maintain the bottleneck capacity, the idle time at the bottlenecks should be minimize, which are cause the delays in the system and the bottleneck also should has all resources to stay busy.

Goldman (n.d) stated a bottleneck is occurring when the production process capacity is lower than demand placed above the operation. The bottleneck operation should keep running during the employees rest or break time to increases the operation efficiency. It is because the concept of bottlenecks and ‘throughput’ are to maximize the operation efficiency and reduce the negative effects of bottleneck in the operation. Although balancing the operation with the bottleneck cannot increase the throughput, but it can decrease the long queues and work-in-process before the bottleneck. Unnecessary product can be eliminated by balancing the operation to have the better production management.

Simulation software is a technological method which have provides the high agility and integration capabilities which important for product design, development and manufacturing efficiency. (Murphy, and Perera, 2002) A simulation can look and acts like as real life process. Simulation is an accurate computer model which can simulate everything such as running a factory assembly line, or the day-to-day operation of a bank. Usually, simulation is using to test the changing in a process, without taking risk when making the changes in their real process. Simulation can assist people to improve their performance by looking at where a queue of work has accumulate, how equipment and staff are being utilized and how long the case take, then the problem should be solve appropriately. Simulation is an important instrument to provide a way in which alternative, policies and plan can be evaluated without doing an experiment on a real system. These methods may help the organization to save cost, reduce time-consuming or can be prohibited simply unpractical to do.

According to Simpson (n.d), sawmill product is used in papermaking, home renovation, construction and etc. Although the main operation of sawmill company is to produce board and timbers, but it also produce the waste such as the bark and saw dust. Sawmill is an equipment which using to cut log. The log is sawed into standard-sized of timbers. Usually, it has three types of saws by using the equipment, which are circular saw, band saw and log gang saw. The capacity of a large sawmill can reach to several hundred thousand board feet per day. (The Columbia Electronic Encyclopedia, 2004)

This study will conduct in Principal Alliance Pallet. A sawmill company allocated at Gemas, Negeri Sembilan. The product produce by this company is timber and wastes. The workers work for one shift a day. Their working hours are 8 hours within 1 hour of rest. The working days are 5 days/week. This company want to improve their operation performance to more productive but there have some bottleneck happen at the operation process, so this study is conducted to help the company to identify the bottleneck area and improve the company operation performance.

1.3 PROBLEM STATEMENT

According to Lee (n.d), bottlenecks are happen when the production level at one station is higher than the subsequent station can catch up, will causing the production line become slowdown. Moore (n.d), emphasized if the bottlenecks point move from one station to another station, the process will more difficult and typical to have the perfect balance. However, this problem still can be solving by define the bottleneck areas and increase the capacity to the maximum level at the slowest bottleneck area.

Bottleneck will make the organization to lost profit or increasing the unnecessary expenses in several ways, which when the operation lost productivity because of employees are unable to work at bottleneck area. When order cannot be fulfilled and dissatisfied customer might cause them look for other company. Lee (n.d)

According to Clark (n.d), a bottleneck has a seriously effect on the efficiency of production. The part before the bottleneck needs to slow down their production because subsequent area cannot handle the capacity. While, the station following the bottlenecks' is operating below their capacity because they do not receive enough input to operate at full capacity. A bottleneck can be solved by adjusting the production level in the sequence where the critical area happens. It might be achieved by installing additional machine in parallel to increase the capacity or increasing the labor. If it is impossible to increase the production in that area, it may be more efficient to reduce production capabilities in the other areas to create efficiency.

Principal Alliance Pallet plan to receive more customer order, since the demand of the timber are increases in this few years. However, they are concern if they cannot satisfy the customer order because the production amount is low. The lower amount of throughput in production is difficult for them to fulfill the large amount of customer order in the short period. Normally, their customer needed to wait two week to receive their order. Two week is not the short period for them to wait. The lower productivity in this company may be caused by the bottleneck happen in the production flow since their production process are not smooth then it will affect the company performance. Therefore, this study will be conduct to identify the bottleneck area in the sawmill production flow of Principal Alliance Pallet. Arena simulation modeling method will be using in this study to assists the company to find bottleneck station in the production process. The company might have an effective operation if those able to reduce the waiting time at the bottleneck part.

1.4 RESEARCH OBJECTIVE

The objectives of this study were:

i. To identify the bottlenecks at the company's operation.
ii. To measure the waiting time at these bottlenecks.
iii. To propose an improvement of this operations.

1.5 RESEARCH QUESTION

To achieve the objectives of this study, the following questions were been asked:

i. Which station is the bottleneck station?
ii. How to reduce the waiting time at these bottlenecks?
iii. What suggestions can be purposed to improve the company production operation based on the assess result?

1.6 SCOPE OF STUDY

Since this research is carrying to evaluate the operation performance at the sawmill production, so this study will be conduct in a sawmill product manufacturing company, Principal Alliance Pallet, in Gemas, Negeri Sembilan. The scope of this research will limited to the staffs in the Principle Alliance Pallet who were currently worked at this company and familiar with the production process.

This study is more focus on the bottlenecks problem in the company operation process and to reduce the waiting time at this bottlenecks' station. An observation will be conduct during the site visit activities to help in collecting data, and then the simulation method will be using to identify the bottleneck station in the process. The observation will doing directly through the operation process. Therefore, after getting the data, a simulation model will developed to help in running the simulation software to identify the bottleneck in the workstation. Then a model experiment through scenario will be conducted to find the solution to minimise the waiting time at the bottleneck.

1.7 SIGNIFICANCE OF STUDY

The significance of this study is to investigate the problem during the operation process at sawmill production company, which has influence the productivity and effectiveness of the production process. This research can be used as a guideline or reference for the company to improve their operation performance. The finding of this study were important to help the company to have the smoothly production process. The information obtained through this study will provide strategies for the company to overcome the bottlenecks problems. Through this research, the bottlenecks station in the production process will be identified by using simulation method. Simulation system will help the company to do the more accurate decision to have the more efficient production flow with reduce the waiting time or increase the speed at these bottlenecks workstation. This study assists the company to save the production time, increase the operation capacity, and improve the efficiency of production process flow.

1.8 OPERATIONAL DEFINITION

Performance:

Performance is defined as the action, task or operation in the terms of how successful it is performed. Performance also can used to measure the capabilities of a machine and product in particular conditions.

Sawmill:

The Columbia Encyclopedia, 6th ed. (2012), described sawmill as the equipment or installation which to cut logs, and then sawed into standard-sized boards and timbers. Generally, it has three types of saws by using the equipment: the circular saw, band saw, and log gang saw. A large sizes of sawmill is possible to have a capacity of several hundred thousand board feet per day.

Production bottleneck:

According to investopedia (n.d), production bottlenecks is a point in the production flow which congestion in a system that happens when workloads arrive at that station more quickly than station can handle them. The inefficiencies of bottlenecks will create a queue and a longer cycle time in the system, which was limit the production system performance. The bottleneck system will have output and throughput.

Simulation:

Smith (1998) defined:

"Simulation is a process of designing a model of a real or imagined system and conducting the experiments by the model. The purpose of simulation experiments is to understand the behavior of the system or evaluate strategies for the operation of the system."

1.9 EXPECTED RESULT

The expected result will focus on to get as much as possible of information to answer the research questions. The expectation of this study is to identifying the bottleneck station in the production process. The longer waiting time in the bottleneck will cause the ineffectiveness of operation performance. In this research, simulation method will be using to identify the bottleneck station and to find the appropriate and suitable solution to reduce the waiting time at the bottleneck station.

Therefore, the expected of this research is to find the problem and try to solve the problem by using the simulation method to improve the company operation performance. By reducing the waiting time in bottleneck station is expected to help the company to improve the production performance which maximum the production capacity and to increase the efficiency process flow.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of the literature review is to convey the knowledge and to provide more detail information about this research topic. This chapter explains about operation performance, bottleneck and sawmill company operation. It acts as guidance for the research objective in this study. The strategy which writers used as a way to begin the literature review proceeded from the general, wider view of the research to the specific problem.

2.2 SAWMILL OPERATION

Sawmill operation is the process of cutting logs into timber. The process includes the cross cutting, debarking, sawing, grading, sorting and packaging. Logs is the basic raw material of sawmill. Although, lumber is the main product of the sawmill operation, but it also produce the by-product such as wood chip, sawdust and residual bark to gain profit. The product is graded into high quality product and low quality product. There have the different size of lumber, according the size specification to meet the customer need and demand.

Zhang (1993) describes sawmill operation is the process of breakdown logs into lumber. Sawmill operation is different from other manufacturing process, because it is no assembly processes. There is only the reduction of the raw material into smaller dimensions. The sawmill product are transform the logs into lumber and by-product. Log is the basic raw material of sawmill. There have two main factor affecting the sawmill performance, which is log throughput and log breakdown. The log throughput is a machine utilization and material flow in sawmills, the higher throughput will affects the mill profit. While, the effect of log breakdown is simpler compare with throughput, because it is define as the higher timber recovery, the higher the income.

According to Sohrabi (2012), there have two classification of sawmill product, which are high-value product and low-value products. High quality lumber pieces are the high-value product, while the low-value product includes the lower quality lumber pieces, wood chips, sawdust and residual bark. The quality of lumber pieces is ranking through grade. The grading is based on the number and location of internal defects been the final dimensions. Although the high-value products are more valuable however, the low-value product also important to supply other sectors of the forestry industry such pulp and paper, biofuel and pellet industries.

2.3 OPERATION MANAGEMENT

Operation is a process or a series of activities that provide a physical good, information or service to the consumer. Beside the process, operation management also include the management of people and resources to provide quality goods and low cost. The operation manager must develop a new strategy for future operation to motivate people to improve their production efficiency without changing the quality of service, and management of day-to-day operation performance required. The system of performance measurement is the process of performance management for organization to manage its strategic and operation performance to promote a proactive system to control the organization activities, tasks and people by allowing an appropriate management decisions. The system of performance measurement is important for the operation management to planning and control. (Perazza, n.d)

2.4 THEORY OF CONSTRAINT

The theory of constraint (TOC) is a change method for organization to have the improvement of the profit. Constraint is one of the factors that limit the organization to gain profit. In manufacturing environment, constraint is occurring in the production processes which call as bottleneck. The constraint part will limited or slow down the operation process. The organization will lose time during the waiting at the constraint and then it will affect the production profit. The TOC might be a guide for the organization to manage their constraints at the same time increase the profit.

Longcore (1999), stated the improvement of operation in productivity is important for manufacturing organization. Organization will lose profit to pay the price on the bottom line, suffering declining profit and loss of market share, when the organization are failed to increase the productivity. The system bottleneck identification is important into improvement process to allow limited resources for the most effective improvement activities. The system bottlenecks also can call as "most constraining operation". The theory of constrain that focus on bottleneck process station should be improve the resources. The losses of bottleneck for an hour will same with lost for a whole system. An hour saved at a non-bottleneck is an illusion.

2.5 BOTTLENECK IN OPERATION SYSTEM

Bottleneck is a production activity which delays the performance of a system and reduce the overall process efficiency. A bottleneck machine will make the production process cannot work smoothly, so the productivity of the machine will be decrease. When the efficiency of the system is decrease, it will holds down the whole system capacity. Therefore, it is important to identify the bottleneck to improve the system performance. Bottleneck might occur in different condition, such as machine breakdown, the first machine capacity is high then the second machine capacity, operator problem and other. There will have the longer waiting time at the bottleneck system which can reduce the system efficiency and affect the system performance.

Bottleneck always occurs in factory, usually in machines or processes which control the throughput of the system. Manufacturing center's need to manage their system throughput, WIP, and cycle time. Throughput is the number of final product produced per unit time by the system, WIP is work in process which the material convert into final product in the system, and cycle time is the average of time needed for raw material to be transformed into a final product. Insufficient throughput leads to the demand cannot be achieved. Excessive WIP need excessive capital and excessive cycle time leads to loss customer orders. So, it can simply to conclude that if any of these parameters which influenced by process variability, process time, process reliability, system bottlenecks and the production control system used are not managed properly, then the manufacturing centers' will loses money. (Elftman, 1999)

Pegels and Watrous (2005) defined bottlenecks as an operation that does not have enough capacity to keep up with the required level of throughput. Bottlenecks generally have a lot of work in process (WIP) inventory accumulate in front of them, and downstream operations generally short of the components produced by the operation of congestion. The constraint is consists of mold set, especially during the busy time when having an excess number of customer orders. The number of molding set-ups that needed is exceeding the production mechanics capacity that able to complete. The molded parts producing will delay in the downstream operations to complete the orders. The constraints do not have a huge amount of work-in-process inventory in front, because the molding of component parts is into the first stage of the production sequence. Constraint is not specific to any product, but it more systematically impacts the production of all products.

Bottleneck is the capacity of resource is less than or equal to the demand. A bottleneck in manufacturing is easy to identified, which it have a stack of work-in-process in front of a resource. But it is difficult to identify the bottleneck in services, because it no stack of work-in-process. System performance can be improves after removing the bottleneck. But the process is repeated, because the removal of one bottleneck same with another bottleneck takes place. Through the theory of constraints, constraints' in a system also called as bottlenecks. Bottlenecks can be processes machines that have limited production capacity or activities that limit the company to achieve their goal. It is important to identify the system bottleneck if possible, because throughput can be improved and WIP can be reduced through reducing the impact of bottleneck in the operation. (Ellis, 2011)

Narayanasamy (2007) mention a production system consists of a set of machines to process the raw material into finish goods. Bottleneck machine is one of the problems that happen in production system. The bottleneck in production system is a flow of product in any system which disrupted by operator failure, machine failure and material failure. The failure of machine would disrupt the whole system. 30 to 40 percent of the system efficiency would reduce through the bottleneck machines and also would holds down the whole system capacity. Therefore, it is important for doing bottleneck identification to reduce the bottlenecks to improve the production system. The bottleneck is identifying in the longest queues length method, lowest production rate, buffer with high WIP, lowest blockage and starvation time. All of this problem can be solve by using the simulation. Appropriate size of buffer should be allocated into bottleneck station for improving the system performance. When the total work-in-process inventory is increase in the system, the WIP is needed to maintain by controlling the output rate of non-constraint machine and buffer after the bottleneck machine to increasing the system performance. The simulation is used to estimate the throughput.

Ucar (2012) agrees maintenance operation should not be considered separately with the making productivity related decisions. Maintenance is important for the smoothness of production system, which on-time repair can improves the production performance of the whole plant when the availability and reliability of the machine increasing. The machine that always breakdown would identify as the bottleneck machine. The bottlenecks identification will be using through simulation method to detect the bottleneck machine. The bottleneck machine initial condition information can see through the machine age, maintenance history, buffer levels, operational status of machines and scheduled production model mix of that shift. The production equipment requires the proper maintenance and management to avoid the disruption in the production operation. Therefore, maintenance management decision making is needed to have the smooth production process.

According to Timilsina (2012), in a manufacturing company, the production line would connect to each other, although they has different production line. Since, the output for one station will be the input for another station. Therefore, bottleneck will occur when one of the lines is broken due to some reason. It is because the broken of one machine will directly affected to other production lines which causing lower lever of output. The system is called as bottleneck when the inflow rate is higher than the outflow rate, it will reduce the system efficiency.

Beside the machine, labor, time and material also is a part of the bottleneck in manufacturing industry. Generally, bottleneck can be described in people constraint, material constraint, equipment constraint, process constraint and management constraint. The most challenges for company are to manage their employee. In any manufacturing unit there have different people working together with different style, experience, and education background. The general constraints because of people are illness, unexpected vacancy, hiring and training problem. The material constraints is the poor inventory management, not accurate forecast, poor production planning and inefficient supplier, which may cause the improper material flow that reduce the production capacity and increase the lead time. The constraint of equipment is consisting of machine breakdown, not accurate planning, lack of spare parts, and improper maintenance make the equipment for manufacturing cannot achieve the current demand. Process constraint includes the quality problems, poor plant layout, insufficient resources and inflexible process, which affected the entire output of the system. Management constraint means the lower performance that has lower output and profit. The objective of the company is not able to achieve such as because of lost power of employee, ineffective flow of material and information. Capacity planning is requiring for the manufacturing operation. The manufacturing capacity planning is to plan for designing plant layout, installing machine, and arranging the factors of production for specific time. The capacity planning should be able to meet the future demand and able to produce the enough goods and service to meet the customer. Capacity planning can help the company to make more profit.

Tamilselvan (2010) found, the efficiency of the production system is determined by the production rate. The machine that has the large volume production system can have higher performance level, which can achieve to 60% to 70% of system capacity. The high utilization machine will always block and impedes other machines, which called as a bottleneck machine. Therefore, it is important to identify the bottleneck and scheduling strategies to reducing the impact of the bottleneck machine to improving the system performance. The bottleneck can be classified based on the duration which is short term bottlenecks and long term bottleneck machine in the system. Short term bottleneck machines are the block into the system performance for short time, while long term bottleneck machine is which has blocked the system performance for long time.

There have many identification method of bottleneck such as, queue length analysis method, machine utilization method and active duration method. Machine utilization method is to identify the bottleneck through calculating average time for each machine spends which the highest utilized machine is more potential to be the bottleneck machine. The queue length analysis method is used to measure the waiting time of the different machines. However, this method is not suitable for the systems that have different queue sizes and no upstream and downstream buffer. The active duration method is each machine can be classified as active and inactive states. The active state is the machine is processing a part, while inactive state is when the machine waits for a new part, blocked by respectively machine and failure time of the machine.

2.6 SIMULATIONS AS THE BOTTLENECK DETECTED TOOL

Simulation is designed a model and conducted the experiments by using the model development. The experiments which conduct into the simulation will look like doing the experiment in the real production system. The simulation software will run with the graphical model to detect the bottleneck part into the production flow. The simulation will automatically analyze the problem and provides a data for the production manager doing a decision making to solve the problem. The simulation can be an instrument for evaluating the system performance.

According to Leporis and Kralova, (2010), simulation-based method is more suitable for manufacturing real production process. Although, it is more time-consuming to produce the simulation model, but the simulation experiments provide the more sufficient information result to detect a bottleneck in the system. An advanced simulation system is offer detailed statistics of the average utilization, waiting, blocking and breakdown to each element of the model as a result of the experiment. In addition, the simulation model also can help the company to determine the possibility of the improvement of the system and verify their impact on the overall system performance.

In manufacturing, the system productivity and quality can be improved through focusing in bottleneck. The bottleneck detection method would be used to identifying the bottleneck location in a production line to help the company to improve their system performance. The time lost at the bottleneck would make the overall system lost the time, so it is impossible for a production system to saved time at a bottleneck. A machine becomes a bottleneck machine when the production rate of the system is higher than other machine. The effectiveness of a system would be confirmed by simulation and then the system improvement is evaluated through the increasing of the bottleneck capacity. All of the machine average duration in the system line can be calculated by using simulation, and it known as active state duration method. The highest average duration machine would identify as the bottleneck machine. The simulation model can automatically analyze the bottleneck to detect the constraints into the running production. The results from the simulation are more accurate in bottleneck analysis and can quickly suggest the improvement strategies in the system. The main purpose of the simulation study is to help the company to improve their production line productivity and efficiency. (Karthikryan, 2010)

Process times is need to balance with the material flow in sawmill operation and to motive the performance of the operators. The operators tend to accelerate the operation when there have a bottleneck in material which waiting to process. There are no materials at the downstream machine when the bottleneck was happen in the upstream machine center. Therefore, the original process pattern needs to be change to have the smooth flow of material. However, the current machine center will have the pressure to speed up the operation process. The process time taken for sawing mills of large grade log is different. The feed speed is adjusted with the height of saw kerfs based on the mills head saws. The area of the face had sawn maybe proportional with the process time. High-speed modems and high processing sawmill are designed for small logs. Beside that the high power machine also is using for the small logs saw, because the process speeds of these machines are almost constant. The process time is solely proportional with material length. This type of sawmill generally have in the softwood dimension sawmills. All of these problems will detect by the simulation method and the new process pattern will be test by the simulation software to find the most appropriate pattern for the process system. (Zhang, 1993)

Bahtiyar (2005) state, simulation is an operation system model which as a tool to evaluating the system performance. Simulation is used to test the operation system before the system is built by using a model, it can reduce the risk of failure to achieve the specification, eliminate the bottleneck, to optimize the performance of system and to avoid the less or excess utilization of resources. Simulation is using to identify the bottleneck station in the production line and help the company to determine the root cause of the problem happen. The problem can be solving well before the implementation because simulation is a highly sensitivity analysis software that can quickly analyses the problematic data. The Arena simulation modeling system is an animated simulation models which need to design and develop an overall graphical model. The place of graphical object will be analysts. The graphical objects include the system components for example as machine, material handling devices and operators. After create the graphical model, the Arena will generates in automatically to analyses the problem.

2.6.1 THE ADVANTAGE AND DISADVANTAGE OF SIMULATION MODELING AND ANALYSIS

Although the simulation method can bring a more benefit to help the company to evaluating their system performance, however it still have some disadvantage through this method.

Simulation modeling is used to predict the future actions or the impacts of the operational input changing, and also used to represent the behavior. Besides that, the simulation modeling also is a process to simulate the real system and to conducting an experiment by using the model to realize the system behavior and to establish strategies for the system operation. Simulation modeling is a highly flexible technology which as the tool for the operation planning and decision making. The advantage of using simulation in operation are can more understanding the system operation, save time to doing the observation of a complex system, can know the system changing effect without disturbed the actual operation and to identify and solving the problem occurring. However, simulation models might more costly compare by other method because it need through the verified and validated. The cost will increase by the increasing of the experiment time. (Sangarayakul, 1998)

According to Bahtiyar (2005), the benefits of simulation modeling are:

1. Can get the better understanding about the system and can observe the system in detail.

2. Learn the interaction of the internal complex system

3. Reduce time to observe the some task to spend time for observe the other more complex task in detail.

4. Learn the effects of the changing of the operation system through the model without disturbed the real system beside can reduce the risk of doing an experiment in the real system.

5. Saved cost for training.

6. Identify the bottleneck station at the system.

7. Improve the system based on the model establish

8. Using animation method to visual the operation

9. Develop robust system to reduce the development time of system

The disadvantages of simulation are:

1. The uncontrollable and random of inputs will affect the real system.

2. The output will be random because of random input.

3. Need a lot of oversimplified assumption of the system and the system represent will be not valid.

CHAPTER 3

RESEARCH METHODOLOGY AND PROCESS DESCRIPTION

3.1 INTRODUCTION

Research methodology is the path to finding answers for research questions. This chapter consists of few sections that explained in detailed which method will be using of this study, how this study was conducted, how to collect the data and how the data were analysed. The simulation model, research design, and data collection techniques also have discussed through this chapter.

3.2 RESEARCH DESIGN

Research design is not just a work plan, but is a master plan or framework which used to conduct the research. There has two basic purposes of research design, first is to provide answer for research question and second is to control the variance during the process of research. Figure below showed the flow for research design:

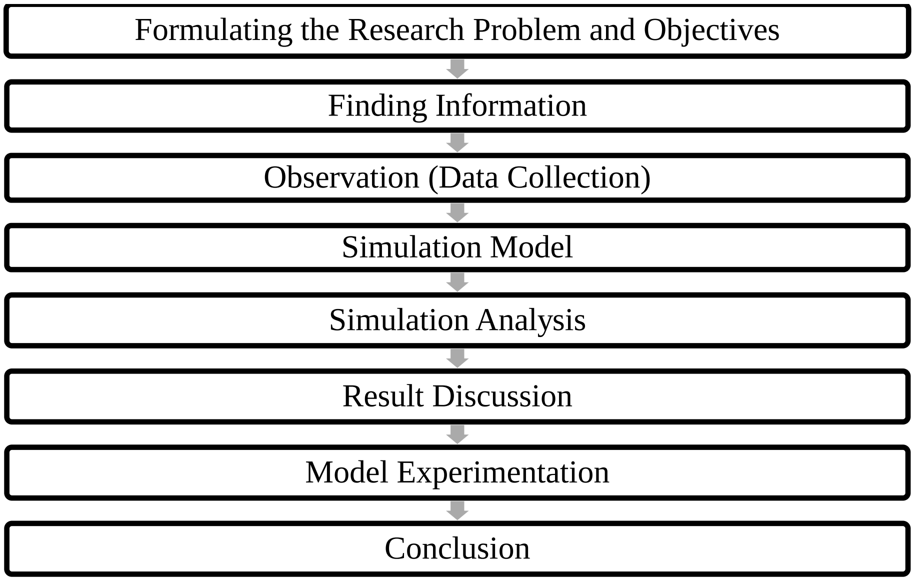


Figure 3.1: The Flow of Research Design

Research design is develop to prevent any unwanted mistake or problem occurs and to ensure the research process is run smoothly according to what had planned. First, consider the problem and formulate the problem. It is the most crucial step in the research process. Research question and objectives was identified and found that most of the researchers agree that the bottleneck in the production process flow affected the performance of production at the sawmill company. This phenomenon creates the intention to do the research regarding the effect of bottleneck into production line toward the operation performance.

After finish the first step, the second step is finding the related and appropriate information regarding to research title to assist completion of this study. After searching the enough material and finish identified the sources, define the problem, research question and research objective, the researcher moved to step 3 and step 4, which are start doing the observation and record research relate data. The observation will conduct directly through the production process. After doing the observation, and collect the data, Arena simulation method is used in this research. Simulation model were be develop and then the data had collect from the observation will be generate by the simulation software. The Arena simulation software will be run in animated visual and this software will help the researcher to analyse the problem and identify the bottleneck part that might occur in the production line. The simulation analysis will be analyses through the result that provide from this simulation software. The result will be discussed after finish doing the analysis. Then model experimentation will be conduct in scenario case study to find the best solution to help the company to increase their operation productivity and efficiency to improve the operation performance. The final step in this research is discussion and conclusion part. The result getting from the data analysis in this research will be discussed in the last part and the conclusion also is made in this stage.

3.3 SIMULATION MODELING WITH ARENA

The Arena simulation methods which using in this research will be described step by step to simulate the real production process of sawmill company by Arena simulation tool. The step for using Arena simulation is show in below figure:

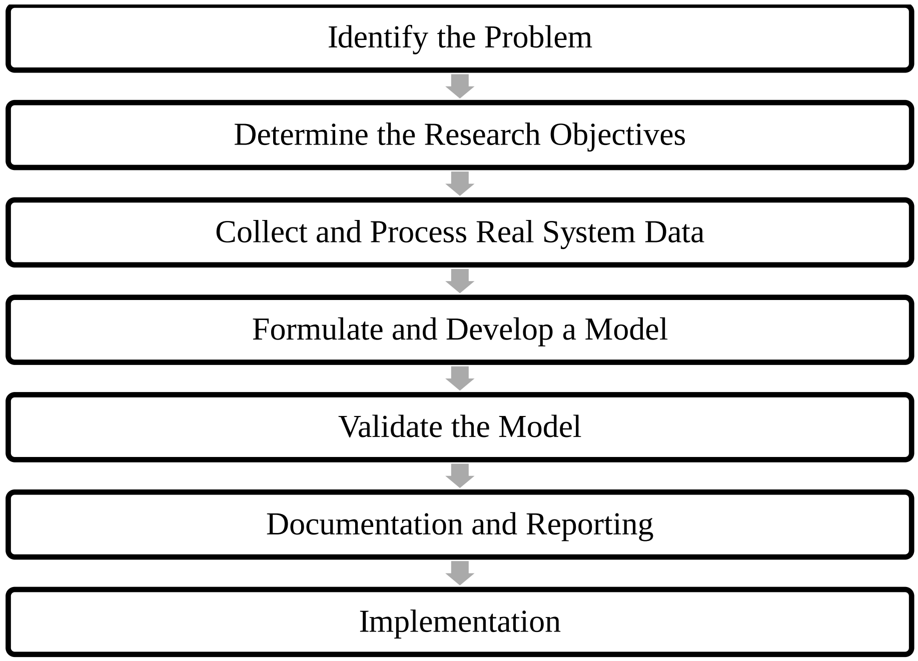


Figure 3.2: Simulation Process

In this research, this simulation method is adapted for evaluating the sawmill operation performance. By using the Arena simulation modeling, it becoming an easy task to identify the location of bottleneck in the production line, then find the solution to improve the operation performance. The simulation method is an appropriate method to evaluate the production performance, because Arena simulation is sensitive software that can detect the bottleneck part in the system and also will analyses the system.

Step 1 and 2: Identify the Problem and Determine the Research Objectives

The research problem and research objectives should be determined in the early stages of research which as the direction for the researcher to complete the task. Due to the title of this research is evaluating the performance of the operation at the sawmill production company, so this research will be conduct in a sawmill company. After discuss with the supervisor and searching some information from book and internet, the problem is considered as how to improve the effectiveness of performance in production process. The objectives are to identify the bottleneck part in the production line by using the simulation method and reduce the waiting time at the bottleneck station. Then, propose some suggestion to improve the operation.

Step 3: Collecting and Process Real System Data

This research can be start with finding the sawmill company which appropriate for this research objective. The company should achieve the research objective which to mitigate the bottleneck problem to improving the organization operation performance. To achieve this research objective some essential data must be collected. These data should be collect to use for either programming part or animation part of the model. The data should be collect for this research is the layout of the production line (Figure 3.3), the machine capacity, and cycle time for sawing a unit of logs. The data will be collect during the observation period.

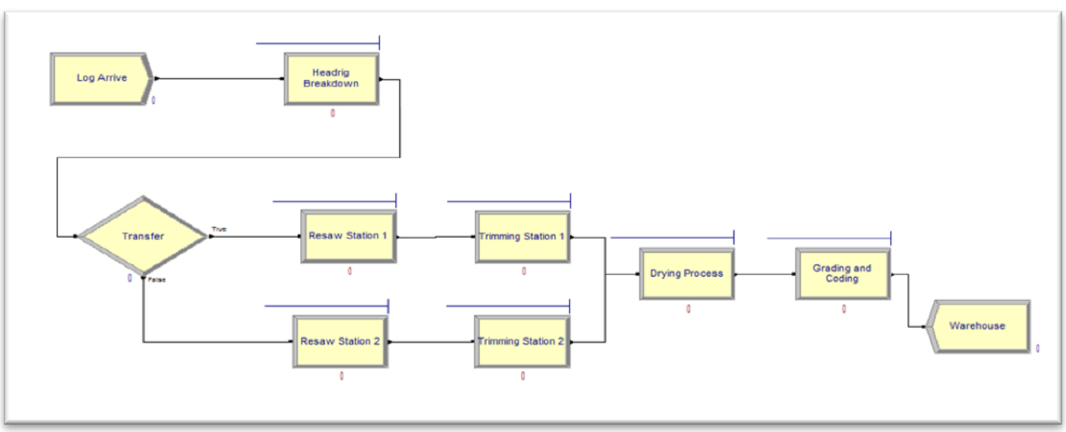


Figure 3.3: The Operation Layout

Step 4: Formulate and Develop a Model

All software programs should be selected by the researcher in this step. A production simulation model should be developed and all the data is perform into the selected program then the simulation model will be formed. Although, the company have produce two type of product which is lumber the main product and by-product such as woodchips and sawdust. However, in this research the study will only focus on the production of the main product, lumber. The simulation program were selected is animated visual program with Arena.

According to Justifying Simulation (n.d), the animation simulation is more powerful because the animation will give the feedback from animation in a guarantee model accuracy, identifies bottleneck, and analyses which the part of the system should be modify to gain the better results. Simulation animations can illustrate the new ideas effectively and easily to understand, and have the clearly demonstrate the effects of the change in the production system through model experimentation. The model simulation result analysis and model experimentation can help to identify the location of bottleneck in the production line, what the effect from the constraint, and suggest the better solution how to reduce the waiting time at the bottleneck to solve the problem without disturb the real system. So it can reduce the risk during the experiment.

Step 5: Validate the Model

To ensure the simulation result is accurate, the model should be justify either the model develop is operates as the original system or not. The real system operation will be compared with the experimental result. The valid of the simulation result will be defined after comparing between the real systems responses with the simulation model response. The historical data is needed in this stage to compare with the experimental data to show the validation of the experiment result. To prove the validation of the model, the differences between the actual sawmill flow output and the simulation output must be in the range of ± 10% of the actual output.

Step 6 and 7: Documentation and Reporting and Implementation

The simulation results are interpreted and analyzed at this stage. After get the result from simulation, the result will be analyses by the researcher into the report and documentation. The problem and solution of this research will be record as the guide or referent for other people when they face the same problem, so they will have the knowledge how to solve the problem in the shorten time. This solution also can help the company to improve their operation performance. The scenario in the model experimentation also will be record in this stage.

3.4 OBSERVATION

An observation will be conduct during this research at one of the sawmill company in Gemas, Negeri Sembilan. The observation method consists of human and the machine operation which occurs when the observation is work. Observation is a way of collecting data by watching a behavior and case in natural condition. There have two types of observation which is direct observation and indirect observation. Direct observation is when watching the interaction, process or behaviors that happen at that time. Indirect observation is when watch the result of the interactions, process or behavior that have happen before. The direct observation will be using in this research. Due to this research title is about the evaluating the performance of the operation at the sawmill production company, so this research will be conduct at a sawmill company and our target is Principal Alliance Pallet at Gemas, Negeri Sembilan area. The main purpose of this observation activity is to observe and investigate either the company has face the bottleneck problem in their production system and they may be need our help to generate some idea to solve the problem. The observation will be conduct to get the information about the machine behavior and the production process performance. The observation will be focus on the production flow, to observe the capacity of the machine, the cycle time for cutting of a piece of lumber, machine effectiveness and etc. The data has collected from observation will be used in simulation process.

3.5 DATA COLLECTION METHOD

This method is explains how to collect the data and what are the method or techniques are used to collect the data. Two major data collection method will be used during this research, which consists of primary data and secondary data. Primary data is the data that has collected for the first time, while secondary data are the data that has been collected and analyzed by someone else. For the primary data method, an observation will be conduct in this research to get the primary data. The observation will be conduct direct to the production process at one of the sawmill company at Gemas, Negeri Sembilan, the information get from the observation will be record for the data analysis and the data which has collected will be generate by using the simulation software. The company will be visited in several times for data collection. The purpose of observation is to get the process layout, to record each machine capacity, the cycle time for machine to cutting a piece of lumber, and to observe the production process performance. Stop watch will be using during this observation activity as the time measurement instrument. If suddenly got problems occur in the production flow during the observation time, it also will be record. For some question or problem that do not clear or cannot direct get answer through the observation also will be directly asking to the organization employee in informal condition to help in collecting data.

For the secondary data collection method, secondary data is acquired after reading the literature review, articles from internet, journals, document from website and books for generating some idea to complete this research. Some website will give the useful information such as showing the step how to using the simulation method, how to analyses the data, what information or data is needed and suitable for this research and so on. The historical data also can gain from the company and from website which people already analyses the result. The historical result will be used to comparing with the result that will get during this research process.

3.6 PROCESS DESCRIPTION

There will be a more detailed description on the sawmill process flow in the real life. The area of this study covers only the sawmill-flow which consist of machine utilization, material flow in sawmills, and production. This description is in order to provide a clearer view of where is actually this study is about and what is the actually happening in the sawmill process.

Most of the manufacturing systems are assemble components into products, however sawmills are different with other because it disassemble logs into lumber and other product. There are 4 main workstations in sawmill process flow. That four workstations consist of headrig breakdown, Re-saw, trimming and grading and storage.

3.6.1 Receiving of Logs

After the logs arrive, logs are unloaded at the log yard. The logs are segregated according to its species, sizes and grade based the log quality. Quality control team (QC) grades all the logs by verify its species and check for defects on each logs. Then the graded logs are labelled and sorted, then store in the log yard for further process.

3.6.2 Sawmill process flow

There have 4 main workstations in the sawmill process flow. The process start from headrig breakdown, then follow by re-saw, trimming and grading and storage.

Station 1: Headrig Breakdown

Selected log from the log yard are loaded into the head rig (head saw) for cross cutting. Headrig is used to breakdown or cross cutting the large logs into flitches and cants. A single band head rig is used to cut flitches and cants. Flitches' cutting is a rough cut board without any straight edges. While a cant cutting is a log that has cut at least have one square face from the log. The large log is split into two for the ripping at a secondary breakdown center called as Re-saw.

Station 2: Re-saw Flow

Once the logs from the Headrig area have been flitches and cants, they are grouped together in a buffer area to wait Re-saw process. Re-saw is used to reduce the processing capacity from the Headrig. A single band Re-saw is used to breakdown the cant into lumber. The flitches and cants are debarked and Re-saw that cut out boards. The waney edges and defects of the boards are remove during the Re-saw process to create parallel edges. The defects on logs are carefully avoided to maximize recovery. The specific thickness of the boards that customer need and want are produce by setting at the Re-saw machine. Then the timbers produced here are delivered to trimming process at the next station.

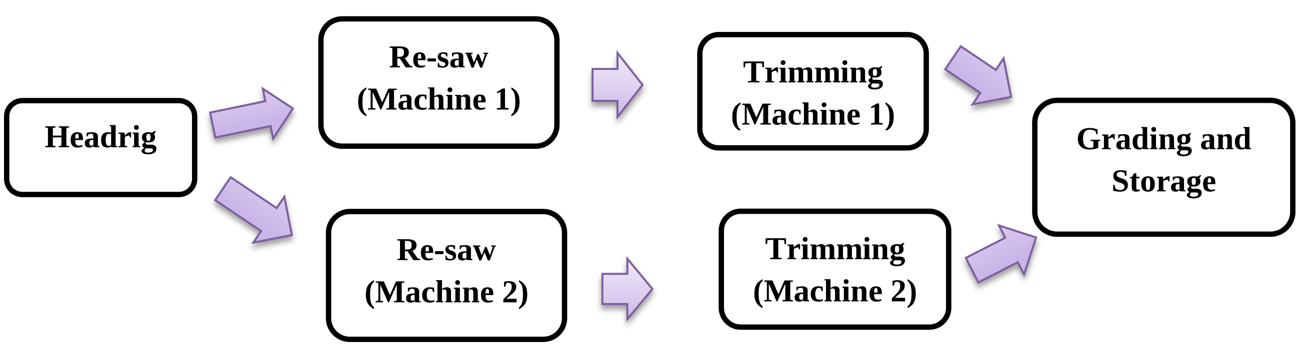
Station 3: Trimming

The boards are manually loaded into the trimming area for the end trimmer process. The function of trimmer is used to cut off the any end defects and square the board into a specific length according the product specification.

Station 4: Grading and Storage

Once the pieces leave the trimmer they are sent to the warehouse where they are collect, sorted and stacked by hand. After the pallet of lumber is full and the lumber is dried to specific moisture content it is then checked again by QC team to ensure its quality. The timbers produced are grading and sorted by quality, size, and lengths into different bundles. Each bundle is documented and labelled using code. The labelled timber bundle is then moved to the sheltered storage area, waiting for shipped to customer.

Figure 3.4: Process Description



3.6.3 Waste

Waste is products which do not qualify, such as the saw dust, woodchips, bark and the pieces of wood. The waste can be sold as a by-product. Waste can be burned as fuel or made into press board. However, waste is not discussed in this study area.

CHAPTER 4

MODEL DEVELOPMENT AND DATA ANALYSIS

4.1 INTRODUCTION

In this chapter, there will be describe in more detailed about the discussions and the explanations on results and findings which based on the method has been describe in chapter 3. Data analysis is the crucial step to support the study by using the simulation method of data collection has been explains in the previous chapter. In this study, the data are gathered from the company of Principal Alliance Pallet in Gemas, Negeri Sembilan.

A simulation model of sawmill process flow is constructed in this study by using ARENA, a simulation software tool. In order to have a greater understanding of the complex sawmill activity in the real word system. ARENA simulation software able to demonstrating, predicting and measuring the production flow in order to achieve the effectiveness, efficiency, detect bottleneck area and optimized operation performance. A discrete simulation model is developing in this study to identify the bottleneck area in the system process flow. Besides data analysis, the model development and the input analysis will also be covered in this chapter.

4.2 MODEL DEVELOPMENT AND INPUT ANALYSIS

4.2.1 Model Development

In this study, the model was develop based on the sawmill process flow chart that will affect the flow throughout. The model was constructing by using modeling shapes called as modules from the Basic Process penal, then parameterized by associated dialog boxes. One *CREATE*, one *DECIDE*, seven *PROCESS* and one *DISPOSE* modules are selected for the model.

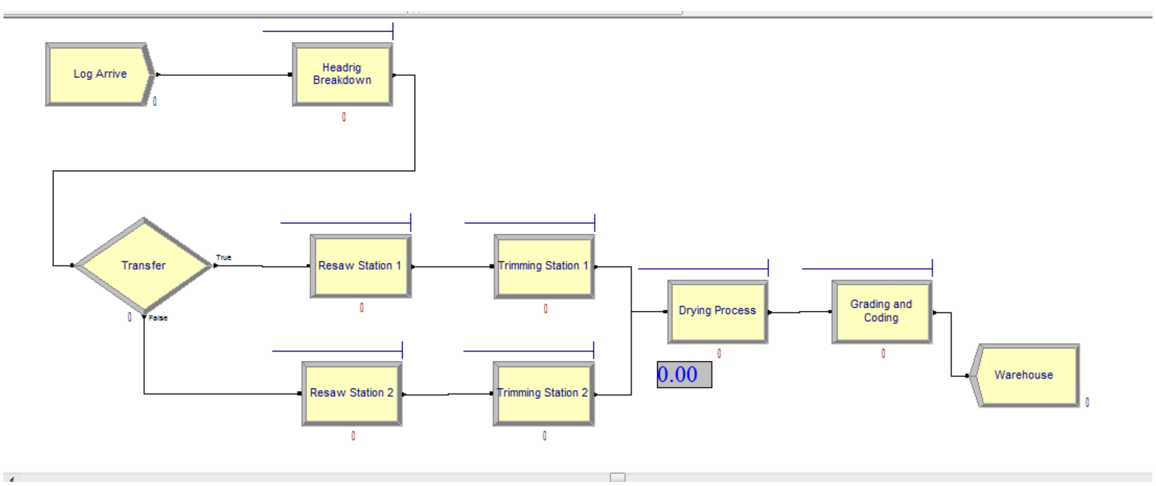


Figure 4.1: Simulation Model

The *CREATE* modules in Arena is the module which giving an instruction of create part to start the process. *CREATE* is used as the start of process flow and entities enter the simulation. The entity in Arena is the object that flow through the system and the object in this study is log. *CREATE* module is the source of arriving log into the system. In this study, the create module is name as Log Arrive. The time between arrivals is Random with a value (mean) of 30 and the units are set to minutes. It can be simply say as each log were enters the process every 30minute randomly until the process is stop running.

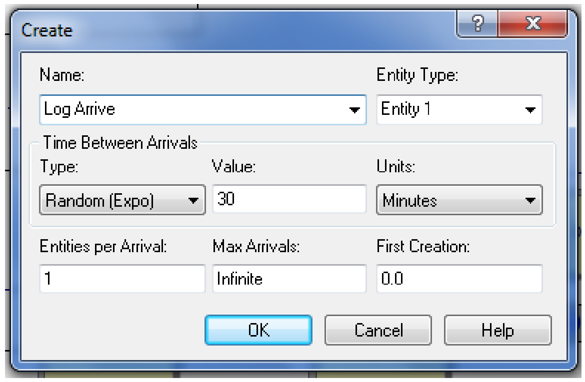


Figure 4.2: Create Module

DECIDE module is make decisions about where to go next based on condition and chance. In this study, the decide module is known as Transfer based on 2-way by Chance with 50% of true and 50% of false. It mean the log after the cross cutting, it will be passes to re-saw machine 1 or re-saw machine 2 by randomly with 50% of chance for both machine.

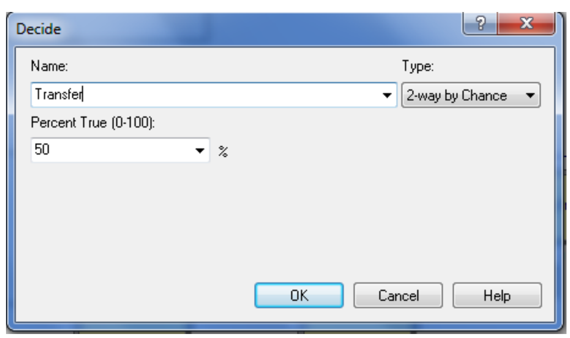


Figure 4.3: Decide Module

The *PROCESS* module is the models of queue-seize-delay-release of resources, or any part of this. Process is the important part in the model flow chat to see the process from the perspective of the entity. During the simulation run, each time an entity enters the process, Arena will calculate a sample from the distribution information that provide from the input analysis. In this study, all of the process is set as constant. The time taken of each part or station is constant for every time the process run. The more detail of the probability distribution can be seen in the input analysis below. The seven process modules are assigning as Headrig Breakdown, Re-saw Station 1, Re-saw Station 2, Trimming Station 1, Trimming station 2, Drying process, and Grading and Coding. All of the process are used standard type with seize delay release and medium (2) priority. The resources in the process are machine and worker. Value is the time taken to complete the process for each station of the flow and the unit is set in minute.

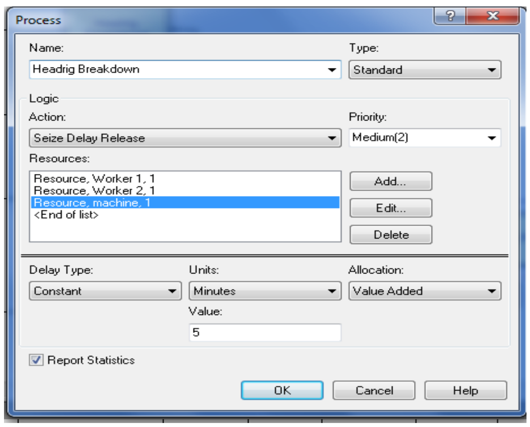


Figure 4.4: Process Module

A *DISPOSE* module in the model is take entities out of the model and record statistics. *DISPOSE* is the end of process flow and entities are removed from the simulation. After the grading and coding process the logs are store in to the warehouse, waiting for shipping to customer.

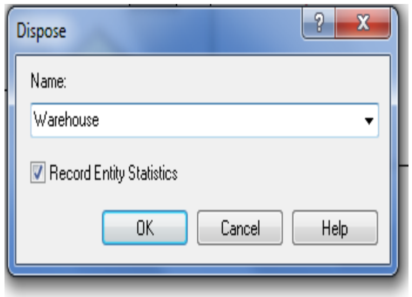


Figure 4.5: Dispose Module

The Queue is used to calculate the waiting time of the entity in each station. The maximum duration to animate queue arrival of every station of process is set as 5minutes. Variable is used to show the number of the entity going in or going out from each station.

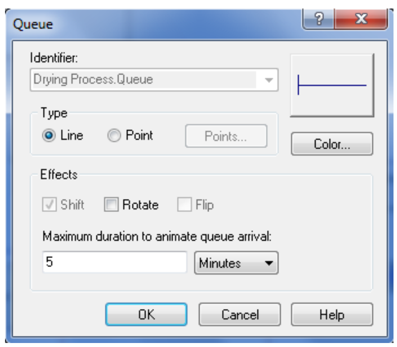


Figure 4.6: Queue Module

4.2.2 Input Analysis

The model parameters and distribution is one of the most important parts in the model development. To have a solidity model, it must be well analysed on the structural modeling and the quantitative modeling to get the logical output and result.

Structural modeling is the flow chat of the model which built based of the real process system. The structure is constructing in the Arena software according the logic aspect. The model is emphasis on the part, variable, resources and so on. The logical structure will come out with logic result.

Quantitative modeling is more on the numerical and distribution specification, where the data is put in the software to contribute for developed model. It is almost like the structural modeling which needs to observe mill operation, but it is better if the data is possible to be taken in the model. The logical and accurate output will best fit with the model when it has the number of units of resources, entity inter-arrival time and processing time which taken from the real process.

In this study, variability of machine cycle time is recorded in a table 4.1 when the observation is conducted whole day. The cycle time is taken start from the headrig breakdown to trimming process only not include drying, grading and coding process. It is because the drying, grading and coding not a machining process so the time taken is not too accurate, so to get the more accurate data, only cycle time of machining is recorded. From the table we can conclude that the total cycle time of the machine from headrig breakdown to trimming process is 30minute to complete sawing one log, because from the record the average of the processing time is 30minute. Which the time needed to breakdown a log is 5minutes, then 15 minutes for re-saw and 10minute for trimming process, so the company able to process 14 logs per days. The time needed for all path of the process is constant for every time of complete process. The same species and the same diameter of log is using in this study. Which only 20 diameter of Meranti wood is used in this experiment to confirm the validation of data collected, with recorded the inter-arrival time of the every time of the process.

The process of drying and grading and coding process is not recorded during the observation because the company is using conventional method to dry the board without using technology, which the board is dry in the sun at least 30minutes to get the specific moisture of board. Then the boards were passed to QC team again to check the defect of the board before sorted in bundle, grading and coding by worker. Although the drying, grading and coding is not a machining process, but it still one of the part of the mill operation and will affect the performance of the whole operation. By the ways, this two of process will also take place in this study to find the bottleneck area in this mill layout and flow. The minimum time of the drying, grading and coding are set in this simulation model which are 30minute for the drying process and 10 minute for the grading and coding process.

In this study, the workers work for one shift a day. Their working hours are 8 hours within 1 hour of rest. The working days are 5 days/week. 10 of replication are set in the Run Setup to obtain an accurate estimate of the average performance. By putting in the actual working hours and days, this will complete the chart flow of the sawmill process in Arena simulation software same with the real system.

Table 4.1: Machine Process Time

Logs in Process	**Arrival Time**	**Finish Time**	**Inter-Arrival Time (Minute)**
1	8:00	8:33	33
2	8:33	9:03	30
3	9:03	9:33	30
4	9:33	10:01	28
5	10:01	10:30	29
6	10:30	11:00	30
7	11:00	11:30	30
8	11:30	12.00	30
Rest Time (12.00-1.00)			
9	1:00	1:32	32
10	1:32	2:02	30
11	2:02	2:32	30
12	2:32	3:02	30
13	3:02	3:34	32
14	3:34	4:06	32

4.3 Data Verification and Validation

Verification and validation are the process to ensure the reliability of model built and simulation. To see whether the results is match with the real system.

D.K.Pace (2004) in an article *Modeling and Simulation Verification and Validation Challenge* define verification as "*Did I build the thing right?"* to determine the model and simulation been built are satisfy and indicated in specification or not. However, validation is define as "*Did I build the right thing?"* The model or simulation is able to support the intended use.

Verification can divide in two aspects which are design and implementation. In the aspect of design it consist all the specification and nothing else are included in the model or simulation design. However in the aspect of implementation it included all the specifications and nothing else are included in the model or simulation as built. To verify the model built in this study, all of the specification setup in the model is nearly same with the process happened in the real sawmill process. The flow chat in the model is design same as actual sawmill process flow in real system. Furthermore, the time put in, the number of resources and the arrangement of the station which design in the model are same as in real life, to ensure that the computer program of the computerized model of Arena and its implementation are correct.

Validation also can divide in two aspects which are conceptual validation and results validation. Conceptual validation happen when the anticipated fidelity of the model or simulation conceptual model is assessed. In the other hand, results validation is happen when the result from the implemented model or simulation are compared with an appropriate referent to demonstrate that the model or simulation can fact support the intended use. In this study simulation, 10 of replications are set in the replication parameters in Run Setup, and then the averages of the output were recorded. The result of output were compared with the output of the real sawmill flow. To prove the validation of the model, the differences between the actual sawmill flow output and the simulation output must be in the range of ± 10% of the actual output. The difference between those two values is computed by using the formula as below:

$$Differences\ (\%) = \frac{Simulation\ output - Actual\ Output}{Actual\ Output}\ x\ 100\%$$

In the simulation output, the model produces on average of 13 units per days of the logs in machine process of eight hours working period. In the real machine process, the actual output is on an average of 14units of logs is produce per days. The difference between the simulation and actual values is 1units which 7.14 percent less in the simulation model. This difference seems to be in a good manner in which the simulation output is not having a big different with the actual output. Therefore, this model can be accepted and valid.

4.4 Data Analysis

4.4.1 Introduction

The statistic result that shows in Arena Simulation Result will be collected for analysing purposes. The statistic result that collected in this study are average waiting time, average queue waiting time, cycle time, and resource utilization to observed the bottleneck from the animations developed in the simulation model. Those aspects are under the performance measurement and these analyses will be carried on next, in result discussion and scenario.

4.4.2 Measuring the Average Waiting Time

Table 4.2: Measuring the Average Waiting Time

Workstation	Average Process Wait Time Per Entity (Minute)	Average Queue Waiting Time (Minutes)	Average Number in Queue (units)
Headrig Breakdown	0.8372	0.8372	0.02519
Re-saw Station 1	1.4610	1.4610	0.02739
Re-saw Station 2	2.0000	2.0000	0.02083
Trimming Station 1	21.729	21.729	0.41431
Trimming Station 2	17.5360	17.5360	0.18267
Drying Process	10.0000	10.0000	0.36302
Grading and Coding	-	-	-

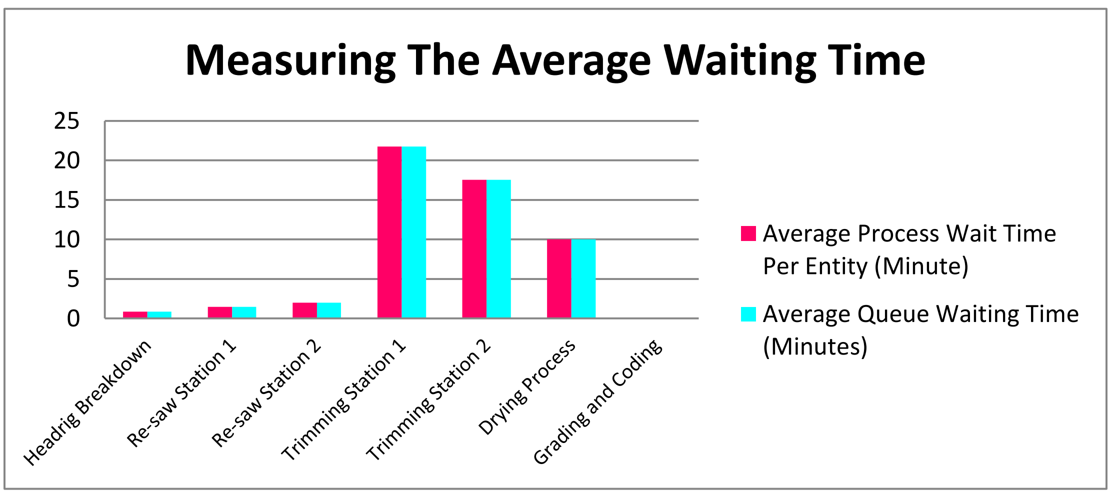


Figure 4.7: Bar Chart of Measuring the Average Waiting Time

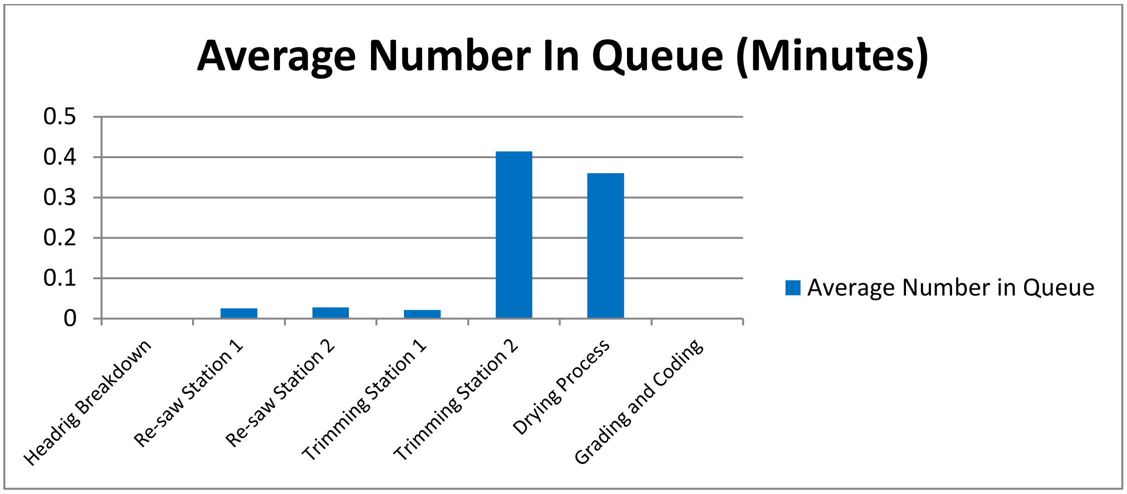


Figure 4.8: Bar Chart of Average Number in Queue (Minutes)

When measuring the average waiting time, the machine with the longest average waiting time is considered to be the bottleneck.

The simulation was implemented using the Arena simulation software and run for 9 hours Arena simulation time and 10 different replications. Average waiting time per entity is measures for the waiting time of process to determine the bottleneck. The measurements of average queue waiting time also were measure because the longest queue instead of the longest waiting time. The waiting time of process and queue length form the Arena simulation result are shown in Table 4.2.

Averagely, Trimming Station 1 has the highest queue length with 0.41431unit of mill in queue and longest process wait time per entity 21.729minute. These may be caused by the longer cycle time in Drying Process workstation which that workstation is allocated after the Trimming Station 1 workstation and has the higher number in. Average number in queue is the bottleneck which has a longest queue before the process, which waiting to be processed. Therefore, Trimming Station 1 is detected as the bottleneck based on the average waiting time method.

4.4.3 Utilization of Machine

Table 4.3: Utilization of Machine

Workstation	**Average of Utilization/ Number of Busy (units)**
Headrig Breakdown	0.14583
Re-saw Station 1	0.28125
Re-saw Station 2	0.15625
Trimming Station 1	0.16667
Trimming Station 2	0.10417

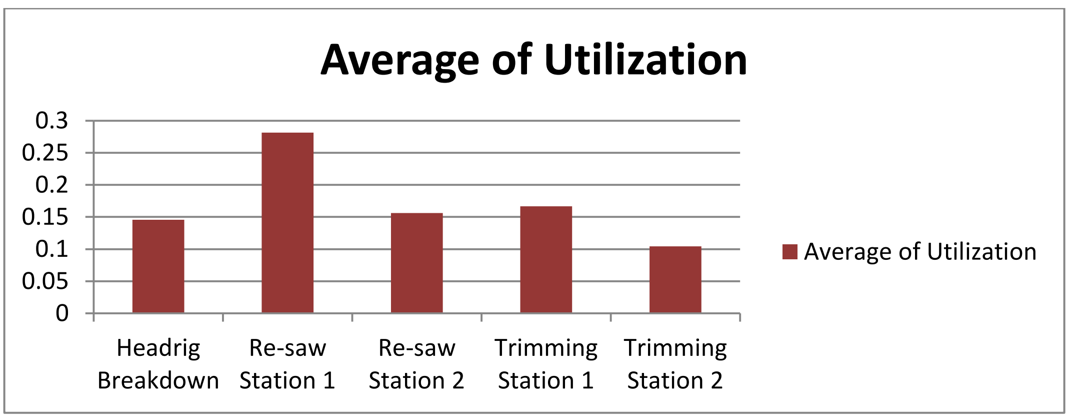


Figure 4.9: Bar Chart of Average of Utilization

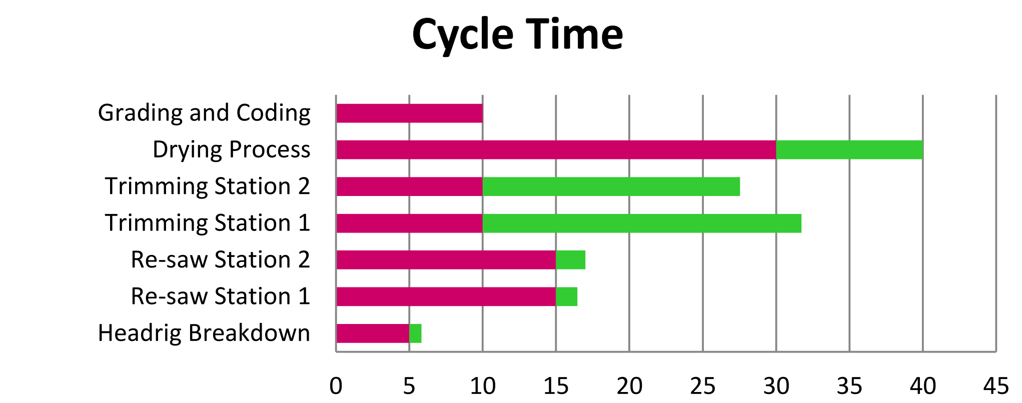
Utilization of the machines is measures by the workload and defines machine with the largest utilization as the bottleneck machine. From the Arena simulation result in above Figure 4.9, we can see that the machine of Re-saw Station 1 has the largest average of utilization is detected as the bottleneck.

An interested phenomenon is that although processes wait the longest time in Trimming Station 1, but it not the busiest. This can be explained by the transfer of the logs from the Headrig Breakdown to the both Re-saw Station 1 and Re-saw Station 2 by chance of 50% of each. Since the chance in the simulation of the log enters the Re-saw Station 1 is bigger so the machine in this workstation will more busy compare with other. The logs arrive more frequently in this workstation.

4.4.4 Cycle Time

Table 4.4: Cycle Time

Workstation	**Average Value added Per Entity (Minute)**	**Average Wait Time Per Entity (Minute)**	**Average Total Time Per Entity (Minute)**
Headrig Breakdown	5.000	0.8372	5.8637
Re-saw Station 1	15.000	1.4610	16.461
Re-saw Station 2	15.000	2.0000	17.000
Trimming Station 1	10.000	21.729	31.729
Trimming Station 2	10.000	17.5360	27.536
Drying Process	30.000	10.000	40.000
Grading and Coding	10.000	-	10.000



	Headrig Breakdown	Re-saw Station 1	Re-saw Station 2	Trimming Station 1	Trimming Station 2	Drying Process	Grading and Coding
Average Value added Per Entity (Minute)	5	15	15	10	10	30	10
Average Wait Time Per Entity (Minute)	0.8372	1.461	2	21.729	17.536	10	0

Figure 4.10: Bar Chart of Cycle Time

Cycle time is the processing time in producing products or services to customers. Cycle time also include the average wait time per entity which the waiting time before the machine is measure on how long a product will wait in queue to be process. In this study, the cycle time is an important aspect in the machine process parts. The cycle times studied in the whole sawmill operation are all in the units of minutes. The Figure 4.10 above shows the data computed from the simulation model for the average of cycle time from the five machine workstation in sawmill production.

In Trimming Station 1, it shows the highest value in the total cycle time for the whole workstation with 31.729 minutes. It is certainly because of the average waiting time per entity in this workstation is higher than the other four machine workstations. The longer queue length in the process make the cycle time of the workstation become higher, then will slow down the operation and directly affect the line performance and capacity of the machine process. Therefore, Trimming Station 1 is the bottleneck machine based on the cycle time measure.

However, when seen the whole process of sawmill not only the machine parts, the average total time per entity show that Drying Process is the highest value of cycle time with 40 minutes to complete the process. The cycle time of Drying Process is higher than the total cycle time of Trimming Station 1. Thus, Drying Process also is the bottleneck in the production process because of the longer time taken in average value added per entity with 30 minutes. The longer process time in the Drying Process will affect the longer queue time in Trimming Station 1 and Trimming Station 2 because the workstation of drying Process is allocated after that both workstation.

CHAPTER 5

MODEL EXPERIMENTATION AND CONCLUSION

5.1 INTRODUCTION

In this chapter, there will be a series of discussion on the model experimentation. The “what-if” analysis will carry out to study and see how the changes made in the model affect the output of the whole sawmill operation. Besides that, there will also some recommendations or suggestions provide in this chapter as well. Before the model experimentation, the result will discussed again, but this time will determine where actually the bottleneck is happen in the sawmill process flow.

5.2 RESULT DISCUSSION

In the previous chapter, the data analyses have been carried out. The problem can be identify and analyzed in more clearly and detail, since the scope has been narrow down after analysing the data.

The analysing of measuring of average waiting time show from the seven workstation in the sawmill process, there has Trimming Station 1 is detected as the bottleneck station. Trimming Station 1 has the maximum average number in queue with the longest average waiting time per entity.

In term of machine utilization, there only five workstations of machine process are analyze. There are Headrig Breakdown, Re-saw Station 1, Re-saw Station 2, Trimming Station 1 and Trimming Station 2. It not includes the Drying Process and Grading and Coding, because there no machine processes in that both workstations. The analysis show the Re-saw Station1 is under the higher utilization compare with other. It may cause by the chance of the simulation for the entity enter the Re-saw Station 1 is bigger than enter the Re-saw Station 2.

Cycle time determine that Trimming Station 1 and Drying Process is the bottleneck in the sawmill process flow. Trimming Station 1 has the highest average wait time per entity, while Drying Process has the highest average value added per entity. The average value added per entity and average wait time per entity will affect the longer cycle time of the process.

Table 5.1: Bottleneck detection methods

Detection Method	**Average Waiting Time**	**Utilization of Machine**	**Cycle Time**
Detected Bottleneck	Trimming Station 1	Re-saw Station 1	Trimming Station 1 and Drying Process

Table 5.1 summarizes the bottleneck detection results. We can see almost all of the method was detected the Trimming Station 1 as the bottleneck workstation, unless utilization of machine method detected that Re-saw Station 1 as the bottleneck workstation.

However, because of the machine utilization is calculate based on the logs arrive frequently prescribed by the chance of the simulation software, so the result from the utilization of machine is consider as not accurate. Besides that, Drying Process also can be identify as bottleneck station because the main factor bottleneck happen in Trimming Station 1 is because of the longest cycle time of Drying Process.

From the Arena simulation result, we can conclude that bottleneck is happen when the average waiting time and cycle time of the process is longer, which will slow down the production process. Moreover, the bottleneck will decrease the productivity and efficiency of the operation and then directly reduces the whole operation performance. The Figure 5.1 show more clearly in simulation animation model that bottleneck was happen in Trimming Station 1 and Drying Process.

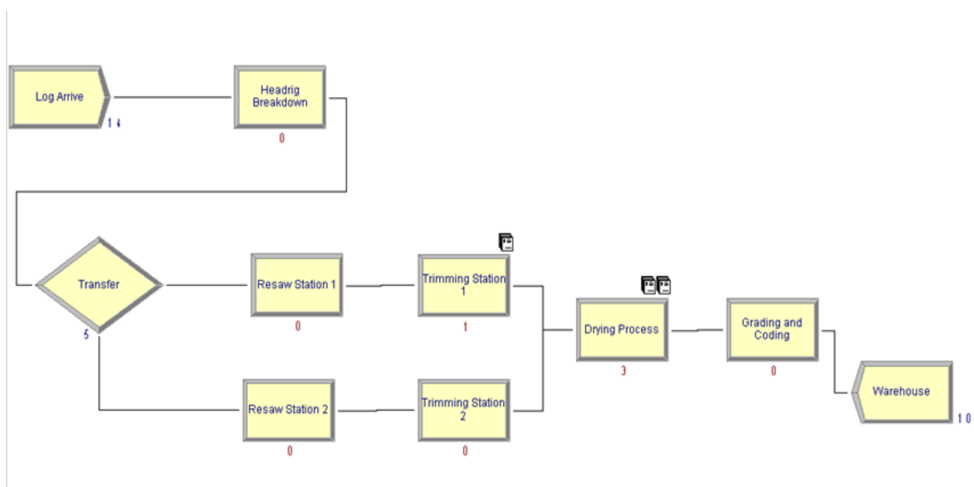


Figure 5.1: Arena Animation Result

5.3 MODEL EXPERIMENTATION

After the verification and validation of model and the data analysis of the result, the experimental of model will carry on the next. In this model experimentation, various types of scenarios could be developed to see the changes of the result. The modification of the model in simulation software are depends on the person who study on the sawmill operation process. The number of what-if analysis to be experimented is due to the problems or errors which need to be investigated. In this study, what-if analysis to be experimented to investigated how to reduce the waiting time at the bottlenecks workstation. In simulations, what-if analysis is important to the management in order to increase the operational performance. There will be scenarios carried out to analyze the changes in term of the sawmill production output.

In this study, we can see that the Trimming Station 1 is not the actual bottleneck station. The bottleneck happen is the effect from the longer cycle time in Drying Process. So we should be focus in the bottleneck area of Drying Process to improve the operational performance of the sawmill process.

5.3.1 Scenario 1: What-if adding one more workstation of Drying Process in the model and in charge by operator 7 and operator 8 separately for reducing the waiting time purpose in Trimming Station 1.

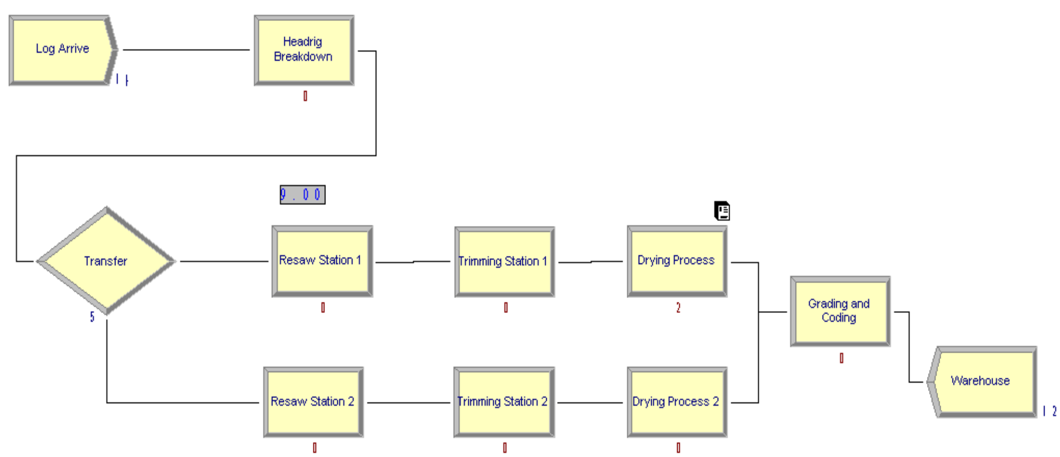


Figure 5.2: Scenario 1 Simulation Model

At the preliminary experiments are done on the sawmill process flow, which Trimming Station 1 is regarded to be the bottleneck workstation of the plant. The bottleneck is happen because of the longer queue waiting time in Trimming Station 1 before passing to the Drying Process workstation. The longer waiting time happen in Trimming Station 1 may be cause by the longer value added time per entity in the cycle time in Drying Process 2.

To reduce the longer waiting time in Trimming Station 1, one more Drying Process workstation is adding in the operation layout and handle by operator 7 and operator 8 separately such as model in Figure 5.2.

The edited new model also has been run for 10 replications and the result show a minor different with the previous model. The waiting time in Trimming Station has been reducing compare to previous model.

Table 5.2: Comparison of Average Queue Waiting Time

Workstation	**Average Queue Waiting Time of Current Model (Minutes)**	**Average Queue Waiting Time of New Model (Minutes)**
Trimming Station 1	21.729	12.293
Trimming Station 2	17.5360	5.000
Drying Process	10.000	1.2500
Drying Process 2	-	0.000

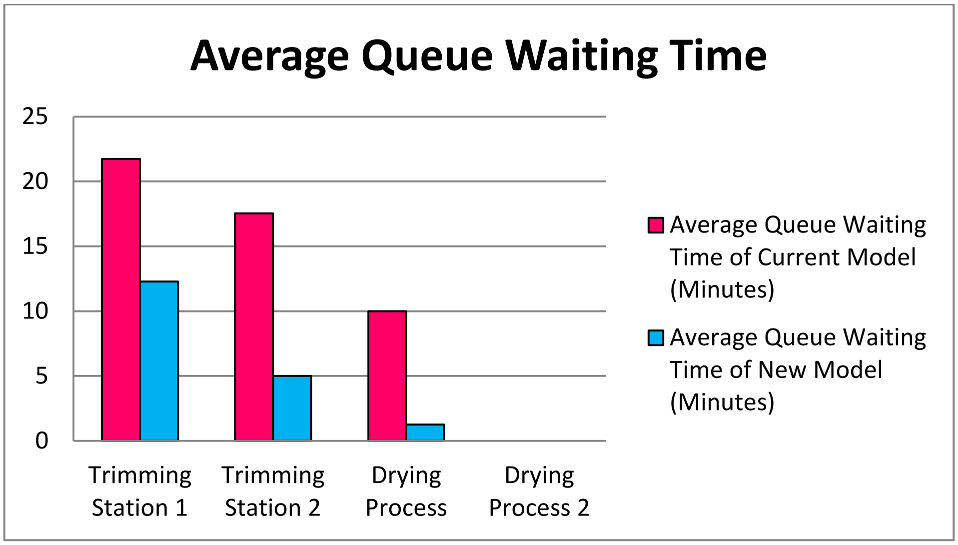


Figure 5.3: Bar Chart of Average Queue Waiting Time

The result show, the average queue waiting time in Trimming Process 1 has decrease 43.43 percent from previous model from 21.729 minutes decrease to 12.293 minutes. Beside that the Drying Process cycle time also has reduces 25 percent from 40 minutes to 30 minute. By reducing the waiting time in the bottleneck, the production of the operation also been improve which the output was increase from 10 units to 12units.

This new layout of operation does not increase the production cost because the company only need to arrange a space for the drying process it not a machine process and the same operator is used. The operator still does the same task, only the place of the process is different.

5.3.2 Scenario 2: What-if move out the operator 7 and operator 8 from Drying Process and replace with the two new operators.

Two station share the common operator is a way that to utilize the resource in the production operation. Although the production improves in term of the resource utilization, but the productivity of the whole operation might be disrupted. This is a contradict situation, but in this study the productivity is always in the first thing to be consider.

This scenario employed to simulate the effect by what if moving out the operators in Drying Process workstation. Then the Drying Process workstation will replace by employed two new operators to in charge in this process. The operator 7 and operator 8 only in charge in 1 process of trimming respectively, which operator 7 in charge in Trimming Station 1 and operator 8 in charge in Trimming Station 2.

Putting two new operators in Drying Process is rather than sharing the same operator with the trimming process. The result shows the total output has increase of 10 percent from 10 units in current to 11units in the new model.

5.3.3 Scenario 3: What-if replace the conventional Drying Process method with higher technology method.

From the data analysis, the main factor of bottleneck was detected is come from the longer cycle time in the Drying Process. Therefore, replace the conventional method in Drying Process with the higher technology method which adds an additional machine such as dry kilns that able to reduce the length of the processing time in the Drying Process workstation. And this is the best and the most effective way to reduce the cycle time in this workstation.

The higher technology method able to finish the processing of the Drying Process in 10 minutes compare to the longer time taken by conventional method which needed at least 30 minutes to done the drying process. The drying processing time can be reducing in 66.67 percent.

The Figure 5.5 below show the simulation model there are no bottleneck happen in the whole operation. And it has the increment in the throughput. The output from the current model is 10 units was increase to 13 units in the new model. The bar chart below also shows the reduction of the total cycle time in the new model.

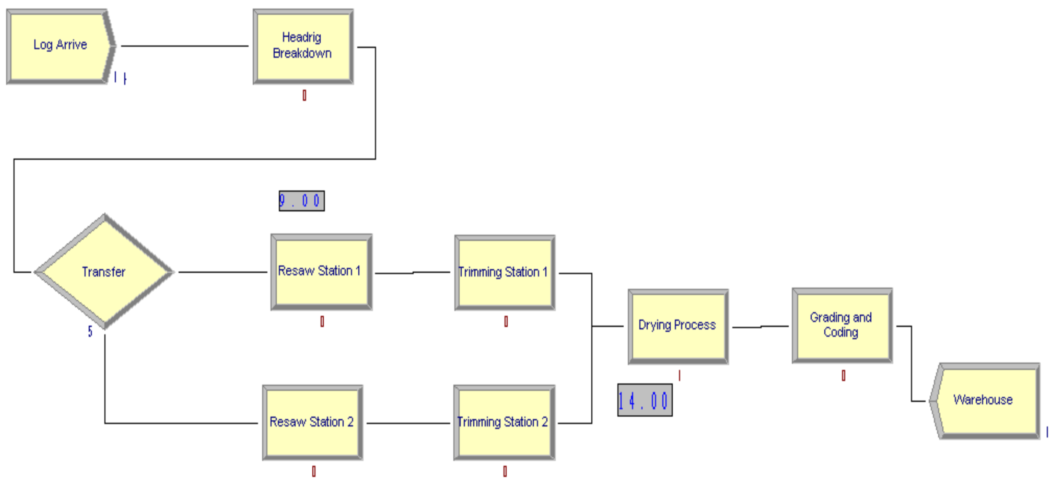


Figure 5.4: Scenario 3 Simulation Model

Table 5.3: Comparison of Total Cycle Time

Workstation	Total Cycle Time of Current Model (minute)	Total Cycle Time of New Model (minute)
Headrig Breakdown	5.8637	5.8637
Re-saw Station 1	16.461	16.461
Re-saw Station 2	17.000	17.000
Trimming Station 1	31.729	15.047
Trimming Station 2	27.536	11.862
Drying Process	40.000	11.153
Grading and Coding	10.000	10.000

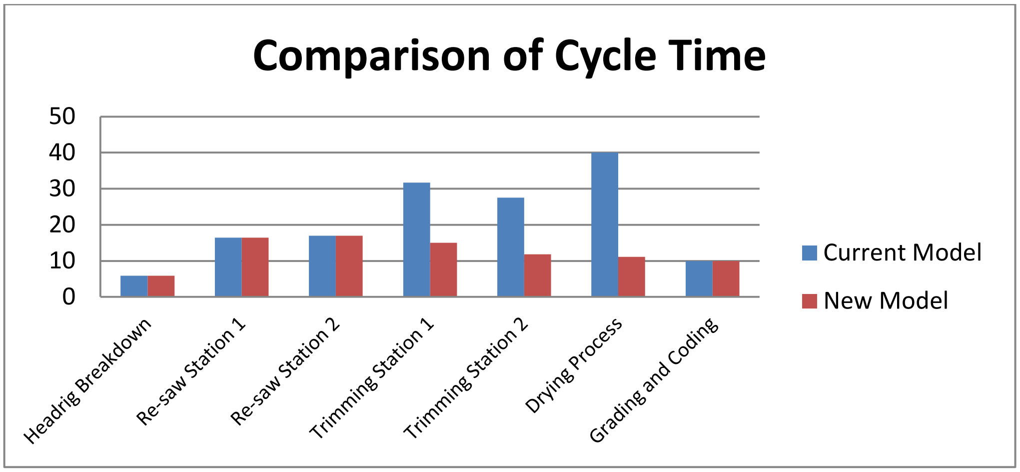


Figure 5.5: Bar Chart of Comparison of Cycle Time

5.3.4 Scenario 4: What-if scenario 1 and 2 scenario are put together in the simulation model.

Previously, the scenario 1 and 2 scenarios are being applied independently and with different results. In scenario 3, there will be a combination of the two scenarios before applies in the new simulation model and run for 10 replications which is the same number of replication runs in the original model. In this time, those two factors are manipulated dependently to each other. The computed result will be compared with the current simulation model as well. Figure 5.7 is the new model combination of model in scenario 1 and scenario 2.

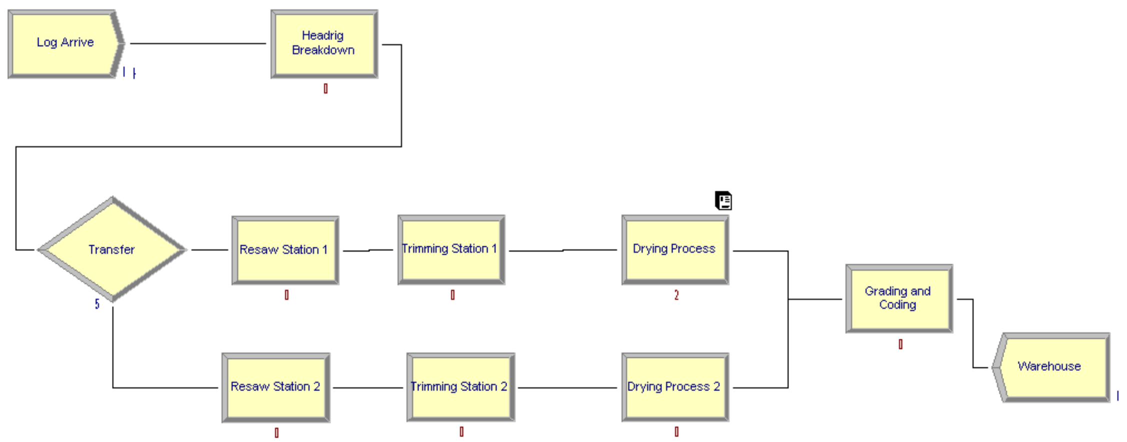


Figure 5.6: Scenario 4 Simulation Model

The combination from the scenario 1 and scenario 2 is one more Drying Process is added in the model which Drying Process 2 to share the load of the Drying Process work. Then the operator 7 and operator 8 are move out from Drying process and replace with the operator 10 and operator 11 to run the Drying Process and Drying Process 2 respectively.

In the result of the newly changed sawmill flow, the output of the sawmill production shows a greater output than those applied scenarios before. The output in this new sawmill production is 12 units. By comparing with the current simulation model, this new simulation model showed an improvement in 2 units which increase 20 percent. A comparison of simulation output in three different scenarios has been shows in Figure 5.8.

Table 5.4: System Output

Model	System Output (units)
Current	10

Scenario1	12
Scenario 2	11
New	12

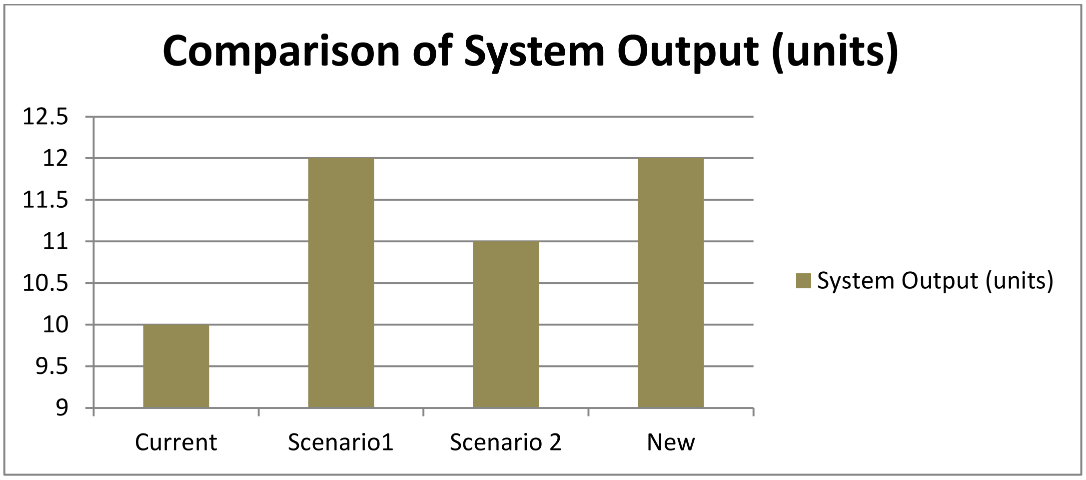


Figure 5.7: Bar Chart of Comparison of System Output

In term of machine utilization, the scenario 1 and the new model show the better result compare with the current simulation model. Although it still have the queue waiting time at the both Trimming Station 1 and Drying Process, but the length of the queue are reduce compare with the current model. These will make the machine work more productive.

In scenario 1 there have 3 workstation have the longer queue waiting time same with the current model. However the queue waiting time still shortest compare with the current model. From the graph Figure 5.9, it shows the new model is better compare with the other two models although the queue waiting time still happens in Drying Process and Drying Process 2. The queue time in Drying Process more short compare with the current model, and the queue time does not affect the other machine operation performance.

Table 5.5: Comparison of Average Queue Waiting Time

Workstation	Average Queue Waiting Time of Current Model (Minutes)	Average Queue Waiting Time of Scenario 1 Model (Minutes)	Average Queue Waiting Time of New Model (Minutes)
Trimming Station 1	21.729	12.293	0.0000
Trimming Station 2	17.5360	5.000	0.0000
Drying Process	10.000	1.2500	4.2953
Drying Process 2	-	0.000	3.0000

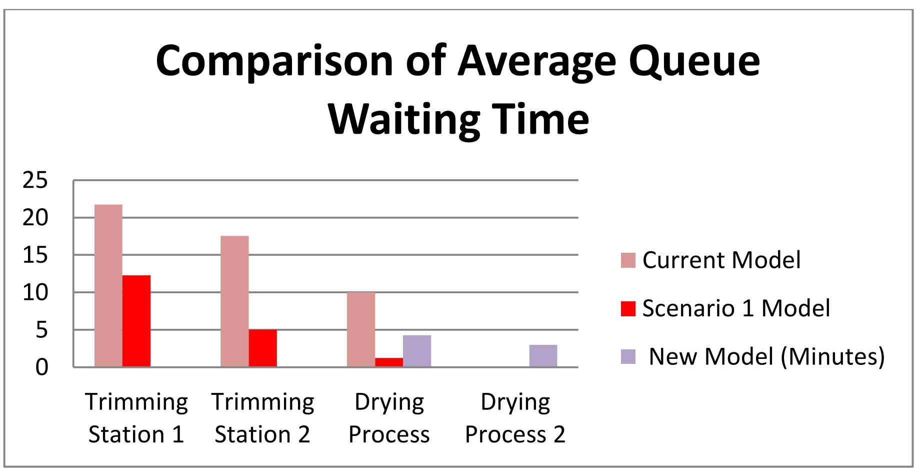


Figure 5.8: Bar Chart of Comparison of Average Queue Waiting Time

The total cycle time in new model show, there are only few reduction in the Dying Process cycle time. But it still is the better, because the times reducing in the Drying Process will affect the cycle time in the Trimming Station 1 and Trimming Station 2. The average waiting time in Trimming Station 1 and Trimming Station 2 is decrease, so the total cycle time in that both workstation is decrease. There still has the improvement in the machine operation productivity although there still have the longer total cycle time in Drying Process because the Drying Process and Drying Process 1 do not affect the machine production, drying process not a machine process.

Table 5.6: Comparison of Total Cycle Time

Workstation	Total Cycle Time in Current Model (minute)	Total Cycle Time in New Model (minute)
Headrig Breakdown	5.8637	5.8637
Re-saw Station 1	16.461	16.461
Re-saw Station 2	17.000	17.000
Trimming Station 1	31.729	10.000
Trimming Station 2	27.536	10.000
Drying Process	40.000	32.766
Drying Process 2	-	33.000
Grading and Coding	10.000	10.941

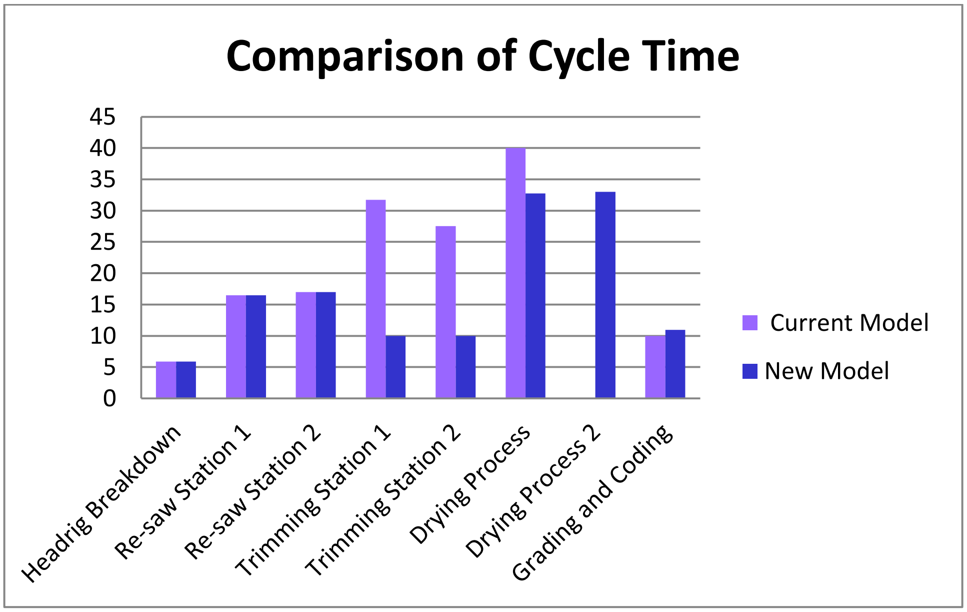


Figure 5.9: Bar Chart of Comparison of Cycle Time

5.4 RECOMMENDATION

In sawmill manufacturing industry; the productivity is the important to fulfill the customer demand. However, bottleneck always blocking the process to operate in more productive. Moreover, it is not easy to identify the bottleneck location in the process and it time consuming. There is the reason why the simulation method is advise in studying for the sawmill operation process.

Simulation is a cost-saving analysis tool and it also assists the users in making a quick and reliable decision. In simulation, there are many things can be done. A test can be carrying out easily only by changing the desired aspect that you want the process to be. Without the disruption in the real operation process, the facility even the resources are able to be manipulated. Experiments in the real operation will costly if the decision making is wrong and the experiment should be do in many time to confirm the accuracy of the result. Normally, the experiment is not encouraged to conduct so many times in the real operation because of budgeting problem. Simulation is software that can reduce the risk in decision making and it can avoid the manager doing the wrong decision. The simulation software can be set the number of replication which the simulation will be run based the number setup and show the more accurate result.

When modification is applied on the developed model, it enables the simulation run as what has been set in the time setup. The simulation software able to compute a result on desired length of time which is based on all the setting like part arrival time, number of stations, process flow, resources allocation and so on. It is able to run the models in daily, months or even in a year in simulation software to come out with the future output. The user can plan for their future plan to improve the operation performance by increase the productivity of the process. They also can analyze the impact of the production performance by calculating the output they will have if they want to do some changing or improvement in the workstation layout design. Improper arrangement or design of the process layout will impact the operation performance and more costly.

The time compression and expansion in simulation allow modeler to speed up or slow down the simulation process for deeply investigation by seeing the flow of part.

Simulation process can speed up or even fast forward in order to see the final result. This is a time saving method rather than by observing in the real operation.

Furthermore, simulation can also act as an "experimental test-bed" to apply a new policy or decision rules in the modeled operation process flow. This can avoid the risk of experimenting on the real operation process. There may have zero information with the new process flow that is about to apply on. However, the "what if" question which relate to the concept and design phases of the new project can be answered in simulation.

In this study, after done the simulation analysis and what if scenarios in model experiment I will recommend the manager to decide the scenarios 1 if they are consider about the budget. The company no need to spend money in prepares a place for the new Drying Process because they only need to find an empty place to place the timber for drying under the sun. However, if budget is not the important problem for them to buying an expensive machine I will recommend the manager to choose the scenario 3 because it more productive and efficient. Both scenarios have the strength, but the right of decision making to choose for the options will back to the manager to consider whether productivity is emphasized or the other aspects.

5.4.1 Impact of Sawmill Operation Improvement

There are much positive impacts that Principle Alliance Pallet can get from the improvement of the operation flow in the sawmill production process. Those impacts are listing as below:

i. *Increasing productivity and fulfilling the customer demand.* Since the "what-if" analysis has been done in virtually in Arena simulation software, the application of the study in simulation software to the real sawmill operation are able to generate a better result than before. The increasing demand of furniture and house nowadays will increase the demand of the timber since they need the timber to produce the product. So, there should be no problem to fulfil the highly demand with the improved production in operation process.

ii. *Earning reputation and loyalty* may attract more investors. Highly customers' satisfaction will earn their loyalty to the company and will increase the company reputation. The strong reputation will attract more investor to invest in company. With the sufficient modal provided from the investors, the company will able to buy the higher technology such as computerize sawmill machine, dry kilns machine and ect. The company can reduce the human resource because most of the works are conduct with machine. The higher technology machine with scanner also can produce the product in higher capacity. The cycle time of each process also will be shorter.

iii. *Fully utilize the resources in operation process.* Resources utilization either operator or machine is the issue which always been concerned in the production line. Idle time of operator and machine is the cost of the company. When the resource utilization is improved the waiting time of the process will be decrease so the productivity will be increase and the number of output also will increase.

5.4.2 Suggestion

There are some suggestions to improve the performance of the operation.

i. *Provide training for operators.* The operation performance can be improved when the operators perform their task with the right skills. There are some processes are needed the certain skill from the operators especially at the bottleneck workstation which the operator needed to manage and work in the suitable speed to utilize the capacity of the process. Some specific training should be giving to those operators.

ii. *Using simulation to study the sawmill operation.* Arena simulation software is the best bottleneck detected method to testing the real operation flow in an animation form. It enables the manipulation of variable such as resources, time, machines, workstation and etc. By manipulating the developed model from the real operation system in simulation software, the users are able to identify the bottleneck workstation in operation process and then doing some experimentation to find the solution to reduce the waiting time in the bottleneck workstation to improve the performance.

iii. *Add additional manpower or machine.* This is the easiest way to increase production at the bottleneck operations. When the potential capacity of the operator is too less than the target output of the process, they should be consider for adding extra machine. Calculate each machine capacity and demand from the bottleneck operation, then add additional machine to reduce the cycle time in that workstation.

iv. *Improve workstation layout.* The workstation layout is the whole process of the operation take place in the flow from the first process to the final process in the real operation. The workstation should design in the best layout with the shortest cycle time which can improve the productivity of the operation process. When the productivity increase the performance of the operation will improve.

5.5 CONCLUSION

The objective of this study was to provide the Principle Alliance Pallet manager with information and recommendations on where the bottleneck allocated in the workstation layout and how to reduce the waiting time at these bottleneck to improve the sawmill operation performance. To determine this information, a simulation model of the mill was developed.

The study of sawmill operation flow is covering seven workstations. There have five machines workstation and two non-machines workstation. It is difficult to exactly to identify the bottleneck area in the production process. The simulation tool shows the bottleneck workstation in animation more clearly than observing in the real process.

The different diameter and hardness of the logs make this study more difficult. The cycle time to saw the small diameter of logs is more shorted compare with the big diameter of logs. The length of the logs also will affect the cycle time of the process. Besides that, the cycle time to saw the hardwood also will longer compare to saw the softwood. To solve this problem and to avoid the inaccurate result, this study only conduct on the 20 diameter of Meranti wood with 18 inch of length.

For the model development in the Arena simulation software, the model needed to be verified and validated, there are only ± 10% of the different range for the output between the actual and simulation output are valid. The "what-if" analysis will carry out for model experimentation which 4 scenarios are generated to seek for improvement of the studied sawmills operation performance.

In this study, the bottleneck in the workstation having been identifies. After the experimental for the simulation model, there have some decision that can be suggest to the manager to improve the performance of the sawmill operation. The improvement in the operation performance can increase the system throughput by reduce the waiting time in the bottleneck workstation. The whole process of simulation is in the software, it not disrupting the real operation. Therefore, there is much problem and costly mistakes can be avoided. It is an effective way for planning of improvement of the operation performance for the whole sawmills process. The simulation method is advisable to use in decision making and as the bottleneck detected tool.

REFERENCES

Bahtiyar, M. 2005. *Simulation modelling of shop floor activities for SMEs in virtual enterprises.* Master. Thesis. University of Middle East Technical.

Clark, W. (undated). Bottleneck theory in operation management (online). http://www.ehow.com/info_7935877_bottleneck-theory-operation-management.html (15 March 2013).

Corporate Info. (undated). Definition for productivity (online). http://www.hkpc.org/index.php?option=com_content&view=article&id=106&Itemid=270&lang=en (20 June 2013)

Elftman, T.M. 1999. *Examination of the effects of bottlenecks and production control rules at assembly stations.* Master. Thesis. University of Florida.

Ellis, S.C. 2011. *A theory of constraints service system improvement method: case of the airline turnaround problem.* Ph.D. Thesis. University of Florida International, Miami, Florida.

Goldman, A. (undated). Operation Management: Elimination Bottlenecks (online). http://www.gaebler.com/Eliminating-Bottlenecks.htm (17 March 2013).

Investopedia. (undated). Bottleneck (online). http://www.investopedia.com/terms/b/bottleneck.asp (26 march 2013).

Justifying Simulation. (undated). Why use simulation? (online). http://www.promodel.com/pdf/Justifying%20Simulation.pdf (10 May 2013)

Karthikryan, A.P. 2010. *Detection of bottlenecks for multiple products and mitigation using alternative process plans.* Bachelor. Thesis. University of Anna, India.

Krajewski, L., Ritzman, L. and Malhotra, M. 2010. *Operations management*: *Processes and supply chains*. (9th Ed.). Prentice Hall: N.J.

Lee, N. (undated). How to fix a bottleneck in production (online). http://smallbusiness.chron.com/fix-bottleneck-production-32326.html (25 March 2013).

Leporis, M. and Kralova, Z. 2010. A simulation approach to production line bottleneck analysis. *International Conference.* Cybernetics and Informatics Vysna Boca, Slovak Republic: 10-13 February.

Longcore, J.R.M. 1999. *Bottleneck identification in cycle time reduction and throughput improvement efforts in an automotive transmission plant.* Master. Thesis. University of Michigan.

Macmillan Dictionary (undated). Efficiency definition. (online). http://www.macmillandictionary.com/dictionary/british/efficiency (23 June 2013)

Martz, K. (undated). How does a sawmill work? (online). http://www.ehow.com/how-does_4895616_a-sawmill-work.html#page=3 (20 March 2013).

Moore, S. (undated). The disadvantages of focused manufacturing (online). http://smallbusiness.chron.com/disadvantages-focused-manufacturing-35836.html (25 March 2013)

Murphy, C.A. and Perera, T. 2002. The definition of simulation and its role within an aerospace company. *Simulation Practices and Theory.* **9**(6-8): 273-291.

Narayanasamy, P. 2007. *Identification and mitigation of bottlenecks in complex production system.* Bachelor. Thesis. University of Anna, India.

Pace, D. K. (2004). Modeling and Simulation Verification and Validation Challenges.

Pegels, C.C and Watrous, C. 2005. Application of the theory of constraints to a bottleneck operation in a manufacturing plant. *Journal of Manufacturing Technology Management.* **16**(3): 302-311.

Perazza, L. (undated). *Analysis of performance evaluation model through the balanced scorecard in a footwear industry.* University of Sagrado Coracao, Jardim Brasil, Brasil.

Sangarayakul, B. 1998. *Use of simulation to analyse block manufacturing methods.* Master. Thesis. University of Virginia Polytechnic Institute and State, Blacksburg, Virginia.

Simpson, M.A. (undated). Sawmilling and lumber product (online). http://www.ehow.com/info_8501545_sawmilling-lumber-products.html (17 March 2013)

Smith, R.D. 1998. Simulation article (online). http://www.modelbenders.com/encyclopedia/encyclopedia.html (26 March 2013).

Sohrabi, P. 2012. *A three-stage control mechanism for the lumber production process of a sawmill based on a power-of-two modelling approach.* Master. Thesis. University of Dalhousie, Halifax, Nova Scotia.

Tamilselvan, P. 2010. *Bottleneck shifting in production lines impact of variability, new detection method and control strategies*. Bachelor. Thesis. University of Anna, India.

The Columbia Electronic Encyclopedia. 2004. Sawmill (online). http://www.reference.com/browse/sawmill (17 March 2013).

The Columbia Encyclopedia, 6th ed.. 2012. Sawmill (online). http://www.encyclopedia.com/topic/sawmill.aspx#1-1E1:sawmill-full (26 March 2013)

Timilsina, B. 2012. *Removing bottleneck from a manufacturing unit: a case studies to betker oy, ylivieska-84100, finland.* Degree. Thesis. University of Applied Sciences, Ylivieska.

Ucar, H. 2012. *Throughput analysis and bottleneck management of production lines.* Ph.D. Thesis. University of Wayne State, Detroit, Michigan.

Wang, Y.C., Zhao, Q.C. and Zheng, D.Z. 2005. Bottlenecks in production networks: an overview. *Journal of System Science and Systems Engineering.* **14**(3): 347-363.

Zhang, G.C. 1993. *An object-oriented simulation system for softwood sawmills.* Master. Thesis. University of Oregon State.

APPENDICES

A Gantt Chart PSM 1

		WEEK													
No.	Research activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Briefing by psm 1 coordinator	■	■												
2	Meeting with supervisor, discussing project title and objectives		■	■											
3	Deciding the topic and objectives		■	■											
4	Getting supervisor's approval of the topic and objectives			■											
5	Preparing project research proposal			■	■	■									
6	Preparing chapter 1, 2, 3					■	■	■	■	■	■	■			
7	Submitting draft chapter 1, 2, 3											■			
8	Correcting and editing chapter 1, 2, 3											■	■		
9	Preparing cover page, content, reference list											■	■		
10	Submitting full report of psm 1												■		
11	Preparing slides for oral presentation													■	
12	Presenting the psm 1														■

B Gantt Chart PSM 2

		WEEK													
No.	Research activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Briefing by psm 2 coordinator	■													
2	Meeting with supervisor, discussing the Simulation model development		■	■											
3	Edit the Simulation Model		■	■											
4	Meeting with supervisor, discussing the simulation result			■											
5	Analysis the Data			■	■	■	■	■	■						
6	Doing result discussion							■	■	■					
7	Discussing with supervisor about the scenario							■	■	■	■	■			
8	Edit and analyze the Scenario											■	■		
9	Doing recommendation and conclusion											■	■		
10	Submitting full report of psm 2												■		
11	Preparing slides for oral presentation													■	
12	Presenting the psm 2														■

C Table of Simulation Result

Summary for Replication 10 of 10

Project: Unnamed Project
Analyst: likching

Run execution date :11/28/2013
Model revision date:11/28/2013

Replication ended at time : 480.0 Minutes
Base Time Units: Minutes

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
Resaw Station 2.VATimePerEntity	15.000	(Insuf)	15.000	15.000	5
Headrig Breakdown.WaitTimePerEntity	.86372	(Insuf)	.00000	4.4000	14
Resaw Station 2.WaitTimePerEntity	2.0000	(Insuf)	.00000	10.000	5
Trimming Station 2.WaitTimePerEntity	17.536	(Insuf)	.00000	25.000	5
Trimming Station 2.VATimePerEntity	10.000	(Insuf)	10.000	10.000	5
Resaw Station 2.TotalTimePerEntity	17.000	(Insuf)	15.000	25.000	5
Trimming Station 2.TotalTimePerEntity	27.536	(Insuf)	10.000	35.000	5
Headrig Breakdown.VATimePerEntity	5.0000	(Insuf)	5.0000	5.0000	14
Drying Process.VATimePerEntity	30.000	(Insuf)	30.000	30.000	10
Grading and Coding.TotalTimePerEntity	10.000	(Insuf)	10.000	10.000	10
Grading and Coding.VATimePerEntity	10.000	(Insuf)	10.000	10.000	10
Drying Process.TotalTimePerEntity	40.000	(Insuf)	30.000	60.000	10
Headrig Breakdown.TotalTimePerEntity	5.8637	(Insuf)	5.0000	9.4000	14
Resaw Station 1.TotalTimePerEntity	16.461	(Insuf)	15.000	25.000	9
Trimming Station 1.TotalTimePerEntity	31.729	(Insuf)	10.000	69.748	8
Resaw Station 1.WaitTimePerEntity	1.4610	(Insuf)	.00000	10.000	9
Drying Process.WaitTimePerEntity	10.000	(Insuf)	.00000	30.000	10
Resaw Station 1.VATimePerEntity	15.000	(Insuf)	15.000	15.000	9
Trimming Station 1.WaitTimePerEntity	21.729	(Insuf)	.00000	59.748	8
Trimming Station 1.VATimePerEntity	10.000	(Insuf)	10.000	10.000	8
Grading and Coding.WaitTimePerEntity	.00000	(Insuf)	.00000	.00000	10
Entity 1.VATime	70.000	(Insuf)	70.000	70.000	10
Entity 1.NVATime	.00000	(Insuf)	.00000	.00000	10
Entity 1.WaitTime	32.378	(Insuf)	.00000	72.897	10
Entity 1.TranTime	.00000	(Insuf)	.00000	.00000	10
Entity 1.OtherTime	.00000	(Insuf)	.00000	.00000	10
Entity 1.TotalTime	102.37	(Insuf)	70.000	142.89	10
Trimming Station 2.Queue.WaitingTime	17.536	(Insuf)	.00000	25.000	5
Resaw Station 1.Queue.WaitingTime	1.4610	(Insuf)	.00000	10.000	9
Quality Control.Queue.WaitingTime	--	--	--	--	0
Headrig Breakdown.Queue.WaitingTime	.86372	(Insuf)	.00000	4.4000	14
Grading and Coding.Queue.WaitingTime	.00000	(Insuf)	.00000	.00000	10
Resaw Station 2.Queue.WaitingTime	2.0000	(Insuf)	.00000	10.000	5
Process 6.Queue.WaitingTime	--	--	--	--	0
Process 7.Queue.WaitingTime	--	--	--	--	0
Drying Process.Queue.WaitingTime	10.000	(Insuf)	.00000	30.000	11
Trimming Station 1.Queue.WaitingTime	21.729	(Insuf)	.00000	59.748	8

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Entity 1.WIP	2.7774	(Insuf)	.00000	5.0000	4.0000
QC worker.NumberBusy	.20833	(Insuf)	.00000	1.0000	.00000
QC worker.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
QC worker.Utilization	.20833	(Insuf)	.00000	1.0000	.00000
Resaw Machine 1.NumberBusy	.28125	(Insuf)	.00000	1.0000	.00000
Resaw Machine 1.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Resaw Machine 1.Utilization	.28125	(Insuf)	.00000	1.0000	.00000
Resaw Machine 2.NumberBusy	.15625	(Insuf)	.00000	1.0000	.00000
Resaw Machine 2.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Resaw Machine 2.Utilization	.15625	(Insuf)	.00000	1.0000	.00000
Worker 1.NumberBusy	.14583	(Insuf)	.00000	1.0000	.00000
Worker 1.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Worker 1.Utilization	.14583	(Insuf)	.00000	1.0000	.00000
Worker 2.NumberBusy	.14583	(Insuf)	.00000	1.0000	.00000
Worker 2.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Worker 2.Utilization	.14583	(Insuf)	.00000	1.0000	.00000
Worker 3.NumberBusy	.28125	(Insuf)	.00000	1.0000	.00000
Worker 3.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Worker 3.Utilization	.28125	(Insuf)	.00000	1.0000	.00000
Worker 4.NumberBusy	.28125	(Insuf)	.00000	1.0000	.00000
Worker 4.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Worker 4.Utilization	.28125	(Insuf)	.00000	1.0000	.00000
Worker 5.NumberBusy	.15625	(Insuf)	.00000	1.0000	.00000
Worker 5.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Worker 5.Utilization	.15625	(Insuf)	.00000	1.0000	.00000
Worker 6.NumberBusy	.15625	(Insuf)	.00000	1.0000	.00000
Worker 6.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Worker 6.Utilization	.15625	(Insuf)	.00000	1.0000	.00000
Worker 7.NumberBusy	.84818	(Insuf)	.00000	1.0000	1.0000
Worker 7.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Worker 7.Utilization	.84818	(Insuf)	.00000	1.0000	1.0000
Worker 8.NumberBusy	.78568	(Insuf)	.00000	1.0000	1.0000
Worker 8.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Worker 8.Utilization	.78568	(Insuf)	.00000	1.0000	1.0000
Worker 9.NumberBusy	.20833	(Insuf)	.00000	1.0000	.00000
Worker 9.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Worker 9.Utilization	.20833	(Insuf)	.00000	1.0000	.00000
machine.NumberBusy	.14583	(Insuf)	.00000	1.0000	.00000
machine.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
machine.Utilization	.14583	(Insuf)	.00000	1.0000	.00000
Trimming Machine 1.NumberBusy	.16667	(Insuf)	.00000	1.0000	.00000
Trimming Machine 1.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Trimming Machine 1.Utilization	.16667	(Insuf)	.00000	1.0000	.00000
Trimming Machine 2.NumberBusy	.10417	(Insuf)	.00000	1.0000	.00000
Trimming Machine 2.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Trimming Machine 2.Utilization	.10417	(Insuf)	.00000	1.0000	.00000

Trimming Machine 2.Utilization	.10417	(Insuf)	.00000	1.0000	.00000
Trimming Station 2.Queue.NumberInQueue	.18267	(Insuf)	.00000	1.0000	.00000
Resaw Station 1.Queue.NumberInQueue	.02739	(Insuf)	.00000	1.0000	.00000
Quality Control.Queue.NumberInQueue	.00000	(Insuf)	.00000	.00000	.00000
Headrig Breakdown.Queue.NumberInQueue	.02519	(Insuf)	.00000	1.0000	.00000
Grading and Coding.Queue.NumberInQueue	.00000	(Insuf)	.00000	.00000	.00000
Resaw Station 2.Queue.NumberInQueue	.02083	(Insuf)	.00000	1.0000	.00000
Process 6.Queue.NumberInQueue	.00000	(Insuf)	.00000	.00000	.00000
Process 7.Queue.NumberInQueue	.00000	(Insuf)	.00000	.00000	.00000
Drying Process.Queue.NumberInQueue	.36302	(Insuf)	.00000	2.0000	2.0000
Trimming Station 1.Queue.NumberInQueue	.41431	(Insuf)	.00000	2.0000	1.0000

OUTPUTS

Identifier	Value
Grading and Coding Number Out	10.000
Headrig Breakdown Number In	14.000
Resaw Station 1 Number In	9.0000
Drying Process Accum VA Time	300.00
Headrig Breakdown Accum Wait Time	12.092
Trimming Station 2 Number In	5.0000
Resaw Station 1 Accum Wait Time	13.149
Resaw Station 2 Accum VA Time	75.000
Trimming Station 2 Accum Wait Time	87.682
Drying Process Number In	13.000
Trimming Station 1 Accum VA Time	80.000
Trimming Station 2 Number Out	5.0000
Grading and Coding Number In	10.000
Drying Process Accum Wait Time	100.00
Grading and Coding Accum VA Time	100.00
Headrig Breakdown Number Out	14.000
Resaw Station 2 Number In	5.0000
Grading and Coding Accum Wait Time	.00000
Drying Process Number Out	10.000
Resaw Station 2 Number Out	5.0000
Trimming Station 1 Number In	9.0000
Headrig Breakdown Accum VA Time	70.000
Resaw Station 2 Accum Wait Time	10.000
Trimming Station 1 Accum Wait Time	173.83
Trimming Station 1 Number Out	8.0000
Resaw Station 1 Accum VA Time	135.00
Trimming Station 2 Accum VA Time	50.000
Resaw Station 1 Number Out	9.0000
Entity 1.NumberIn	14.000
Entity 1.NumberOut	10.000
QC worker.NumberSeized	10.000
QC worker.ScheduledUtilization	.20833
Resaw Machine 1.NumberSeized	9.0000
Resaw Machine 1.ScheduledUtilization	.28125
Resaw Machine 2.NumberSeized	5.0000
Resaw Machine 2.ScheduledUtilization	.15625
Worker 1.NumberSeized	14.000
Worker 1.ScheduledUtilization	.14583
Worker 2.NumberSeized	14.000
Worker 2.ScheduledUtilization	.14583
Worker 3.NumberSeized	9.0000
Worker 3.ScheduledUtilization	.28125
Worker 4.NumberSeized	9.0000
Worker 4.ScheduledUtilization	.28125
Worker 5.NumberSeized	5.0000
Worker 5.ScheduledUtilization	.15625
Worker 6.NumberSeized	5.0000

Worker 7.NumberSeized	19.000
Worker 7.ScheduledUtilization	.84818
Worker 8.NumberSeized	16.000
Worker 8.ScheduledUtilization	.78568
Worker 9.NumberSeized	10.000
Worker 9.ScheduledUtilization	.20833
machine.NumberSeized	14.000
machine.ScheduledUtilization	.14583
Trimming Machine 1.NumberSeized	8.0000
Trimming Machine 1.ScheduledUtilization	.16667
Trimming Machine 2.NumberSeized	5.0000
Trimming Machine 2.ScheduledUtilization	.10417
System.NumberOut	10.000

D Table of Simulation Result of Scenario 1

Replication ended at time : 480.0 Minutes
Base Time Units: Minutes

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
Resaw Station 2.VATimePerEntity	15.000	(Insuf)	15.000	15.000	5
Headrig Breakdown.WaitTimePerEntity	.86372	(Insuf)	.00000	4.4000	14
Resaw Station 2.WaitTimePerEntity	2.0000	(Insuf)	.00000	10.000	5
Drying Process 2.WaitTimePerEntity	.00000	(Insuf)	.00000	.00000	5
Trimming Station 2.WaitTimePerEntity	5.0000	(Insuf)	.00000	25.000	5
Trimming Station 2.VATimePerEntity	10.000	(Insuf)	10.000	10.000	5
Resaw Station 2.TotalTimePerEntity	17.000	(Insuf)	15.000	25.000	5
Trimming Station 2.TotalTimePerEntity	15.000	(Insuf)	10.000	35.000	5
Headrig Breakdown.VATimePerEntity	5.0000	(Insuf)	5.0000	5.0000	14
Drying Process.VATimePerEntity	30.000	(Insuf)	30.000	30.000	7
Grading and Coding.TotalTimePerEntity	10.725	(Insuf)	10.000	15.000	12
Grading and Coding.VATimePerEntity	10.000	(Insuf)	10.000	10.000	12
Drying Process 2.TotalTimePerEntity	30.000	(Insuf)	30.000	30.000	5
Drying Process.TotalTimePerEntity	30.000	(Insuf)	30.000	30.000	7
Drying Process 2.VATimePerEntity	30.000	(Insuf)	30.000	30.000	5
Headrig Breakdown.TotalTimePerEntity	5.8637	(Insuf)	5.0000	9.4000	14
Resaw Station 1.TotalTimePerEntity	16.461	(Insuf)	15.000	25.000	9
Trimming Station 1.TotalTimePerEntity	22.293	(Insuf)	10.000	39.748	9
Resaw Station 1.WaitTimePerEntity	1.4610	(Insuf)	.00000	10.000	9
Drying Process.WaitTimePerEntity	.00000	(Insuf)	.00000	.00000	7
Resaw Station 1.VATimePerEntity	15.000	(Insuf)	15.000	15.000	9
Trimming Station 1.WaitTimePerEntity	12.293	(Insuf)	.00000	29.748	9
Trimming Station 1.VATimePerEntity	10.000	(Insuf)	10.000	10.000	9
Grading and Coding.WaitTimePerEntity	.72559	(Insuf)	.00000	5.0000	12
Entity 1.VATime	70.000	(Insuf)	70.000	70.000	12
Entity 1.NVATime	.00000	(Insuf)	.00000	.00000	12
Entity 1.WaitTime	10.932	(Insuf)	.00000	42.637	12
Entity 1.TranTime	.00000	(Insuf)	.00000	.00000	12
Entity 1.OtherTime	.00000	(Insuf)	.00000	.00000	12
Entity 1.TotalTime	80.932	(Insuf)	70.000	112.63	12
Trimming Station 2.Queue.WaitingTime	5.0000	(Insuf)	.00000	25.000	5
Resaw Station 1.Queue.WaitingTime	1.4610	(Insuf)	.00000	10.000	9
Quality Control.Queue.WaitingTime	--	--	--	--	0
Headrig Breakdown.Queue.WaitingTime	.86372	(Insuf)	.00000	4.4000	14
Grading and Coding.Queue.WaitingTime	.72559	(Insuf)	.00000	5.0000	12
Resaw Station 2.Queue.WaitingTime	2.0000	(Insuf)	.00000	10.000	5
Process 6.Queue.WaitingTime	--	--	--	--	0
Drying Process 2.Queue.WaitingTime	.00000	(Insuf)	.00000	.00000	5
Process 7.Queue.WaitingTime	--	--	--	--	0
Drying Process.Queue.WaitingTime	1.2500	(Insuf)	.00000	10.000	8
Trimming Station 1.Queue.WaitingTime	12.293	(Insuf)	.00000	29.748	9

E Table of Simulation Result of Scenario 2

Identifier	Value
Grading and Coding Number Out	11.000
Headrig Breakdown Number In	14.000
Resaw Station 1 Number In	9.0000
Drying Process Accum VA Time	330.00
Headrig Breakdown Accum Wait Time	12.092
Trimming Station 2 Number In	5.0000
Resaw Station 1 Accum Wait Time	13.149
Resaw Station 2 Accum VA Time	75.000
Trimming Station 2 Accum Wait Time	.00000
Drying Process Number In	14.000
Trimming Station 1 Accum VA Time	90.000
Trimming Station 2 Number Out	5.0000
Grading and Coding Number In	11.000
Drying Process Accum Wait Time	154.87
Grading and Coding Accum VA Time	110.00
Headrig Breakdown Number Out	14.000
Resaw Station 2 Number In	5.0000
Grading and Coding Accum Wait Time	.00000
Drying Process Number Out	11.000
Resaw Station 2 Number Out	5.0000
Trimming Station 1 Number In	9.0000
Headrig Breakdown Accum VA Time	70.000
Resaw Station 2 Accum Wait Time	10.000
Trimming Station 1 Accum Wait Time	.00000
Trimming Station 1 Number Out	9.0000
Resaw Station 1 Accum VA Time	135.00
Trimming Station 2 Accum VA Time	50.000
Resaw Station 1 Number Out	9.0000
Entity 1.NumberIn	14.000
Entity 1.NumberOut	11.000
QC worker.NumberSeized	11.000
QC worker.ScheduledUtilization	.22917
Resaw Machine 1.NumberSeized	9.0000
Resaw Machine 1.ScheduledUtilization	.28125
Resaw Machine 2.NumberSeized	5.0000
Resaw Machine 2.ScheduledUtilization	.15625
Worker 1.NumberSeized	14.000
Worker 1.ScheduledUtilization	.14583
Worker 2.NumberSeized	14.000
Worker 2.ScheduledUtilization	.14583
Worker 3.NumberSeized	9.0000
Worker 3.ScheduledUtilization	.28125
Worker 4.NumberSeized	9.0000
Worker 4.ScheduledUtilization	.28125
Worker 5.NumberSeized	5.0000
Worker 5.ScheduledUtilization	.15625
Worker 6.NumberSeized	5.0000
Worker 6.ScheduledUtilization	.15625

Worker 7.NumberSeized	9.0000
Worker 7.ScheduledUtilization	.18750
Worker 8.NumberSeized	5.0000
Worker 8.ScheduledUtilization	.10417
Worker 9.NumberSeized	11.000
Worker 9.ScheduledUtilization	.22917
machine.NumberSeized	14.000
machine.ScheduledUtilization	.14583
Worker 10.NumberSeized	12.000
Worker 10.ScheduledUtilization	.74401
Worker 11.NumberSeized	12.000
Worker 11.ScheduledUtilization	.74401
Trimming Machine 1.NumberSeized	9.0000
Trimming Machine 1.ScheduledUtilization	.18750
Trimming Machine 2.NumberSeized	5.0000
Trimming Machine 2.ScheduledUtilization	.10417
System.NumberOut	11.000

F Table of Simulation Result of Scenario 3

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
Resaw Station 2.VATimePerEntity	15.000	(Insuf)	15.000	15.000	5
Headrig Breakdown.WaitTimePerEntity	.86372	(Insuf)	.00000	4.4000	14
Resaw Station 2.WaitTimePerEntity	2.0000	(Insuf)	.00000	10.000	5
Trimming Station 2.WaitTimePerEntity	1.8624	(Insuf)	.00000	5.0000	5
Trimming Station 2.VATimePerEntity	10.000	(Insuf)	10.000	10.000	5
Resaw Station 2.TotalTimePerEntity	17.000	(Insuf)	15.000	25.000	5
Trimming Station 2.TotalTimePerEntity	11.862	(Insuf)	10.000	15.000	5
Headrig Breakdown.VATimePerEntity	5.0000	(Insuf)	5.0000	5.0000	14
Drying Process.VATimePerEntity	10.000	(Insuf)	10.000	10.000	13
Grading and Coding.TotalTimePerEntity	10.000	(Insuf)	10.000	10.000	13
Grading and Coding.VATimePerEntity	10.000	(Insuf)	10.000	10.000	13
Drying Process.TotalTimePerEntity	11.153	(Insuf)	10.000	20.000	13
Headrig Breakdown.TotalTimePerEntity	5.8637	(Insuf)	5.0000	9.4000	14
Resaw Station 1.TotalTimePerEntity	16.461	(Insuf)	15.000	25.000	9
Trimming Station 1.TotalTimePerEntity	15.047	(Insuf)	10.000	25.000	9
Resaw Station 1.WaitTimePerEntity	1.4610	(Insuf)	.00000	10.000	9
Drying Process.WaitTimePerEntity	1.1538	(Insuf)	.00000	10.000	13
Resaw Station 1.VATimePerEntity	15.000	(Insuf)	15.000	15.000	9
Trimming Station 1.WaitTimePerEntity	5.0475	(Insuf)	.00000	15.000	9
Trimming Station 1.VATimePerEntity	10.000	(Insuf)	10.000	10.000	9
Grading and Coding.WaitTimePerEntity	.00000	(Insuf)	.00000	.00000	13
Entity 1.VATime	50.000	(Insuf)	50.000	50.000	13
Entity 1.NVATime	.00000	(Insuf)	.00000	.00000	13
Entity 1.WaitTime	7.3341	(Insuf)	.00000	28.761	13
Entity 1.TranTime	.00000	(Insuf)	.00000	.00000	13
Entity 1.OtherTime	.00000	(Insuf)	.00000	.00000	13
Entity 1.TotalTime	57.334	(Insuf)	50.000	78.761	13
Trimming Station 2.Queue.WaitingTime	1.8624	(Insuf)	.00000	5.0000	5
Resaw Station 1.Queue.WaitingTime	1.4610	(Insuf)	.00000	10.000	9
Quality Control.Queue.WaitingTime	--	--	--	--	0
Headrig Breakdown.Queue.WaitingTime	.86372	(Insuf)	.00000	4.4000	14
Grading and Coding.Queue.WaitingTime	.00000	(Insuf)	.00000	.00000	13
Resaw Station 2.Queue.WaitingTime	2.0000	(Insuf)	.00000	10.000	5
Process 6.Queue.WaitingTime	--	--	--	--	0
Process 7.Queue.WaitingTime	--	--	--	--	0
Drying Process.Queue.WaitingTime	1.0714	(Insuf)	.00000	10.000	14
Trimming Station 1.Queue.WaitingTime	5.0475	(Insuf)	.00000	15.000	9

G Table of Simulation Result of Scenario 4

File Edit Format View Help

Analyst: likching   Model revision date:12/ 2/2013

Replication ended at time : 480.0 Minutes
Base Time Units: Minutes

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
Resaw Station 2.VATimePerEntity	15.000	(Insuf)	15.000	15.000	5
Headrig Breakdown.WaitTimePerEntity	.86372	(Insuf)	.00000	4.4000	14
Resaw Station 2.WaitTimePerEntity	2.0000	(Insuf)	.00000	10.000	5
Drying Process 2.WaitTimePerEntity	3.0000	(Insuf)	.00000	15.000	5
Trimming Station 2.WaitTimePerEntity	.00000	(Insuf)	.00000	.00000	5
Trimming Station 2.VATimePerEntity	10.000	(Insuf)	10.000	10.000	5
Resaw Station 2.TotalTimePerEntity	17.000	(Insuf)	15.000	25.000	5
Trimming Station 2.TotalTimePerEntity	10.000	(Insuf)	10.000	10.000	5
Headrig Breakdown.VATimePerEntity	5.0000	(Insuf)	5.0000	5.0000	14
Drying Process.VATimePerEntity	30.000	(Insuf)	30.000	30.000	7
Grading and Coding.TotalTimePerEntity	10.941	(Insuf)	10.000	16.292	12
Grading and Coding.VATimePerEntity	10.000	(Insuf)	10.000	10.000	12
Drying Process 2.TotalTimePerEntity	33.000	(Insuf)	30.000	45.000	5
Drying Process.TotalTimePerEntity	32.766	(Insuf)	30.000	45.000	7
Drying Process 2.VATimePerEntity	30.000	(Insuf)	30.000	30.000	5
Headrig Breakdown.TotalTimePerEntity	5.8637	(Insuf)	5.0000	9.4000	14
Resaw Station 1.TotalTimePerEntity	16.461	(Insuf)	15.000	25.000	9
Trimming Station 1.TotalTimePerEntity	10.000	(Insuf)	10.000	10.000	9
Resaw Station 1.WaitTimePerEntity	1.4610	(Insuf)	.00000	10.000	9
Drying Process.WaitTimePerEntity	2.7660	(Insuf)	.00000	15.000	7
Resaw Station 1.VATimePerEntity	15.000	(Insuf)	15.000	15.000	9
Trimming Station 1.WaitTimePerEntity	.00000	(Insuf)	.00000	.00000	9
Trimming Station 1.VATimePerEntity	10.000	(Insuf)	10.000	10.000	9
Grading and Coding.WaitTimePerEntity	.94107	(Insuf)	.00000	6.2928	12
Entity 1.VATime	70.000	(Insuf)	70.000	70.000	12
Entity 1.NVATime	.00000	(Insuf)	.00000	.00000	12
Entity 1.WaitTime	5.5945	(Insuf)	.00000	28.930	12
Entity 1.TranTime	.00000	(Insuf)	.00000	.00000	12
Entity 1.OtherTime	.00000	(Insuf)	.00000	.00000	12
Entity 1.TotalTime	75.594	(Insuf)	70.000	98.930	12
Trimming Station 2.Queue.WaitingTime	.00000	(Insuf)	.00000	.00000	5
Resaw Station 1.Queue.WaitingTime	1.4610	(Insuf)	.00000	10.000	9
Quality Control.Queue.WaitingTime	--	--	--	--	0
Headrig Breakdown.Queue.WaitingTime	.86372	(Insuf)	.00000	4.4000	14
Grading and Coding.Queue.WaitingTime	.94107	(Insuf)	.00000	6.2928	12
Resaw Station 2.Queue.WaitingTime	2.0000	(Insuf)	.00000	10.000	5
Process 6.Queue.WaitingTime	--	--	--	--	0
Drying Process 2.Queue.WaitingTime	3.0000	(Insuf)	.00000	15.000	5
Process 7.Queue.WaitingTime	--	--	--	--	0
Drying Process.Queue.WaitingTime	4.2953	(Insuf)	.00000	15.000	8
Trimming Station 1.Queue.WaitingTime	.00000	(Insuf)	.00000	.00000	9

DISCRETE-CHANGE VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Final Value
Entity 1.WIP	2.1590	(Insuf)	.00000	5.0000	2.0000
QC worker.NumberBusy	.25000	(Insuf)	.00000	1.0000	.00000
QC worker.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
QC worker.Utilization	.25000	(Insuf)	.00000	1.0000	.00000
Resaw Machine 1.NumberBusy	.28125	(Insuf)	.00000	1.0000	.00000
Resaw Machine 1.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Resaw Machine 1.Utilization	.28125	(Insuf)	.00000	1.0000	.00000
Resaw Machine 2.NumberBusy	.15625	(Insuf)	.00000	1.0000	.00000
Resaw Machine 2.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Resaw Machine 2.Utilization	.15625	(Insuf)	.00000	1.0000	.00000
Worker 1.NumberBusy	.14583	(Insuf)	.00000	1.0000	.00000
Worker 1.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Worker 1.Utilization	.14583	(Insuf)	.00000	1.0000	.00000
Worker 2.NumberBusy	.14583	(Insuf)	.00000	1.0000	.00000
Worker 2.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Worker 2.Utilization	.14583	(Insuf)	.00000	1.0000	.00000
Worker 3.NumberBusy	.28125	(Insuf)	.00000	1.0000	.00000
Worker 3.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Worker 3.Utilization	.28125	(Insuf)	.00000	1.0000	.00000
Worker 4.NumberBusy	.28125	(Insuf)	.00000	1.0000	.00000
Worker 4.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Worker 4.Utilization	.28125	(Insuf)	.00000	1.0000	.00000
Worker 5.NumberBusy	.15625	(Insuf)	.00000	1.0000	.00000
Worker 5.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Worker 5.Utilization	.15625	(Insuf)	.00000	1.0000	.00000
Worker 6.NumberBusy	.15625	(Insuf)	.00000	1.0000	.00000
Worker 6.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Worker 6.Utilization	.15625	(Insuf)	.00000	1.0000	.00000
Worker 7.NumberBusy	.18750	(Insuf)	.00000	1.0000	.00000
Worker 7.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Worker 7.Utilization	.18750	(Insuf)	.00000	1.0000	.00000
Worker 8.NumberBusy	.10417	(Insuf)	.00000	1.0000	.00000
Worker 8.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Worker 8.Utilization	.10417	(Insuf)	.00000	1.0000	.00000
Worker 9.NumberBusy	.25000	(Insuf)	.00000	1.0000	.00000
Worker 9.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Worker 9.Utilization	.25000	(Insuf)	.00000	1.0000	.00000
machine.NumberBusy	.14583	(Insuf)	.00000	1.0000	.00000
machine.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
machine.Utilization	.14583	(Insuf)	.00000	1.0000	.00000
Worker 10.NumberBusy	.49040	(Insuf)	.00000	1.0000	1.0000
Worker 10.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Worker 10.Utilization	.49040	(Insuf)	.00000	1.0000	1.0000
Worker 11.NumberBusy	.31250	(Insuf)	.00000	1.0000	.00000
Worker 11.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Worker 11.Utilization	.31250	(Insuf)	.00000	1.0000	.00000
Trimming Machine 1.NumberBusy	.18750	(Insuf)	.00000	1.0000	.00000

Worker 5.NumberSeized	5.0000
Worker 5.ScheduledUtilization	.15625
Worker 6.NumberSeized	5.0000
Worker 6.ScheduledUtilization	.15625
Worker 7.NumberSeized	9.0000
Worker 7.ScheduledUtilization	.18750
Worker 8.NumberSeized	5.0000
Worker 8.ScheduledUtilization	.10417
Worker 9.NumberSeized	12.000
Worker 9.ScheduledUtilization	.25000
machine.NumberSeized	14.000
machine.ScheduledUtilization	.14583
Worker 10.NumberSeized	8.0000
Worker 10.ScheduledUtilization	.49040
Worker 11.NumberSeized	5.0000
Worker 11.ScheduledUtilization	.31250
Trimming Machine 1.NumberSeized	9.0000
Trimming Machine 1.ScheduledUtilization	.18750
Trimming Machine 2.NumberSeized	5.0000
Trimming Machine 2.ScheduledUtilization	.10417
System.NumberOut	12.000

Trimming Machine 1.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Trimming Machine 1.Utilization	.18750	(Insuf)	.00000	1.0000	.00000
Trimming Machine 2.NumberBusy	.10417	(Insuf)	.00000	1.0000	.00000
Trimming Machine 2.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Trimming Machine 2.Utilization	.10417	(Insuf)	.00000	1.0000	.00000
Trimming Station 2.Queue.NumberInQueue	.00000	(Insuf)	.00000	.00000	.00000
Resaw Station 1.Queue.NumberInQueue	.02739	(Insuf)	.00000	1.0000	.00000
Quality Control.Queue.NumberInQueue	.00000	(Insuf)	.00000	.00000	.00000
Headrig Breakdown.Queue.NumberInQueue	.02519	(Insuf)	.00000	1.0000	.00000
Grading and Coding.Queue.NumberInQueue	.02353	(Insuf)	.00000	1.0000	.00000
Resaw Station 2.Queue.NumberInQueue	.02083	(Insuf)	.00000	1.0000	.00000
Process 6.Queue.NumberInQueue	.00000	(Insuf)	.00000	.00000	.00000
Drying Process 2.Queue.NumberInQueue	.03125	(Insuf)	.00000	1.0000	.00000
Process 7.Queue.NumberInQueue	.00000	(Insuf)	.00000	.00000	.00000
Drying Process.Queue.NumberInQueue	.10291	(Insuf)	.00000	1.0000	1.0000
Trimming Station 1.Queue.NumberInQueue	.00000	(Insuf)	.00000	.00000	.00000

Identifier	Value
Grading and Coding Number Out	12.000
Headrig Breakdown Number In	14.000
Resaw Station 1 Number In	9.0000
Drying Process Accum VA Time	210.00
Drying Process 2 Accum VA Time	150.00
Drying Process 2 Number In	5.0000
Headrig Breakdown Accum Wait Time	12.092
Trimming Station 2 Number In	5.0000
Resaw Station 1 Accum Wait Time	13.149
Resaw Station 2 Accum VA Time	75.000
Trimming Station 2 Accum Wait Time	.00000
Drying Process 2 Accum Wait Time	15.000
Drying Process Number In	9.0000
Trimming Station 1 Accum VA Time	90.000
Trimming Station 2 Number Out	5.0000
Grading and Coding Number In	12.000
Drying Process Accum Wait Time	19.362
Drying Process 2 Number Out	5.0000
Grading and Coding Accum VA Time	120.00
Headrig Breakdown Number Out	14.000
Resaw Station 2 Number In	5.0000
Grading and Coding Accum Wait Time	11.292
Drying Process Number Out	7.0000
Resaw Station 2 Number Out	5.0000
Trimming Station 1 Number In	9.0000
Headrig Breakdown Accum VA Time	70.000
Resaw Station 2 Accum Wait Time	10.000
Trimming Station 1 Accum Wait Time	.00000
Trimming Station 1 Number Out	9.0000
Resaw Station 1 Accum VA Time	135.00
Trimming Station 2 Accum VA Time	50.000
Resaw Station 1 Number Out	9.0000
Entity 1.NumberIn	14.000
Entity 1.NumberOut	12.000
QC worker.NumberSeized	12.000
QC worker.ScheduledUtilization	.25000
Resaw Machine 1.NumberSeized	9.0000
Resaw Machine 1.ScheduledUtilization	.28125
Resaw Machine 2.NumberSeized	5.0000
Resaw Machine 2.ScheduledUtilization	.15625
Worker 1.NumberSeized	14.000
Worker 1.ScheduledUtilization	.14583
Worker 2.NumberSeized	14.000
Worker 2.ScheduledUtilization	.14583
Worker 3.NumberSeized	9.0000
Worker 3.ScheduledUtilization	.28125
Worker 4.NumberSeized	9.0000
Worker 4.ScheduledUtilization	.28125

H Process Description

Receiving of Logs


Station 1: Headrig Breakdown



Station 2: Re-saw Flow



Station 3: Trimming


Station 4: Grading and Storage