PRODUCTION LINE: EFFECT OF DIFFERENT INSPECTION STATION ALLOCATION UNDER ACCEPTS REJECT INSPECTION POLICY

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ABSTRACT

Manufacturing system is one of the most important parts in any organization as it produces the output of the company which will generate the profit. It consists partly of the production line which plays the role as the centre of production to create the end product which could be half finished or the full product. It is a big problem for the company to determine which is the better arrangement and combination of the tools or machines available in this area of the organization as different combination will greatly impact the productivity of the production line together with the profit of the company. This research intend to analyze a new production line in a metal stamping company based on the complain from the company and try to explore the better layout or arrangement in the production line in reflect to the complained problem and constrain of the provided of accept the defect and repair inspection policy. The production line is first being analyzed in response to complain through computer simulation. After the problem had been identified, the researcher tried different alternatives in the attempt to seek for the better layout or arrangement in the production line. The effect of different inspection station allocation layout is then being evaluated in term of the production time. The research has resulted in the finding of the cause for the long production time in the factory which is the long inspection steps which consumed much of the production time. After a few alternatives have been explored in allocating the inspection station, it is obvious that the current approach of the production line is the better one. Even by reducing the number of inspection station, interesting enough, the production time does not seem to decrease but yet increased. This finding contradicts the normal thought of fewer stations means shorter time. This finding could be the founding basic in the future research regarding the allocation of the inspection station following certain provided

policy. This is also very helpful in real life practice in company as to help them improve their production time. As for the time being, there is yet a research addressing this issue pertaining the given inspection policy.

ABSTRAK

Sistem pembuatan adalah salah satu bahagian yang paling penting dalam mana-mana organisasi kerana ia menghasilkan output syarikat yang akan menjana keuntungan. Ia terdiri sebahagiannya dari barisan pengeluaran yang berperanan sebagai pusat pengeluaran untuk menghasilkan produk akhir yang separuh siap atau produk penuh. Ia adalah satu masalah besar bagi syarikat yang berkenaan untuk menentukan susunan yang lebih baik dan gabungan alat atau mesin yang terdapat di kawasan ini sebagai kombinasi yang berlainan dan dapat memberi kesan kepada produktiviti barisan pengeluaran serta keuntungan syarikat. Kajian ini adalah untuk menganalisis satu barisan pengeluaran baru dalam syarikat "metal stamping" berdasarkan aduan dari syarikat terbabit dan cuba untuk meneroka susun atur yang lebih baik dalam barisan pengeluaran dalam mencerminkan masalah yang diadukan dan kekangan yang dihadapi. Sebagai permulaan, barisan pengeluaran dianalisis sebagai respon kepada aduan dengan mengggunakan simulasi komputer. Setelah masalah dikenal pasti, penyelidik telah mencuba beberapa alternatif dalam usaha untuk mendapatkan susun atur atau perkiraan yang berbeza yang lebih baik dalam barisan pengeluaran yang berkenaan. Kesan susun atur stesen pemeriksaan yang berbeza kemudiannya dinilai dalam bentuk masa pengeluaran. Kajian ini telah menghasilkan dapatan bagi punca bagi masa pengeluaran yang lama di mana ianya terletak pada langkah-langkah pemeriksaan yang memakan banyak masa pengeluaran. Selepas beberapa alternative diterokai dalam memperuntukkan stesen pemeriksaan, ia jelas menunjukkan bahawa pendekatan sedia ada barisan pengeluaran adalah yang terbaik. Walaupun dengan mengurangkan bilangan stesen pemeriksaan, masa pengeluaran tidak berkurang malah semakin meningkat. Penemuan ini bercanggah dengan pemikiran biasa di mana stesen yang kurang, bermakna masa yang lebih singkat.

Penemuan ini boleh menjadi asas dalam penyelidikan masa depan mengenai peruntukan stesen pemeriksaan berdasarkan polisi tertentu yang telah disediakan. Ia juga sangat membantu dalam amalan kehidupan sebenar syarikat untuk membantu mereka memperbaiki masa pengeluaran. Buat masa ini, masih belum terdapat kajian yang cuba menangani isu ini.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

According to Groover M.P., (2010), manufacturing can be defined in two ways, one technologically, and the other one economically. Manufacturing in the technological term means the application of physical and chemical processes to alter the geometry, properties, or appearance of a given starting material to make parts or products. It also includes assembly of multiple parts to make products. In the economic term, manufacturing means, the transformation of materials into items of greater value by means of one or more processing or assembly operations. In easy words, manufacturing adds value to the material by changing its shape or properties, or by combining it with other materials that have been similarly altered.

Basically, this process is not as easy as it seems. A lot of problems could occur during this process which requires a lot of preparation and consideration so that everything will run as it should. Two main method can be done to achieve this desire, one is through the rigorous on the floor tests combined with mathematical problem solving, and the other one through the simulation by the aid of computer software which will give the prediction on how well the whole or partly processes of manufacturing could be done to be compared with the real one.

These two processes start quite a long time ago to help the people in the manufacturing field to make decisions which will greatly affect the company future. But the preferable method is to use the computer simulation which is cheaper and more appropriate in the new millennium as we are really lack of time in doing many things including manufacturing.

This research intends to look upon the situation of the manufacturing system specifically in the production line to help the possible improvement of the manufacturing system in term of the application of the simulation software. As being cited in previous research, it is widely recognized that innovation is a key factor in sustaining Malaysia's competitiveness in the face of rapid globalization (Chandran. *et. al*., 2009) and the productivity in the production line is an element in maintaining that competitiveness. While there have been few studies on innovation (Hobday,1996; Rasiah, 2003; Narayanan and Wah, 2000) and internationalization of R&D activities (Ariffin and Figueiredo, 2004) in Malaysia, less attention has been paid to analyzing the issue as a system hence providing little evidence for any significant policy directions which in this case the implementation of simulation software. Furthermore, the need to visualize the system will attract more attention from the managerial line to incorporate possible alternatives into the company itself and simulation come in handy as the answer (Swenseth. *et.al*. 2002).

1.2 Background of study

Manufacturing has become part of all human activity since a long time ago until it is quite impossible to track back when all of this whole process started. This is because, human body itself is a very complex system which produces a lot of things such as voice, movement, idea to create a book, journal and the list seems endless. If we really want to establish this entire event, we must find the first human or creature that live in this world. But the problem is, after centuries, scientist kept finding the older human body than the previous finding.

On a focused manner, the history of manufacturing can be separated into two subjects. The first one is man's discovery and invention of materials and processes to make things, while the second one is the development of the systems of production.

Groover M.P. (2010) stated that the event of human discovery to invent materials and processes to make things started several millennia ago. Some of the processes are the casting process, hammering (forging), and grinding which dated back more than 6000 years ago.

For this research, the focus is towards the understanding of the production systems and possible improvement in the productivity. Thus, an efficient production line design as part of a manufacturing system is a vital problem for some companies (Yaman. R 2008). In order to make this research possible, an organization had been selected as the place to conduct this study. The chosen company is a Metal Industry in Perak Darul Ridzuan.

Metal Industry is a company which manufactures and supply the inner component for machines such as computer, booster, oil pump and many more. This company started the operation in 1994. There are more than 70 employees which work in this company. Recently, there is no software or advance technique being employed in order to assist the managers to understand and subsequently improve on the productivity of the company. In this case, this research intend to help them to understand and improve their productivity through the utilization of computer software which in this case, ProModel. The focus is more towards the production line in the company which they process and join the components to create a product.

1.3 Problem statement

"The possible permutations and combinations of work pieces, tools, pallets, transportation vehicles, transport routes, operations, etc., and their resulting performance, are almost endless. Computer simulation has become an absolute necessity in the design of practical systems, and trend towards broadening its capabilities is continuing as system move to encompass more and more of the factory", Kochan (1986).

Today's complex, unpredictable and unstable marketplace requires flexible manufacturing systems capable of cost-effective high variety-low volume production in frequently changing product demand and mix.

From the above statement, we could see that the problem in the manufacturing system is endless as it composed of many variables that contribute towards the productivity in manufacturing. It is very wise for the managerial people in this area to select the right method to determine the ideal combination and arrangement of those factors so that the productivity of the manufacturing system will be maximized or at least improved. Production line is one of the components in the manufacturing system. A slight different in the arrangement of the entities will bring a big different in the outcome such as profit, unit of product being produced and much more.

To further support the above statement, a real example of the problem in the manufacturing system should be included. Based on the cases being handled by ProModel Software Company (a software company which provide simulation software to simulate the manufacturing system), a lot of problems being faced in the manufacturing process can be successfully overcome with the use of a computer simulation like theirs. One of the examples where this simulation software could be implemented is in Metal Industry. The company wants to improve and increase its production capacity, quality, and net profit. According to their experience, they do not have any bottleneck on the production and procurement part of the manufacturing. They are having some curiosity in a recently developed production line for a new product requested by their customer.

They have to implement an exhaustive step of inspection as prepared and requested by the customer themselves. Due to strict agreement of the customer with the factory, the details of the steps in the production line could not be included or explained too much in this research. They just allow exposing it generally.

Basically this new production line was developed to produce a part from a cashier machine, to be specific, the part to cut the paper inserted into the cash machine or the receipt. In the time being this is the sole product being produced in the production line. There are generally 24 steps or stations to produce this product. The production line processes the input in batches of 50 each time. From the 24 steps required, there are 9 stations of inspection all over the production line. The inspection station is more concentrated in the beginning of the line which appears nearly after each step.

Sometimes, the demands for the product fluctuate. In moment of low demand, the factory is comfortable and could meet the demand in time while following the required steps. But then, when the demand is high, the rigorous steps could hinder from high production due to long time of production with limited available time frame. In moment like this they wish that they could eliminate some steps in order to save some production time to produce more item as ordered. Figure 1.1 shows the fluctuation of demand and the available production time in 2011.

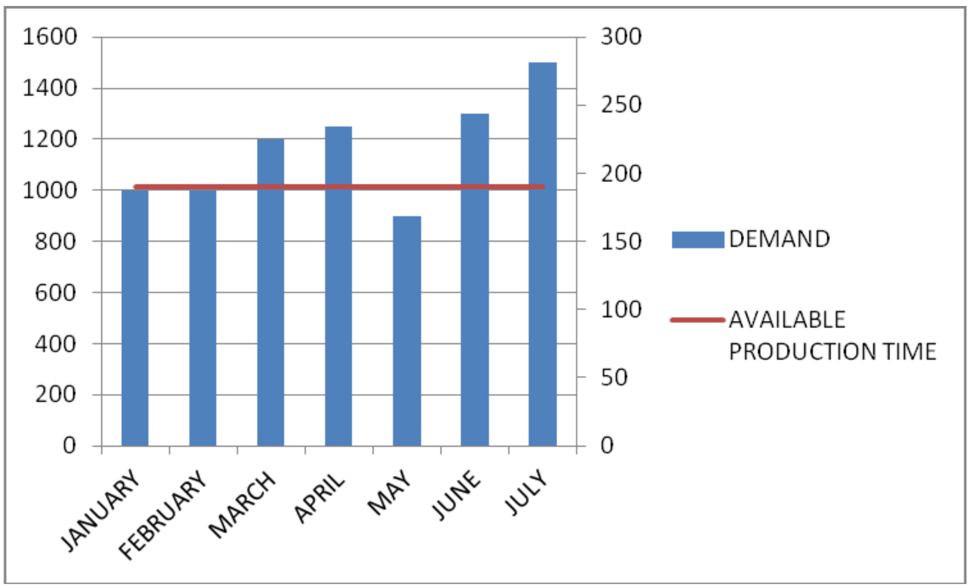


Figure 1.0: Pareto chart of demand against the available production time for 2011

Based on the experience of the worker, some steps could be combined but never be skipped such in the many steps of inspection. They have not yet tested this in reality and wish to see how it will impact on the production time. This has attracted the attention of the manager in charge and the researcher of the affect of this action on the production time. For this reason, they have decided to explore a number of scenarios to help in this problem. This problem could be helped by a production line simulation, and this solution may also improve most of the outcomes for the business. They also stipulate the following limitations (problem statements):

- the solution must not require high investment and technology;
- the solution must follow the inspection policy of the acceptance of the defective units which requires repairing of the defective units after detection;
- solution must not require highly skill workers (they should be trained in a few working days);
- the processes or steps in the production of the product cannot be skipped but can be combined.

The above idea suggests that there is a need for a simulation technology in order to overcome the manufacturing problem.

Basically there are two ways in accomplishing this objective. The first method is by field measurement which is costly and time consuming. While the second method is through computer simulation which had been mentioned and proposed in the above statement. It also could be derived that the application of simulation being even broader, relevant and practical as the time passes by suitable with the technological change that continuously happen. Simulation is considered as an increasingly important computer aid to the design process, partly because of the growing complexity of manufacturing systems, and partly because of their dynamic and stochastic behaviour (Carrie, 1988; Kochhar, 1989; Law and Haider, 1989; Baldwin *et.al*, 2005). Simulation is one type of modelling, and it offers many benefits including in the manufacturing system and production line (Bhaskar *et al*., 1994; Giaglis *et al*., 1999; Lee and Elcan, 1996).

1.4 Research question

a) What is the problem in the new production line?

b) What are the alternatives to improve the current production line?

c) What is the effect of different inspection allocation on the production time within these limitations?

- the solution must not require high investment and technology;
- the solution must follow the inspection policy of the acceptance of the defective units which requires repairing of the defective units after detection;
- solution must not require highly skill workers (they should be trained in a few working days);
- the processes or steps in the production of the product cannot be skipped but can be combined.

1.5 Research objective

The study aims to achieve the following objectives:

i. To evaluate the current approach of the production line.
ii. To propose a few alternatives in the production line within the scope of the given inspection policy.
iii. To investigate the impact of different inspection station allocation on the production time through the usage of computer simulation within the scope of acceptance of defective units and repair inspection policy.

1.6 Research scope

This research focused on the production line which is applicable in the area of the manufacturing system in any organization in Malaysia. In accordance with this research and suitable with the research objective, it will be conducted in the production line in a metal stamping company. This company manufactures parts and components for petrol pump, ATM (Automated Teller Machines) machines and others. The variable to be measured is the productivity of the company based on the computer simulation that will be done. This research also tests only the different scenario of inspection policy being implemented in the production line based on the acceptance of defects and repair inspection policy.

1.7 Importance of research

1.7.1 To understand the problem in the production line.

1.7.2 To propose alternatives and select the better strategy to complete the manufacturing process in the production line in a timely manner.

1.7.3 To understand the effect of different inspection station allocation under the given inspection policy.

1.7.4 Can examine the various scheme of inspection policy.

1.7.5 Can simulate the production line in a realistic, flexible, and marginal cost compared to mathematical model and experimentation.

1.7.6 Giving the suggestion to the related department or organization on the method available to plan the production system.

1.7.7 Provide some idea or foundation for further research in the production area.

1.8 Research overview

In order to achieve the objectives of the research, Chapter 2 does include the related definitions and literature review on the previous research in the related field. While in Chapter 3, the methodology to acquire the listed objectives will be presented. Moving to Chapter 4 the results to answer the research questions and objectives will be apparent. The fifth chapter will discuss on the result and how it may benefit in the future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The next step in completing this research is to review the past literature on the same or related area of study that is connected to the research being done. Moreover this chapter will further explain on what this research are all about and how the previous scholar or researchers conduct their study in the related areas together with their findings. The definition of the essential terms in this will be explained and the related literatures also will be unveiled to better serve the understanding of the reader.

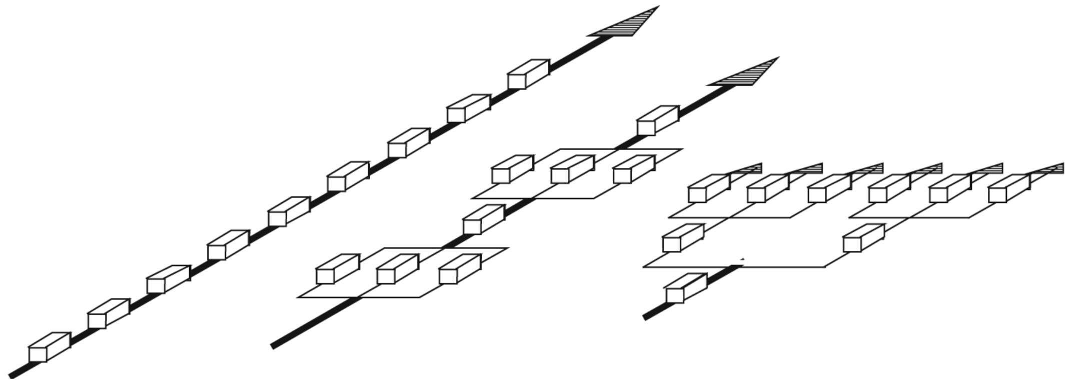
2.2 Production line definition

"Production line is a series of arranged workstations so that the product moves from one station to the next, and at each location a portion of the total work is performed on it (Groover M.P, 2010)." This is where the materials available in the manufacturing system being processed and joined together to create a product which could be neither finished product or half finished product which will be supplied for another process.

Basically there are two main types of production line. The first type of production line is where every product is identical. As an example is the production line to produce a car, there is only one type of window, one type of door, one type of tyre and so on to produce a single type of car.

While the second type of production line is the mixed-model production line. This type of production line applies to the situations where there is soft variety in the product made on the line. Modern automobile is an example, where there are many types of car body, door, tyre and so on to produce many types of cars. Cars coming off this production line have variations in options and trim representing different models and in many cases different nameplates of the same basic car design.

From those two types of production lines, according to Jonsson, *et al.* (2004), there are several flow patterns or design of the production line. The first type is the single product flow pattern. The second pattern is the semi-parallel product flow pattern, and the last pattern is the parallel product flow pattern.



Note: From left to right: a single product flow pattern (e.g. a traditional assembly line), a semi-parallel product flow pattern (e.g. the Volvo Kalmar plant), and a parallel product flow pattern (e.g. the Volvo Uddevalla plant)

Figure 2.1: Patterns of the assembly/production line (Jonsson, *et al.* (2004))

Figure 2.2: Modern car production lines (http://en.wikipedia.org/wiki/Assembly_line)

Flow lines, of which, production lines are an example is the most commonly used system in a mass production environment. Production lines enable the processing of complex products by workers who have received a short training period (Gunasekaran and Cecile, 1998). Thus, an efficient production line design as part of a manufacturing system is a vital problem for some companies.

2.3 Productivity definition

“Productivity is generally defined as the relation of output (i.e. produced goods) to input (i.e. consumed resources) in the manufacturing transformation process”, (Sumanth, 1994). While according to Stefan, (2005), the meaning of productivity can vary, depending on the context within which it is used across the fields. But basically, productivity is a measure of output from a production process, per unit. For example, labour productivity is typically measured as a ratio of output per labour-hour (an input).

Subsequently, an increase in productivity is characterized by a shift of the production function and a consequent change to the output/input relation. The formula of total productivity is normally written as follows:

- Total productivity = Output quantity / Input quantity

According to changes in input and output, productivity has to be measured all-encompassing of both quantitative and qualitative changes. In practice, quantitative and qualitative changes take place when relative quantities and relative prices of different input and output factors alter. In order to emphasize qualitative changes in output and input, the formula of total productivity shall be written as follows:

- Total productivity = Output quality and quantity / Input quality and quantity

The other way of calculating productivity is partial productivity. Measurement of partial productivity refers to the measurement solutions which do not meet the requirements of total productivity measurement. Partial productivity measurement is equally important as it is being practicable as indicators of total productivity. In practice, measurement in production means measures of partial productivity. In this case, the objects of measurement are components of total productivity, and interpreted correctly, these components are indicative of productivity development. The term of partial productivity illustrates well the fact that total productivity is only measured partially or approximately. In a way, measurements are defective but, by understanding the logic of total productivity, it is possible to interpret correctly the results of partial productivity and to benefit from them in practical situations.

These are the typical solutions of partial productivity:

i) Single factor productivity

ii) Value added productivity

iii) Unit cost accounting

iv) Efficiency ratios

v) Managerial control ratio system

Single-factor productivity refers to the measurement of productivity that is a ratio of output and one input factor. A most well-known measure of single-factor productivity is the measure of output per work input, describing work productivity. Sometimes it is practical to employ the value added as output. Productivity measured in this way is called Value-added productivity. Also, productivity can be examined in cost accounting using Unit costs. Then it is mostly a question of exploiting data from standard cost accounting for productivity measurements. Efficiency ratios, which tell something about the ratio between the values produced and the sacrifices made for it, are available in large numbers. Managerial control ratio systems are composed of single measures which are interpreted in parallel with other measures related to the subject. Ratios may be related to any success factor of the area of responsibility, such as profitability, quality, position on the market, etc. Ratios may be combined to form one whole using simple rules, hence, creating a key figure system.

The measures of partial productivity are physical measures, nominal price value measures and fixed price value measures. These measures differ from one another by the variables they measure and by the variables excluded from measurements. By excluding variables from measurement makes it possible to better focus the measurement on a given variable, yet, this means a more narrow approach. Table 2.1 below was compiled to compare the basic types of measurement. The first column presents the measure types, the second the variables being measured, and the third column gives the variables excluded from measurement.

Table 2.1: Comparison of basic productivity measure types (Saari 2006)

TYPE OF MEASURE	Variables to be measured	Variables excluded
Physical	Quantity	Quality and distribution
Fixed price value	Quantity and quality	Distribution
Nominal price value	Quantity, quality and distribution	None

2.4 Simulation definition

According to Schriber (1987), simulation is "the modelling of a process or system in such a way that the model mimics the response of the actual system to events that take place overtime". During the last three decades there has been a dramatic increase in the use of simulation to design and optimise manufacturing and warehousing systems (Hollocks, 1992). There are three main reasons for the increase in use of simulation in manufacturing. Firstly, increasing competition as a result of greater emphasis on automation to increase productivity, quality, and reduce costs, has led to an increased complexity which can be analysed only by simulation. Secondly, there has been a large-scale reduction in the cost of computer hardware required to run the simulation models, in addition to the availability of advanced simulation software. Thirdly, the introduction of animation has resulted in a greater understanding of simulation by non-simulationists such as managers and manufacturing engineers (Baldwin. *et al*. 2005).

In accordance with this study, the concern of the simulation is via the usage of computer software to imitate the real situation that take place inside an organization, in particular, the manufacturing process. In an easy word, simulation is the process of imitating a dynamic system using a computer model in order to evaluate and improve system performance. Through the study of the behaviour of the model, we can insights about the behaviour of the actual system and the possible improvement to be made.

Simulation is a well-established methodology that has received great attention in the literature, has a widespread application base in manufacturing and offers, at least in theory, to be an attractive approach to supporting manufacturing management. There is a wealth of literature on the subject and most offer guidelines for undertaking a simulation study (e.g. Law and Kelton, 1991; Pidd, 1988; Von Uthman and Becker, 1999). Several more studies have employed simulation for evaluating and investigating the application of production methodologies and tools. For example, Chan and Smith (1993), Lovell (1992) and Wu (1994) investigate just in time (JIT) (Meta Software Corporation Design, 1992), Schafer and Meredith (1993) consider cellular manufacturing, and Schian and Morrison (1992), Yenradee (1994) and Yavuz and Satir (1995) consider optimised production technology.

Computer simulations are used to model the new improved operation prior to its implementation. Software programs, such as, Microsoft Visio, Excel, and Arena, can be used to map, analyze and simulate the changes incorporated to the operation (Edson, 1999; Garbowski, 2000, b; Walkenbach, 1999; Kelton et al., 2002). Microsoft Visio has an excellent interface with both Microsoft Excel and Arena.

Figure 2.3: Example of computer simulation (http://www.promodel.com/solutions/manufacturing/manufacturing-example-model.asp)

2.5 ProModel

ProModel is the acronym for production modeller by PROMODEL Corporation which is a simulation tool for modelling various manufacturing and service systems, Harrell *et al.* (2011). This simulation software could be used to model the manufacturing system prior to the real implementation so that the cost and investment on the decision to raise the productivity is not wasted and maximized. This software covers job shops, conveyors, transfer lines, mass production, assembly lines, flexible manufacturing systems, cranes, just in time systems, kanban systems, and so forth.

ProModel focus on resource utilization, production capacity, productivity, inventory levels, bottlenecks, throughput times, and other performance measures. It is a discrete event simulator and intended to model discrete systems. The time resolution to simulate the event or system is controllable and adjustable which ranges from 0.01 hours to 0.00001 seconds. This software uses a graphical user interface (GUI) and also compatible to be used with Windows operating system such as Windows XP, Me, 2000, 98, 95, or NT. It utilizes all Window features such as standard user interface, multitasking, built-in printer drivers, and “point and click” operation. It also provides an online help system and a trainer.

Based on the book produced by the PROMODEL Corporation, Harrell *et al.* (2011), the basic modelling element which needed in order to start the simulation is locations, entities, arrivals and processing.

2.5.1 Locations.

Locations represent fixed places in the system where entities are routed for processing, delay storage, decision making, or some other activity. It requires some type of receiving locations to hold incoming entities. Other than that, the processing locations where entities have value added to them is also needed.

2.5.2 Entities.

Anything that a model can process is called an entity. The examples of entities are parts or widgets in a factory, patients in hospital, customers in a bank or a grocery store, and travellers calling in for airline reservations.

2.5.3 Arrivals.

Arrivals are the mechanism for defining how entities enter the system. The entities can be in a single form or in batches. The number of entities arriving at a time is called the batch size (Qty each). The time between the arrivals of successive entities is called interarrival time (Frequency). The total number of batches of arrivals is the occurrences. The batch size, time between successive arrivals, and total number of batches can be either constants or random (statistical distributions).

2.5.4 Processing.

Processing describes the operations that take place at a location. This can be the amount of time an entity spends there, the resources it needs to complete processing, and anything else that happens at the location, including selecting an entity's next destination.

2.6 Relation between productivity and simulation

After going through journals and books, it could be identified how strong the correlation between computer simulation and manufacturing system in determining and improving the productivity of the system itself. As being written previously, productivity being measured by calculating the ratio between input and output. It is not an easy task in order to achieve the optimal productivity, as it had been said by Park *et al*. (2002), “difficult lies in the need to synchronize several processes to create a flow through the plant. There are larger numbers of constraints and very little work in process is allowed.”

From the above statement, we could see that the higher managerial position want to cut off as much work as possible so that the cost needed through the manufacturing process could be minimized greatly. In contrast to that demand, higher productivity rate is being desired by the higher authority of the organization. A tool that could solve this big problem is in dire need, but at the same moment, will not consume a large proportion of the cost required.

This is where computer simulation comes with a big hand to help the company achieve that seemingly impossible desire. According to Harrel *et al.* (2011), rather than leave decisions to chance, simulation provides a way to validate whether or not the best decision are being made. Furthermore, simulations avoid the expensive, time consuming, and disruptive nature of trial-and-error techniques. It is no longer relevant to rely on the traditional trial-and-error methods with the emphasis today on time based competition. The power of simulation lies in the fact that it provides a method of analysis that is not only formal and predictive, but is capable of accurately predicting performance of even the most complex systems.

The need and urge to implement computer simulation in the manufacturing process can easily being seen by the words of Shi (2001),” An international contractor has reported productivity improvements due to the simulation ranging from 30% to 300%. In this case, for every hour of simulation analysis used a saving of $2,500 achieved in 1999”.

In this statement we can easily see the simple figure of how the computer simulation could affect the productivity of the manufacturing system. Even though the example taken was from a construction site, but it is still a manufacturing system. Although construction even rather complicated as it deals with people (human resource), materials, costs, elements of nature (weather etc) and much more. A computer simulation still could provide some form of solution which is worth while to be considered.

Based on that, it is wise to select the right method to coordinate all of the resources available so that it could be used to the maximum to achieve the highest productivity efficiency level and nothing would be wasted. It also mean the move or choice to manipulate the computer simulation software is the right way as it is less costly but could make a really big difference.

Some of the application of computer simulation:

-estimate the possible delays,

-productivity determination and improvement,

-resource management and optimization,

-system stochastic response to unforeseen conditions

-ability to respond to random and dynamic features in the operation of the system

(Zayed and Halpin, 2001)

In addition, Marmon (1991) and Luk (1990) emphasised the use of simulation to study design, construction and production phases of the facilities in order in order to justify and fine tune the impacts on process design changes.

2.7 Relevant literature on facility layout.

Table 2.2: Literatures on facility layout

No.	Author	Year	Approach	Measurement	Discussion
1)	Hong et. al.	2011	Simulation.	Time/ speed.	This research focuses on the design of the egg inspecting/grading process. It emphasized on the required steps in egg grading and the speed. The production line itself is an inspection.
2)	Judi et. al.	2011	Simulation.	Total surface area.	The emphasized improvement is focused on the layout of the computer laboratory based on a few established shapes and the one proposed by the researcher.
3)	Xiaohong et. al.	2011	Simulation.	Manufacturing cost.	The emphasized improvement is focused on the layout of the manufacturing system based on the minimum manufacturing cost.
4)	Junzheng et. al.	2011	Genetic algorithm & simulation.	Manufacturing cost.	The emphasized improvement is focused on the layout of the manufacturing system based on the set-up cost, holding cost, material handling cost and facility allocation cost.
5)	Miller et. al.	2011	Simulation.	Movement & speed.	This research tackled the problem of the conveyer layout in the production line which concern on the ease or less movement and the speed.
6)	Lizhi et. al.	2011	Mathematical model & simulation.	Distribution cost.	This research emphasized the problem of the distribution considering centralized or decentralized layout options.
7)	Seyed et. al.	2011	Mathematical modeling.	Manufacturing efficiency (distance traveled to retrieve parts,	This research tries to look upon the influence of different work cell layout towards the efficiency of the manufacturing system.

				average daily output of engines, labour cost per unit produced, and the amount of time the engine remains in each cell)	
8)	Vasudevan et. al.	2010	Simulation.	Throughput.	This research discusses on how to improve the production line by mainly alternating with two options or scenarios which is the change of crane efficiency in the production line
9)	Niu et. al.	2010	Simulation.	Ergonomic.	The improvement is emphasized on how to transform the current production line into being ergonomic.
10)	Jayachitra R. and Prasad P. S. S	2010	Genetic algorithm & simulation.	Machine utilization, throughput, average distance travelled by parts and average work-in-process	This research test these three layouts in the chosen company: i) virtual cellular layout ii) existing functional layout iii) classical cellular layout
11)	Hemanta Doloi	2010	Simulation.	Time Utilization Combined with strategic business objectives.	The focus of the research is more on decision making based on business objectives and facility layout.
12)	Chen G.Y.H	2007	Ant Colony Optimization.	Total cost.	This research tries to test different dynamic facility layout by using the Ant Colony Optimization method.
13)	Bozer and Hsieh.	2005	Quadratic assignment problem.	Throughput.	Different types of conveyors were tested such as discrete space, fixed window and closed loop in determining the layout.
14)	Chiang and Lee.	2004	Genetic-based algorithm	Flow cost.	Addresses the joint problem of the cell formation and the intercell layout, in which machine cells are located along a linear flow layout.
15)	Saad, S.M. and Lassila, A.M.	2004	Heuristic.	Resource requirements and material	In this paper, various fractal cell configuration methods for different system design

				movements.	objectives and constraints are proposed
16)	Chien T.K	2004	Systematic layout planning	Multiple objective decision making & analytic hierarchy process.	The focus of the research is developing a procedure on decision making in term of selecting facility layout based on Muther's systematic layout planning procedure.
17)	Gopalakrishnan et. al.	2003	Splitting departmental approach.	Material handling costs.	This research tries to look upon the different layout based on data acquisition module, a pair-wise departmental exchange module, a layout development module, and a graphical representation module.
18)	Castilloy, I. and Peters, B.A.	2003	Heuristic.	Inter-department unit load size, intra-department material handling cost, inter-department material handling cost, user-specified space filling curve, and part process routing information.	In this paper, it considers manufacturing systems in which replicates the same machine type which may exist in the facility.
19)	Selim H.M.	2002	Heuristic.	Design flexibility.	This research compared different cellular manufacturing layout design presented in a graph as a new way of arranging the manufacturing.
20)	Huq et. al.	2001	Simulation.	Time & throughput.	This research tries to compare the performance of functional layouts and the cellular layouts which produce better productivity.
21)	Shouman et. al.	2001	Artificial intelligent.	Cost.	Different techniques were tested such as fuzzy logic, genetic algorithms and neural network in order to determine the layout of facility.
22)	Yang et. al.	2000	Systematic layout planning	Multiple objective decision making & analytic hierarchy process.	The focus of the research is developing a procedure on decision making in term of selecting facility layout.
23)	Rooks B.	2000	Simulation.	Bottleneck & investment	The development of new simulation software based

				return.	on two company case study was proposed and it focuses on the assembly line layout improvement.
24)	Caron et. al.	2000	Simulation.	Time.	Compared random or cube per order index (COI)-based storage policies.
25)	Kerns F.	1999	Strategic facilities planning	Key principles & key stages in facility layout planning.	Outlines the evolution of facilities design to the point where it is capable of supporting an organization's strategic content. Explains the key principles of strategic facility planning (SFP)
26)	Brooks A.	1998	Survey Ergonomic.	Ergonomic.	Highlight the improvement of the facility layout emphasizing on the ergonomic criteria.
27)	D.J. Hall, & T.Q. Ford	1998	Heuristic.	Meeting the requirements of the company, management by prevention, cost of quality and error- free work.	Provides a link between the total quality philosophy and building design/factory layout.
28)	Wainwright C.E.R.	1996	Queuing theory.	Cost, size and scheduling effectiveness.	The focus of the research is to alternate layout approach based on the queuing theory.

The extant research on the facility layout problem is broad and extensive; and the layout design problem was tackled using different approaches. Examples of approaches and techniques include: mathematical models based on queuing theory (Wainwright, 1996), simulation (Caron et al., 2000; Huq et al., 2001; Rooks, 2000; Lizhi et. al., 2011; Seyed et. al., 2011), strategic facilities planning (Kerns, 1999), ergonomics (Brooks, 1998), a systematic layout planning (SLP) (Yang et al.; 2000; Chien, 2004), heuristic (Hall and Ford, 1998; Selim, 2002; Castilloy and Peters, 2003; Saad and Lassila, 2004), artificial intelligent (Shouman et al., 2001), a splitting departmental approach (Gopalakrishnan et al., 2003), a genetic-based algorithm (Chiang and Lee, 2004), and quadratic assignment problem (Bozer and Hsieh, 2005) and much more just to name a few such as Chien T.K (2004), Vasudevan et. al. (2010), Niu et. al. (2010), Jayachitra R. and Prasad P. S. S (2010), Hemanta Doloi (2010), and Seyed et. al. (2011) as being listed in the above table.

The layout design problem has been an active research area in the past years. Sule (1994) argued that the facility layout problem is a long-term, costly proposition, and any modifications or rearrangements of the existing layout represent a large expense and cannot be easily accomplished. Canen and Williamson (1998) presented in chronological order, a non-exhaustive survey of the most representative and historical computer software for facility layout evaluation. Shouman et al. (2001) presented a summary of the most recent developments of conventional algorithms and intelligent techniques for FLP.

Sha and Chen (2001) developed a new approach for combining the quantitative and qualitative objectives to resolve the facility layout problem, and offered a new measure of solution quality, the probability of superiority for the determination of the probability that one layout is better than the others. They reported that optimal-seeking methods are computationally infeasible for large layout problems. However, they were optimistic that their proposed approach will be helpful in assisting the layout planners to select good-quality solutions in practical facility-layout problems. Chiang (2001) presented an integrated visual facility layout design system to solve layout problems with geometric constraints on a continuous planar site. Vongpisal and Sangswang (2003) developed a program that applied the Computerized Relationship Layout Planning (CORELAP) principles to construct a facility layout from the SLP principle, by reference to minimize distance-weighted adjacency-based objective that considered rectilinear distance and adjacency in a unique way by using the concept of the total closeness rating (TCR).

Gopalakrishnan et al. (2003) introduced a split departmental facility layout generation system that developed layouts based on minimizing material handling costs. The system consists of a data acquisition module, a pair-wise department exchange module, a layout development module and a graphical representation module. They reported that the developed system flow-oriented material handling cost could be reduced significantly by adopting the split departmental approach. In 2004, Gopalakrishnan et al., developed a system that integrates raw material storage, inventory management, scheduling, and rack system design with facility layout development for

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