CHAPTER 2
THEORETICAL BACKGROUND AND LITERATURE REVIEW

This chapter aims to explain the theoretical background and literature review of the previous studies on the related topics. The topics in this research are about Production Capacity, Capacity Planning, Time Study, and Rough-Cut Capacity Planning. Here are the details as described below.

2.1. Production Capacity

According to Reid and Sanders (2013), Production capacity is a maximum level or rate of the output that could be reached by an enterprise or production facility. Production capacity includes the machines, humans or workers, the plant, materials, tools and equipment, and other things needed in order to create the output.

There are two kinds of capacity, which are Design Capacity and Effective Capacity. Design Capacity is the maximum rate of output in the ideal condition. While Effective Capacity is the maximum rate of output that can be achieved by the firm in normal condition. For example, the system in a company is designed to produce 32 units per hour. But, considering other aspects such as breaks, allowances, and breakdown time, the firm is only able to produce 28 units per hour. Utilization of the capacity can be an indicator to consider whether the system is good enough or not. When the real system can produce nearly to the maximum rate of output in ideal condition, it can be concluded that the system is good.

2.2. Capacity Planning

According to Reid and Sanders (2016), Capacity Planning is a process to estimate the maximum rate of the output that could be produced by the company in the certain period of time. If an enterprise does not have an accurate calculation of their capacity, then some problems may occur. The production can be either too low which cannot fulfill the customer demands or too much or overproduction. When the firm cannot fulfill the customer demands on time, it may affect their customer satisfaction rate, which could make the customer to choose another company. On the other hand, overproduction is considered as one type of wastes in the concept of Lean Manufacturing.

Once the company willing to increase their production capacity, some alternatives can be used for them. Subcontracting is reliable if the company need the additional capacity in short period of time. Else, the company could do overtime to fulfill the demand. Those alternatives are useful for short-range capacity planning. For medium to long-range capacity planning, the company needs to increase their resources in the certain level, which will help them to produce more.

2.2.1. Capacity Planning Decision

There are several steps needed to take decision which related to capacity planning. The first one is to identify the capacity requirements. It means, the current level of capacity must be calculated, and compare it with the desired capacity in the future. The desired capacity can be identified using forecasting method for capacity. There are two types of forecasting method, which are quantitative forecasting and qualitative forecasting. Quantitative method often used because it is an objective approach to do forecasting, and there are some exact formulas to do it. In short, quantitative method is more exact based on calculation rather than qualitative method. But, some condition or factors that may influence the forecasting result could not be included in the quantitative method. That is why the qualitative method is also needed. Qualitative method is based on judgement or opinion of experts in the certain field. The experts will validate the result of the quantitative method, based on their knowledge and experiences. Besides, find the gap between current and future condition is also important in order to how much additional resources needed in the future.

The second one is to develop the capacity alternatives. Set of alternatives are needed to be developed to test all of the possible solutions that may increase company's capacity. There are three basic alternatives related to capacity planning, which are to do nothing, expand large at once, or expand the plant step by step. Do nothing means the company evaluates their capacity and no need for them to do any expansion. If it is necessary, the company could do expansion immediately or do some small expansions. The last step is to evaluate those alternatives. The evaluation is used to find out the best solution, which enables the company to meet the future capacity requirements. There are some tools that may be used for decision-support aids by the top level management, such as decision tree.

2.2.2. Considerations in Capacity Planning

Capacity planning does not concern about finding the right amount of capacity only. It is also concern about the economies value of its processes. When company enlarges their facility, there might be some additional or changes in the total cost needed. There are two terms that related to this point, which are Economies of Scale and Diseconomies of Scale.

a. Economies of Scale

   There are two types of cost, which are fixed cost and variable cost. Economies of Scale concern about how to minimize the production cost for each product, or it is known as unit cost. In short, when a company produced more product, the unit cost decreased. This condition happened because the fixed cost needed is divided into larger amount of product. The example is when a bakery produced ten pieces of bread. The setup cost of fixed cost would be divided into ten. Meanwhile, the fixed cost needed for producing ten pieces are equal or similar to twenty pieces. It means, if the company produced twenty pieces, actually there is no significant changes in the fixed cost. It would be divided into twenty, which makes the unit cost become lower. But, it does not mean that the more output always create lower unit cost. Another consideration is about Diseconomies of Scale.

b. Diseconomies of Scale

   Once the company keeps increasing the production output, there might be some problems and additional cost occur. When the company produced more than their capability, it would make them to hire more workers or adding some machines or other resources, which make the fixed cost increase as well. Another thing is about the cleaning up or post activities needed after the production ran. For example, residual of product will also increase if the production output increase. Another is about the cleaning up process of the machine or surround layout to produce the product. There might be some tools need to be placed in its original places. Or, maintenance for the machine needed to prepare it for the next production. If the production output increase, those activities would also increase. That is why finding the best level for the production is required for an enterprise. The illustration is shown in Figure 2.1.

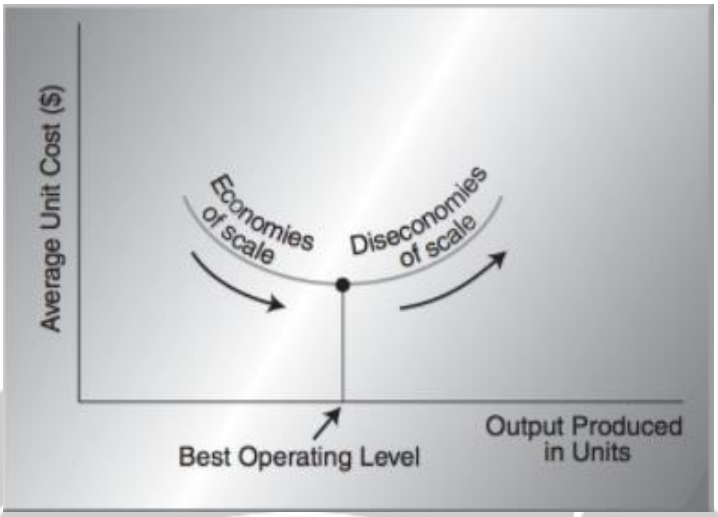

Figure 2.1. Best Operating Level (Reid and Sanders, 2013)

The best operating level are different for each type of facility's scale. One working-person would have different best operating level compared to three working-person. The larger the facilities, the more product could be produced. It means the unit cost for each product would also be decreased along with the increment of operating level. The theory is described in Figure 2.2.

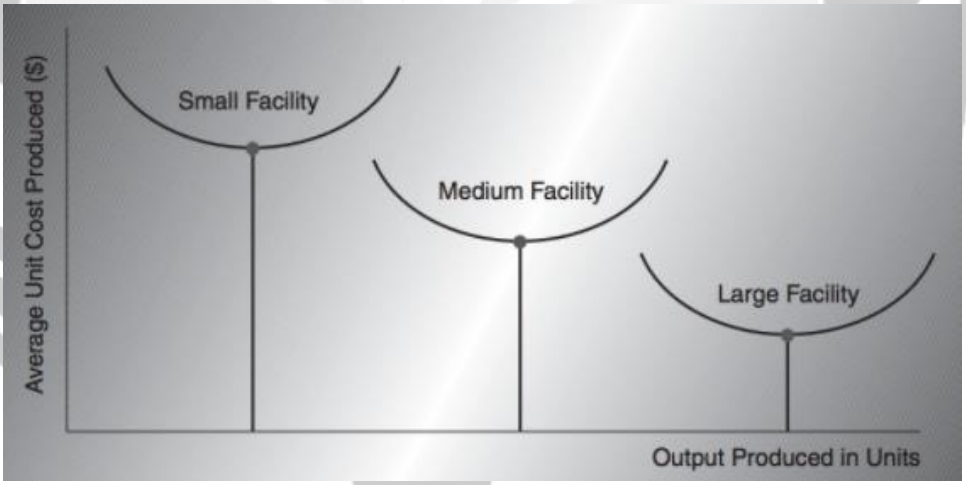

Figure 2.2. Best Operating Level for Different Kind of Facility (Reid and Sanders, 2013)

There are some alternatives for increasing the output level, such as doing overtime production, subcontracting other companies, or for long-term period, the company could enlarge their own facilities. Besides, the capacity planning also has to consider about the forecasting result for the next period. Overproduction should be avoided by the company.

2.2.3. Capacity Planning in Make-to-Order Enterprises

Make to order system enable the company to manufacture their product once they have gotten the order. The product variety is high, and even in some cases, the product could be customized. According to *Chen* et. al. (2009), the differences between make-to-stock (MTS) and make-to-order (MTO) system are about the standard processes and the inventory level. MTS system has its standard products which using the standardized processes, while the MTO system does not have the standard. MTS system holds some finished products in the inventory as the buffer, in order to fulfill sudden increment of the customer demand. The policy cannot be used for MTO system, since the product has lower demand level for each product variety. In order to overcome with that situation, MTO system reserves its capacity. If there is a sudden increment in the customer demand, the company could operate on its full capacity to cope with it. Effectiveness and efficiency in managing the available capacity are very important in MTO system.

Based on the period length, there are three types of capacity planning, which are long-term, medium-term and short-term capacity planning. Long-term capacity planning for make-to-order system is nearly the same with what it should be in the make-to-stock system. It focuses on the annual resources requirement and development of technologies to enable an enterprise to perform more efficiently. There might be some consideration in long-term capacity planning, such as the locations and capacities of the production plant, the supplier's capability, new technologies or techniques in the production process, and the operation modes.

Medium-term capacity planning is used for monthly or quarterly plan. In order to do medium-term planning, it should consider about the labor level, inventory policy, utilization of the resources, facility modifications, outsourcing, and supplier's contracts.

2.3. Previous Studies about Capacity Planning

This research focused on planning the production capacity in order fulfill the demand on time. Doing capacity planning by analyzing the current resources performances and calculating for some additional resources that may be needed.
The research began with studying some previous studies related to Capacity Planning and its tools. Here is the searching method that is used in order to find out the necessary researches.

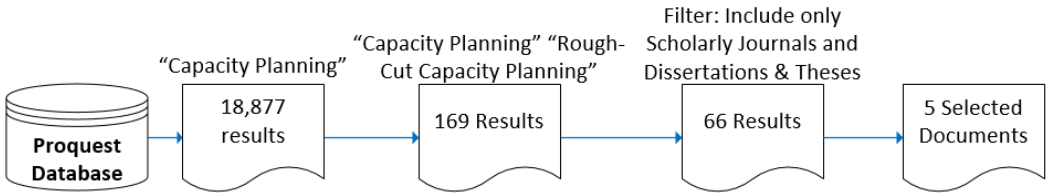

Figure 2.3. Searching Method Used for Capacity Planning Articles

There are five documents selected for the literature review because it is the most relevant with this research. Those documents were selected because it was shown as the top search and the most relative with the research. The details of those documents are explained below.

Table 2.1. Literature Review of Previous Studies about Capacity Planning

Numb.	Author(s)	Title	Objective	Tools	Additional Information
1	Jonsson and Mattsson, (2002)	Use and Applicability of Capacity Planning Method	Finding the most commonly used capacity planning method.	Survey and statistical tools	RCCP and CRP are the two most common capacity planning method that were used by companies (especially in Swedish companies)
2	Burcher, (1992)	Effective Capacity Planning	Find the most appropriate method for capacity planning, including the time study method	Survey and statistical tools	RCCP is selected by some companies because it is easier to be understood and more reliable to be implemented.
3	Gyulai et. al. (2014)	Capacity Planning and Resource Allocation in Assembly System Consisting of Dedicated and Reconfigurable Lines	Capacity of assembly lines	Discrete-event simulation and machine learning techniques	Dynamic and complex changes in the market push the enterprises to be able to react on those changes quickly.
4	Chen et. al. (2009)	The Capacity Planning Problem in Make-to-Order Enterprises	Optimal Capacity Plan	Mathematical Modelling	If there is a sudden increment in the customer demand, MTS system will utilize their reserved inventory, while MTO system uses their reserved capacity.
5	Marvel et. al. (2007)	Integrating Simulation into the Redesign of a Capacity Planning Process	Production Volumes	Simulation	Ensuring the feasibility of the production plan and to identify possible bottlenecks, based on inventory availability, for the production schedule.

2.4. Time Study

According to Reid and Sanders (2013), Time study is used to set the standard time needed by a worker to perform a single job. It is done by doing an observation for each employee and each job which is taken for more than one replication. There are several steps needed in doing Time Study such as:

1) Selecting the relevant job
2) Discuss with the appropriate worker
3) Break the job into several small activities that might be easier to recognize
4) Determine how many cycles needed to observe a single job
5) Time each job, record the result, and calculate the worker's performance
6) Calculating the normal time
7) Calculating the standard time

2.4.1. Calculation of Number of Cycles Needed

Some initial observations are needed in order to calculate the number of cycles needed. There is no standard about how many initial observations should be done. It can be five, ten or more cycles. The formula for calculating the number of cycles needed for each job is by:

$$n \geq \left[\frac{z}{a} \times \frac{s}{\bar{x}}\right]^2 \quad (2.1)$$

where:

n = the number of cycles needed

z = the number of normal standard deviations needed

s = the standard deviation of the sample

a = a desired accuracy

$\bar{x}$ = the mean of sample observations

The desired accuracy or confidence level might differ for each problem. Usually, a problem related to engineering field use 95% of confidence level. The higher confidence level it means the more accurate the result. But, if it is set to too high level, then it will require many sets of data.

After the number of cycles needed is known, then the next step is either the researcher should take other observation based on the calculation or directly goes to the next

analysis. The minimum number of cycles for each process may be different between one to the others. Then, if has fulfill the requirement of number of cycles needed, the normal time and standard time are calculated.

2.4.2. Calculation of the Normal Time

Normal time is the mean observed time that are normalized by considering the performance rating factor of the related worker. Time study approach also consider about the performance-rating factor and the frequency of occurrence. In some cases, when the workers were being observed, some workers tend to do it faster than their common processing time, and some do it slower. The normal performance rating factor (PRF) is equal to 1.0. It means, the workers did their job as the same as their habitual work. If it is above 1.0, it means that the workers did it faster. The performance rating factors is aimed to give a fair standard of the normal time for both workers and the company. Below is attached the performance's rating factor in Figure 2.4.

Skill			Effort		
+0.15	A1	Superskill	+0.13	A1	Excessive
+0 13	A2		+0.12	A2	
+0.11	B1	Excellent	+0.10	B1	Excellent
+0 08	B2		+0 08	B2	
+0 06	C1	Good	+0 05	C1	Good
+0 03	C2		+0 02	C2	
0 00	D	Average	0 00	D	Average
−0 05	E1	Fair	−0 04	E1	Fair
−0.10	E2		−0 08	E2	
−0 16	F1	Poor	−0.12	F1	Poor
−0 22	F2		−0 17	F2	
Conditions			**Consistency**		
+0 06	A	Ideal	+0 04	A	Perfect
+0 04	B	Excellent	+0 03	B	Excellent
+0.02	C	Good	+0 01	C	Good
0 00	D	Average	0 00	D	Average
−0 03	E	Fair	−0.02	E	Fair
−0.07	F	Poor	−0.04	F	Poor

Figure 2.4. Westinghouse Performance Rating Table (Barnes, 1980)

Another thing is about the frequency of occurrence. There might be some working elements that should be done for each process, then the value of frequency of occurrence (FoC) equal to 1. But, some elements were done for every two cycles, then the value is equal to 0.5. If it was done for every five cycles, it means the value is 0.2. Therefore, the calculation for the normal time is:

$$NT = (MOT)x\ (PRF)\ x\ (FoC) \tag{2.2}$$

where:

NT = the normal time

MOT = mean observed time

PRF = Performance-rating Factors

FoC = Frequency of Occurrence

2.4.3. Calculation of the Standard Time

Standard time means the standard duration of a process that should be taken by a qualified worker with its related tools in order complete a certain job, by considering the allowances time for personal fatigue and unavoidable delays. There are allowances for each job that are done by the workers, such as when the workers need to go to restroom, fatigue, or having bad working posture and movement. The allowances are needed in order to determine the standard time of each working process, as the workers cannot work continuously without getting some break. The breaks are important for the workers to rid of their fatigue and doing personal needs such as going to restroom. Below is attached the allowances table in Figure 2.5 and Figure 2.6.

Faktor	Contoh Pekerjaan	Kelonggaran (%)		
A. Tenaga yang dikeluarkan				
		ekivalen beban	Pria	Wanita
1. Dapat diabaikan	Bekerja dimeja, duduk	tanpa beban	0,0-6,0	0,0-6,0
2. Sangat Ringan	Bekerja dimeja, berdiri	0,00-2,25 kg	6,0-7,5	6,0-7,5
3. Ringan	Menyekop, ringan	2,25-9,00	7,5-12,0	7,5-16,0
4. Sedang	Mencangkul	9,00-18,00	12,0-19,0	16,0-30,0
5. Berat	Mengayun palu yang berat	19,00-27,00	19,0-30,0	
6. Sangat Berat	Memanggul beban	27,00-50,00	30,0-50,0	
7. Luar Biasa Berat	Memanggul karung berat	di atas 50 kg		
B. Sikap Kerja				
1. Duduk	Bekerja duduk, ringan		0,00-1,0	
2. Berdiri diatas dua kaki	Badan tegak, ditumpu dua kaki		1,0-2,5	
3. Berdiri diatas satu kaki	Satu kaki mengerjakan alat kontrol		2,5-4,0	
4. Berbaring	Pada bagian sisi, belakang atau depan badan		2,5-4,0	
5. Membungkuk	Badan dibungkukan bertumpu pada kedua kaki		4,0-10	
C. Gerakan Kerja				
1. Normal	Ayunan bebas dari palu		0	
2. Agak terbatas	Ayunan terbatas dari palu		0-5	
3. Sulit	Membawa beban berat dengan satu tangan		0-5	
4. Pada anggota badan terbatas	Bekerja dengan tangan diatas kepala		5-10	
5. Seluruh anggota badan terbatas	Bekerja dilorong pertambangan yang sempit		10-15	
D. Kelelahan Mata *)				
			Pencahayaan baik	Buruk
1. Pandangan yang terputus-putus	Membawa alat ukur		0,0-6,0	0,0-6,0
2. Pandangan yang hampir terus menerus	pekerjaan-pekerjaan yang teliti		6,0-7,5	6,0-7,5
			7,5-12,0	7,5-16,0
3. Pandangan terus menerus dengan fokus berubah-ubah	Memeriksa cacat-cacat pada kain		12,0-19,0	16,0-30,0
			19,0-30,0	
4. Pandangan terus menerus dengan fokus tetap	Pemeriksaan yang sangat teliti		30,0-50,0	

Figure 2.5. Allowances Table 1 (Sutalaksana, et. al, 2006)

E. Keadaan Temperatur Tempat Kerja **)

	Temperatur (C)	Kelemahan Normal	Berlebihan
1. Beku	Dibawah 0	diatas 10	diatas 12
2. Rendah	0-13	10-0	12-5
3. Sedang	13-22	5-0	8-0
4. Normal	22-28	0-5	0-8
5. Tinggi	28-38	5-40	8-100
6. Sangat Tinggi	diatas 38	diatas 40	diatas 100

F. Keadaan Atmosfer *)**

1. Baik	Ruang yang berventilasi baik udara segar	0
2. Cukup	Ventilasi kurangbaik, ada bau-bauan (tidak berbahaya)	0-5
3. Kurang Baik	Adanya debu-debu beracun, atau tidak beracun tetapi banyak	5-10
4. Buruk	Adanya bau-bauan berbahaya yang mengharuskan menggunakan alat-alat pernapasan	10-20

G. Keadaan lingkungan yang baik

1. Bersih, sehat, cerah dengan kebisingan rendah	0
2. Siklus kerja berulang-ulang antara 5-10 detik	0-1
3. Siklus kerja berulang-ulang antara 0-5 detik	1-3
4. Sangat bising	0-5
5. Jika faktor-faktor yang berpengaruh dapat menurunkan kualitas	0-5
6. Terasa adanya getaran lantai	5-10
7. Keadaan-keadaan yang luar biasa (bunyi kebersihan, dll)	5-15

*) Kontras antara warna hendaknya diperhatikan
**) Tergantung juga pada keadaan ventilasi
***) Dipengaruhi juga oleh ketinggian tempat kerja dari permukaan laut dan keadaan iklim
Catatan pelengkap : Kelonggaran untuk kebutuhan pribadi bagi : Pria − 0 - 2,5 %
Wanita − 2 - 5,0%

Figure 2.6. Allowances Table 2 (Sutalaksana, et. al, 2006)

Then, after the value of allowances had been determined, the standard time is calculated. The value of standard time is gotten from the formula below.

$$ST = (NT)\ x\ (1 + Allowances) \quad (2.3)$$

where:

ST = the standard time

NT = normal time

$Allowances$ = Allowances in decimal units

There are several factors that have been considered in the previous performance rating, and it appears also in the allowances table. Those factors are such as the working temperature, working atmosphere, and working environment in the allowances, which are the same with the factor of condition in the performance rating table. Therefore, those factors are not included in calculating the standard time in order.

2.5. Previous Studies about Time Study

Time study is needed in this research in order to calculate the standard time for each operation and for each family product. Therefore, before doing the real-time study, it is important to find some journals that are related to time study and this research.

There are several journals that are described briefly. The way of finding the literature itself is attached on Figure 2.7.

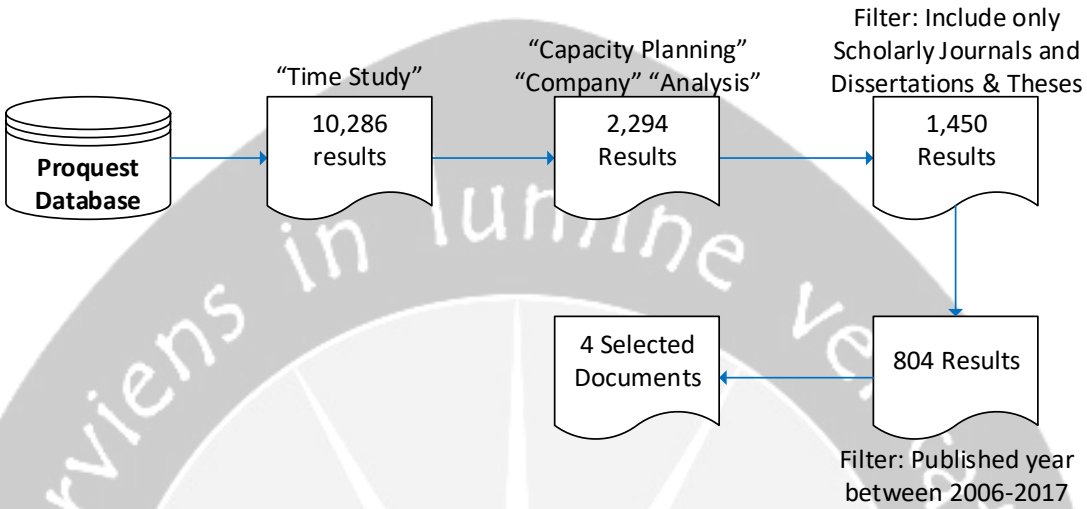

Figure 2.7. Searching Method Used for Time Study Articles

There are four documents selected for the literature review because it is the most relevant to this research. Those documents were selected because it was shown as the top search and also the most relative with the research. The details of those documents are explained below.

Table 2.2. Literature Review of Previous Studies about Time Study

Numb	Author(s)	Title	Objective	Tools	Additional Information
1	Palander et al., 2012	Automatic Time Study Method for Recording Work Phase Times of Timber Harvesting	Analyzing the gap between manual time study and automatic time study.	Automatic Time Study	Manual and automatic time study might need different work phase. The advantages of automatic time study are: 1.) able to identify the most important work phases since large amounts of data are available, 2.) it provides more systematic and accurate recording of the work phases.
2	Novoa and Mendez, 2008	Bootstrap methods for analyzing time studies and input data for simulations	Analyze time studies and input data for discrete-event simulations	Bootstrap Methods	Bootstrapping is a non-parametric technique and its inferences are strong in the absence of normality. The implementation of bootstrap techniques are viable alternatives to improve the data collection and statistical analysis phases of time study, stochastic assembly line balancing problems, and discrete-event simulation projects since bootstrap allow exploiting further the information available from small samples and produce reliable results.

Table 2.2. Continuation

Numb	Author(s)	Title	Objective	Tools	Additional Information
3	Goubergen and Cauwenberghe, 2007	Using Time Studies for Quantifying Waste and Improvement Opportunities in Work Methods	Identifying Non-Value Added Activities	Time Study	Quantify all types of waste using a detailed time study analysis
4	Rao et al., 2014	Time Study and Inventory Management of a Bearing Manufacturing Line	Increase the total production	Time Study and Inventory Calculations	Every machine has its own standard time, but it varies depending on the operative's ease of working, his interest and fatigue, the machine breakdown levels, etc. Therefore the time study is made used to calculate the standard times of each machine (operation)

2.6. Rough-Cut Capacity Planning (RCCP)

According to Reid and Sanders (2016), Rough-Cut Capacity Planning (RCCP) is a rough estimation of the workload in a certain period of time on the critical resources. This method is usually used for evaluating the Master Production Schedule (MPS) that were made with the purpose of knowing the estimation of future customer demand. In short, by doing a Rough-Cut Capacity Planning (RCCP), it enables the company to figure out the feasibility of the planned production schedule.

There are two different main results from the RCCP analysis, either the Master Production Schedule (MPS) is feasible or not. If the MPS is feasible to the company, then the company may concern more about the other aspects, such as the utilization and effective work time of the related workers. On the other hand, if the MPS is not feasible, it means that some adjustments are needed. If the problem is related to the capacity of man power, then the adjustment may come from the employment policy, such as hiring more workers, doing overtime or subcontracting.

Capacity Planning using Overall Planning Factors (CPOPF) is a well-known rough-cut capacity planning technique. The planning factors enable the company to know the difference between level of their workload and the available capacity from the resources. The method can be used to evaluate any type of resources, such as the man power, machines or tools, and the raw material. From the result of the analysis, it can be figured out how much the difference between the needed and available capacity. If the workload are too high, then the company should add their resources. On the other hand, if the capacity is too big, the company may decrease the resources.