

CHAPTER 2

LITERATURE REVIEW AND THEORETICAL BACKGROUND

2.1. Literature Review

Ferdiani, et al. (2018) studied the impact of installing new machines toward the production capacity of mats at Sukoda Unggul and Damarjati Maslahat. Both businesses experience low production capacity, while the demand for the product is higher than the available capacity. Ferdiani, et al. (2018) implemented the improvement by installing additional sewing and embroidery machines. The result of the research was the production of mat per day increased from 300 mats to 400 mats.

Furthermore, Safitri, et al. (2022) found that by increasing the number of operating machines at Omah Tempe Lestari, higher productivity will be achieved. The business experienced some delays due to the long process time of separating the skin of soybeans. Safitri, et al. (2022) suggested that the installation of additional machines for the process would reduce the operation time and result in higher productivity and efficiency.

In addition, Nugroho, et al. (2021) recognized that the problem for reaching the production target at PT Mitsuba Indonesia was caused by the lack of tools in the semi-automated assembly line. Thus, the operation time at PT Mitsuba Indonesia became longer and the production capacity was lower than expected. By utilizing more tools in the assembly line, the operation time was reduced by 10.99%. Shorter cycle time increased the productivity of the company.

Meanwhile, Suparjo & Prabowo (2018) identified the production capacity at UD Barokah, a shoe manufacturer. The company wanted to implement a new production strategy to increase production capacity. The alternative solutions that Suparjo & Prabowo (2018) offered were adding more work hours, hiring more workers, and sub-contracting the products. The finding found that adding more work hours increased the production capacity and it was more cost effective compared to the other alternatives.

Moreover, Ningrum (2016) studied the impact of adding more shifts toward a project duration. The study also investigated the impact on the project's overall costs. After evaluating the scenario, Ningrum (2016) discovered that by adding more work shifts, the total cost was reduced by Rp 1,240,225,176 from the original

cost of Rp 90,620,898,879. Also, the study found that the duration of the project would be shorter. Thus, the impact of adding more work shifts would reduce the cost and the duration of a project.

Comparable to Ningrum (2016), Putra (2022) reviewed the effect of more work hours and shifts on the cost and the duration of a project in Batang, Central Java. By considering the overtime by maximum four hours per day, the cost of the project became lower by 0.1% and the project would be finished 3.26% quicker. However, by implementing more shifts, the total cost would be lower by 0.25% and the projected duration would be shorter by 8.37% than the original estimated time. These findings by Putra (2022) implied that more work shifts could lower the total cost and shorter operation time.

Meanwhile, Alfiansyah & Kurniati (2018) analyzed gloves production and they found multiple wastes in the production system. The waste led to inefficient and ineffective production processes. The company experienced potential profit loss due to this issue. Alfiansyah & Kurniati (2018) used Operation Process Chart, Value Stream Mapping (VSM), and Waste Assessment Model (WAM) to identify the waste of the gloves company.

Like Alfiansyah & Kurniati (2018), Sudjianto, et al. (2013) used Value Stream Mapping to reduce the waste of a cigarette company. The Value Stream Mapping method was used by Sudjianto, et al. (2013) to identify value-added activities and non-value-added activities or waste in the company. They managed to conclude that there were three types of waste. The waste is inventory, transportation, and waiting. The improvements after the identification reduced the total lead time by 5.82%.

Then, Tambunan, et al. (2018) also used VSM to implement lean manufacturing at Shoes and Care, a shoe cleaning business. Based on the VSM analysis, the motion waste added 23% of the actual time needed to do the service. By improving the working method and adding assisting tools, the time for non-value-added activities was reduced by 5%.

Moreover, Maulana (2019) chose Value Stream Mapping as the method for waste identification for the housing industry. Similar with Sudjianto, et al. (2013), Maulana (2019) identified the value-added activities and non-value-added activities by using the VSM method. The research found that the waste for the housing industry was inventory, waiting, and motion.

In addition, Putri, et al. (2017) used the Waste Assessment Model to identify the waste of a project or a company. Putri, et al. (2017) researched waste identification for production line at PT KHI Pipe Industries. They found that the highest wastes were defects, overproduction, and inventory. Putri, et al. (2017) then proceeded to use Fault Tree Analysis to find the root causes of the wastes. The improvement proposed includes on-the-job training, regular machine maintenance, better inventory storage, and the use of better materials.

Then, Hatpito, et al. (2019) found that the waste percentage for defects, inventory, and motion were the highest for the road construction project using the Waste Assessment Model. That waste was the cause of the delays, and it may occur because of the non-productive elements of the project. Hatpito, et al. (2019) proposed some improvements, such as work method improvements and preventive measures of defects caused by the weather.

Since minimizing the waste can increase company's profit, Jufrijal & Fitriadi (2022) identified the waste of Crude Palm Oil (CPO) with Waste Assessment Model. They found three critical types of waste, namely overproduction, defects, and waiting. Next, Jufrijal & Fitriadi (2022) utilized the cause-and-effect diagram method to find the root causes of the wastes.

2.2. Theoretical Background

2.2.1. Production System

A collection of organized people, equipment, and operations to conduct manufacturing processes in a business is called a production system (Groover, 2015). There are two major components of a production system. They are facilities and manufacturing support systems. Factory and plant layout as well as manufacturing systems are included in the facilities. Meanwhile, manufacturing support systems consist of product design, manufacturing planning, manufacturing control, and business functions.

The facilities of a production system are the physical facilities supporting the business, such as the equipment, the production machines and tools, and the factory. The plant layout, the physical arrangement of the equipment in the factory, also includes as facilities. An individual cell consisting of a single equipment and a worker to complete the operations of products is called manufacturing systems (Groover, 2015). Most of the time, a company needs more than one worker and

one machine to finish their products. In that case, complex manufacturing systems apply in most of the companies, where multiple machines and workers are required. A series of machines and workers can be described as a production line (Groover, 2015).

In addition, manufacturing support systems can make the production facilities work efficiently. Designing, planning, and control are the crucial functions of a company, and they are done by manufacturing support systems. These support systems do not have direct contact with the product itself. However, they assist in planning and controlling the process throughout the factory (Groover, 2015). Thus, the manufacturing support systems play an important role in a production system.

2.2.2. Time Study

To develop an efficient work system, time standards must be established. These standards can be based on estimations, historical records, or measurements (Niebels & Freivalds, 2012). One of the most popular measurement techniques is direct time measurement using a time measurement tool, such as a stopwatch. Some other techniques include pre-determined time systems, work samplings, or time formulas (Niebels & Freivalds, 2012). When an analyst uses a time study method, the individual must also consider human natures, such as fatigue or personal needs. Therefore, the analyst must consider allowances for unavoidable delays (Niebels & Freivalds, 2012).

Before performing the time study, a set of fundamental requirements must be met. One of them is to ensure that the operator knows the job well and can perform the task without confusion or misunderstandings about the technique. The work must also be standardized before the study to avoid a misuse of the study due to the alterations of the work (Niebels & Freivalds, 2012).

Some equipment to perform a time study are a stopwatch, videotape camcorders, time study board, time study forms, time study software, and training equipment (Niebels & Freivalds, 2012). A stopwatch is one of the most common equipment for time study, while videotape equipment can also be useful at the same time. There are two types of stopwatches, the traditional one or the electronic stopwatch. Due to the expensive price of the conventional stopwatch, the digital or electronic one is more popular nowadays (Niebels & Freivalds, 2012).

2.2.3. Adjustments and Allowances

When using a time study, the analyst must consider the workers' nature as a human being. A worker's performance may not follow the exact standard set before the study is conducted; thus, certain adjustments must be considered (Niebels & Freivalds, 2012). These adjustments can include an increase in the time measured or a decrease in the time observed to set the standard for a qualified worker. For over-qualified workers, an increase of the time must be made, and a decrease of the time must be done for under-qualified workers (Niebels & Freivalds, 2012).

One of the commonly used rating systems for adjustments was founded by Westinghouse Electric Corporation (Niebels & Freivalds, 2012); therefore, it is called the Westinghouse system. This system sets four contributing factors in assessing the operator's performance, namely skill, effort, conditions, and consistency (Niebels & Freivalds, 2012). Skill is defined as "proficiency at following a given method", while effort means a "demonstration of an effective work" (Niebels & Freivalds, 2012). Moreover, conditions are considered as whether the working conditions may affect the worker's performance, such as light, temperature, and noise (Niebels & Freivalds, 2012). Last, consistency means the worker's consistency in performing the task.

Figure 2.1. until Figure 2.4. illustrates the rating system for each Westinghouse component.

Table 11.2 Westinghouse System Skill Ratings

+0.15	A1	Superskill
+0.13	A2	Superskill
+0.11	B1	Excellent
+0.08	B2	Excellent
+0.06	C1	Good
+0.03	C2	Good
0.00	D	Average
-0.05	E1	Fair
-0.10	E2	Fair
-0.16	F1	Poor
-0.22	F2	Poor

Source: Lowry, Maynard, and Stegemerten (1940), p. 233.

Figure 2.1. Westinghouse System Skill Ratings

(Source: Niebels & Freivalds, 2012)

Table 11.3 Westinghouse System Effort Ratings

+0.13	A1	Excessive
+0.12	A2	Excessive
+0.10	B1	Excellent
+0.08	B2	Excellent
+0.05	C1	Good
+0.02	C2	Good
0.00	D	Average
-0.04	E1	Fair
-0.08	E2	Fair
-0.12	F1	Poor
-0.17	F2	Poor

Source: Lowry, Maynard, and Stegemerten (1940), p. 233.

Figure 2.2. Westinghouse System Effort Ratings

(Source: Niebels & Freivalds, 2012)

Table 11.4 Westinghouse System Condition Ratings

+0.06	A	Ideal
+0.04	B	Excellent
+0.02	C	Good
0.00	D	Average
-0.03	E	Fair
-0.07	F	Poor

Source: Lowry, Maynard, and Stegemerten (1940), p. 233.

Figure 2.3. Westinghouse System Condition Ratings

(Source: Niebels & Freivalds, 2012)

Table 11.5 Westinghouse System Consistency Ratings

+0.04	A	Perfect
+0.03	B	Excellent
+0.01	C	Good
0.00	D	Average
-0.02	E	Fair
-0.04	F	Poor

Source: Lowry, Maynard, and Stegemerten (1940), p. 233.

Figure 2.4. Westinghouse System Consistency Ratings

(Source: Niebels & Freivalds, 2012)

Besides adjustments, analysts for time studies are required to consider allowances. Allowances are considered because time study is done on a certain point only and unavoidable delays may not be observed (Niebels & Freivalds, 2012). Other than the unavoidable delays, other time losses, such as personal needs or machine downtime may also fail to be counted. To cover these flaws, allowances must be considered.

There are two common types of allowances, namely constant and variable allowances (Niebels & Freivalds, 2012). The constant allowances include personal needs and basic fatigue. The standardized personal need is 5% and basic fatigue allowance for most workers is 4%, so a 9% allowance is necessary (Niebels & Freivalds, 2012). Following the basic 9% allowances, variable allowances may be applied, if necessary. The International Labor Office in 1957 created a set of rating systems considering various factors. Some of the factors are the position of the workers, light level, noise level, attention requirements, and mental strain. Figure 2.5. shows the ILO recommended allowances.

Table 11.9 ILO Recommended Allowances

A. Constant allowances:	
1. Personal allowance	5
2. Basic fatigue allowance	4
B. Variable allowances:	
1. Standing allowance.	2
2. Abnormal position allowance:	
a. Slightly awkward.	0
b. Awkward (bending).	2
c. Very awkward (lying, stretching).	7
3. Use of force, or muscular energy (lifting, pulling, or pushing):	
Weight lifted, lb:	
5	0
10	1
15	2
20	3
25	4
30	5
35	7
40	9
45	11
50	13
60	17
70	22
4. Bad light:	
a. Slightly below recommended.	0
b. Well below.	2
c. Quite inadequate	5
5. Atmospheric conditions (heat and humidity)—variable	0–100
6. Close attention:	
a. Fairly fine work.	0
b. Fine or exacting.	2
c. Very fine or very exacting	5
7. Noise level:	
a. Continuous.	0
b. Intermittent—loud	2
c. Intermittent—very loud	5
d. High-pitched—loud.	5
8. Mental strain:	
a. Fairly complex process	1
b. Complex or wide span of attention	4
c. Very complex.	8
9. Monotony:	
a. Low	0
b. Medium	1
c. High.	4
10. Tediousness:	
a. Rather tedious	0
b. Tedious	2
c. Very tedious.	5

Figure 2.5. ILO Recommended Allowances

(Source: Niebels & Freivalds, 2012)

2.2.4. Observed Time, Normal Time, and Standard Time

To set a standard time for a task, an activity, or an operation, there are three types of time units to be considered, namely observed time, normal time, and standard time. Observed time or cycle time is the average of the data obtained from direct

observations of the time study (Putra & Jakaria, 2020). Thus, to calculate the observed time, the following equation is used (Putra & Jakaria, 2020).

$$OT = \frac{\sum x}{n} \quad (2.1)$$

Description:

OT = observed time

x = data

n = number of observations

Meanwhile, normal time is the time needed to complete the task while considering the performance rating or the adjustments (Putra & Jakaria, 2020). The following formula can be used to calculate the normal time (Putra & Jakaria, 2020).

$$NT = OT \cdot (1 + R) \quad (2.2)$$

Description:

NT = normal time

R = performance rating

Then, considering the interruptions, such as personal needs, fatigue, and unavoidable delays, an analyst should add additional allowances to the normal time (Niebels & Freivalds, 2012). Therefore, to measure the standard time (ST), the following calculation can be used (Niebels & Freivalds, 2012).

$$ST = NT \cdot (1 + a) \quad (2.3)$$

Description:

a = allowances percentage

2.2.5. Data Uniformity Test

Before a set of data is used for analysis, a uniformity test is first done. Data uniformity test is done to ensure that the data is collected from the same system (Putra & Jakaria, 2020). Data uniformity test can be used by implementing a control chart (Putra & Jakaria, 2020). A control chart is considered a suitable tool for evaluating the uniformity of the data obtained from observations. To choose the correct type of control chart, the analyst must consider the type of data they are dealing with. If the data type is attribute data, where the data is more qualitative, then the suitable charts are p-chart and c-chart (Hadisantono, 2021). However, if the data is variable data, where the data is more of a measurement, the suitable control charts are mean (X bar) chart or range (R) chart (Hadisantono, 2021).

To perform a data uniformity analysis, first, the data must be input into subgroups (Putra & Jakaria, 2020). The calculation of the subgroups can use the following formula.

$$\text{Number of Subgroups} = 1 + 3.3 \log n \quad (2.4)$$

Description:

n = number of data

Then, the upper control limit (UCL) and the lower control limit (LCL) of the control chart can be calculated using the following formula (Putra & Jakaria, 2020).

$$UCL = \bar{x} + 3\sigma \quad (2.5)$$

$$LCL = \bar{x} - 3\sigma \quad (2.6)$$

Description:

$\bar{x}$ = the average of the data

k = a constant

σ = standard deviation

Meanwhile, the standard deviation can be calculated using the following formula (Putra & Jakaria, 2020).

$$\sigma = \sqrt{\frac{\sum (x_i - \bar{x})^2}{(n-1)}} \quad (2.7)$$

Description:

x_i = data

$\bar{x}$ = average of data

n = number of data

2.2.6. Data Adequacy Test

Besides data uniformity test, another test that should be done before using a set of data is data adequacy test. Data adequacy test is done to determine the minimum number of samples to represent the whole population (Putra & Jakaria, 2020). Before starting the data adequacy test, the analyst should set a confidence level and degree of accuracy (Putra & Jakaria, 2020). Normally, in a time study for work measurement, a confidence level of 95% and 5% degree of accuracy are used (Putra & Jakaria, 2020). Those levels mean that at least 95 out of 100 data will have a deviation of 5% (Putra & Jakaria, 2020). The following formula can be used to perform a data adequacy test (Putra & Jakaria, 2020).

$$N' = \left[\frac{k}{s} \cdot \sqrt{\frac{n \cdot \sum x^2 - (\sum x)^2}{\sum x}} \right]^2 \quad (2.8)$$

Description:

N' = minimum number of samples

k = confidence level

s = degree of accuracy

n = number of data

x = data

2.2.7. Gang Process Charts

A gang process chart is a diagram to analyze the productive percentage of each worker in a work group (Putra & Jakaria, 2020). By using the gang process chart, the activity of every worker at a specific point of time can be analyzed. Therefore, the workers with higher idle time can be investigated. In conclusion, the gang process chart is used to conclude whether non-productive workers exist in the work group analyzed (Putra & Jakaria, 2020).

The advantages of using the gang process chart are as follows (Putra & Jakaria, 2020).

- a. Give information on the activities done by every worker.
- b. Provide analysis of productive percentages for the members in a work group.

Moreover, in creating a gang process chart, the following principles must be followed (Putra & Jakaria, 2020).

- a. A header consisting of the task, department, chart number, the cartographer, and the date of creation.
- b. An identification of each activity with the symbols, time, and distance.
- c. Productive percentage of each of the workers.
- d. The description of each activity.

Figure 2.6. illustrates an example of a gang process chart.

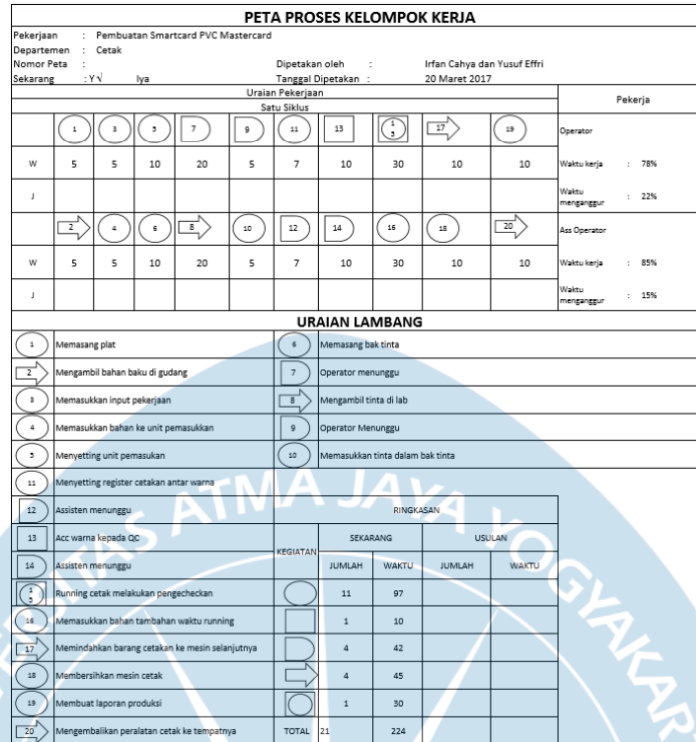


Figure 2.6. Gang Process Chart Example
(Putra & Jakaria, 2020)

2.2.8. Flow Diagram

A flow diagram gives the researchers better illustration and visualization of the facility's layout and every activity happening on the flow. Since all activities are illustrated, the flow diagram may help to indicate backtracking or possible congestion. Therefore, it is useful to develop an ideal factory layout (Niebels & Freivalds, 2012). Figure 2.7. shows an example of a flow diagram.

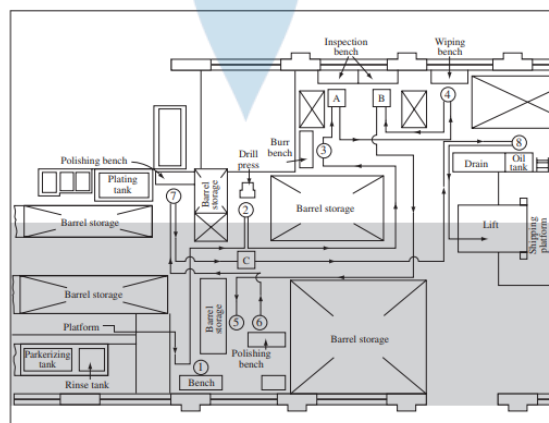


Figure 2.7. Flow Diagram Example
(Niebels & Freivalds, 2012)

2.2.9. Lean Production and Seven Waste Framework

If fewer resources are used to do more work, it can be called lean production. It can also mean fulfilling customers' demand and satisfying their expectations. The term "lean production" itself came from the researchers at the Massachusetts Institute of Technology. They tried to describe the production operations at the Toyota Motor Company in Japan in the 1980s (Groover, 2015).

The base foundation of the Toyota production system is elimination of waste in the process (Groover, 2015). In Japanese, it is called *muda*. So, there are three categories of activities in manufacturing, they are actual work, auxiliary work, and *muda*. Actual work means all value-added activities to the product itself. Meanwhile, auxiliary work supports the actual work, such as material handling. Then, there is *muda*, activities that are non-value-added and do not support the value-added activities (Groover, 2015).

While designing the Toyota production system, there are seven forms of waste that can be eliminated (Groover, 2015). The seven wastes are as follows.

- a. Defects,
- b. Overproduction,
- c. Excessive inventories,
- d. Unnecessary processing steps,
- e. Unnecessary worker's movements,
- f. Unnecessary transport and material handling, and
- g. Waiting.

Defective parts can be eliminated by a quality control system. Meanwhile, the overproduction and excessive inventories will increase costs in warehousing, storage equipment, additional workers to handle the excessive inventory, additional workers to produce the overproduced products, and other operating costs to produce the excessive parts. Then, unnecessary processing steps, such as unnecessary work elements, unimportant hand and body movements, inappropriate tools, safety hazards, and poor ergonomics, add more non-value-added activities to the process. Moreover, the unnecessary transport and material handling may happen due to the workplace layout inefficiency, plant layout inefficiency, non-ideal material handling method, the distance between production machines being too far, larger equipment than necessary, and conventional batch production. The last form of waste is waiting time, where workers must wait before

performing a task. Some examples of the waiting waste are as follows (Groover, 2015).

- a. Waiting for materials delivery,
- b. Waiting due to the assembly line disruption,
- c. Waiting because of the broken machine,
- d. Waiting for machine set up, and
- e. Waiting for the automatic processing cycle to be performed.

2.2.10. Value Stream Mapping

A value stream is everything that exists in the transformation from the raw materials to the final product (Tapping, 2003). It considers all actions, both value-added and non-value-added activities, needed to produce a product, such as the production flow from the supplier to the final customer and the design flow from the concept to the launch of the product (Rother & Shook, 1999). The term “value” indicates that something valuable for the customers is being created, while the term “stream” refers to the chronological flow of operations and activities to produce the product (Tapping, 2003).

Furthermore, value stream mapping is a tool to visualize the flow of material and information as a product goes through the value stream (Rother & Shook, 1999). There are two types of the value stream map, which are the current value stream map and the “future” value stream map, which depicts the condition of the value stream after improvements (Rother & Shook, 1999).

To do a value stream mapping, the first thing to do is to select a product family (Rother & Shook, 1999). Selecting a product family prevents the analysis from becoming overly complicated and useless. Moreover, by identifying the product family, the mapping process will be focused on the product with a non-ideal process and there will be less hassle in collecting the data.

After the identification of the product family, the current state map is created (Rother & Shook, 1999). The current state map is done by observing and gathering the information from the shop floor. This map will become the basis for the future state map and the proposed improvement at the later stage. Next, the future state map is made by analyzing the current state map created in the previous step (Rother & Shook, 1999). From the current state map, the process where improvements can be made is determined and the future state map is the visualization of how the value stream map will be after improving the faulty process.

Finally, based on the future state map, improvements can be made to develop a better system (Rother & Shook, 1999). The planning on the improvement implementation must be described thoroughly. As the improvement is made and the future state map becomes more real, a new map should be created to illustrate the most recent value stream of the analyzed system.

2.2.11. Waste Assessment Model

Waste Assessment Model is a method developed to identify and eliminate waste in a system (Rawabdeh, 2005). This method illustrates the relationship among the seven wastes in the seven-waste framework, namely overproduction, waiting, transportation, excess processing, inventory, motion, and defect. The assumption of this method is that every waste exists in the plant, all wastes are related, and they affect one another.

To do a waste assessment model, the first thing to do is to create the Waste Assessment Questionnaire (Rawabdeh, 2005). An example of a Waste Assessment Questionnaire is shown in Figure 2.8. Then, the total score of each waste can be obtained based on the response of the questionnaire. Next, the total weight for each waste is symbolized in the Waste Relationship Matrix. Finally, the score and the values for each waste can be found by converting the weight from the Waste Relationship Matrix.

No	Pertanyaan	Pilihan Jawaban	Skor
1	Apakah i mengakibatkan atau menghasilkan j	a. Selalu	4
		b. Kadang-kadang	2
		c. Jarang	0
2	Bagaimana hubungan antara i dan j	a. Jika i naik, maka j naik	2
		b. Jika i naik, maka j tetap	1
		c. Tidak tentu, tergantung keadaan	0
3	Dampak j dikarenakan i	a. Tampak secara langsung dan jelas	4
		b. Butuh waktu untuk terlihat	2
		c. Tidak terlihat	0
4	Menghilangkan akibat i terhadap j dapat dicapai dengan cara...	a. Metode <i>engineering</i>	2
		b. Sederhana dan langsung	1
		c. Solusi instruksional	0
5	Dampak j dikarenakan oleh i berpengaruh kepada	a. Kualitas produk	1
		b. Produktivitas sumber daya	1
		c. <i>Lead time</i>	1
		d. Kualitas dalam produktivitas	2
		e. Kualitas dalam <i>lead time</i>	2
		f. Produktivitas dalam <i>lead time</i>	2
		g. Kualitas, produktivitas, dan <i>lead time</i>	4
6	Sebesar apa dampak i terhadap j akan meningkatkan <i>lead time</i>	a. Sangat tinggi	4
		b. Sedang	2
		c. Rendah	0

Figure 2.8. Waste Assessment Questionnaire
(Rawabdeh, 2005)