



SIX SIGMA METHOD APPROACH IN THE PREVENTION OF OCCUPATIONAL ACCIDENTS ON THE SOLID WASTE COLLECTOR IN SOUTH JAKARTA

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ABSTRACT

Six Sigma method is one method of management approaches aimed at making decisions based on facts and based on the use of data using special tools and methodologies. This study deals with the methodology of Six Sigma approach in reducing the incidence of occupational accidents in the collection of solid waste in South Jakarta. The fundamental problem-solving approach is done by following the DMAIC (Define-Measure-Analyze-Improve-Control) in order to reduce the process variation and improvement process results. Analysis of the problem also using some tools such as Pareto diagrams, Fishbone diagrams and Analytical Hierarchy Process. Research conducted at the Department of cleanliness of South Jakarta as research subjects in order to analyze and determine the cause of the problem of workplace accidents solid waste collection. Results show DPU approximately 0.22 and approximately 220000 and a target DPMO sigma level is 3.554. Moreover, the results of AHP calculation using Expert Choice software indicate the most significant factor is the method with 0.392 weights. In addition, the sub-causes of the most dominant in workplace accidents collecting solid waste, such as, lack of safety equipment around 0.833 and pleasant environment around 0.833.

Keywords: six sigma, pareto, fishbone, AHP, solid waste management, accident, DKI Jakarta.

INTRODUCTION

Global challenges occur in almost all over the world as a result of the emergence of the problem of solid waste. The problem is influenced by several factors such as population increase is not unstoppable, urbanization, limited resources and industrialization. Furthermore, there are several factors that encourage not optimal waste management in developing countries. For example, the lack of financial resources, inadequate management, technical skills in the city and the government has not been optimal [1]. Solid waste defined as the end product of the activities and public consumption. There are various sources that may be used as the subject of waste generation, such as, households, commercial establishments, markets, stores, industries and farms. Some stakeholders associated with the disposal and waste management provide serious attention considering the impact that may result to the environment and human health [2]; [3]

As described previously that the rate of population growth and economic development are several of the factors that led to an increase in the amount of waste. For example, the Jakarta Cleanliness Agency is only able to serve the transport of garbage around 14.700m³ from total waste production approximately 23,400 m³ per day. A study conducted Steinberg, found that the behavior of people who throw solid waste in rivers, drainage channels and empty places are a result from waste collection services is not optimal [4].

Cointreau *et al.*, underlines there is several activities in term of solid waste management, such as collection, recycling and commercial and industries solid waste collecting and treatment [5]. The high number in solid waste generation encourage the difficulties and

complexity of waste collection, In addition, the transportation of solid waste transfer from household also proved another problem. Generally, solid waste collection conducted by Cleanliness Agency and coordinated with other stakeholders in DKI Jakarta, such as government agencies on the small villages. Furthermore, solid waste collection in general using garbage collectors in Indonesia that financed from redistribution fees. There are numerous potential risks in the solid waste management process, such as collection of sources, the process of transfer and the location of recycling or disposal in landfill [6]. For illustration, work accidents on the garbage collectors may occur in the process of garbage collection in residential locations. Based on data from the Labor Department DKI Jakarta, reported around 81,169 cases of work accidents in January to September 2003 [7].

In general, the disposal of solid waste directly into the open spots and not put into closed containers is a common practice in developing countries. Consequently, the use of traditional hand manually and is often done by the garbage collectors [5]. Manual disposal waste collectors from households has the potential health risks and accidents, for example, broken glass, cans edges are not cut off safely [8]. Several of the causes that contribute to an increase in workplace accidents often influenced by several factors. For instance, working conditions are unhealthy, unsafe and not use personal protective equipment.

Studies on solid waste management has been excessively done in practices of collection and disposal of waste in Indonesia. However, the garbage collector has not received attention, particularly related to studies on occupational health and safety risks. The policy makers associated with the occupational health and safety have



challenges in order to minimize potential risks. As a result, some stakeholders began to perform a variety of methods, for example by applying the six sigma method. This is because in any existing procedures in the six sigma method has interesting opportunities and challenges. This study aims to minimize potential health and safety risks to garbage collectors by applying the six sigma method. Numerous of areas of study that have been applying Six Sigma methods in order to improve performance, such as manufacturing industry [9], health and safety [10], environmental management systems [11]. Six Sigma methods have numerous basic values such as the principles of process improvement, statistical methods, systems management, continuous improvement and refinement relevant financial. The target of continuous improvement in minimizing hazard risk of solid waste collection needs to be improved.

SIX SIGMA METHOD

There are two key things that become important in the six sigma method, which is the quality and performance improvement. Hoerl (2001) noted that some combination of process improvement, operative trained and focused bottom-line encourages enormous financial benefits [12]. Furthermore, Pande *et al.*, Defines Six Sigma as a comprehensive system that has a target to maintain and increase business profits [13]. This can be done because this method comes with some understanding, such as the customer's needs, the use of factual data, and statistical method in the analysis, focusing on the management, improvement and re-creation of business processes. Furthermore, Chinvigai expressed the same thing that Six Sigma focuses on process improvement and variation minimization problem solving supported by statistical approaches and methods of reduction of defects / problems [14].

Overall, there are three different functions on six sigma methods, such as metrics, systems management and methodology [15]. Furthermore, Goodman explains the function of the quality metrics illustrate the scale of companies that use 3.4 defects per million opportunities (DPMO). In addition, six sigma management system functionality is the company's business strategy and methodology functions illustrated by the use of DMAIC models [16]. DMAIC pattern used by Motorola in the repair of problem solving using data and process tools [17]. The DMAIC cycle consists of five phases of process improvement, such as, Define, Measure, Analyze, Improve and Control [18].

- Define: the problem to be solved should be predetermined, this includes the potential that can happen to customers and potential profits. Or in other words, the company carrying out the process of identifying the problems that need to be repaired.
- Measure: Identifying characteristics of the product / process oriented on customer needs. The Company also undertakes the development of a data collection plan and perform the comparison data to determine the problems and shortcomings.

- Analyze: Represents the process of identifying the root causes of defects and sources of variation. The company carries out the determination of the variation in the process is the source of the cause of the problem and prioritize opportunities in order to improve in the future.

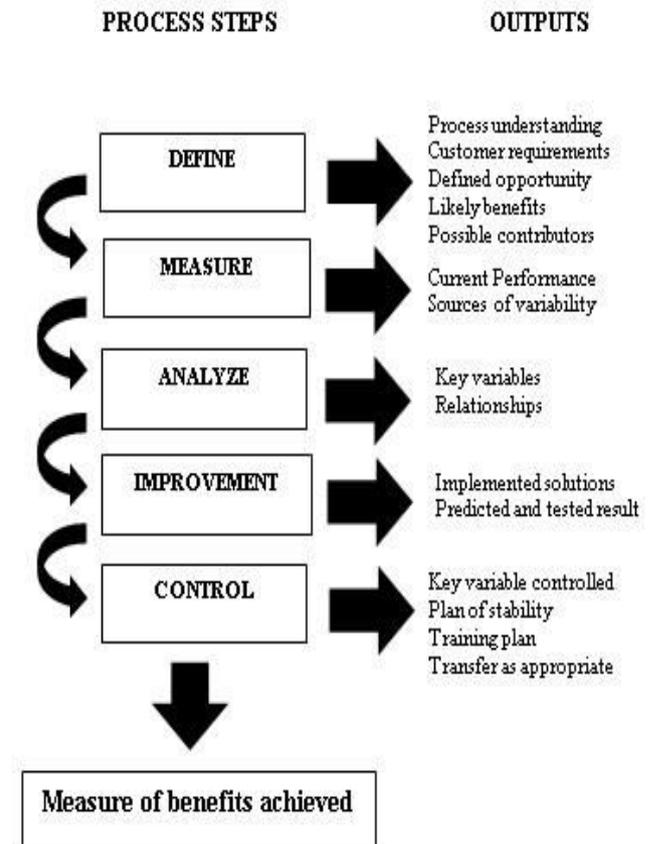


Figure-1. The six sigma DMAIC process and key outputs [19].

- Improved: is the cycle of improvement in relation to the increase in the removal or reduction of variation. The company carries out the development of alternative solutions and increase the implementation of the plan will be carried out. The company also determines an increase in the process what needs to be done.
- Control: the final stage of the DMAIC cycle that provides certainty that the process should always be documented and monitored in order to meet customer needs. The benchmarks of success of this cycle are how companies can maintain and monitor the process. The company also makes the implementation of system improvements and structures sustainable manner.

METHOD AND MATERIAL

The study was conducted in the Srengsengsawah Jagakarsa, South Jakarta. This district has an area of about 6.75 km² consisting of 19 RW and 156 RT. Kelurahan



Srengsengsawah is the most extensive area in Jagakarsa and is inhabited by about 17 736 inhabitants [20]. Data was collected by interview, which was made in a structured schedule setting and use questionnaires adapted and validated, such as: OSHA Respirator Medical Evaluation Questionnaire (Mandatory) - 1910,134 App C. Solid waste management and health and safety risk: Epidemiology and assessment to support risk reduction. The questionnaire were methods to gather information on garbage collectors associated with the potential risk of occupational diseases. Survey respondents using a questionnaire addressed to 25 people collecting garbage in the Village area Srengsengsawah. The garbage collector is a garbage collector in each region. All respondents participated voluntarily and guarded their privacy to increase the certainty of respondents to provide the requested information. The questionnaire is structured on the garbage collector and some pictures taken at the location of the research is the primary data in this study. In addition the direct observation of the components of solid waste at the study site. Data collection was conducted in August 2014. The questions are divided into two parts, the first part of the questionnaire which is designed to explore the socio-demographic information. Furthermore, the second part is designed to gather information regarding the level of knowledge of the garbage collector, especially related to practices when carrying out the task, the level of concern the use of safety equipment, the most common musculoskeletal disorders and injuries in general suffered. Descriptive statistics were used to analyze the data that has been obtained. Both qualitative and quantitative data that has been collected is used to provide an explanation of the study. Furthermore, three people will be selected as key informants, such as academia, the Jakarta Cleanliness Agency and government officials in South Jakarta. The three men were chosen in order to assess the ranking factors that cause accidents by using AHP. A questionnaire was used to obtain data associated with the application method of AHP

RESULT AND DISCUSSION

a) Define

Define is the first phase from six sigma method. There are four steps in the define phase, such as the process of investigation and work environment, SIPOC chart preparation, information gathering and the issue of setting. Clarify the subject priorities in the prevention of occupational accidents solid waste collector. In order to obtain a detailed description of the process chart SIPOC used at this stage. Generally, this chart is helpful in determining the direction of the process or scheme stream and profits. SIPOC is an abbreviation of Supplier, Input, Process, Output, and Customer. SIPOC diagram for the process of the prevention of occupational accidents solid waste collector is given in Table-1.

Table-1. SIPOC diagram of the prevention of occupational accidents solid waste collector.

Supplier	Input	Process	Output	Customer
Households Offices Markets Roads	Safety rules Work method	Collecting Transfer Removals Completed hazard assessment	Safety behavior Zero injuries Safe work procedures Improvement healthy workers	Worker Government Policy makers

Data collection is required in order to determine the size and nature of the problem to be solved. This is one of the stages of the determination from methods of Six Sigma. Jagakarsa is one of the districts in South Jakarta. In addition, Jagakarsa is one of the most extensive regions. Furthermore, it has the largest garbage dumps, where around 44 polling stations. Jagakarsa district area is one of the most extensive regions that have the largest garbage dumps, where the open polling station is around 44. Moreover, Setiabudi and Mampang Prapatan possess only one depot respectively. For the region Pasar Minggu, possess around nine concrete tanks as a temporary waste storage site of the community. The south Jakarta government has also created and determine numerous point's location of temporary waste storage. It aims in order to provide the service of transporting waste. Generally, the process of collection and the transfer of garbage from households in the community carried out manually. The community provides waste management fees coordinated by the head of the RT or RW. In order to obtain a clearer picture of household garbage collection process and the transfer process to the polls can be seen in the pictures below.

Based on the pictures, it can be seen that the collection of the household solid waste potentially against the risk of occupational disease. For example, the garbage collectors do not use personal protective equipment such as masks, gloves and boots. In the process of waste separation at the top of the cart the garbage collectors will likely face a situation where garbage is disposed of by the community can be consist of metal fragments derived from household appliances, lamps, glasses and bottles. This is because people still have a lack of awareness of the separation from the household.



Figure-2. Garbage collection from the household [21]



Figure-3. The removal of garbage from the household to cart [21].



Figure-4. The transfer process waste from households to the polls [21].

b) Measure

The second phase of the process is the DMAIC method Measure, where there are several key steps, such as process mapping, data collection, measurement sigma level, and calculate the ratio injuries. In order to understanding more detailed about the process of occupational accidents and relationships between factors used six sigma chart. The application of six sigma is intended to identify processes that may potentially cause accidents. There are several processes that can be seen as the cause of accidents at garbage collectors, such as, lack of knowledge, poor of education background, lack of safety equipment, poor healthy living habits, not ergonomic working position and working tool. According to the survey that was conducted on several of the respondents to obtain information about the characteristics of accidents that are used as a basis for improvement. The proportion of composition of workplace accidents is shown in Table 3 below. The analysis performed in this phase to determine any types of work accidents is highly important. To be able to demonstrate the critical nature of every type of work accidents, Pareto charts are used as one tool in the six sigma method in Figure-5.

Table-2. The answers of respondents to social status.

No.	Question	Responses
1	Age	
	20-25	5
	26-30	8
	31-35	4
	35-40	5
	>45	3
2	Education	
	Senior high school	5
	Junior high school	10
	Elementary school	7
	Never go to school	3
3	Marital status	
	Married	16
	Single	4
	Widower	5

Source: Rimantho [21]

Table-2 above provides information on the social status of the respondents. Furthermore, from the question of age, obtained information that approximately 32% from respondents aged 26-30, and only about three people or 12% over 45 years. In addition, questions related to the educational background of the responses obtained that approximately 10 people, or roughly 40% have completed junior high school education. Moreover, there are only about five people who graduated from high school and three representing around 12% never went to school. Furthermore, respondents who claimed to have married about 16 people, or around 64% and approximately four people or roughly 16% expressed single.

Table-3. The response from the respondents to the health problems caused by work.

Statement	Responses	Percentage (%)
Workers suffered of musculoskeletal disorders due to work	19	0.2
Workers with hearing loss due to noise during highway	14	0.146
Workers suffered puncture wound as a result of not using gloves	21	0.22
Workers never fell slip from work	13	0.137
Workers suffered respiratory problems due to work	15	0.157
Workers suffered gastrointestinal disorders	13	0.137
Total	95	

Source: Rimantho [21]

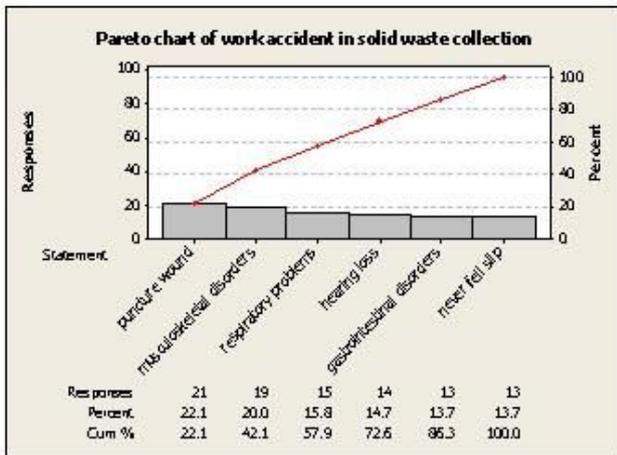


Figure-5. Pareto chart of work accident.

The Pareto picture above explains that about 22% from lower back location associated with Workers suffered puncture wound as a result of not wearing gloves and 20% was associated with the workers suffered of musculoskeletal disorders due to work. The cumulative percentage was 22% workers suffered puncture wound as a result of not wearing gloves, so that the greatest improvement in the prevention of occupational accidents collector solid waste can be achieved by focusing efforts on reducing Workers suffered puncture wound as a result of not wearing gloves.

In order to assessment in the process capability to produce defect-free products, the determination and measurement of process defects per unit (DPU) and defects per million opportunities (DPMO) needs to be done.

$$Yield = 1 - Defective Ratio \tag{1}$$

With pay attention that the normal distribution model is sufficient to estimate the level of sigma process:

$$\sigma \text{ level} = \Phi^{-1} (Y) + s \tag{2}$$

$$Y = Yield/100$$

Where:

Φ^{-1} = the inverse cumulative function of normal distribution

s = the shift of the mean and is assumed to be 1.5 the standard deviation on the long run.

The average shift either to the right or to the left is assumed to be approximately $\pm 1.5 \sigma$ in the long term of life processes. Assumptions used to calculate the sigma level and DPMO calculations. Therefore, consideration of the shaft maximum sigma is calculated as follows:

$$DPU = 1 - Y \tag{3}$$

$$DPMO = DPU * 10^6 \tag{4}$$

The Yield data collected from data above are used to calculate the sigma level as follows:
The injuries ratio was 22%, then

Yield = 1- defective ratio = 1 – 0.22 = 88% Therefore, Y = 0.88

Substituting in equation (2), then,

$$\sigma \text{ level} = \Phi^{-1} (0.88) + 1.5$$

$$= 1.1749 + 1.5$$

$$= 2.674$$

$$DPU = 1 - Y$$

$$= 1 - 0.888$$

$$= 0.22$$

$$DPMO = DPU * 10^6 = 0.22 * 10^6 = 220000$$

As previously assumed that the expected injuries ratio target is 2%, then:

$$DPU = 0.02$$

Thus,

$$Yield = 1 - DPU = 1 - 0.02 = 0.98$$

$$\text{Target } \sigma \text{ level} = \Phi^{-1} (Y) + s$$

$$= \Phi^{-1} (0.98) + 1.5$$

$$= 3.554 \text{ sigma}$$

c) Analyze

The third stage of the DMAIC process is to define the main causes of workplace accidents. Fishbone diagram is applied in order to analyze the root cause of the problem. Several factors such as human, machine, material, method of work and the work environment is used to identify the main factors that cause accidents. To be able to identify the causal factors that influence the occurrence of workplace accidents can be done by conducting brainstorming. Figure 3 below illustrates the causal diagram accidents on the solid waste collector. Analytical Hierarchy Process (AHP) is also applied as a model of assessment factors causing accidents. Reason for using this method is the ability of this method in assessing and making a critical priority of different causes of occupational accidents in solid waste collection. AHP has been widely applied in research related to environmental management, such as, the management of excess mercury [22], the determination of the essential factors in the management of electronic waste in Surabaya [23] and the selection of disposal sites and waste management complexity reduction [25].

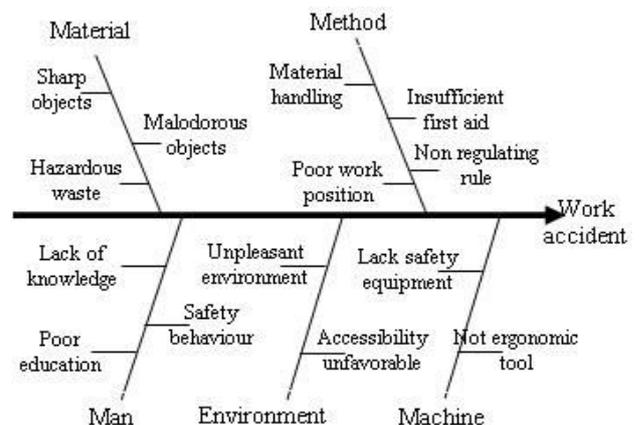


Figure-6. Fishbone diagram of factors leading of work accidents in solid waste collection



AHP method is applied to obtain priority main causes of workplace accidents solid waste collection. Factors that may be the cause of accidents made by Fishbone diagram assuming the need to rank the potential impact of workplace accidents. Fishbone diagram consists of several key factors to analyze the factors causes of accidents, such as, man, material, machine, method and environment. Furthermore, these five factors will be assessed in pairwise comparisons in AHP. Pairwise comparisons aims to obtain rankings main cause problems. Studies conducted by Ishizaka explained that the AHP will create the model, weight assessment, weighted aggregation and sensitivity analysis [25]. Furthermore, there are four steps used by the AHP in determining the causes of accidents variables solid waste collection. This can be done by grouping the elements are homogeneous and comparison with other elements significantly. In addition, the relevance of interrelated factors must show the relationship with the factor of higher rank. The AHP hierarchical structure of decision-making is the overall goal to be achieved on the first level. Similarly, the factors that were significantly associated with the decision on the second level and the next level. Expert Choice software applied to process data obtained by questionnaires distributed to the five respondents were considered to have a decision-making competence of occupational accidents garbage collector. Table-4 below shows the results of pairwise comparison in AHP.

Table-4. Weighted main and sub-causes pairwise with AHP.

Main Cause	Weight of main cause	Sub - cause	Normalized Weight of Sub-Cause
Man	0.308	Lack of knowledge	0.475
		Poor education background	0.092
		Insufficient safety behaviour	0.275
		Body postural	0.158
Material	0.098	Hazardous waste	0.202
		Sharp object	0.701
		Malodorous objects	0.097
Machine	0.143	Not Ergonomic	0.167
		Lack of safety equipment	0.833
Method	0.392	Poor work position	0.223
		Material handling	0.141
		Insufficient first aid	0.070
		Non regulating rule for safety	0.565
Environment	0.059	Accessibility unfavorable	0.167
		Unpleasant environment	0.833

The Figure-7 shows the results of pairwise comparisons using a software expert choice at the level of the factors that cause accidents collecting solid waste. In addition, the results also indicate the Method factors the

most important in weight rankings around 0.392. Furthermore, the human factor of about 0.308 machines factors approximately 0.143; material and environmental factors 0.098 and 0.059 respectively.

As explained earlier that fishbone diagram gives an overview significantly to the factors that cause accidents collecting solid waste. Thus, the results of the analysis of several expert opinions based on the AHP method show that there are several sub-causes of the problem of accidents, such as, Non regulating rules for safety, lack of knowledge of the operators, lack of safety equipment (PPE), sharp objects, unpleasant environment. Consequently, in order to increasing refinement problem of workplace accidents in accordance with the available resources can be a Six Sigma process improvement.

d) Improve

The next analysis process within the six sigma method is Phase improvements. This stage provides several alternative most likely solutions to be implemented. Alternative solutions aim to alter or reduce the significant factors that could potentially lead to accidents on the solid waste collection. Thus, to be able to reduce the occurrence of workplace accidents in the solid waste collection can be done several activities as follows:

Lack of safety equipment may be eliminated by providing personal protective equipment for solid waste collection. For example: to reduce the occurrence of slip can use the boot, providing a protective mask in accordance with the standard of health in order to reduce the pungent odor, gloves that fit the body size of the operator and in accordance with the type of work that needs to be addressed, work clothes that can protect workers, helmet or cap which is able to protect workers from the hot sun. The use of personal protective equipment is not only able to protect workers from potential hazards that may arise during the work, but also can provide a sense of confidence for operators who use it. Furthermore, the use of personal protective equipment has also been widely applied and used as a standard operating procedure that should be followed in several developed countries.

Unpleasant environment may be done by renovating and improving solid waste temporary shelters that are tailored to the health and environmental standards. The choice of location also must be of particular concern and not cultivated close to the location of housing residents. By improving and enhancing the site conditions can reduce the potential for environmental pollution, reduce environmental aesthetics and reduce the incidence of vector-borne diseases, such as flies, mice, cockroaches and other bacteria.

Sharp objects, in order to reduce the occurrence of injury from a sharp object punctured, then several the activities that can be done is to separate the solid waste types are made of glass or other sharp objects and potentially pose a



risk of injury to operators of solid waste collection. This separation can be done at the source of solid waste in the household.

People are expected to have the awareness to separate hazardous solid waste from home. Furthermore,

local governments are also expected to provide special facilities to accommodate the solid waste types of glass. The provision of rubbish bin specific to the type of glass can be done in coordination with the leadership of their respective areas.

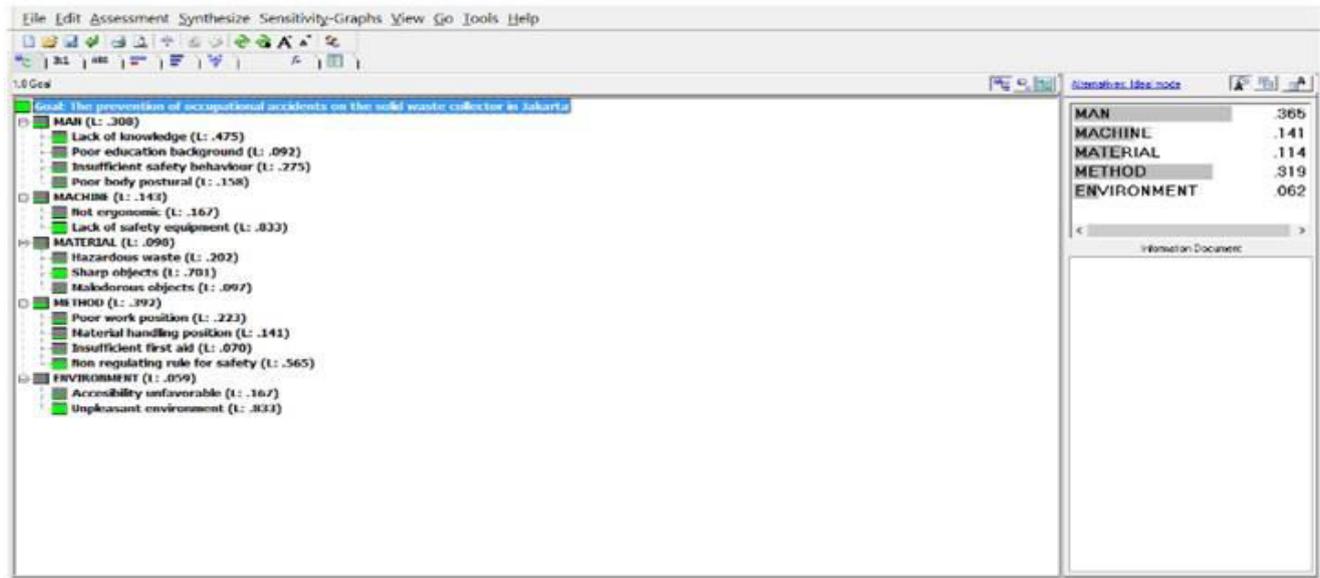


Figure-7. Weighted main and sub-causes pairwise using expert choice.

Lack of knowledge, in order to increase knowledge, awareness and behavior of the garbage collector operator may conduct several activities, such as, provide training on a regular basis. This training can consist of several aspects, such as health and occupational safety, healthy habits. This training can be provided that is adapted to the educational level of the operator. Thus, by providing the training can reduce accidents garbage collector. The participation of policy makers is needed in providing attention to improving knowledge about the health and occupational safety of solid waste collection.

Non regulating rule for safety, standard operating procedures (SOP) or regulations on health and occupational safety need to be created in order to reduce accidents to solid waste collectors. The policy makers should protect these informal workers from potential accidents. The protection afforded to workers in the form of solid waste can be regulation or SOP. Regulation may be made will be guidance and instructions for every stakeholder associated with solid waste collection activities, especially related to occupational health and safety.

e) Control

Controlling is the final stages of the Six Sigma of DMAIC method. This stage aims to monitor the implementation of the reduction of the activity of potential accidents solid waste collection. This stage is considered to have an important role to provide assurance that the entire process of the important factors causing accidents

has decreased significantly. In addition, this phase should also be able to ensure that the proposals that have been given may be implemented in order to implement the objectives expected. In addition, the development of standardized systems through modifications to policies, regulations, procedures and other management systems must may be realized by the stakeholders in the framework of the protection of workers collecting solid waste. The process of developing a modified system of health and safety protection aims at the provision of the certainty of continuous improvement. Moreover, in order to improve the safety culture in the workplace, local government, employees and safety procedures are paramount. Thus, for the six sigma program should be supported by adopting systemic control system. This has a specific reason that the process of six sigma should have the certainty of continuous improvement. For example, application of statistical control charts may provide oversight of the process of reduction in the number of work accidents in solid waste collection. It also will may illustrate that the decline process is under control or not. Furthermore, statistical process control applications can also provide observations on the consistency of the process and make the process under control.

CONCLUSIONS

Health and Safety of solid waste collection becomes important at this time in developing countries and implementation of six sigma is very important to reduce the potential for workplace accidents the solid waste collection. Six Sigma may be used to identify and



improve the potential hazards that may occur in the solid waste collection and may improve the health and well-being of the operator. Application of the of DMAIC phases of Six Sigma methods may be a bridge in an effort to decrease the factors that have the potential accidents of solid waste collection. In addition, application of the AHP method can also help rank the dominant factors to the decrease of the potential hazard to solid waste collection. As a systemic method, the Six Sigma is able to provide a solution reduction potential accident. Integration with other methods of making six sigma is also effective in improving the improvements that will be achieved. This research requires more advanced research to improve the ability of six sigma in reducing the number of workplace accidents in every aspect of life.

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