Analysis of risk failure of solid waste management processes in universities: Case Study of Pancasila University Jakarta

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Abstract. The concern for environmental impacts is environmental degradation. One of the environmental problems is solid waste which has the potential to cause dangerous risks. Therefore, this study will analyze the risk of solid waste management factors at the university using the Failure Mode Effect Analysis (FMEA) method. Some information about risk factors from the solid waste management process was collected using literature studies and Ishikawa diagrams. The number of experts or experts used in this study was 5 people. The expected results of this study will be able to show the value of the Risk Priority Number (RPN) of the factors that are the target of the study. Furthermore, from this value, the level of risk can be known from each factor. Thus, risk evaluation (priority risk to be controlled) in the solid waste management process is focused on the highest risk category. The results of this study can be a guideline for evaluating solid waste management in universities in Indonesia and other developing countries. Various developments to improve the results of this study need to be carried out that will be useful for future actions.

Keywords: Solid waste; Ishikawa diagram; FMEA; Risk; RPN

1. Introduction
Solid waste is often defined as the result of human activities that are considered to have no value and are then discarded [1]. Waste streams have different characteristics, both hazardous and non-hazardous waste sourced from industry, commercial, housing and institutions [2]. The flow of waste produced by institutions throughout the world is currently experiencing a significant increase. For example, the World Bank reported a municipal waste generation of around 1.3 billion tons in 2012 and would increase by around 2.2 billion by 2025 [3]. This shows that there is an increase in the rate of waste generation per capita per day. Thus, local governments need to manage waste wisely. However, seeing the increase in the volume of solid waste is deemed necessary to involve various institutions in its management. The involvement of various institutions makes it possible to intervene at the level of production and consumption. In addition, interventions through increasing public awareness and optimizing the implementation of regulations can also encourage more sustainable waste management.

Universities as institutions of higher education are always regarded as agents of social and political change. The existence of higher education is not only a center of learning but also educates decision-making processes in society. Therefore, universities should contribute to solving environmental problems, including solid waste management. This is in line with the mission of higher education institutions to not only produce knowledgeable graduates but also to contribute to society through social services, community transformation, and environmental sustainability. Therefore, this study is aimed at analyzing the risk of solid waste management factors at the university using the Failure Mode Effect Analysis (FMEA) method. Some information about risk factors from the solid waste management process was collected using literature studies and Ishikawa diagrams. The number of experts or experts used in this study was 5 people. The expected results of this study will be able to show the value of the Risk Priority Number (RPN) of the factors that are the target of the study. Furthermore, from this value, the level of risk can be known from each factor. Thus, risk evaluation (priority risk to be controlled) in the solid waste management process is focused on the highest risk category. The results of this study can be a guideline for evaluating solid waste management in universities in Indonesia and other developing countries. Various developments to improve the results of this study need to be carried out that will be useful for future actions.

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makers. In addition, the role of higher education institutions also makes a significant contribution to promoting sustainable development [4]. Thus, the role of universities in waste management is one of the keys to the success of sustainable waste management.

Studies related to waste management in higher education have been carried out by researchers. For example, waste management at the University of Idaho, the USA which focuses on the type of waste, waste material flow and financing effectiveness [5]. Furthermore, Bailey et al. analyzed recycling practices as a solution for solid waste management at the West Indies University, Cave Hill Campus, Barbados [4]. In addition, research related to the analysis of characterization and composition of solid waste was also carried out at the University of Wolverhampton [6]. Studies on students at five universities in the UK related to cellphone use and disposal have also been carried out [7]. A study by Kiprop on the characterization of solid waste and the potential for recycling at East African Catholic University [8]. Meanwhile, waste management in universities is also carried out by Mwilu which focuses on the sustainability of solid waste management [9]. Similar research was also carried out by Zhang who emphasized reforesting the university through the management of sustainable solid waste [10]. In addition, the evaluation of solid waste management was carried out by Sepetu at the Mwanza public education institution, Tanzania [11].

Pancasila University is one of the private universities in DKI Jakarta, Indonesia which also faces challenges related to waste management to participate in realizing SDGs in universities. Although the University of Pancasila is one of the largest universities in DKI Jakarta, there is no comprehensive study of solid waste management. This research is an effort to identify potential failures of solid waste management processes that will serve as measures to prevent environmental damage and decrease the quality of human health.

Failures in the process of solid waste management can cause serious obstacles to achieving the SDGs goals. Failure in the process of solid waste management can have a significant impact on the success of universities, but there has not been much research related to the sustainability of solid waste management that has been carried out in DKI Jakarta. This question is very important for universities or other stakeholders to be able to take a role in creating a better environment.

One method that can be used to analyze the risk of failure of solid waste management processes is Failure Modes Effect Analysis (FMEA). This method is a structured approach to analyze the potential failure modes at one level and find out their impact on the next sub-system level [12; 13]. The definition of failure mode is an information of the non-functioning of an element, sub-system, or system as expected [14]. FMEA can be used in identifying potential system failures, impact evaluations and this can be interpreted as determining the severity and incidence [15]. The purpose of this method is to provide recommendations for the most likely interventions in order to anticipate process failures affecting users and customers.

The FMEA method has been widely applied in terms of environmental management. For example, impact evaluation systems integrated management systems on environmental indicators [16]. Environmental risk assessment of factory activities that have an impact on bird habitat [17]. Restructuring the FMEA method in order to resolve environmental problems from system failures to identify and evaluate environmental impacts throughout the product life cycle [18]. Furthermore, the application of the FMEA method to evaluate environmental requirements and integrate the product eco-design process [19]. However, FMEA research related to the potential failure of the solid waste management process has not been performed. Thus, this study aims at risk assessment in the management of solid waste at the Pancasila University, using the FMEA technique to determine the risk priority numbers for the failure of the solid waste management process. This research is useful for verifying the feasibility of the FMEA methodology for assessing the risk of failure in solid waste management, which has not been investigated. The results in terms of the RPN identify factors that have a risk of failure from a management perspective. Some interventions as a proposed improvement in the management process can also be suggested from this study to achieve sustainable management of solid waste.
2. Methodology
The research methodology is the steps that will be taken in research to achieve the desired goals. The problem-solving steps in the analysis of potential failures in solid waste management by applying the FMEA approach can be explained as follows:

a. Determine the factors and sub-factors of the system or design to be analyzed. The system to be analyzed is a solid waste management process carried out at the Pancasila University in Jakarta.
b. Identify types of failure (failure mode). At this stage, identification of any deviations from the process caused by changes in variables that affect the management process will be carried out. The identification process using a diagram Ishikawa diagram to determine the causes and consequences of the process of solid waste management.
c. Identify the consequences of failure (effect of failure). At this stage, the consequences or consequences of failure mode will be identified at a later stage, operating processes, products, customers and or government regulations.
d. Identify the cause of failure that occurs in the process that occurs (cause of failure). At this stage, it will identify what factors and sub-factors can make the process fail.
e. Set Severity Rating (S).
f. Establish an Occasion Rating (O).
g. Identifies the current control that has been done to prevent failure mode. At this stage, there will be the identification of activities that have been carried out by the university to overcome the process failure that occurred.
h. Establish Detection Rating (D).
i. Determine the value of the Risk Priority Number (RPN). The RPN confirms the priority level of failure [15]. The value of RPN depends on the value of the severity rating, occurrence rating, and detection rating. The formula used to calculate RPN is:

\[ RPN = S \times O \times D \]  

3. Result and discussion
The target of this research is the management of solid waste at the Pancasila University, this study uses the Ishikawa diagram and the FMEA method to identify the problem of the process of risk of failure of solid waste management and gives priority to the solution to this problem. Based on the results of the brainstorming with several experts, several factors have the potential to cause the failure of the solid waste management process. These factors are listed in table 1 below.

| Table 1. The potential factors to cause the failure of the solid waste management process |
|---|---|
| Factors | Sub-factors |
| Technology | • Technology is not environmentally friendly  
• Lack of security and tool safety  
• Lack of physical and technical infrastructure  
• Insufficient amount of technology  
• Special disposal and processing facilities not yet available |
| Policy | • Compliance with regulations  
• Lack of leadership support  
• Policy conflict  
• Poor data management |
| Social | • Lack of perception and participation of campus residents  
• Social conflict |
Based on a literature review related to the solid waste management process, it can be formulated cause and effect described by Ishikawa diagrams in figure 1 below.

**Figure 1. Ishikawa diagram**

After the implementation of risk identification, the next step is a risk assessment. Based on the assessment by experts, the results of the Risk Priority Number are presented in table 2 and figure 2.

**Table 2. Risk Assessment Process for managing solid waste**
Based on the results shown in the figure above related to the value of RPN, it can be concluded that the overall management of solid waste at the Pancasila University has the potential to meet the risk of failure. In figure 3, it can be seen that the highest RPN value is around 900, which is in the Lack of physical and technical infrastructure sub-factor. In addition, all sub-factors have high to very high values (critical). Therefore, based on table 2, precautionary measures need to be taken to reduce the potential failure of the management process in the future.

The results of the risk assessment as described above can be interpreted that the potential failure of the solid waste management process is very large. Thus, this may disrupt the dimensions of sustainable development in relation to solid waste management. This research has helped in identifying various risk factors that could potentially weaken the sustainability of solid waste management.
management at Pancasila University. Several risk factors have been identified such as technology, policy, social, and recycling.

![Figure 3. FMEA results from each factor](image)

Environmental and human health issues related to solid waste management are well known and many jurisdictions have implemented programs to manage solid waste. Solid waste management programs are not the same in terms of effectiveness. However, the overall goal is to reduce or eliminate the negative impacts associated with improper disposal and management of solid waste [20].

The definition of the management process is more focused on factors that have the potential to cause a malfunction of the solid waste management system. The factors that are the focus of this research include technology, recycling, regulation, and social. Based on the analysis results show the high potential risk of failure in the physical and technical infrastructure sub-factors. This is due to the unavailability of the landfill and the special processing of solid waste at the Pancasila University. Amoyaw-Osei et al., also showed that the use of technologies that are not environmentally friendly in the recycling process has the potential to cause the risk of environmental damage and deterioration in human health [21]. Reducing the consequences of hazards can be done by improving technology in reducing environmental impacts [22]. Improvement of supporting facilities in the environmental management process at the UNDIP campus greatly influences the success of environmental management [23].

Disposal facilities and special processing of solid waste are one of the factors driving the emergence of risks in the management of solid waste. Waste management is one of the weaknesses in developing countries. This is because the development of waste management service infrastructure has not been able to keep up with economic developments [24]. The availability of waste treatment infrastructure requires physical resources such as the availability of land, water, energy resources, location, and others [25]. Generally, the waste produced is still mixed with hazardous and toxic wastes. Thus, it requires comprehensive management. The study conducted by Peirce and Davidson explains that one of the important factors in the management of hazardous waste is the existence of long-term processing and storage facilities based on optimal location aspects [26]. Processing facilities aim to minimize disruption and the impact of adverse risks on the environment and public health.

Waste management facilities should be supported by appropriate technology. From a technology perspective, the use of technology by humans is aimed at increasing productivity and obtaining maximum profits. Some technological development efforts can be found in the recycle process, minimizing waste and changing the production process. Furthermore, knowledge of the ecological cycle of the type of material and in accordance with natural systems must be taken into consideration in environmentally friendly technological innovations. Increased environmental problems caused by
the use of technology are more dominant than the increase in the population [27]. Environmentally friendly technology must be adapted to the local socio-economic and cultural and environmental conditions.

In order to reduce the potential risk, there are several proposed strategies for improving the solid waste management system at the Pancasila University. For example, strengthening policies regarding the implementation of 3R such as improvements to existing regulations. In addition, institutions can develop technical infrastructure by using environmentally friendly technologies such as composting, bio-pore and manufacturing of small-scale waste power plants.

4. Conclusion
Solid waste has different characteristics, both hazardous and non-hazardous waste sourced from industry, commercial, residential and institutional. The solid waste stream has the potential to cause management process failures. Risk failures in the process of managing solid waste may cause serious obstacles to achieving the SDGs goals. This article highlights several factors and sub-factors that have the highest failure value in solid waste management at Pancasila University. Technological factors with the Lack of physical and technical infrastructure sub-factor with a value of around 900 RPN are categorized as High risk (Critical) and need to be improved. This research can be additional information for researchers related to risk management of solid waste management.

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