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Research Article

Development of Safety Planning using Risk Breakdown Structure to Improve Safety Performance on Construction Project

R.A. Machfudiyanto*, Y. Latief, and A. Monang

Department of Civil Engineering, Faculty of Engineering, Universitas Indonesia

Abstract: The bridge construction project, especially at the Elevated Trans Jakarta Road Project is a type of work with high complexity and is located in an open location, so many conditions of the potential hazards may arise. The lack of risks that can be identified and their control in safety planning documents will result in a continually arising job accident rate. The study objectives are to (i) identify the stages of the implementation, as well as the risk factors that have potential hazards, (ii), analyze the dominant risk factors in each stage of activity, and (iii) develop Safety Planning based on Regulation of Minister of Public Works No.05/PRT/M/2014 to improve the safety performance. The study was conducted qualitatively, by analyzing data on the perception of the questionnaire to the respondents who had experience in the project, and then the data were processed by Analytic Hierarchy Process (AHP) to get priority risk factors. The study results showed that there were 65 events of the risks which were identified as potentially dangerous, and 15 dominant risks that affected the OHS performance. Furthermore, the identification of risk response was performed, and risk level review was also conducted the risk response, review results showed a significant reduction in the risk level. It was concluded that OHS performance increased when safety planning was structured appropriately which was marked by decreased potential hazards following the applicable risk response.

Keywords: Safety planning, Risk Breakdown Structure, Construction Project, Safety Performance.

1. INTRODUCTION

The construction sector in Jakarta has been continually improved by the local government to overcome existing. One of the issues that become the flagship program of the Provincial Government of Jakarta is the alleviation of traffic congestion. Some of the main causes of traffic congestion in Jakarta is the uncontrolled vehicle growth of 8-10%, which is not comparable with the growth of roads by 0.01% per year with the current movement of vehicles in the city center and the movement of vehicles from the settlement towards the city center [1]. The traffic congestion problem could affect economic growth, the productivity of urban communities as well as the use of vehicle fuel. Overcoming traffic congestion in Jakarta is directed to the concept of Macro Transportation Pattern (MTP). In the concept of MTP, the development of infrastructure to support mass transportation is one way to unravel congestion in Jakarta. Jakarta Provincial Government is currently continuing to develop the lanes for Bus Rapid Transit (BRT), which is known by the name of Trans Jakarta, to serve the entire area of Jakarta. Limited land becomes a major limiting factor in the development of Trans Jakarta lanes, so flyover over the existing road was built to overcome the problem [2]. The bridge construction project, especially the Elevated Trans Jakarta Road project is a type of work with high complexity, has a large project value, involves a lot of labors, heavy equipment, worked on areas with open condition, and has high vehicular traffic and mobility of society around the job site [3]. With the situation of the project site, then there are quite a lot of conditions with potential dangers that can arise when safety planning is not executed properly, even it is one of the reasons the project is classified to have a high accident rate. [4] The project stages of the Elevated Trans Jakarta Road are considered to represent all kinds of bridges in Jakarta due to the high complexity that the case study type is quite

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*Corresponding Author: R.A. Machfudiyanto < rossyarmyn@gmail.com>

relevant for this study.

The cause of the high level of accidents at work during bridge construction, is due to the unavailability of risk factors identification and evaluation of construction companies, especially in the case of Construction Safety. The result of the bid document submission from the contractor indicated that the contractor has not been able to convey the completeness of the risk factors and risk responses in detail for each activity stage so that the risks that could occur during the work were not well identified. The lack of risks that can be identified along with the safety control in the document may cause continually increasing workplace accidents along with contractor incomprehension to anticipate every hazard that may arise [5].

Based on the description that has been described above, then some research problems can be formulated, namely, what are the activity stages and risk factors that have a potential hazard in the implementation/ bridge development process in Jakarta? Are there any dominant risk factors in each activity stage of the implementation/ bridge development process in Jakarta? and How is risk-based safety planning to improve the OHS performance.

The study objectives are to identify the stages of the implementation as well as the risk factors that have potential hazards, analyze the dominant risk factors in each stage of activity, and develop Safety Planning based on Regulation of Minister of Public Works No.05/PRT/M/2014 to improve the OHS performance on the bridge construction work [6].

1. LITERATURE REVIEW

Bridges in Jakarta consist of several types, namely the bridge that crosses the river, the bridge that crosses the highway interchange, the bridge that crosses the trail intersection, and the bridge that is built along the elevated highway known as Non-Toll Flyover or Elevated Trans Jakarta Road. The bridge construction project in Jakarta as the object of this study is an intersection bridge project namely Elevated Trans Jakarta Road.

Safety plan document which is applicable in the construction work in the Public Work field in Indonesia, particularly in the projects in Jakarta, was produced concerning the Regulation of Minister of Public Works No. 05/PRT/M/2014 dated April 22, 2014, regarding Guidelines for Safety and Health System [7] of Public Works Construction field. The Safety planning document in the regulation is known as the Contract Work Safety and Health Plan document.

Safety plan document on a bridge construction project in Jakarta, especially on hazard identification, risk assessment, priorities, OHS risk control, and the person in charge is complete and detailed by the service providers referring to the attachment of Regulation of Minister of Public Works No. 05/PRT/M/2014. Thus, this section will be the focus of discussion in this study. Referring to the Ministry of Public Works, then there was only one example of activity in the hazard identification, risk assessment, priority, and OHS risk control, so there was no format for project work in the enclosure of to the Regulation of Minister of Public Works.

According to [8] safety indicators aim to monitor the level of safety in the system, motivate, and provide sufficient information to the management to decide how to act. Meanwhile, according to [9] the focus of safety indicators for the big danger is always based on the accident indicator or lagging indicator, which means that it is based on the number of accidents that occurred.

Risk management is a system that aims to identify and quantify all the risks of a business or project so that decisions can be made on how to manage risk. A risk management system practical, realistic and should be cost-effective. In general, the risk management system consists of five stages, namely [10]:

1. Identification of risk, identify the risk source and type
2. Classification of risks, consider the types of risks and their effect on people or organization
3. Risk analysis, evaluate the consequences associated with this type of risk, or combination of risk by using the analytical technique.
4. The attitude of risk, any decision about the risk that will be influenced by the attitude

of the person or organization in decision making.

5. Risk response, consider the risks should be managed well, transferred to another party, or save it.

2. METHODOLOGY

Risks or uncertainties that arise in every stage of this project activities would have an impact on the OHS performance, in which the accident rate was increased. With the existence of the phenomenon then what are the risk factors that had potential hazards and affected the OHS performance? What are the actions against the major risks for the project can be completed with a low accident rate?.

The dependent variable (Y) is the target as the focus of this study, namely in the form of the safety performance of the project. While the independent variable (X) contains the problem to be observed or investigated, namely in the form of risk factors in each activity stage that had potential hazards and could affect the safety performance, that there 65 risk factors as the independent variables and would be used in this study, as shown in Table 1 below.

Table 1. Variables of Safety Planning

S. No.	Work Type	Work Description		Risk Factor
1	General Work	Field Supervision	X1	Mild/moderate accident (exposed to working tools and sharp objects).
			X2	Traffic accident while topography activity
		Tool Mob/Demobilization	X3	Slip while topography activity
			X4	The accident during tool maneuvering
			X5	Accident at the time of mobilization of heavy equipment
		Work Electrical Installation	X6	Electric shock accident during electrical installation work
		Direction Keet	X7	Fall from height during direction Keet construction
		Traffic arrangements	X8	Hit by passing vehicles during traffic regulation
		Land Clearing	X9	Exposed to working tools during the work land clearing work
2	Dismantling Work	Masonry demolition and construction	X10	Crushed by Stone while masonry demolition and construction
		Demolition of asphalt/concrete pavement	X11	Exposed to working tools during the demolition of asphalt/concrete pavement
		Demolition of massive concrete structures	X12	Exposed to concrete fragments during the demolition of massive concrete structures
3	Groundwork	Ground Excavation and Soil Pile	X13	Buried by avalanches during ground excavation work
			X14	Fall into a dug hole during ground excavation work
			X15	Exposed to working tools during soil pile work
			X16	Exposed to excavator swing during pile work
			X17	Exposed to truck maneuver during pile work
4	Drainage Work	Drainage Channel Work	X18	Hit by a crane during channel installation work
			X19	Exposed to crane backward during channel installation work
			X20	Exposed to material released because of the broken sling during channel installation work

S. No.	Work Type	Work Description		Risk Factor
5	Foundation Work	Bored pile Work	X21	Exposed to the utility grid during bored pile drilling work
			X22	Accidents due to the boring tool are collapsed and rolled during bored pile drilling work
			X23	The road is dirty and slippery due to mud during bored pile drilling work
			X24	Traffic jam due to loading queues of drilling material waste
			X25	The road is dirty/slippery due to the soil is spread on the street during drilling material waste loading work
			X26	Workers fall into the boring holes during iron reinforcement work
			X27	Workers are scratched, pinched by iron, and crushed by objects from above during iron reinforcement work
			X28	Eyes are exposed to weld beams and flux, electrocuted during welding work
			X29	Pipes are loosened/fall into boring holes during tremie pipe installation work
			X30	Traffic jam due to mixer truck queue during foundry work
6	Substructure Work	Pile cap Work	X31	Tremie Pipes are jammed to the Concrete Setting during foundry work
			X32	Workers are buried by main road landslide during pile cap excavation work
			X33	Workers are exposed to mortar and falling objects from above during work floor foundry
			X34	Workers are crushed by falling bricks during pile cap brick formwork work
			X35	Workers are bumped, crushed, and hands are scratched by iron during pile cap iron reinforcement work
			X36	Traffic jam to due to truck mixer queue during pile cap foundry work
		Pier Column Work	X37	The road is dirty and slippery due to gravel or concrete are scattered on the road during pile cap foundry work
			X38	Fall from height during pier column iron reinforcement work
			X39	Workers are bumped and fall from height during pier column formwork construction
			X40	Formwork falls and hits the road users during pier column formwork construction work
			X41	Traffic jam to due to truck mixer queue during pier column foundry work
			X42	The road is dirty and slippery due to gravel or concrete are scattered on the road during pier column foundry work

S. No.	Work Type	Work Description		Risk Factor
		Single Pier Beam Work	X43	Falling objects crushed the passing vehicles during formwork and single pier beam iron reinforcement works
			X44	Scaffolding shoring is stuck, hit by passing vehicle during formwork and single pier beam iron reinforcement works
		Double Pier Beam Work	X45	Scaffolding shoring is stuck, hit by passing vehicle during formwork and double pier beam iron reinforcement works
7	Girder Bridge Work	Girder Bridge Work	X46	Heavy equipment and box girder are hit by another vehicle during the mobilization of PC girder beam
			X47	Box girder falls during the mobilization of PC girder beam
			X48	Exposed to crane sling which is broken during the mobilization of PC girder
			X49	Exposed to strand metal cutting tools during PC girder stressing work
			X50	Exposed to strand metal during PC girder stressing work
		Box Girder Erection	X51	Fall from height during the implementation of the segment erection
			X52	Crushed by box girder which is lifted
			X53	Fall into the void hole of the box girder during Strand Fixity installation above Pier Segment
			X54	Tools are overturned and collapsed during the erection with service crane tool
			X55	Fall from height during the installation of strand fixity fishing rope on the pier head
			X56	Bumped, pinched by spreader beam during the spreader installation
			X57	Sling, spreader beam is broken, segments fall and the crane is rolled on the implementation of segment erection
			X58	Carrier crane falls during the implementation of the erection
			X59	Pier Segment lifting is not balanced to collide with boom crane during the implementation of the segment erection
			X60	Fall from a height while setting Pier Segment to Pier Head
			X61	Crushed by box girder while setting Pier Segment to Pier Head
		Box Girder Erection by using Launcher tool	X62	The strap (steel cable) of the launching gantry tool is broken
			X63	Accidents due to the overthrow of the launching gantry
8	Pavement Work	Grained and asphalt pavement	X64	Hit by a motor grader/heavy equipment
			X65	Exposed to the asphalt layer

3. RESULTS AND DISCUSSION

The results of this study were AHP and risk level analysis to determine the grade and the levels of the identified risk factors. The purpose of this analysis is to answer the research questions about the major risk events in each activity stage of the project development process, as shown in the following table.

From the analysis of the risk level, there 10 risk events that had an H (High) level and five risk events that had an M (Medium) level which represented each stage of activity. The risk events that often occur at every stage of Elevated Jakarta Road Project development activity and their causes, consequences, and how the preventive and corrective response actions, as well as the review of the results to the selected risk response, will be discussed in the next section (Table 2).

From the analysis of the risk level in the preceding discussion (Table 3), the next stage is the identification of the risk response for each dominant risk. The results of the selected risk response showed a significant reduction in the level of risk, so the risk response could be applied to minimize the risk events and influenced the increased safety/

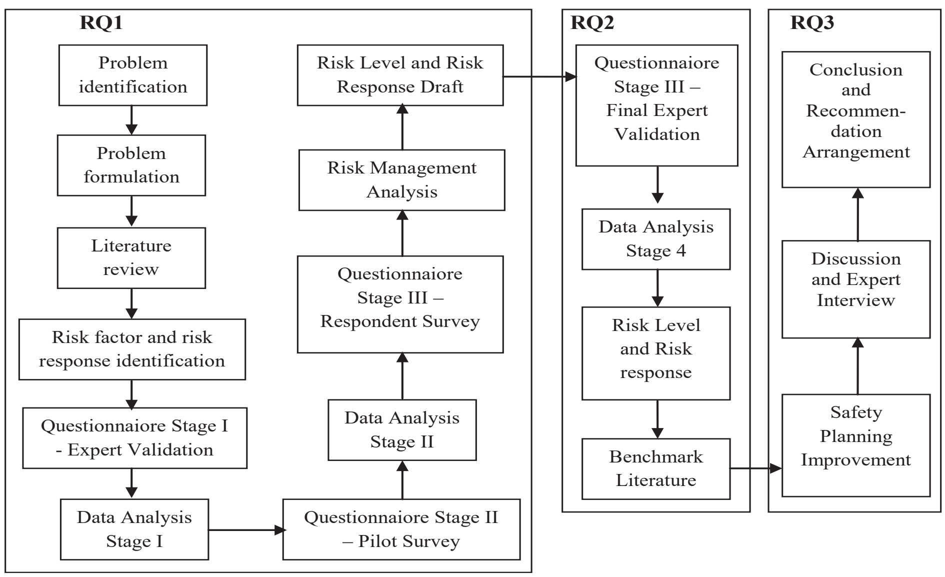

Fig.1. Research Flowchart

Table 2. Result of Risk Level

Risk Level		Variable		Risk Factor
1	H	X51	Girder Bridge Work	Fall from height during girder box erection work
2	H	X38	Substructure Work	Fall from height during pier column iron reinforcement work
3	H	X23	Work Foundation	The roads are dirty and slippery due to mud during the bored pile drilling work
4	H	X60	Girder Bridge Work	Fall from a height while setting Pier Segment to the Pier Head
5	H	X62	Girder Bridge Work	The strap (steel cable) of the launching gantry tool is broken
6	H	X55	Girder Bridge Work	Fall from height during the installation of strand fixity fishing rope on the pier head
7	H	X52	Girder Bridge Work	Crushed by box girder lifted during box girder erection work
8	H	X43	Substructure Work	Falling objects to the road and befall the passing vehicles during formwork and single pier beam iron reinforcement works
9	H	X39	Substructure Work	The worker is collided and fall from height during pier column formwork manufacture

Risk Level		Variable		Risk Factor
10	H	X54	Girder Bridge Work	Tools are overturned and collapsed during the erection with service crane tool
11	M	X64	Pavement Work	Hit by a grader motor/heavy equipment during grained pavement work
12	M	X7	General Work	Fall from height during the keet direction construction
13	M	X14	Groundwork	Fall into a dug hole during ground excavation work
14	M	X20	Drainage Work	Exposed to detached materials due to broken sling during channel installation work
15	M	X12	Dismantling Work	Exposed to concrete fragments during the massive dismantling of concrete structure

Table 3. Summary of risk factors, levels, and risk control

No.	Risk Factor		Risk level	Safety Risk Control	Risk Level Review
1	X23	The road is dirty and slippery due to mud during bored pile drilling work	0,21337 (H)	- Ensure that there is no dirt spilled and tires have been cleaned - Installation of signs and placement of personnel - Establishment, dissemination, and evaluation of SOP/WI - Making the wash boy & sandbag dam	0,0363 (L)
2	X38	Fall from height during pier column iron reinforcement work	0,22530 (H)	- The use of a safety belt and PPE - Installation of K3 signs - Installation of the step platform - Establishment, dissemination, and evaluation of SOP/WI	0,0290 (L)
3	X39	Workers are bumped and fall from height during pier column formwork construction	0,18845 (H)	- The use of a safety belt and PPE - Installation of K3 signs - Installation of the step platform - Establishment, dissemination, and evaluation of SOP/WI	0,0191 (L)
4	X43	Falling objects crushed the passing vehicles during formwork and single pier beam iron reinforcement	0,19383 (H)	- Installation Safety Net - Installation of K3 signs - Establishment, dissemination, and evaluation of SOP/WI	0,0243 (L)
5	X51	Fall from height during the implementation of the segment erection	0,23751 (H)	- The use of a safety belt and PPE - Installation of K3 signs - Safety patrols/supervisor on duty - Establishment, dissemination, and evaluation of SOP/WI	0,0401 (L)
6	X52	Crushed by box girder which is lifted	0,19744 (H)	- Training, certification for operator and audit on another equipment - Periodic checking on the sling binding and lifting point sign - Establishment, dissemination, and evaluation of SOP/WI	0,0221 (L)
7	X54	Tools are overturned and collapsed during the erection with service crane tool	0,18423 (H)	- Training, certification for operator and audit on another equipment - Checking the crane capacity and condition - Checking the slope of the runway	0,0180 (L)
8	X55	Fall from height during the installation of strand fixity fishing rope on the pier head	0,19773 (H)	- The use of a safety belt and PPE - Installation of K3 signs - Installation of step platform	0,0325 (L)
9	X60	Fall from a height while setting Pier Segment to Pier Head	0,20895 (H)	- The use of a safety belt and PPE - Installation of K3 signs - Installation of bridge inspection - Establishment, dissemination, and evaluation of SOP/WI	0,0336 (L)
10	X62	The strap (steel cable) of the launching gantry tool is broken	0,20133 (H)	- Periodic checking and launching strap replacement - Checking the certification of launching strap tool - The sling installation method (load distribution)	0,0352 (L)

OHS performance [11].

4. CONCLUSION

Based on test results and analysis that have been performed, several conclusions can be drawn from this study, namely:

The stages of implementation of bridge development activities in Jakarta in particular Elevated Trans Jakarta Road project identified eight stages of activities, among others: (1) General Work, (2) Dismantling Work, (3) Ground Work, (4) Drainage Work, (5) Foundation Work, (6) Substructure Work, (7) Girder Bridge Work and (8) Pavement Work. While there was a total of 65 risk factors with harmful potential as can be seen in Table 1.

There were 15 dominant risk event variables (X51, X38, X23, X60, X62, x55, X52, X43, X39, X54, X64, X7, X14, X20 and X12). The dominant risks emerged when the environmental conditions of the project had high community mobility around the project as in this study project. Then the risk response is identified as a subject for ranking the dominant risk level for the selected risk response so that the risk level could be reduced.

The results of this study can be used as subjects in the development of safety planning and as a complement to the enclosure of Regulation of Minister of Public Works 05/PRT/M/2014 on bridge construction work in Jakarta, especially the Elevated Road project which can be used both as an assessment matter of service provider auction process and guidance for contractors in the preparation of safety planning.

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