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Analysis of Occupational Safety and Health Risks in Steel Box Girder Installation Work on Bridges Using Hirarc and Jsa Methods

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ABSTRACT
Construction projects are activities that must be completed within limited time and resources. This research aims to identify risky activities and make control efforts to reduce the level of hazard risk in the installation of steel box girder on the bridge. This research used a mixed methods approach, combining quantitative and qualitative methods. Data were collected through surveys and interviews with 60 respondents from 35 bridge projects. The results showed that there were 29 variables of work accident risk factors, including 3 variables with moderate risk levels, 24 variables with high risk levels, and 2 variables with extreme risk levels. The highest risk factors were mobilization that caused congestion and crane overturning during girder lifting that caused operators to fall. To reduce the risk level, efforts are made to ensure all work is done correctly, conduct regular safety inspections, and ensure an effective communication system in the installation of steel box girders on the bridge. The findings can serve as a basis for policy makers to develop better OHS regulations and guidelines, as well as provide valuable information for the development of more effective safety training programs for workers in the construction sector.

Keywords: Risk Analysis, Work Accidents, Preventive Measures

INTRODUCTION

Construction projects are activities that must be completed within limited time and resources. They aim to achieve specific goals. Bridge construction projects have different characteristics compared to other types of projects. This includes road works, buildings, dams, and various other infrastructure (Nurtika et al., 2023) (Lirawati, 2021). As technology advances, bridge construction must be planned to meet transportation requirements in terms of comfort, safety, and beauty. Bridge construction work consists of lower and upper structures. The steel box girder is the top of the bridge, which is used for spans and long and curved geometry. The shape and type of box girder cross-section affect the ability and durability of the bridge. The box girder itself is a structural beam on the bridge that receives loads from the slab and then passes on to the column, which has a high elastic modulus and tensile strength (Ongkosurya & Supartono, 2019), (Ma'arif, 2023), (Sutomo & Amal, 2023).

In the work of installing steel box girder in its implementation, the level of risk of work accidents is quite high, because the activities are very complex (Fahmi Abbas, 2019). However, awareness of risks in the application of occupational safety and health is still lacking on the magnitude of work risks. Every work method used in bridge construction has a risk of danger that cannot be eliminated and can be predicted or controlled (Komalasari et al., 2024).

According to the Regulation of the Minister of Public Works Number: 05/PRT/M/2014 concerning Guidelines for Occupational Safety and Health Management Systems states that occupational safety and health is all forms of activities to ensure and protect occupational safety and health through efforts to prevent work accidents due to construction work (KemenPUPR RI, 2014). However, occupational safety and health also have another meaning, namely efforts to ensure and build a healthy and comfortable work environment for workers (Septian, 2024).

Work accidents are a direct result of work processes, highlighting the critical importance of effective risk management in construction projects. In the context of this study, the methods employed—such as mixed methods for risk identification and assessment—are essential for understanding the specific hazards associated with steel box girder installation. By analyzing these risks, the research connects directly to the title, emphasizing how the application of Earned Value Analysis and Earned Schedule Method can improve time and cost control, ultimately reducing the likelihood of work accidents. This correlation underscores the necessity of integrating safety measures into project management strategies in construction to enhance overall project outcomes. These accidents are not only caused by work equipment but can occur by human resources (Oktafia et al., 2024). The occurrence of work accidents in the work of installing steel box girders in several bridges is a serious problem, considering the need for these activities continues to increase.

Research (Rini et al., 2023) This study discusses data from the BPJS Ketenagakerjaan in November 2022 in Indonesia. There were 265,334 cases of work accidents, which were stated to have increased by around 13.26% from 234,270 cases in 2021. In 2019-2021, accidents occurred as much as 64.4%, 27% traffic accidents, 8.2% accidents outside the workplace, and 0.3% accidents in other places. So, the focus of this research is to identify risky activities according to the level of risk and make control efforts to reduce the level of risk of danger in the work of installing steel box girders on several bridges.

The purpose of this research is to identify risky activities in the process of installing steel box girders in bridge projects, and analyze the level of risk by categorizing it based on the impact and likelihood of work accidents. In addition, this research aims to develop effective control strategies to reduce the level of risk identified, as well as raise awareness about the importance of occupational safety and health (OHS) in the construction field. The benefits of this research include improved work safety for workers in the field, which in turn is expected to reduce the risk of accidents. By identifying and controlling risks, construction projects are expected to run more efficiently and on time. The results of this study can also serve as a basis for policy makers in drafting better OHS regulations and guidelines, as well as provide valuable information for the development of more effective safety training programs for workers in the construction sector.

RESEARCH METHODS

This research uses mixed method or mixed method, which is a procedure in a quantitative approach because it produces data in the form of numbers, and qualitative because it produces data in the form of descriptions.

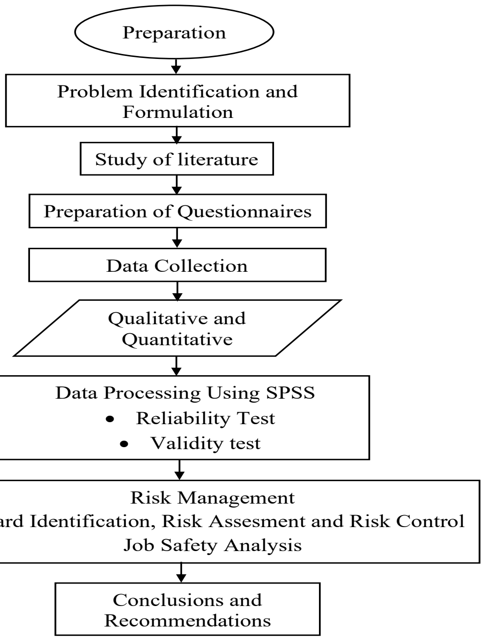

Figure 1 Framework of Thought

Object of Research

In this research, the work of installing a steel box girder on the bridge is the focus of the object to be studied.

Data Collection

In this data collection, 60 respondents were surveyed to determine the risk factors for work accidents, ranging from the lowest to the highest levels. This study also aims to establish proposed strategies for controlling the identified risks associated with the installation of steel box girders on bridges. By analyzing the responses, we can better understand the various risk factors and develop effective mitigation strategies tailored to enhance safety in these construction processes. In determining the sample size, use the Slovin formula to calculate the number of samples required (Santoso, 2023). The assessment indicators in this study are the level of impact and the level of possibility with a Likert scale of 1 to 5, ranging from 1 (very low), 2 (low), 3 (medium), 4 (high) and 5 (very high) with the following variables:

Table 1. Question Variables

Variable	Information
X1.1	Planning
X1.1.1	Clearing Areas
X1.1.1	Material fallout
X1.1.2	There are workers who are hit by sharp objects
X1.2	Personnel Preparation
X1.2.1	There are workers who are exposed to chemical diseases due to occupational risks
X1.3	Traffic Management Preparation (Coordination of related parties, public notification and preparation of signs)
X1.3.1	Traffic engineering errors can cause work accidents
X1.3.2	Traffic jams in the surrounding area
X1.3.3	Lack of K3 coordination which results in losses to local residents

Variable	Information
X1.4	Weather Mitigation
X1.4.1	Workers were struck by lightning during extreme weather
X1.5	Checking the readiness of heavy equipment (crawler crane)
X1.5.1	Work accidents due to heavy equipment damage
X1.6	Checking slings
X1.6.1	The sling broke which caused the girder to fall, causing the worker to fall on the material
X1.7	Checking steel assembly
X1.7.1	Accidents to body parts
X1.8	Tool box meeting
X1.8.1	Workers do not receive important work-related information
X1.9	Preparation of transportation equipment (crawler crane)
X1.9.1	Was hit by a conveyance
X2	Work
X2.1	Mobilization of steel box girders using multi-vehicles to the field
X2.1.1	Hit & run over during mobilization
X2.1.2	Mobilization causes congestion
X2.1.3	Overturned multi axle truck
X2.1.4	Hitting other objects while the truck is maneuvering
X2.2	Installation of slings, shackles and lifting gear
X2.2.1	Hand scratched by sharp object
X2.2.2	The worker was caught in a tool
X2.2.3	Workers crushed by material
X2.3	Lift up 1m
X2.3.1	Workers crushed by material
X2.3.2	The sling broke during girder lifting
X2.4	Loading test
X2.4.1	The crawler crane heavy equipment was damaged
X2.4.2	Workers crushed by material
X2.5	Transport according to altitude SOP
X2.5.1	Planning failure
X2.6	Swing
X2.6.1	Bungcrane due to excess tonnage
X2.7	Installation of steel box girder edge slings
X2.7.1	The girder fell causing workers to be hit by material
X2.7.2	The sling broke during girder lifting
X2.7.3	The crane tipped over while lifting the girder

Determination of the number of respondent samples taken from a population of 33 with a tolerance level of 5% error from a data accuracy level of 95% using the formula:

$$n = N/(1+N.e^2)$$

Where:
n = Sample size
N = Population size
e = margin of error

Sample Calculation:
N = 33
e = 5%
n = $33/(1+33 \times (0.05)^2) = 30{,}484$
From the sample calculation, using the Slovin formula, 30.484 was rounded to 30.

Typical case sampling is used based on the possibility and can be considered normal because, in one field of work, it is clear that they have the same experience and are considered normal.

RESULTS AND DISCUSSION

Respondent Characteristics

This study obtained the results of the characteristics of 60 respondents from 35 bridges consisting of each experienced including HSE, Supervisor, Site Manager (SM), Quality Control (QC), Quality Surveyor (QS), Surveyor and other fields regarding the work method of installing steel box girder on the bridge.

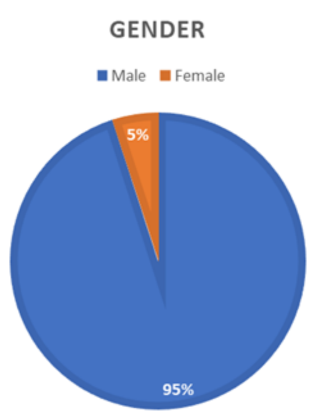

Figure 2 Gender diagram

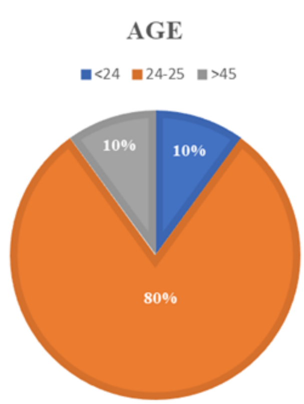

Figure 3 Age Chart

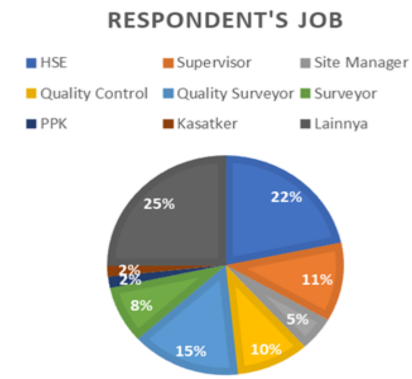

Figure 4 Diagram of Respondent Workers

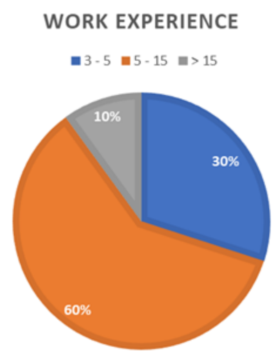

Figure 5 Work Experience Diagram

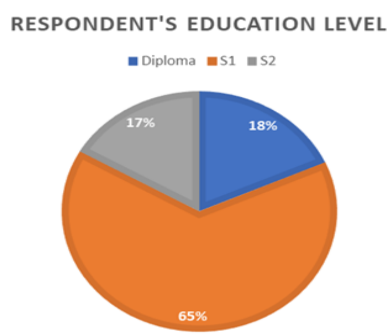

Figure 6 Last Education Diagram

Validity Test

The validity test is to assess whether a measuring instrument is valid or invalid. The measuring instrument is a question variable in the questionnaire. It is said to be valid if the question variable can reveal something that is measured on the questionnaire (Janna & Herianto, 2021). The critical r value of product-moment in the validity test of this impact and possibility is 0.254, which is obtained from the formula of (n-2) or df (60-2) = 58. After calculating using IBM SPSS Statistic 23 software, it is known that the calculated r-value of all question items is above the critical r-value of product-moment on each variable declared valid.

Table 2. Impact Validity Test

	Valid	N	%
Cases	Valid	60	100.0
	Excluded[a]	0	0.0
	Total	60	100.0

Table 3. Possibility Validity Test

	Valid	N	%
Cases	Valid	60	100.0
	Excluded[a]	0	0.0
	Total	60	100.0

Reliability Test

The reliability test serves to determine the consistency of the measuring instrument to remain consistent. It is said to be reliable if it produces the same results despite repeated measurements. The reliability test in this study uses the internal consistency method with Cronbach's alpha reliability coefficient, which has a value range of 0.00 to 1.00. The level of alpha reliability in the assessment of impact and possibility is as follows:

Table 4. Cronbach Alpha Assessment of Impact and Likelihood Levels

Cronbach's alpha value (r)	Reliability level
0.00-0.20	Very Low
0.21-0.40	Low
0.41-0.60	Medium
0.61-0.80	High
0.81-1.00	Extreme

Table 5. Calculation Results of Impact and Possibility Reliability Tests

k	$\Sigma\sigma^2$	σ^2	r11
29	42,376	552,202	0.956
29	38,962	552,193	0.958

From the calculation of the impact and likelihood reliability tests above using the Cronbach alpha method, the resulting r11 is 0.956 impact reliability and 0.958 likelihood reliability.

Table 6. Cronbach's alpha value Impact

Cronbach's alpha value (r)	Reliability level
0.956	Extreme

Table 7. Cronbach's alpha values Possible

Cronbach's alpha value (r)	Reliability level
0.956	Extreme

Hazard Identification, Risk Assessment and Risk Control

Hazard identification, risk assessment and risk control is a method of identifying, analyzing hazards and controlling risks used to systematically review a work process (Syarif et al., 2023).

Hazard Identification

Risk identification or hazard identification is a systematic effort made to determine the potential hazards in a job (Ramadhan, 2017). The results obtained from identifying potential risks in the work of installing steel box girder on 35 bridges by recording according to the level of impact and level of possibility.

Risk Assessment

Risk assessment is the stage of risk identification results by looking at the assessment of impact and possibility to determine the level of risk or risk ratting (Giananta et al., 2020). From the risk assessment on the work of installing steel box girders on 35 bridges, accurate data is obtained, taking into account the characteristics of impact and probability. The average value of impact and likelihood is calculated using Microsoft Excel to obtain a risk index and risk level based on matrix scale risk index mapping based on impact and likelihood categories. The results of the risk assessment include:

Table 8. Categories of Impact and Likelihood

Description	Action
Extreme	Workers may be at risk of occupational accidents and work may not be performed.
High	Medical Treatment Cse (MTC) work accident cases for workers who require expert treatment by a professional medical team.
Medium	Minor accidents that require action to reduce the risk of work accidents
Low	Work accidents that almost occur, can still be avoided and do not cause serious work accidents.

After knowing the value of each risk index, the next step is to map the risk index matrix.

Risk Control

Risk control is the implementation of overcoming potential hazards that have been identified in a job. Potential hazards can be overcome by determining the priority scale of the hierarchical approach. Prevention to reduce potential occupational safety and health hazards can be done based on elimination, substitution, engineering, administration, and personal protective equipment (PPE) (Sarah & Susilawati, 2023). From the results of risk control through a hierarchy of control approach where a sequence in controlling risks that may arise from several levels in sequence at the work of installing steel box girder in 35 bridges get the following results:

Table 9. Medium Level Risk Control

Level Risk	Potential hazard	Risk control
Medium	There are workers who are exposed to chemicals	Clean the work area from chemicals
	Worker struck by lightning	Coordination with surrounding BMKG
	Planning failure	Coordination with surrounding BMKG

Table 10. High Level Risk Control

Level Risk	Potential hazard	Risk control
High	Clearing Area	
	Material Fall	Carry out TBM before working using personal protective equipment according to SNI
	There are workers who are hit by sharp objects	Carry out TBM before working using personal protective equipment according to SNI
	Preparation of Traffic Management (Coordination Of Related Parties, Public Notification And Preparation Of Signs)	
	Traffic engineering errors can cause work accidents	Coordinate with all related parties and access users
	Traffic jams in the surrounding area	Coordinate with all related parties and access users
	Lack of K3 coordination which results in losses to local residents	Hold a meeting before progress begins and work using personal protective equipment according to SNI
	Checking the Readiness of Heavy Equipment (Crawler Crane)	
	Work accidents due to heavy equipment damage	Re-inspection of the crane using a competent engineer ensures safe mobilization
	Checking Slings	
	The sling broke causing the girder to fall, causing the worker to fall on the material	Slings must be free from defects, appropriate belt loops, appropriate belt joints, appropriate belt condition, appropriate hooks

	Checking Steel Assembly	
	Accidents to body parts	Coordinate with the crane operator and obey signs
	Tool Box Meeting	
	Workers do not receive important work-related information	Hold a meeting before progress begins and work using personal protective equipment according to SNI
	Preparation of Transportation Equipment (Clawler Crane)	
	Was hit by a conveyance	Coordinate with crane operator and comply
	Mobilization of Steel Box Girders Using Multiple Vehicles To The Field	
	Hit & run over during mobilization	Comply with the signs that are listed in the project area using personal protective equipment according to SNI
	Overturned multi axle truck	Check that the car's coaster mounts are driven with the silos still in effect
	Hitting other objects while the truck is maneuvering	Re-inspection of the crane using a competent flagman ensures safe mobilization
	Installation Of Slings, Shackles And Lifting Gear	
	Hand scratched by sharp object	Workers use personal protective equipment
	The worker was caught in a tool	Workers use personal protective equipment
	Workers crushed by material	Workers can pay close attention to the tool checklist
	Lift Up 1m	
	Workers crushed by material	Workers can pay attention to the tool checklist before using the tool
	The sling broke during girder lifting	Slings must be free from defects, appropriate belt loops, appropriate belt joints, appropriate belt condition, appropriate hooks
	Loading Test	
	The clawler crane heavy equipment was damaged	Re-inspection of the crane using a competent flagman ensures safe mobilization
	Workers are hit	Check the tools well and understand the work SOP
	Swing	
	Bungcrane due to excess tonnige	The condition of the tool checklist received by the crane does not have excess tonnage
	Steel Box Girder Edge Slings	
	The girder fell causing workers to be hit by material	The condition of the tool checklist received by the crane does not have excess tonnage, Slings must be free from defects, appropriate belt loops, appropriate belt joints, appropriate belt condition, appropriate hooks
	The sling broke during girder lifting	Slings must be free from defects, appropriate belt loops, appropriate belt joints, appropriate belt condition, appropriate hooks
	Lack of coordination and communication between contractors, consultants and project owners	Conduct coordination meetings before work begins and understand progress

Table 10 Extreme Level Risk Control

Level Risk	Potential hazard	Risk control
Extreme	Mobilization Of Steel Box Girders Using Multiple Vehicles To The Field	
	Mobilization causes congestion	Coordinate with SATLANTAS to avoid traffic jams or accumulation of vehicles
	The crane tipped over while lifting the girder causing the operator to fall	
	Steel Box Girder Edge Slings	Machine checklist, operational instruments, telescope, drum/wheel, sling, SIO, SILO, rotary, and wind meter

Job Safety Analysis

Job safety analysis (JSA) is the process of identifying hazards associated with each job that can cause significant damage before an accident occurs and determining ways to reduce the level of risk (Ramadhana & Abdullah, 2020). After identifying jobs that have medium, high, and extreme levels of danger, it can be made into a job safety analysis for risk control measures to minimize work accidents in the work of installing steel box girders on 35 bridges.

Of the 29 variables, the researcher only took 2 levels with the extreme or highest risk index as the following representative:

Tabel 12 Highest Risk Factor Variables

Sequence of Basic Job Steps	Hazard	Risk	Consequences	Recommended Action
Steel Box Girder Mobilization Using Multi Vehicles To The Field	Mobilization Causes Congestion	Work Will Be Disrupted	Causing Accidents For Road Users	Coordinate with traffic unit to avoid traffic jams or accumulation of vehicles and Install warning signs before erection begins well in advance regarding steel box girder installation
The Crane Tipped Over While Lifting The Girder Causing The Operator To Fall	Workers have accidents	Component damage	Causing worker accidents	Machine checklist, operational instruments, telescope, drum/wheel sling, sio and silo, daram sling rotary and wind meter

The highest risk factor variable is mobilization, causing congestion when mobilizing steel box girders using multiple vehicles to the field. Therefore, it is important to carry out risk control, namely requiring coordination with the traffic unit so that there is no congestion or accumulation of vehicles and installing notification signs before erection begins in advance regarding the installation of steel box girders on the bridge. The second variable is the crane reversed when lifting the girder, causing the sling to limit the edge of the steel box girder. To carry out these risk control measures, namely by checking the machine, operational instruments, telescope, drum /wheel, sling, SIO, SILO, rotary, and wind meter.

CONCLUSION

Based on the results and discussion, it can be concluded that during the installation of steel box girders in 35 bridges, there were 29 work accident factors, including 3 medium-risk level variables, 24 high-risk level variables, and 2 extreme-risk-level variables. Of the 29 risk factors, efforts to control work accidents are very important to reduce the level of risk that can be done including Ensuring all workers are properly trained on safety procedures and have training certification, conducting regular construction site safety inspections to identify potential hazards and risks, monitor weather conditions and work environment, ensure effective communication systems are in place and provide instructions on emergency procedures, and review and evaluate security procedures regularly to ensure they remain relevant and update as needed.

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