Constraint and Fault Tree Analysis in Safety Construction System Integration

N. Fitri, A. Bhaskara, and A. Purbiantoro

Abstract Construction projects is an activity contains many elements of hazard and causes a poor record in terms of occupational safety. Therefore, occupational safety is always an aspect that have to be regenerated, caused by the problem complexities which includes issues in terms of humanity, legal aspects, accountability and the image of the organization. This research aims to determine the level of accuracy in the field of the application of occupational safety management systems based on engineering judgement, identify and analyze the potential risk of loss/work accident using the Fault Tree Analysis (FTA) method and plan mitigation to reduce the scope of construction work in progress. This research is a quantitative analysis which is done by collecting primary data through interviews and observations and secondary data in the form of data from the construction project. FTA used to investigate potential work accidents by analyzing the direct causes to the underlying causes of the accident. The results show the level of implementation accuracy of the Occupational Safety Management System that has been applied obtained an assessment rate of 97.29% and included in the satisfactory rating level, however after a probability assessment based on engineering judgement there are indications of doubts of 23.37% of the results. The FTA causality results found several events tendencies potentially lead to loss, events such as workers not using personal protective equipment, workers acting carelessly, and lack of work experience are events that often occur in FTA basic events.

Keywords Audit · Causalities · Constraint · FTA · Safety construction system

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1 Introduction

Work safety means how someone protecting themselves or others. Because of workload happening in construction sites require a worker to get the protection so that they could work maximally. Work safety is the most crucial factor in achieving the project's goals. The maximum performance of triple constrains (cost, quality and time) is meaningless if the rate of occupational safety is being ignored.

Construction is an event with a high-risk for an accident. Therefore, the service providers are required to apply the management system of work safety as an action for resolving the accident risk that might occur. Concerning guidance to apply the management system of occupational safety and health in Indonesia, one of them is based on Indonesian Government Regulation No. 50 the year 2012 [1].

The regulation mentioned specific terms and conditions that every company employing worker above or 100 (a hundred) people or has a high level of potential dangers is required to apply The Management System of Occupational Health and Safety or Occupational Health and Safety Assessment Series (OHSAS 18001:2007) which integrated by Company Management System [2]. The requirement is including Company investment due to an obligation arranged in the Law of The Republic of Indonesia.

Through the implementation of the Management System of Work Safety, it is expected that the company is able to have a Safety, healthy, efficient, and productive environment. Further, the implementation of management system of work safety also helps the owner of Company to execute the standard of Occupational health and Safety which also became a public guide both nationally and internationally.

2 Literature Review

Constraint and fault tree analysis in this research is an integration system between audit and causalities structure for find out the basis trigger which cause of construction accident by fault tree analysis method. There are two basic influential literature used in this research.

2.1 Domino Theory

Construction accidents can be prevented just by identifying the root causes of accidents, which is possible by accident investigation techniques such as theories of accident causation and human errors. Accident prevention has been defined by Heinrich as 'An integrated program', a series of coordinated activities, directed to the control of unsafe personal performance and unsafe mechanical conditions, and based on certain knowledge, attitudes, and abilities. Some other synonyms for accident prevention have been emerged later such as loss prevention, loss control, total loss control, safety management, incidence loss control [3] Heinrich was the pioneer in the Accident causation theories. He described the accidents causation theory, man and machine relationship, frequency and severity relation, unsafe acts reasons, management role in accident prevention, costs of accidents and the impact of safety on efficiency [4]. Heinrich's domino theory has been modified and updated over the years with greater emphasis on management as an original cause of accidents. The management-based theories define management as responsible for causing accidents, and they attempt to recognize failures within the management system [5].

The sequential domino representation was continued by Bird and Germain (1985) who acknowledge that the Heinrich's domino sequence had underpinned safety thinking for over 30 years. They recognized the need for management to prevent and control accidents in what were fast becoming highly complex situations due to advances in technology. They developed an updated domino model which they considered reflected the direct management relationship with the causes and effect of accident loss and incorporated arrows to show the multilinear interaction of the cause-and-effect sequence. This model became known as the *Loss Causation Model* and was again represented by line of five dominos, linked to each other in a linear sequence [6]. The updated and modified sequence of events is [7]:

(a) Lack of control/management (inadequate program, inadequate program standard, inadequate compliance to standard)
(b) Basic causes/origins (basic causes: (1) personal factors, (2) job factors)
(c) Immediate causes/Symptoms (sub-standard act and condition)
(d) Incident (contact with energy and substance)
(e) Loss (property, people, process)

2.2 Fault Tree Analysis

A fault tree analysis can be simply described as an analytical technique, whereby an undesired state of the system is specified (usually a state that is critical from a safety standpoint), and the system is then analyzed in the context of its environment and operation to find all credible ways in which the undesired event can occur [8].

As deductive approach, FTA stars with an undesired event, such as failure of main engine, and the determines (deduces) it causing systematic, backward stepping process. In the determining the cause fault tree is constructed as a logical illustration of the events and their relationships that are necessary and sufficient result in the undesired event, or top event [9].

2.3 Assessment

Main indicator for assessment in this research is based on Government Regulation of Indonesia Republic Number 50 Year 2012 about Application System of Occupational Safety and Health is basic. Determination of audit criteria are divided into three level as follows.

1. Initial Level Assessment
   Assessment of Management System of Occupational Health and Safety for 64 criteria's
2. Transition Level Assessment
   Assessment of Management System of Occupational Health and Safety for 122 criteria's
3. Advance Level Assessment
   Assessment of Management System of Occupational Health and Safety for 166 criteria's

3 Research Method

The method used in this research is quantitative which is systematic, planned, and structured from the preliminary to its design. Primary data was obtained from the interview and observation focused on the work process and site condition which potential of an accident. The first step, data analyzed by audit assessment and the result is specified detailly by FTA to find out the basic potential accident in construction work on progress. Mind mapping of this research presented as follows (Fig. 1).

3.1 Research Instrument

The research instrument refers to the Application of Management System of Occupational Health and Safety, and Indonesian Government Regulation No. 50 the Year 2012 appendix II, also the integration of OHSAS 18001. The following is a broad line research instrument submitted to the resource person (Table 1).

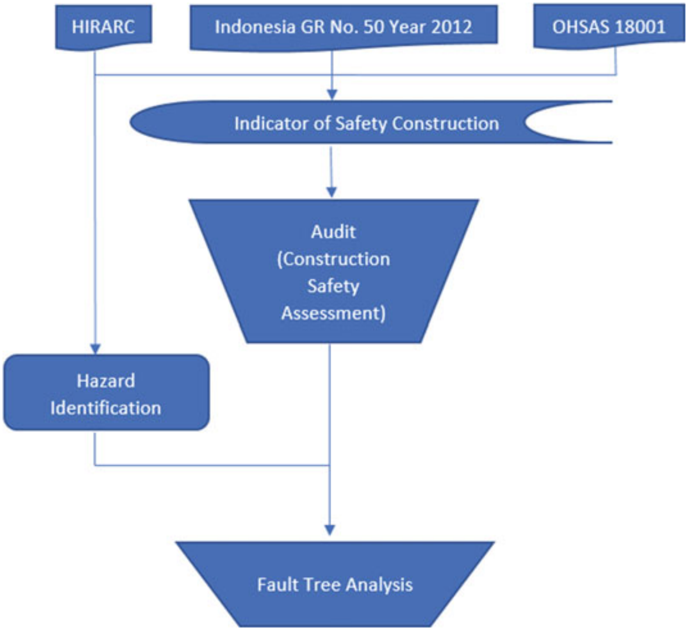

Fig. 1 Mind mapping (outcome flowchart)

Table 1 Research instrument grids

Element criteria	Sub element	Total
Development and commitment maintenance	1.1.1–1.4.10	25
Creation and documentation of occupational health and safety plan	2.1.1–2.4.1	13
Planning control and contract review	3.1.1–3.2.4	8
Document control	4.1.1–4.2.3	7
Work secure based on occupational health and safety	5.1.1–5.9.1	53
Monitoring standard	6.1.1–6.4.5	22
Report and deficiencies correction	7.1.1–7.3.6	9
Management and material loading	8.1.1–8.2.3	7
Collection and data usage	9.1.1–9.2.2	5
Occupational health and safety usage	10.1.1–10.1.3	3
Skill and abilities development	11.1.1–11.5.1	14
Grand total		166

4 Result and Discussion

Output Mapping of this study is as follows:

4.1 Data Collection Results

The percentage level of the implementation of the work safety management system which has been applied by the service provider for the building project of hospital service is (Table 2):

$$\frac{(\text{Critical Category} \times 0) + (\text{Major Category} \times 50) + (\text{Minor Category} \times 100)}{\text{Total Audit Criteria}} \times 100$$

$$\frac{(0 \times 0) + (9 \times 50) + (157 \times 100)}{166} \times 100$$
$$= 97.29\%$$

Classification of Assessment Colour

See Fig. 2.

Description:

a. Critical Sub
   - Not applying criteria
   - There are findings that result in a fatality

b. Major Sub
   - Unqualified for laws and regulation
   - Neglecting one of Occupational Health and Safety principals; and
   - There is minor for an audit category in some sections.

c. Minor Sub
   - Consistent to comply with the requirements of the standard of laws and regulations, handbook, and some other references
   - The Implementation of Occupational Health and Safety is qualified

Probability and Possibility Analysis

The probability number of the research instrument is obtained from the discussion group between the writer and the people involved in construction project whereas the possibility number is several engineering judgments of the writer based on direct observation in each project site. The average of the probability and the possibility will

Table 2 Research instrument grids

Criteria number	Score	Type	Criteria number	Score	Type
1			5.7		
1.1			5.7.1–5.7.7	100	Minor (Green)
1.1.1–1.1.5	100	Minor (Green)	5.8		
1.2			5.8.1–5.8.2	100	Minor (Green)
1.2.1–1.2.6	100	Minor (Green)	5.9		
1.3			5.9.1	100	Minor (Green)
1.3.1–1.3.3	100	Minor (Green)	6		
1.4			6.1		
1.4.1–1.4.10	100	Minor (Green)	6.1.1–6.1.7	100	Minor (Green)
2			6.2.1–6.2.8	100	Minor (Green)
2.1.1–2.1.5	100	Minor (Green)	6.3		
2.1.5	50	Major (Yellow)	6.3.1–6.3.2	100	Minor (Green)
2.2			6.4		
2.2.1–2.2.3	100	Minor (Green)	6.4.1–6.4.5	100	Minor (Green)
2.3			7		
2.3.1–2.3.4	100	Minor (Green)	7.1		
2.4			7.1.1	100	Minor (Green)
2.4.1	100	Minor (Green)	7.2		
3			7.2.1	100	Minor (Green)
3.1			7.3		
3.1.1–3.1.4	100	Minor (Green)	7.3.1–7.3.4	100	Minor (Green)
3.2			7.3.5–7.3.6	50	Major (Yellow)
3.2.1–3.2.4	100	Minor (Green)	7.4		
4			7.4.1	100	Minor (Green)
4.1			8		
4.1.1	100	Minor (Green)	8.1.1–8.1.4	100	Minor (Green)
4.1.2	50	Mayor (Yellow)	8.2		
4.1.3–4.1.4	100	Minor (Green)	8.2.1–8.2.3	100	Minor (Green)
4.2			9		
4.2.1–4.2.3	100	Minor (Green)	9.1		
5			9.1.1–9.1.3	100	Minor (Green)
5.1			9.2		
5.1.1–5.1.8	100	Minor (Green)	9.2.1–9.2.2	100	Minor (Green)
5.1.9	50	Major (Yellow)	10		
5.1.10–5.1.11	100		10.1		
5.1.12	50	Major (Yellow)	10.1.1–10.1.3	100	Minor (Green)

(continued)

Table 2 (continued)

Criteria number	Score	Type	Criteria number	Score	Type
5.1.13	100	Minor (Green)	11.1		
5.1.14	50	Major (Yellow)	11.1.1–11.1.7	100	Minor (Green)
5.1.15	100	Minor (Green)	11.2		
5.1.16–5.1.18	100	Minor (Green)	11.2.1–11.2.2	100	Minor (Green)
5.1.19	50	Major (Yellow)	11.3		
5.1.20–5.1.23	100	Minor (Green)	11.3.1–11.3.2	100	Minor (Green)
5.2			11.3.3	50	Major (Yellow)
5.2.1–5.2.4	100	Minor (Green)	11.4		
5.3			11.4.1	100	Minor (Green)
5.3.1–5.3.2	100	Minor (Green)	11.5		
5.4			11.5.1	100	Minor (Green)
5.4.1–5.4.4	100	Minor (Green)			
5.5					
5.5.1–5.5.8	100	Minor (Green)			
5.6					
5.6.1–5.6.2	100	Minor (Green)			

After the audit of 166 advanced criteria level, the results are:
(1) Critical category (Score = 0), there is 0 criteria
(2) Major category (Score = 50), there are 9 criteria
(3) Minor category (Score = 100), there are 157 criteria

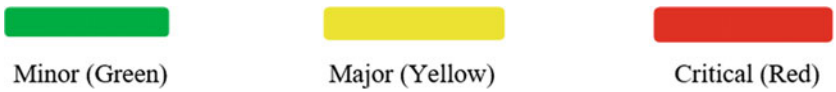

Fig. 2 Classification of Assessment Colour

be taken as the determinant number which is used to determine the average number in each element. In this case, both the probability and the possibility are divided into three rating scale 0–3, 4–6, 7–9 [10].

After the analysis of probability and possibility, obtained a result for the percentage level of the implementation of the work safety management system which has been applied by the service provider about 74.60%. The result is lower 23.37% than Survey data Collection which shows 97.29% due to the service provider unable to showing the evidence that they already applied the principal or the criteria of the implementation of Management System of Occupational Health and Safety Indonesian Government Regulation No. 50 the Year 2012 Appendix II integrated by OHSAS 18001. The comparison results between survey data and probability and possibility analysis based on engineering judgment are shown at Fig. 3.

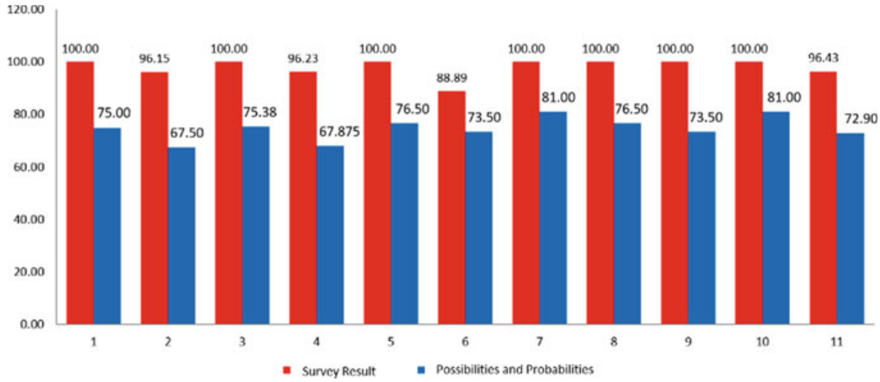

Fig. 3 Probability and possibility and survey result chart

4.2 *Constraint Analysis by FTA*

Based on the Domino theory in this study, figuring FTA for a basic event is an unsafe act or unsafe condition event, so that the basic event can be eliminated by performing cut set ranking with Boolean algebra for simplifying/reducing so the accident events and injury would not occur. Here are an FTA depiction and a discussion of potential work accidents on the scope of construction in progress.

Potential Hazards of Tower Crane Operation (TC)

The result of Modeling Fault Tree Analysis (FTA) of Potential Hazard of Tower Crane Operation (Fig. 4).

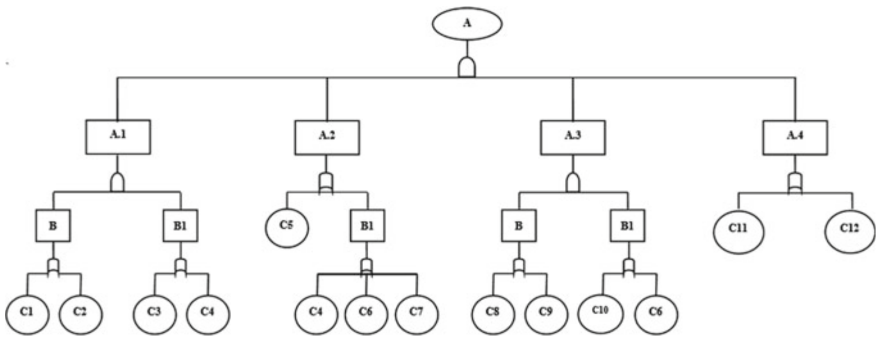

Fig. 4 FTA Graphic model of potential hazard in Tower Crane Operation

Table 3 The event description on the graphical model of the tower crane operation

No.	Symbol	Description	No.	Symbol	Description
1	A	The potential hazard on tower crane operation (TC)	11	C.4	Workers act recklessly such as joking, smoking and working out of procedure
2	A.1	Falling worker or workers hit by falling objects when the erection	12	C.5	The rotation portion and the height of the tower crane does not match to the field
3	A.2	Striking the surrounding building	13	C.6	Lack of experience/the expertise is not suitable
4	A.3	The broken sling rope	14	C.7	There is no communication between TC operator and the foreman
5	A.4	Struck by lightning	15	C.8	The absence of danger sign
6	B	Technique factors	16	C.9	There is no inspection of work equipment or routine checks before the operation
7	B.1	Workers factor	17	C.10	Working out of procedure
8	C1	Less socialization of Occupational Health and Safety officer	18	C.11	The absence of lighting rod at the top of Tower Crane (TC)
9	C2	Absence of danger sign around Tower Crane area	19	C.12	Operate during heavy rain
10	C.3	Not using the personal protective equipment			

Description:
See Table 3.

FTA Data Analysis:

The next step after creating the FTA graphic model is further analyzing the basic event that leads to the top event by looking for a minimal cut set obtained from analysis results using the Boolean algebra of distributive law. Operator notation of Boolean logic used for OR gate is an addition symbolized by (+) whereas for AND gate is a multiplication symbolized by (·)

A	= A1 . A2 . A3 . A4	B	= C1 + C2
A1	= B . B1	B1	= C3 + C4
A2	= C5 + B1	B1	= C4 + C6 + C7
A3	= B . B1	B	= C8 + C9
A4	= C11 + C12	B1	= C10 + C6

From the Boolean algebra shown above, then a minimum cut set is sought to find a combination of several events until the results no longer to be reduced/simplified. The results of the combination of these events are called the cause of the peak event.

A =	A1 . A2 . A3 . A4
=	(B . B1) . (C5 + B1) . (B . B1) . (C11 + C12)
=	((C1 + C2) . (C3 + C4)) . (C5 + (C4 + C6 + C7)) . ((C8 + C9) + (C10 + C6)) . (C11 + C12)
=	(C1 + C2 + C3 + C4) . (C5 + C4 + C6 + C7) . (C8 + C9 + C10 + C6) . (C11 + C12)

From the results of the analysis using boolean algebra, there are 4 minimum cut sets, which are the combination of basic events that can cause the potential of a hazards accident in tower crane operation. The following are basic events that probably cause the potential accident in tower crane operation along with a discussion of risk that can be applied (Table 4).

Potential Hazards of the Formwork

The results of the Fault Tree Analysis (FTA) depiction of the potential dangers of the formwork (Fig. 5).

Description:
See Table 5.

FTA data Analysis:

Minimal Cut set using algebra Boolean law:

A	= B1 . B2 . B3	C2	= D3 + D4
B1	= C1 . C2	C1	= D5 + D6 + D7
B2	= C3 . C4	C2	= D8 + D3
B3	= C1 . C2 . C3	C1	= D5 + D1 + D9
C1	= D1 + D2	C2	= D10 + D11 + D4 + D8
		C3	= D12 + D13 + D14

Event Combination result:

A	= B1 + B2 + B3
	= (C1 . C2) + (C1 . C2) + (C1 . C2 . C3)
	= ((D1 + D2) . (D3 + D4)) + ((D5 + D6 + D7) . (D8 + D3)) + ((D5 + D1 + D9) . (D10 + D11 + D4 + D8) . (D12 + D13 + 14))
	= (D1 + D2 + D3 + D4) + (D5 + D6 + D7 + D8 + D3) + (D5 + D1 + 9 + D10 + D11 + D14 + D18 + D12 + D13 + D14)

Table 4 Results of Boolen algebra analysis and risk control

No.	Basic event combination	Combination description	Risk control
1	C1, C2, C3, C4	The operation of tower crane has the potential to cause the risk of falling worker/hit by a falling object accident. This incident able to occur due to 4 (factors) which are the lack of OHS socialization or the lack of supervision from OHS officers, the absence of danger sign around crane tower operations, workers do not use the personal protective equipment and workers act recklessly	• Implementation of morning safety talks before starting work • Socialization of occupational health and safety program • Provide personal protective equipment (PPE) for workers • Conduct supervision of workers to comply by prescribed procedures) • Installation of falling hazards sign and prohibition to drop object around the tower crane operation site
2	C5, C4, C6, C7	Tower crane operation could potentially lead to the tower crane incident hitting the building around. The incident can appear if the rotation area and the height of tower crane does not match to the field, recklessness of worker, and the cut of communication between TC operator and foreman	• Engaging the expert/tower crane operator who owns the "Work Permit" of relevant agencies • Supervise the workers to work in accordance with the prescribed procedures • Provide HT for communication tools used between operator and foreman
3	C8, C9, C10, C6	Tower crane operation has the potential to break its sling ropes during the operation. The incident can occur due to the absence of warning signs and no inspection of work equipment or routine checks is carried out, working out of procedure/working with unsuitable expertise	• Routine inspection of construction tools and ensuring everything has been running as procedure that have been applied before starting work • Installing a warning sign (ADJUST LIFT CAPACITY)
4	C11, C12	Tower crane operation has the potential to cause tower crane events to be struck by lightning. The event can occur due to the absence of a lightning rod at the top of tower crane or occurs because tower Crane continues to operate during heavy rains	• Installing the lightning rod at the top of tower crane • Prohibit the operation of tower crane when the weather is raining heavily, and the strong wind

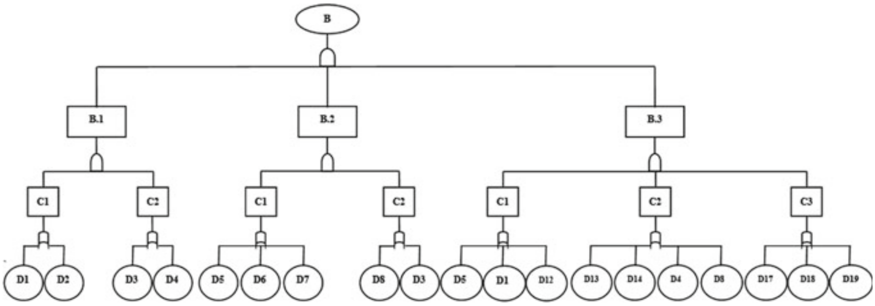

Fig. 5 The FTA graphic model of the potential dangers of the formwork

Table 5 The event description on the graphical model of the formwork

No	Symbol	Description	No.	Symbol	Description
1	B	Potential dangers of formwork	12	D.5	The absence of a warning sign
2	B.1	The collapse of the formwork	13	D.6	An error in lifting materials/equipment to a higher place
3	B.2	workers hit by falling objects and exposed to sharp instruments	14	D.7	Storing materials that are out of place
4	B.3	Falling at height	15	D.8	Workers do not use PPE
5	C1	Technical factors	16	D.9	Production pressure
6	C2	Worker factors	17	D.10	Lack of experience
7	C3	Environmental factors	18	D.11	Worker Fatigue
8	D.1	Lack of supervision from the officer	19	D.12	Poor lighting in the workplace
9	D.2	An error when assembling the completeness of reinforcement	20	D.13	Slippery work floor
10	D.3	Recklessness of the workers	21	D.14	Disregarded safety sign in construction sites
11	D.4	Performing without complying with the prescribed procedures (Joking, smoking, etc.)			

From the result of the analysis using the Boolean algebra, it is obtained 3 minimum cut sets taken from a combination of basic events. Here is the basic event tendency cause a potential accident in formwork installation along with a discussion of its risk control that able be applied (Table 6).

Table 6 The results of Boolean algebra analysis and risk control

No.	Basic event combination	Combination description	Risk control
1	D1, D2, D3, D4	Collapsed formwork events can occur due to several factors such as the absence of supervision while operation, an error when assembling the completeness of reinforcement and worker's faults	• Implementation of morning safety talk before starting work • Perform installation inspection of the work equipment such as: cross bracing, scour, ties, base mount clamp, scaffolding, etc. to ensure if it is installed correctly or not a ll • Inspect the installation of work equipment such as: cross bracing, scour, ties, • Supervise the workers to work in accordance with the standard operating procedures
2	D5, D6, D7, D8, D9	The incidence of workers hit by a falling object and exposed to a sharp instrument could occur due to the absence of warning sign, an error in lifting material/equipment to a higher place, the position of the object or equipment that is not in its place, workers do not use PPE while working, or occur due to recklessness of the workers	• Installation warning signs of falling object and prohibition to drop object • Supervise the workers to work in accordance with the standard operating procedures • Require all workers to use APD/PPE
3	D10, D11, D12, D13, D14, D15, D16, D3, D4	The incidence of workers falling from the height could be occur when the worker works inadequate to their expertise, fatigue workers, workers do not use PPE, Poor lighting in the worksite, Slippery work floor, and workers neglect Occupational Health and Safety signs	• Socialization of Occupational, health and safety program • Provide personal protective equipment (PPE) for workers • Require all workers to use adequate PPE around the worksite • Held the *Safety Induction* when welcoming new workers

Potential Hazards of The Reinforcement Work

The results of the Fault Tree Analysis (FTA) depiction of the potential dangers in reinforcement work (Fig. 6).

Description:
See Table 7.

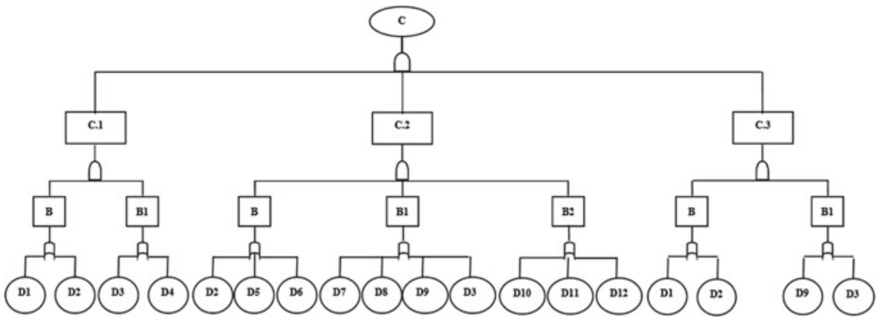

Fig. 6 The FTA graphic model of potential dangers in the reinforcement work

Table 7 The event description on the graphical model of the reinforcement work

No.	Symbol	Description	No.	Symbol	Description
1	C	Potential dangers of reinforcement work (assembly/fabrication)	11	D5	Lack of supervision
2	C.1	workers hit by a falling object, exposed to a sharp instrument, being caught in or between objects	12	D6	Production pressure
3	C.2	Worker falls on the installation of column reinforcement	13	D6	Production pressure
4	B	Technical factors	14	D7	Lack of experience
5	B1	Worker factors	15	D8	Fatigue worker
6	B2	Environment factors	16	D9	Performing without complying with the prescribed procedures (Joking, smoking, etc.)
7	D1	Lack of socialization of occupational health and safety	17	D10	Poor lighting in the workplace
8	D2	The absence of warning sign	18	D11	Slippery work floor
9	D3	Worker do not use ADP/PPE equipment	19	D12	Disregarding occupational health and safety sign in the workplace
10	D4	The recklessness of the workers			

FTA data Analysis:

Minimum Cut set using Boolean algebra law:

C	= C1 . C2 . C3	B	= D2 + D5 + D6
C1	= B1 . B2	B1	= D7 + D8 + D9 + D3
C2	= B . B1 . B2	B2	= D10 + D11 + D12
C3	= B1 . B2	B	= D1 + D2
C1	= D1 + D2	B1	= D9 + D3
B	= D1 + D2		
B1	= D3 + D4		

Event Combination Result:

C	= C1 + C2 + C3
	= (B . B1) + (B . B1 . B2) + (B . B1)
	= ((D1 + D2) . (D3 + D4)) + ((D2 + D5 + D6) . (D7 + D8 + D9 + D3) . (D10 + D11 + 12)) + ((D1 + D2) . (D9 + D3))
	= (D1 + D2 + D3 + D4) + (D2 + D5 + D6 + D7 + D8 + D9 + D3 + D10 + D11 + D12) + (D1 + D2 + D9 + D3)

From the result of the analysis using the Boolean algebra, it is obtained 3 minimum cut sets taken from a combination of basic events. Here are the basic event that can cause a potential accident in reinforcement work along with a discussion of its risk control that can be applied (Table 8).

5 Conclusion

Based on audit results then its unable to depend 100% to justify the safety construction climate on construction sites, need to be supported by other justification such as FTA approach for specified causations. The conclusion results from both of approach as follows.

1. The percentage level of implementation of occupational safety management system that has been applied by the service provider based on the result of the survey obtained a valuation rate of 97,29%, but after the probability assessment based on engineering judgment, researchers have doubts of 23,37% of the results.
2. Through the analysis using the Fault Tree Method, there are several events that could potentially lead to work accident on the scope of operating tower crane, formwork and reinforcement work. Events such as workers do not use APD (personal protective equipment), recklessness of worker, the absence of supervision from the officer and not working according to their expertise/lack

Table 8 Results of Boolen algebra analysis and risk control

No.	Basic event combination	Combination description	Risk control
1	D1, D2, D3, D4	The incidence of workers hit by a falling object and exposed to sharp objects in the reinforcement work could occur due to lack of socialization of Occupational Health And Safety, the absence of warning sign, workers do not use PPE while working, or occur due to negligence of the workers such as dispose of an object from a higher place	• Implementation of safety talk morning before starting the work • Supervise the workers to work in accordance with the standard operating procedures • Require all workers to use adequate PPE in the construction sites • Installing of warning signs of falling object and prohibition to drop object
2	D2, D5, D6, D7, D8, D9, D3, D10, D11, D12	The incidence of workers falling from the height when working on reinforcing steel able to occur due to the absence of warning sign, poor of supervision, high pressure of production, worker works not suitable to his expertise, fatigue worker, workers do not use PPE, poor lighting in the workplace, slippery work floor, and workers neglect safety signs around the worksite	• Installing the safety sign of falling hazard • Held safety induction when welcoming a new worker
3	D1, D2, D9, D3	The incidence of worker pinched by bar cutter and bar bender occur due to lack of supervision from officer, the absence of warning sign, performing without complying with the prescribed procedures or working without using PPE	• Socializing the safety program • The machine must be provided with a safety cap • Requiring all workers to use the adequate PPE (gloves, helmet & safety shoes • Held safety induction every welcoming a new worker • Installing the warning sign of pinched hazard

if work experience are the most common events in basic event Fault Tree Analysis. To anticipate the events, the company carries out risk control by holding safety induction to new workers, requiring workers to always use PPE during activities, socializing the Health and Safety program, and asking all workers to participate in the Occupational Safety Program that has been designed to allow the company's target regarding work safety known as zero accident able be realized.

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