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The Security Cost as Part of Construction Safety Cost: Case Study of Flats Construction

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ABSTRACT

Indonesia is currently experiencing a rapid increase in infrastructural development, including the construction of flats. This has led to a rise in construction-related accidents due to the lack of an appropriate safety budget for projects and further worsened by the separatist movement, theft, and vandalism, specifically in the eastern part of Indonesia. Therefore, this research aims to prove that factors, such as construction location and building height, affect construction safety costs in flats. The research found that safety costs consist of 3 parts, namely general, specific, and security costs. The construction safety cost was simulated using Monte Carlo analysis, which showed the amount of safety cost in flats construction in Eastern Indonesia, is higher than the Western part. Furthermore, the safety cost for more than 3-storey flats is higher than those for 3-storey. This shows that the location affects the cost of additional security. In addition, the building height also affects construction safety costs due to differences in the scope of work contained in the WBS.

1. INTRODUCTION

According to the Safety Committee of the Indonesian Construction Accident Investigation Agency, the high intensity of construction accidents is caused by the inability of contractors to implement a construction safety management system optimally due to a lack of construction safety budget [1]. Construction safety costs are still considered an additional expenditure by contractors, impacting the low implementation of construction safety management [2].

Construction safety is related to technical and work accidents at construction sites and theft, vandalism [3], and threats from separatist groups, specifically for projects located in Eastern Indonesia, such as in the Papua project [4]. The shooting of 31 trans-Papua project workers by an armed criminal group in Nduga Papua on December 1-2, 2018, was Indonesia's worst and most pathetic incident. This incident was a follow-up attack on the burning of excavators and bulldozers on March 15, 2016, as well as the attack by 16 people on road construction workers in the Nduga region, Papua, on December 12, 2017 [5]. In addition, theft and vandalism occurred in 10 building construction projects in Bukittinggi [6]. Berg and Hinze stated that theft and vandalism on construction sites of a commercial industry can affect productivity and drain profits [7].

Flats, one of the infrastructures constructed to reduce the housing backlog in Indonesia from 5 million in 2019 to 3.9 million in 2024, is a national development plan. However, this target must be supported by the implementation of accident-free construction, such as a construction safety management system. The construction of flats varies in location and building height and this affects the construction safety cost [8, 9].

Therefore, this research aims to simulate the calculation of safety costs in flats constructions influenced by the location and building height. According to this research, construction safety cost consists of general, specific, and security costs. The simulations were analyzed using the Monte Carlo method through Crystal Ball 3.0 software to obtain the lowest, highest, and most likely safety cost.

2. METHODS

There are two main steps in this research, the first calculates the amount of construction safety, while the second performs a Monte Carlo analysis to determine the optimal amount needed. The factors affecting construction safety cost and its findings were used as the theoretical basis in determining the calculation steps in this present research. Some of the factors include location, building height, WBS (work breakdown structure), work methods, risks, control systems, programs, general and specific safety costs [9]. These factors are arranged into the steps used in this research, as shown in Figure 1. The first step is the preparation of WBS, followed by the identification of hazards and risk assessment of the activities obtained. According to ISO 45001: 2018, the following hazards need to be considered during building construction.

a) work organization consists of social factors, such as workload, working hours, victimization, harassment and bullying, as well as leadership and organizational culture.

b) routine and non-routine activities as well as situations, including hazards arising from 1) infrastructure, equipment, materials, substances, and the physical conditions of the workplace, 2) product and service design, research, development, testing, production, assembly, construction, service delivery, maintenance and disposal, 3) human factors, and 4) how the work is performed.

c) past relevant incidents, internal or external to the organization, including emergencies, and their causes.

d) potential emergency situations.

e) people, consisting of 1) those with access to the workplace and their activities, such as workers, contractors, and visitors, 2) those in the vicinity of the workplace capable of being affected by the activities of the organization, 3) workers at a location not under the direct control of the organization.

f) other issues include 1) the design of work areas, processes, installations, machinery/equipment, operating procedures, and work organization, such as their adaptation to the needs and capabilities of the workers involved, 2) situations occurring in the vicinity of the workplace caused by work-related activities under the control of the organization, and 3) situations not controlled by the organization and occurring in the vicinity of the workplace, which is capable of causing injury and ill health to persons in the workplace.

g) actual or proposed changes in organization, operations, processes, activities and the OH&S management system.

h) changes in information associated with hazards.

According to ISO 45001: 2018, OHS risk assessment is carried out for the identified hazards while considering the effectiveness of existing controls.

Furthermore, the hazard control is prepared to an acceptable level, and the resources needed to carry out the control are identified and used to calculate the cost of construction safety. The results were analyzed to obtain the optimal amount of cost using Monte Carlo analysis.

The data used for the simulation was a Bill of Quantity (BoQ) document for 15 flats passed by the Ministry of Public Works and Public Housing of Indonesia from 2019-2020. The locations are spread throughout the country, and the flats heights used as objects are between 3-8 floors because the project was characterized as a moderate risk. Previous theoretical research also showed the flow used in calculating and simulating the costs required to implement a construction safety management system, as shown in Figure 1.

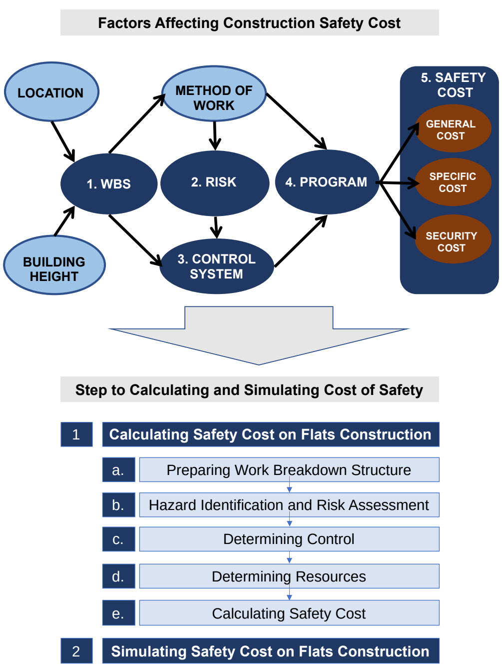

Figure 1. Factors affecting construction safety cost [9, 10] and step to calculating and simulating cost

2.1 Calculating construction safety cost on flats

2.1.1 Preparing WBS

WBS is used to define the hierarchy of the total scope of work that needs to be carried out by the project team to complete its objectives [11]. It manages and defines the total scope of the project and states the job specifications in the statement [12]. Furthermore, WBS consists of 5 levels, namely the “Project’s name,” “Construction Primary Element,” “Type of Work, Package, Design Alternative/Method of Work,” and “Activity” [13-15].

The preparation of the WBS on the 15 projects that became the object of study was carried out by means of a literature research, which was validated by 3 experts each on structure, architecture, mechanical and electrical engineering, thereby culminating in 12 experts. The preparation of WBS is carried out to identify hazard risks in each of its activities [16-18].

2.1.2 Hazard identification and risk assessment

The following step is to identify hazards and assess the level of risks in all activities obtained in WBS, using a literature study validated by 5 experts. In PUPR Ministerial Regulation Number 10 of 2021, hazard identification is conducted to determine the cause of injury, equipment, and environmental damage, as well as loss of worker's life and material.

Furthermore, the identified hazard risks are analyzed for frequency and severity to determine the level of risk. There are 5 levels of frequency and severity used as a measure to determine the level of risk for each identified risk. According to PUPR Ministerial Regulation Number 10 of 2021, all identified risks are grouped into 3 (three) levels, namely low (1-4), moderate (5-12), and high levels (15-25), as shown in Table 1 [19].

Table 1. Risk assessment

	Severity				
Frequency	**1**	**2**	**3**	**4**	**5**
1	1	2	3	4	5
2	2	4	6	8	10
3	3	6	9	12	15
4	4	8	12	16	20
5	5	10	15	20	25

2.1.3 Determining control

Determination of control is carried out in accordance with the control hierarchy in ISO 45001: 2018, namely elimination, substitution, engineering control, Administrative Control, and Personal Protective Equipment. According to the Minister of PUPR Regulation No. 10 of 2021, there are 9 components for determining control, namely safety plan preparation and reporting; safety socialization, promotion, and training; work protective equipment and personal protective equipment; insurance and license; safety personnel; health facilities; signage; expert consultation; and other safety equipment and activities.

2.1.4 Determining resources

According to PUPR Ministerial Regulation Number 10 of 2021, 9 components are needed for each safety resource, which is analyzed using expert validation to obtain the standard requirements. It is also used to determine the processes needed to calculate the amount for each resource, specifically for flat construction, as shown in Table 2.

Table 2. Components of construction safety cost and the requirement in flat projects

No	Safety Component	Requirement	Resources	Amount
1	Safety Plan Preparation and reporting			
	Preparing safety plan	Each project prepares a safety plan, instruction, and procedure	Paper and binding	1 ream of paper and 5 bindings
	Instruction & procedure			1 ream of paper and 1 binding
	Providing weekly and monthly reports	Each project prepares a monthly report during implementation	Paper and binding	2 reams of paper, and (time of execution) x binding
2	Safety socialization, promotion, and training			
	Safety induction	It is implemented on people entering the work site for the first time	snacks (bottled drinking water)	Total workers + 10% (guests)
	Safety briefing	It is always conducted before executing a job		Total workers
	Safety meeting	Periodic meetings related to the implementation safety construction safety		Total workers
	Safety training	Every worker is required to attend at least once	Instructor	1 instructor for 50 workers
	HIV/AIDS Socialization		Consumption	Total workers
	Safety simulation		seminar kit	Total workers
	Banner	Each floor consists of 4 types of banners, namely 5R, project regulations, completeness of PPE, and safety information	banners	4 x number of building floors
	Poster	Every floor has 5 posters associated with COVID-19, health, and safety rules	poster	5 x number of building floors
	Safety information board	1 project at least 1 piece at the entrance	Information board	1 piece
3	A. Work Protective Equipment (WPE)			
	Safety net	Along the side of the project, which is directly adjacent to the community	Safety net	the length along the side of the project that is directly adjacent to the community
	Lifeline	Every worker working at height	Lifeline	2 activities x building length
	Safety deck	along the side of the tallest building	Wire mesh 3 x 2 m, iron pipe frame	The length along the side of the longest building
	Guardrail	Prepared every side of the building with a height of more than 2 meters	Guardrail	Length of the building perimeter x number of floors
	Safety line	Every dangerous area needs to be prepared with safety lines to prevent the risk of falling, flammability, etc.	Safety line	2 x length of building perimeter
	Fall arrester	A tool to hold someone's body from falling	workers working at height	Number of workers working at height
	Disaster safety equipment	Every construction project needs to have at least 2 pcs of each tool	stretcher, emergency light, flashlight, siren, body bag, etc.	Each tool has at least 2 pieces
	B. PPE (Personal Protective Equipment)			
	Safety helmet	Everyone on the project site e.g., workers, guests, suppliers, should use a safety helmet.	Safety helmet	Total workers + 10%
	Safety goggles	Every worker should use safety goggles during sawing, welding, etc.	Safety goggles	The number of workers
	Face shield	Every welding worker should use a face shield and ear protection tools	Face shield	The number of workers
	Ear protection		Ear protection	The number of workers
	Face mask	Every ceramic and grinding worker should use a face mask	face mask	The number of workers
	Safety gloves	Every worker must be mandated to use safety gloves	safety gloves	Total workers
	Safety shoes	Everyone on the project site, specifically those in the managerial levels and guests, should use safety shoes.	Safety shoes	Number of manager-level workers and guests on the project
	Rubber shoes	Every worker should wear rubber shoes	Rubber shoes	Total workers
	Safety Harness	Every worker working at height should use a safety harness	Safety harness	Number of workers working at height
	Safety vest	Everyone on the project site should use a safety vest	Safety vest	Total workers + 10%
	Apron/coveralls	Every welding worker should use apron/coveralls	workers welding	The number of workers
4	Insurance and License			
	Heavy Equipment license	Heavy equipment need to be licensed before usage	License documents	Number of heavy equipment to be used
	Heavy Equipment Operator License	Heavy equipment operators must be licensed	License documents	Number of workers operating heavy equipment
	Environment permit	Every construction project should have an Environmental permit	Permit documents	1 permit
5	Safety Personnel			
	Safety expert	Every construction project should have a ratio, safety expert: worker – Low risk is 1:60	Can be a safety expert or safety officer	safety expert: worker – Low risk is 1:60 – Medium risk is 1:50

		– Medium risk is 1:50 – High risk is 1:40		– High risk is 1:40
	Emergency responders	There should be at least 1 person in each flat during construction	e.g.: Fireman	Minimum 1 person
	First aid officer		First aid officer	Minimum 1 person
	Traffic officer		Traffic officer	Minimum 1 person
	Security	At least 2 and 4 persons in each flat during the project construction process on Western and Eastern Indonesia.	security	Western part: minimum 2 person Eastern part: Minimum 4 person
6	Health facilities			
	First aid kit	Every construction project should have a First aid kit	First aid kit	Type A: 25 people Type B: 50 people Type C: 100 people
	Fogging equipment	Every construction project on eastern Indonesia should have fogging equipment	Fogging equipment	Eastern Indonesia minimum 1
	Early medical examination	Every worker should be medically examined before starting any project	early medical examination	Total workers
7	Signage			
	Signage	Signage should be placed in visible places on every floor.	Signs, warnings, obligations, information, etc.	4 types of signage x number of floors
	Warning light stick	Every construction project should have Traffic control tools	Warning light stick	Number of traffic officers
	Rotary lamp	Every construction project should have a warning lamp placed at the entrance.	Rotary lamp	1 piece
	Area delimiter	Every construction project should limit movement to hazardous area.	Area delimiter	Along the side of hazardous area
	Perimeter protection	Fencing should be installed around the site perimeter adjacent to streets.	the weld mesh-type fencing panels	along the site perimeter adjacent to streets
8	Expert consultation			
	Technical safety expert	Every construction project should consult design standards with complex implementation methods, specifically for medium and high-risk projects.	Technical safety expert	1x consultation
9	Other safety equipment and safety activity			
	Fire extinguisher	Every project should have 2 pcs fire extinguisher per floor for preventing fire hazard	Fire extinguisher	2x the number of floors
	Sirens	Every project should have at least 1 pcs tool for signaling an emergency	sirens	1 piece
	Safety flag	Every project should have at least 1 pcs safety flag to strengthen its implementation commitment.	Safety flag	1 piece
	Inspection and audit	Every project should implement inspections and audits.	document	1 time/document
	Investigating and report	Every project must endeavor to conduct investigations.	1 x in 1 project period	1 time/document
	CCTV	every eastern Indonesia project must be used to protect against external interference	CCTV	Minimum 4 pcs

2.1.5 Calculating safety cost

This sub-section is associated with the process of setting the unit price of the resource, which is determined using the construction cost index issued by the BPS in 2020. Furthermore, the construction cost index is used as a proxy of geographical adversity of a region, where the more difficult the location, the higher the price level in the area [1].

2.2 Monte Carlo analysis

The optimal construction safety cost in the flat construction project was calculated using Monte Carlo analysis with the help of Crystal Ball 3.0 software. The general step of the simulation process was conducted using a triangular distribution, which is frequently used in practice for project evaluation and review (PERT). First, determine the assumptions of the lowest and highest construction safety costs to be the minimum and maximum values, then determine the mean. It is also used to determine the risk analysis because a decision maker's subjective viewpoints are more easily turned into parameter estimates, with a minimum, maximum, and most likely values [20].

The construction safety cost was inputted by grouping, where A represents Location and B Height. In Group A, the fifteen study objects are grouped into 2, namely Western and Eastern Indonesia. Meanwhile in Group B, they are grouped into 2, namely the 3-storey flat project and the 4 to 8-storey flat project.

3. RESULT AND DISCUSSION

3.1 Risk analysis

The construction safety cost of the 15 projects was calculated by initiating the preparation of WBS for each of the flats according to the WBS standard. The process involved is shown in Table 3 with some of the WBS standards for flats prepared, such as level 4 for the deep foundation work package, as well as several choices of work methods and activities [18]. The table shows that WBS was prepared to identify hazard risks in each of the activities.

The hazard risks identified were further analyzed to determine their frequency and severity levels. Moreover, the hazard risk control was determined based on the potential level assessment, as shown in Table 3. The hazard risk control shown in Table 4 is determined based on its hierarchy and 9 control components.

It is also important to note that the hazard risk controls are often grouped, specifically to determine and prioritize high-risk levels on the project field. Meanwhile, this research only implemented the control at high and moderate levels.

Several hazards are identified in flats development in Eastern Indonesia due to its location, such as vandalism, theft, and separatism. Experts determine the level of risk and control of these hazards, as shown in Table 5. Damage or loss of heavy equipment and materials, as well as increased security cost, are needed to reduce these occurrences [3].

Several safety construction components needed in accordance with the controls established in the previous step were used to determine these resources. The sub-components required for each activity in accordance with WBS are also shown in Table 6. Therefore, to reduce social conflicts such as vandalism, theft, and separatism attack, construction projects should install security cameras, perimeter protection, employ additional security personnel, and use sirens [3]. This means that additional costs are required to eliminate the negative impacts of social conflict.

Table 3. Activities in WBS, hazard identification, and risk assessment

WBS LV 4. Deep Foundation/ Method of Work: Driven Pile					
WBS LV 5 Activity	**Hazard**	**Risk Assessment**			
		F	**S**	**F. S**	**Rate**
Erection	Workers hit by piles	2	5	10	Medium
	Workers hit by sling crane	3	3	9	Medium
	Workers crushed by piles during lifting	2	5	10	Medium
Pole Splicing	Fire due to leaking tube	2	3	6	Medium
	Respiratory problems due to welding fumes	2	3	6	Medium
	Burns	3	2	6	Medium
	Irritation of the eyes due to smoke	4	1	4	Low

Table 4. Hazard risk control

Potential Risk	Control
WBS LV 5. Erection	
Workers hit by piles	Inspecting equipment, conducting load analysis to determine its capacity, and carrying out maintenance Using a helmet, reflector vest, and safety shoes Installing heavy equipment hazard signs Creating area delimiter
Workers hit by sling crane.	Using a helmet, reflector vest, and safety shoes Installing heavy equipment hazard signs Creating area delimiter
Workers crushed by piles during lifting.	Providing adequate lighting Inspecting equipment and conducting load analysis according to the carrying capacity and equipment maintenance Using a helmet, reflector vest, and safety shoes Installing heavy equipment hazard signs Creating area delimiter
WBS LV 5. Pole Splicing	
Fire due to leaking tube	Fire extinguisher preparation Installing fire hazard signs
Respiratory problems due to welding fumes	Using a mask Providing health facilities
Burns	Using gloves, safety shoes, and helmet Providing health facilities
Irritation of the eyes due to smoke	Using eye protection Providing health facilities

Table 5. Hazard identification, risk assessment, and control for eastern Indonesia

Hazard	**Risk Assessment**				**Control**
	F	**S**	**F. S**	**Rate**	
Material Damage/loss due to vandalism/theft	3	2	6	Medium	Strengthen the security system
Separatism movement	2	5	15	Medium	

Table 6. Summary of construction safety component needs

WBS level 5 Activity	**Safety Component**																
	General cost											**Specific cost**		**Security cost**			
	Safety Helmet	Safety vest	Safety shoes	Face mask	Safety glasses	gloves	Safety expert	Fire extinguisher	First aid kit	Area Delimiter	signage	Heavy equipment License	Heavy Equipment Operator License	CCTV	Security personnel	sirens	Perimeter protection
Erection	●	●	●				●		●	●	●	●	●				
Pole Splicing	●		●	●	●	●	●	●	●		●						
Additional safety component in Eastern Indonesia														●	●	●	●

Table 7. Construction safety cost analysis

No.	Project Name	Height (floor)	General Cost (IDR)	Specific Cost (IDR)	Security Cost (IDR)	Safety Cost (IDR)
	Western Indonesia					
1	Indragiri Hulu	3	60,372,859	110,669,924	-	171,042,784 (0.91%)
2	Sarolangun	3	55,981,764	98,483,301	-	154,465,066 (0.83%)
3	East Kotawaringin	3	63,298,168	111,895,579	-	175,193,748 (0.81%)
4	Surakarta	3	61,293,674	80,122,169	-	141,415,844 (0.87%)
5	PIAT UGM	3	63,279,376	77,10,626	-	140,790,003 (1.05%)
6	Pesisir Barat	3	61,293,674	97,232,519	-	158,526,194 (0.88%)
7	Brebes	3	62,414,938	76,056,727	-	138,471,666 (0.83%)
8	Bengkulu	4	56,833,674	86,26,378	-	143,100,054 (0.51%)
	Eastern Indonesia					
9	Sorong	3	59,258,066	129,434,587	51,377,018	240,069,672 (1.01%)
10	Ternate	3	66,043,589	108,320,074	42,885,775	217,249,439 (1.05%)
11	Tambrauw	3	69,927,230	92,500,435	25,108,320	187,535,986 (0.73%)
12	Tanimbar	3	71,142,223	110,379,349	43,675,342	225,196,915 (0.90%)
13	Manado	6	72,550,992	352,890,538	70,246,290	495,687,822 (1.17%)
14	Makassar	6	67,534,581	335,950,684	67,140,612	470,625,878 (1.23%)
15	Kubu Raya	8	73,115,427	268,901,900	56,337,116	398,354,445 (0.88%)

Table 8. Monte Carlo simulation results

Category	Simulation Result		
	Minimal Cost	Maximal Cost	Average
A. By Location			
Western part (3 floors)	0.72% IDR 144,347,420	0.85% IDR 171,326,990	0.78% IDR 156,783,546
Eastern part (3 floors)	0.89% IDR 195,504,701	1.06% IDR 231,099,591	0.98% IDR 213,859,064
B. By Height			
3 floors	0.80% IDR 177,619,079	0.96% IDR 200,721,330	0.89% IDR 189,286,556
4 to 8 floors	0.86% IDR 423,254,587	1.03% IDR 471,302,603	0.94% IDR 447,070,174

Motion-sensitive cameras with infrared features are used by staff to visualize, monitor and notify the security personnel of potential unwanted guests. In addition, it is necessary to build a perimeter fence which is the best form of protection to limit movement in and out of the project site while providing additional security guards to patrol and the main gate as well as the use of sirens to signal the workers of any suspicious movements.

The calculation results from 15 projects were grouped into 2 (two), with the first based on location, west and east, while the second was based on building height equal to or greater than 3 floors, as shown in Table 7. This division was to prove the difference in the construction safety cost based on the height of the building and the construction site.

3.2 Monte Carlo analysis

Table 8 shows the Monte Carlo simulation results for the construction safety cost in the 15 projects. The construction of 3-storey flats in western Indonesia was found to be averagely 0.78% of the project value, which is lower than 0.89% recorded in the eastern part of the country. Furthermore, the average value for constructing 3-storey flats in both the western and eastern parts of Indonesia was 0.89% of the project value. Meanwhile, those with more than 3 floors, such as 4-8 floors, required 0.94% of the project value.

The implementation of construction work in Eastern Indonesia requires an additional security component to prevent social conflict. This causes the proportion of construction safety costs in eastern Indonesia to be greater than in the western region.

4. CONCLUSIONS

The calculation results and Monte Carlo simulation showed the construction location affects the safety cost. This is evident from the 0.11% difference in the percentage of the project value required in constructing flats with the same designs in the eastern region compared to those in the western part. It was also discovered that the difference in building height influences the amount of construction safety cost as indicated by the IDR 257,783,618 recorded between flats with 3 floors and above. Therefore, the following conclusions were determined:

- Cost of construction safety consists of 3 parts, namely general, specific, and security costs.
- The safety cost on flats construction is generated in 5 steps starts with preparing WBS, hazard identification and risk assessment, determining control, analyzing resources, and calculating safety cost.
- The higher the proposed building floor, the greater the risk of danger generated.
- The higher the proposed building floor, the more control is needed.
- The amount of safety costs in flats construction for location in Eastern Indonesia is higher than the Western region due to the addition of security cost.
- The amount of safety cost for 4 to 8-storey flats is higher than those 3-storey flats.

This research is expected to be used by project owners and contractors to understand and apply the flow of calculating construction safety cost as well as to implement policies related to its range with due consideration for the location and height of the building. It is also expected to guide job owners in assessing the reasonableness of the bid price submitted by bidders for construction safety costs in the process of selecting a work service provider.

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