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PRIMARY RESEARCH

Risk analysis using simulation: A case study of contruction industry

Herlinda Rachmasari [1*], Imam Baihaqi [2]

[1] Department Management of Technology, Sepuluh Nopember Institute of Technology, Surabaya, Indonesia

[2] Department Management of Business, Sepuluh Nopember Institute of Technology, Surabaya, Indonesia

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Abstract

Over time and over budget can not be denied occur in a construction project. One of them is caused by supply chain management who less effective to overcome these problems. Purpose of this research is to build a modeling that can detect supply chain risk factors by simulating changes and the impact on the risk of time and cost of the project. Risk register is performed by identifying risks based sources of uncertainty surrounding supply chain. That identification is classified into the life cycle stages of construction, it can more easily analyzed. Historical data for the probability and impact can be simulated through field observation, survey questionnaires and interviews with 15 respondent. The final result of this study found that out of 30 risks that have been carried out monte simulation, 4 risks are included in the high risk assessment, 11 risks are entered in the medium risk assessment and 15 the risk of entering the risk assessment is low. 4 risks that get high scores are then interviewed with the main contractor project manager to find the risk management strategy. The response of these 4 risks is to reduce the impact of risk by following the operational standards of construction projects in the form of material permit applications and permits to carry out work, and noticing the amount of supply in the warehouse should not be less than 30% so there is no waiting time in the field. The results of this study will be able to provide reports to the project manager so that they can anticipate the impact of supply chain risk construction that may occur in the implementation of construction

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INTRODUCTION

The construction of real estate development is a process of making a space into something used with an idea and ends when consumers or tenants physically occupy a place that built by a team of developers (Aloini, Dulmin, Mininno, & Ponticelli, 2012; Tangpornpaiboon & Puttanapong, 2016). The involvement of many parties, both organizations and individuals in the process of products in the construction industry also indirectly will form a complex supply chain conditions (H. Ahmed, 2017; Mohd Saman, Abdullah, Baba, Shaifuddin, & Mokhtar, 2015). With increasingly limited urban land, a challenge for developers to more innovative and strategic to develop their business. The complexity of the construction supply chain can cause risks in a construction project. If the issue not solved soon so can lead to difficulties in achieving project objectives especially to timeline, cost and quality.

Risk management supply chain construction used as an approach that prioritizes the most problematic problems in the project that have risk and making respond to avoiding (Aloini et al., 2012; Beamon, 1998; Global Standard, 2004; Kwak & Ingall, 2007; Montasser & El-Nakeeb, 2017). According to Bankvall, Bygballe, Dubois, and Jahre (2010), K. B. Ahmed A. and Amornsawadwatana (2007)and H. Ahmed (2017) explains that supply chain management is critical, improve the performance of a construction project where the construction supply chain management cycle change is inevitable and can be the impact on the project.

*corresponding author: Herlinda Rachmasari
†email: herlindamasari@gmail.com

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The changes will continue to occur and continue to give effect to the project deadlines and over costs. Supply chain management has proven to be a management strategy in managing projects involving many parties participate, suppliers and materials (Bhalerao, 2016; Cahyo, 2008; Ozyurek & Uluturk, 2016). By managing the supply chain can be the key of success that effective in reducing costs and delays in construction projects.

Several studies have been conducted to examine the factors in the supply chain. One of them is by using a model that can estimate a significant impact on the progress of the supply chain project. H. Ahmed (2017) in his research revealed the effect of changes in construction supply chain risk at the time and the cost of construction projects in Canada using Monte Carlo models. Monte Carlo model is used because it has proven to provide information easily to the project manager. The information can be anticipated during construction than other models. Identifying risk early can be an advantage in reducing the impact on project duration and costs rather than analyzed at the end of the project.

Focus materials supply in this research based on Work Breakdown Structure (WBS) that can be seen in Figure 1.

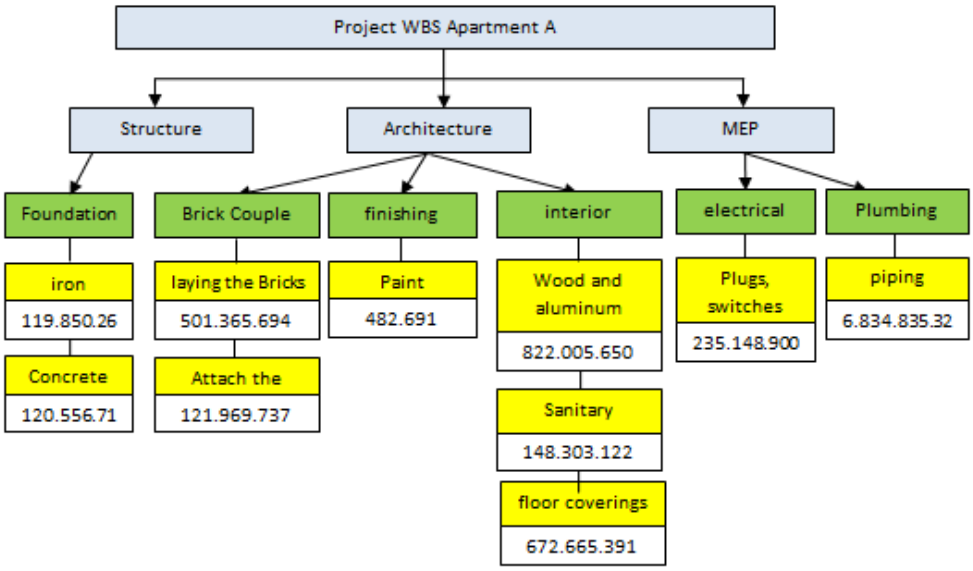

FIGURE 1. WBS project of apartment A Note: The cost on Rupiah (Rp)

The highest costs in the materials supply of these materials further cumulative using Pareto diagram. This diagram set value thus found the value of the highest to lowest by the principle that 80% of 20% problems. Table 1 shows that pipes and aluminum and wooden frames have a cumulative value of the high cost of close to 80%. So the reference material for interview and questionnaire in this study is pipes and aluminum and wooden frames.

TABLE 1. Type of work with the high cost

No.	Description	Price (Rp)	%	Cumulative	% Cumulative
1	Plumbing	6.834.835.321	71%	6.834.835.321	71%
2	Kusen Wood & Aluminum	822.005.650	9%	7.656.840.971	80%
3	Final Floor	662.091.833	7%	8.318.932.804	87%
4	Couple of Wall	501.365.694	5%	8.820.298.498	92%
5	Electrical Installation	235.148.900	2%	9.055.447.398	94%
6	Sanitary	148.303.122	2%	9.203.750.520	96%
7	Ceiling	121.969.737	1%	9.325.720.257	97%
8	Cor	120.556.715	1%	9.446.276.972	98%
9	Pembesian	119.850.268	1%	9.566.127.239	99%
10	Paint	482.691	1%	9.614.396.340	100%
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From the explanation above, the research use simulation models to estimate the impact of changes because of risk of pipes and aluminum and wooden frames. The purpose of the research is to identify the risk in material that could potentially make a risk during construction at each stage of the life cycle supply chain construction, developing models that can detect the change of risk, perform simulation models to measure the impact, and provide strategies of each supply chain activities. This paper is structured in three stages. The first stage is to identify risk factors, the second stage is risk assessment, and the third stage is to determine the risk response.

METHOD

The study begins with the study of literature related references. These results are from identification through questionnaires to 15 respondents in construction projects Apartment A. The main respondents are project manager, site manager, quality control/quality surveyor and logistics When the risk acquired, an assessment of risk by data processing using monte carlo simulation with assistance of Risk program. The framework research can be seen in Figure 2 below.

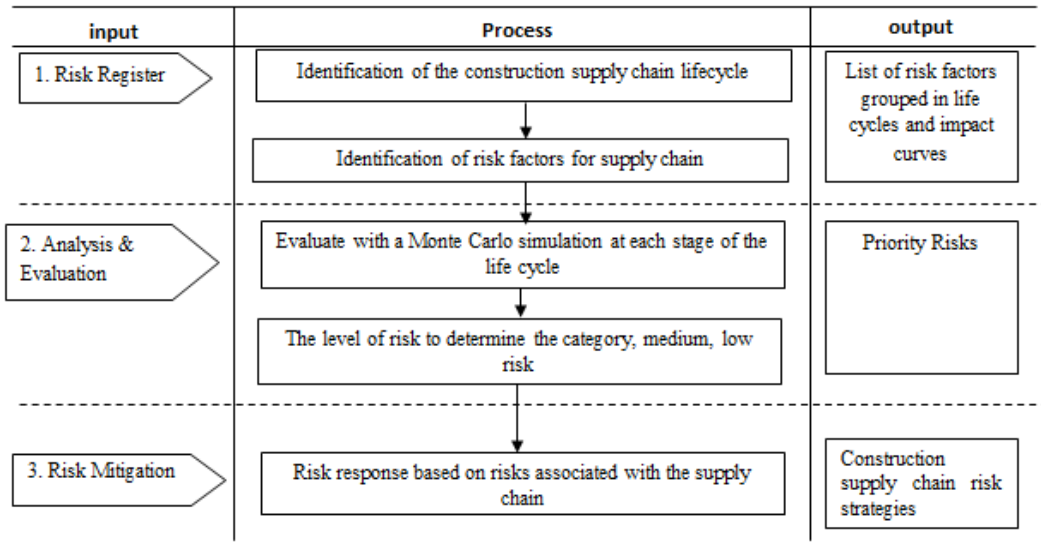

FIGURE 2. Framework research

Case Study

The method that described before is applied in an apartment building construction project A. Project Apartment A has seven towers with the numbers of stories 4-8 floors. Size of the project is 20.818 m2 and have 229 units. The factors that been found in the literature review will be grouped into the life cycle of the construction supply chain which are design lifecycle, procurement lifecycle, transportation lifecycle, and warehouse/fabrication lifecycle. It can be seen in Figure 3 below.

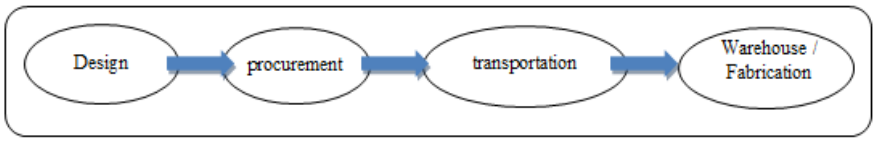

FIGURE 3. Life cycle of supply chain construction

Risk Register

Identification the risk factor is through two stages of the questionnaire. The first stage of the questionnaire is to discover the relevance of these risk to project Apartment A. Questionnaire is given to 5 respondents. The main respondents are project manager, site manager, quality control / quality surveyors and project logistics of apartment A. From 32 risk were found from the study of literature, there are only 30 supply chain risk that have relevance based on life cycle categories. Its shown in Table 2 below.

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TABLE 2. Risk of supply chain construction

No.	Life Cycle	Code	Supply chain risk
1	Phase Design	D1	Changes in bookings due to uncertainty in scheduling contractors
2		D2	Additional ordering material for spec changes
3		D3	Retransmission of material for the job error from the instruction given is not clear
4		D4	Retransmission of material due to differences in the drawings and specifications are accepted
5		D5	Errors in the material specification/differences between BQ and images that lead to a lack of the material supply project
6		D6	Incomplete detail design resulted immaturity quantity of material to be booked
7		D7	Booking additional material due to changes in the function space
8		D8	Planning the material is not ripe result in waste material
9		D9	The change agent causing specification changed
10		D10	Special requests of special clien beyond the initial design
11	Phase Procurement	P1	Material delivery delays due to the limited stock of suppliers
12		P2	Reorder material because the material is still lacking to meet the needs of the job
13		P3	Trouble finding material
14		P4	Delays delivery of materials for the non-current financial problems
15		P5	Quality materialnyg discrepant with antecedent standardize/disharmonious specifications
16		P6	If the contractor has done a price agreement with the supplier but do not immediately file a Purchase Order (PO) and may expand the associated risk costs in case of escalation of the market price (increase the value of the currency, etc.)
17	Phase Transportation	T1	Material long waiting time
18		T2	Origin of material material export
19		T3	Retransmission of material because the material quality is not within specifications as booking
20		T4	The lack of managerial ability of sub-contractors so that work is not timely and delays in procurement of materials
21		T5	Communication between subcontractors less running smoothly
22		T6	Material delays due to transport accidents
23	Phase Warehouse & Fabrication	W1	Material losses of the contractor because there is time wasted waiting for reply
24		W2	Material delays due to production constraints in factory
25		W3	Negligence of subcontractors and contractors in the handling of the material causing the supply of materials which are not stored appropriately
26		W4	Material transportation equipment damage can lead to a job when implementation is delayed
27		W5	Reorder for damage/loss of material in storage warehouse
28		W6	Material is too early to arrive at the project because it is not exactly the time of booking of material needs that meet the storage warehouse and can cancel the remaining material
29		W7	Thes implementation time
30		W8	The disassembly of material that has been installed

The second stage of risk register is the main questionnaire. Main questionnaires was conducted to determine how much influence the risk of the activities of the supply chain and the impact with criteria of the probability are possibility of 1 (impossible to happen 0-10%), 2 (Less likely the case 11% - 40%), 3 (Between happening/not happening 41% - 60%), 4 (Likely to occur 61% - 80%), and 5 (very possible 81% - 100%). While the criteria for the impact are 1 (not important 0-2%), 2 (small 3% - 5%), 3 (middle 6% - 10%), 4 (large 11% - 15%), and 5 (very large with a deviation more than 15%).

Monte Carlo Simulation

Monte Carlo simulation is used with the aim to investigate the likelihood and consequences of risk - the risk of time and cost. Step simulation done of

1. Determine the probability of the likelihood and consequences frequency at each risk
2. Creating a cumulative probability of prior probabilities
3. Determining the interval of cumulative probability
4. Creating a random number 1-100
5. Doing step 1-4 each respondent.

Step - this step will be carried out in the life cycle of the construction supply chain to facilitate risk assessment. The output of the simulation calculations Monte Carlo simulation is a value in the likelihood and consequences of each risk. Likelihood to influence the consequences will be shown by the graph scatterport. The results of the simulation is then performed the order of priority of risk - the risk to be addressed further through an action plan or risk mitigation. The simulations will be analyzed using Excel software.

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Simulation in the critical of each stages of the life cycle

Appropriate steps - steps in monte carlo simulations described in the previous section, the value of simulation likelihood that have been found will be multiplied by the value of the simulation. To see the level of risk in the risk of life cycle design, procurement, transportation, warehouse/fabrication in accordance with the Table below.

TABLE 3. The resume of forecast value in life cycle supply chain construction

	Risk	Value Simulation Likelihood Value	Simulation Consequences	LXC
D1	Changes in bookings due to uncertainty in scheduling contractors	4.07	3.33	13.55
D2	Additional ordering material for spec changes	4.33	2.93	12.69
D3	Retransmission of material for the job error from the instruction given is not clear	2,67	2.33	6.22
D4	Retransmission of material due to differences in the drawings and specifications are accepted	3.53	2,73	9.64
D5	Errors in the material specification/differences between BQ and images that lead to a lack of the material supply project	3.13	3.20	10.02
D6	Ditail incomplete design resulted immaturity quantity of material to be booked	3.07	2.33	7.15
D7	Booking additional material due to changes in the function space	3.60	2,73	9.83
D8	Material planning that does not mature results in waste of material	2,93	2,27	6,65
D9	Change in PIC consultant so that the specs change	3,07	3,00	9,21
D10	Special requests from special clients are outside the initial design	3,87	3,13	12,11
P1	Material delivery delays due to the limited stock of suppliers	3.20	3.80	12,16
P2	Reorder material because the material is still lacking to meet the needs of the job	3.27	3.00	9.81
P3	Trouble finding material	3.33	3.00	9.99
P4	Delays delivery of materials for the non-current financial problems	3.73	2.87	10.71
P5	Quality material which does not match that in the standardize/is not within specifications	3.13	2.40	7,51
P6	If the contractor has done a price agreement with the supplier but do not immediately file a Purchase Order (PO) (increase in value of the currency)	4.07	3.20	13,02
T1	Material long waiting time	3.93	2.60	10,22
T2	Origin of material/material export	3.07	3.00	9.21
T3	Retransmission of material because the material quality is not within specifications as booking	3.47	2,73	9.47
T4	The lack of managerial ability of sub-contractors so that work is not timely and delays in procurement of materials	3.85	3.73	14.36
T5	Communication between subcontractors less running smoothly	3.07	2.47	7.58
T6	Material delays due to transport accidents transporting materials	3.33	2.90	9.66
W1	Material losses of the contractor because there is time wasted waiting for reply	3.73	3.27	12.20
W2	Material delays due to production constraints in factory	3.47	3.00	10.41
W3	Negligence of subcontractors and contractors in the handling of the material causing the supply of materials which are not stored appropriately	3.27	2,73	8.93
W4	Material transportation equipment damage can lead to a job when implementation is delayed	3.27	3.13	10.24
W5	Reorder for damage/loss of material in storage warehouse	3.87	3.00	11.61
W6	Material is too early to arrive at the project because it is not exactly the time of booking of material needs that meet the storage warehouse and can cancel the remaining material	4.20	2.80	11.76
W7	Thes one work package implementation time	4.50	3.47	15.62
W8	The disassembly of material that has been installed	4.30	3.33	14.32

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From the above table the highest risk is at design risk is booking changes because the uncertainty of the schedule that has been made by the contractor has the highest value of 13.55. Meanwhile the highest risk is at procurement risk if the contractor has done a chance but do not immediately file a Purchase Order (PO) with a value of 13.02. This risk has a probability that sometimes appears but it can result in a considerable impact. The highest risk of lifecycle transport with value 14.36 is the lack of managerial sub contractor so that work is not timely and delays in procurement of materials. And from lifecycle warehouse seen that the timing of the field, it can be a buildup of material in the warehouse so that other materials can not be done delivery to the project site. This could hamper the other work packages with a value of 15.62. The comparison between likelihood and concequence of each lifecycle can be seen on below.

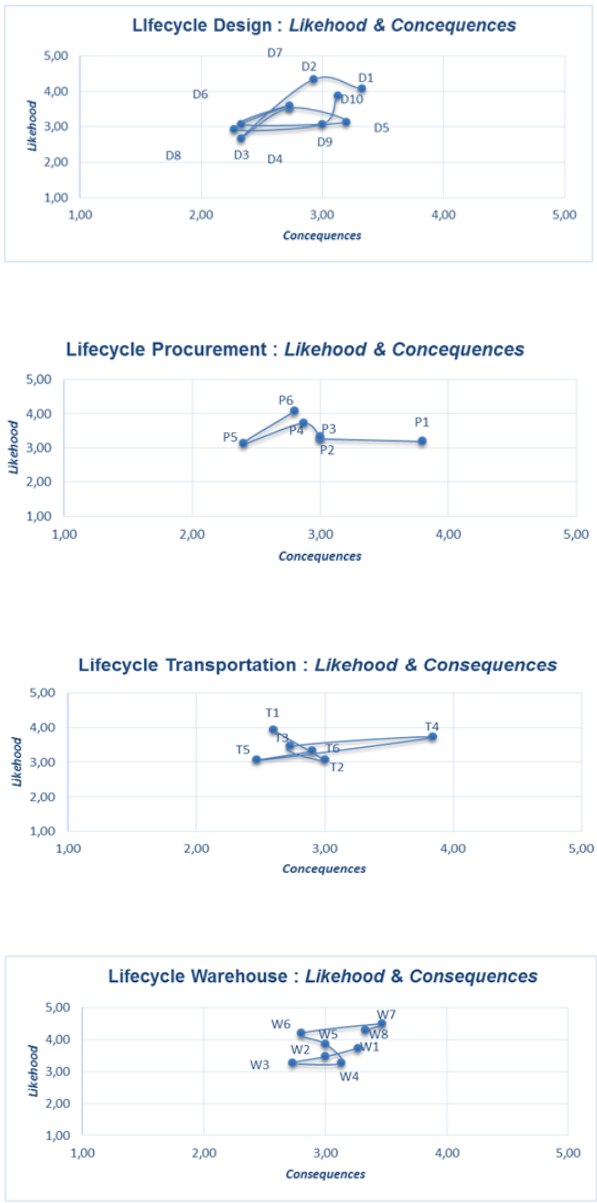

FIGURE 4. The Comparison of between likelihood and concequence of each lifecycle

Risk Assessment

Assessment is using different levels of risk in order to know the level of risk that needs to be transferred, mitigation, avoiding or accepted. The risk level is determined using a calculation of the average value from the probability cross with average value of variable impact on the life cycle of the construction supply chain. The results of calculation of risk level will be used to determine a response that have priority risks. The risk assessment can be seen in Table 4 below.

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TABLE 4. Levels of risk

No.	Code	Indicators of Genesis	R = LXC	Cumulative Frequency	% Cumulative Frequency	Risk Rankings
1	W7	Thes one work package implementation time	15.62	15.62	5%	High risk
2	T4	The lack of managerial ability of sub-contractors so that work is not timely and delays in procurement of materials	14.36	29.98	9%	
3	W8	The disassembly of material that has been installed	14.32	44.30	14%	
4	D1	Changes in bookings due to uncertainty in scheduling contractors	13.55	57.85	18%	
5	P6	If the contractor has done a price agreement with the supplier but do not immediately file a Purchase Order (PO) (increase in value of the currency)	13,02	70.87	22%	Medium risk
6	D2	Additional ordering material for spec changes	12.69	83.56	26%	
7	W1	Material losses of the contractor because there is time wasted waiting for reply	12.2	95.76	30%	
8	P1	Material delivery delays due to the limited stock of suppliers	12,16	107.92	34%	
9	D10	Special requests of special clien beyond the initial design	12.11	120.03	38%	
10	W6	Material is too early to arrive at the project because it is not exactly the time of booking of material needs that meet the storage warehouse and can cancel the remaining material	11.76	131.79	42%	
11	W5	Reorder for damage/loss of material in storage warehouse	11.61	143.40	45%	
12	P4	Delays delivery of materials for the non-current financial problems	10.71	154.11	49%	
13	W2	Material delays due to production constraints in factory	10.41	164.52	52%	
14	W4	Material transportation equipment damage can lead to a job when implementation is delayed	10.24	174.76	55%	
15	T1	Material long waiting time	10,22	184.98	59%	
16	D5	Errors in the material specification/differences between BQ and images that lead to a lack of the material supply project	10.02	195.00	62%	Low risk
17	P3	Trouble finding material	9.99	204.99	65%	
18	D7	Booking additional material due to changes in the function space	9.83	214.82	68%	
19	P2	Reorder material because the material is still lacking to meet the needs of the job	9.81	224.63	71%	
20	T6	Material delays due to transport accidents transporting materials	9.66	234.29	74%	
21	D4	Retransmission of material due to differences in the drawings and specifications are accepted	9.64	243.93	77%	
22	T3	Retransmission of material because the material quality is not within specifications as booking	9.47	253.40	80%	
23	D9	PIC change agent causing the spec change	9.21	262.61	83%	
24	T2	Origin of material/material export	9.21 271.82	86%		
25	W3	Negligence of subcontractors and contractors in the handling of the material causing the supply of materials which are not stored appropriately	8.93	280.75	89%	

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Table 4. Continue

No.	Code	Indicators of Genesis	R = LXC	Cumulative Frequency	% Cumulative Frequency	Risk Rankings
26	T5	Communication between subcontractors less running smoothly	7.58	288.33	91%	
27	P5	Quality material which does not match that in the standardize/is not within specifications	7,51	295.84	94%	
28	D6	Detail incomplete design resulted immaturity quantity of material to be booked	7.15	302.99	96%	
29	D8	Planning the material is not ripe result in waste material	6.65	309.64	98%	
30	D3	Retransmission of material for the job error from the instruction given is not clear	6.22	315.86	100%	

From the level of priorities risk that have been found from calculating in risk assessment is divided into three levels. The value between 100% - 80% is a high risk, 40% - 79% is a moderate risk and 0% -39% are low risk. In Figure 5 seen 30 construction supply chain variable there are 4 variables at high risk, 11 variables are at medium risk and 15 variables are at low risk.

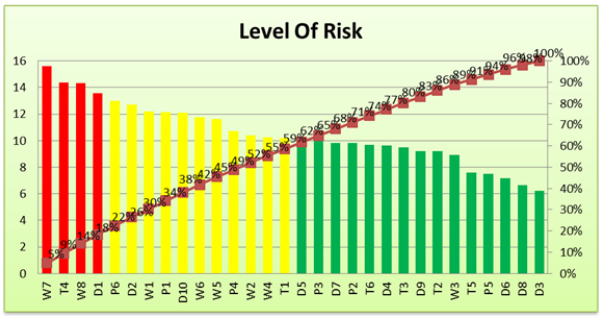

FIGURE 5. Risk ranking by pareto diagram

DISCUSSION

Based on the results of the risk assessment supply chain of construction in the diagram above (Figure 5) it can be seen any risks that enter into the category of high risk, medium, and low. From the initial research methods, it is determined that the risk is a priority for the response sought risk is the risk - the risk included into high category. From the results of the abovementioned agreement, the Project Manager is given the opportunity to choose a response and provide feedback openly in order to take decisions unanimously. The risk responses are summarized in the table below.

TABLE 5. Response of supply chain risk priority construction projects

Code	Risk	Potential Drawbacks	Response Measures
W7	Thes one work package implementation time	The order can not be performed because the work on the field is not ready and cost possible to grow	Reduction →, The impact should be redirected to the supervisor to request a permit implementation of the architectural structure and MEP.
T4	The lack of managerial ability of sub-contractors so that work is not timely and delays in procurement of materials	Work that is not timely because delays in procurement of materials	Reduction → comply with operational standards (SOP) established a construction company
W8	The disassembly of material that has been installed	Time wasted because such work is done back home	Reduction → requesting the permission of execution may be submitted in advance so as to reduce the error when the work on the construction project
D1	Changes in bookings due to uncertainty in scheduling contractors	Work in the project can not be done until the material arrives at the project	Reduction → supervising work on a regular basis. If the goods in the warehouse is less than 30% of the number of field implementation should be immediate booking. No need to wait for the time will do the job

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CONCLUSION

This research demonstrating the construction supply chain risk simulation at each life cycle stage of the supply chain which are construction design, procurement, transportation and warehouse/fabrication with the conclusions of the study as follows:

1. From the results of Pareto analysis conducted sampling of the material used in the questionnaire is on the supply piping plumbing job.
2. Of the 32 risk factors that have been found in previous studies, found 30 risk factors from the results of a preliminary survey to experts in the field of construction supply chain. And the results of the main survey is the dominant value (likelihood) and impact on the project (Consequences) at each life cycle of construction supply chain.
3. Monte carlo simulation results using random digit interval and found that:

a. At the stage of the design lifecycle highest risk occurs in the change booking because of the uncertainty contractors in scheduling with a value of 13.55.

b. At the stage of the procurement lifecycle highest risk occurs in when the contractor has done a price agreement with the supplier but do not immediately file a Purchase Order (PO) (rise in currency value) to the value of 13.02.

c. At the stage of the transportation lifecycle risk is highest in the lack of managerial ability of sub-contractors so that work is not timely and delays in procurement of materials with a value of 14.36

d. At the stage of Life cyle warehouse/fabrication of highest risk occurs in thes one work package implementation time with a value of 15.62

4. Risk response done in accordance with the ranking of the different levels of risk. The risks that fall into the high risk of re-interviews will be conducted by the project manager. Of the four categories of risk into totally disconnected high risk of harm reduction is done by following the operational standards of construction projects in the form of an application for permission material and permits execution of the work, and with regard to the amount of supplies in warehouses can not be less than 30% in order to avoid the waiting time in the field
5. Recommendations for risk response are more on mature design planning, routine coordination meetings, and good cooperation with suppliers.

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