



Risk assessment of the causes of cost overrun of project XYZ

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ABSTRACT

Keywords:

risk assessment

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Cost overrun is a phenomenon that often occurs in the construction of a construction project. The purpose of this study is to analyze the main factors causing cost overrun in project XYZ based on the results of sensitivity analysis to the variables that form RAP. The results show that the cost element of subcontractors has a very large effect on the total RAP of the subcontractor, and the most dominant work affecting is steel work and panel sandwich work. The RAP weight of the work that affects the RAP is between 22.84% and 43.39%, followed by panel sandwich works and bridge steel work. It is recommended that PT X evaluate the performance of each related bureau, especially the estimating and engineering bureaus, in calculating RAP analysis and considering potential long-term risks.

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INTRODUCTION

The rapid population growth is one of the reasons for the government to increase infrastructure development to improve people's living standards. In addition, infrastructure is also a symbol of the progress of a country that can be seen, therefore construction products are one of the nation's assets (Bear, 2020; Ho, 2020). Rani (2016) explained that in the era of globalization, the development of the construction world is increasingly rapid, both in terms of technology, project capacity, and funds needed and absorbed for these projects. The development of construction services in Indonesia is marked by many large-scale projects built by the government and the public. The construction sector is also an asset for the nation and state as a symbol of national progress. This is evidenced by the large contribution of construction to Indonesia's economy, which is quite large to the Gross Domestic Product (GDP).

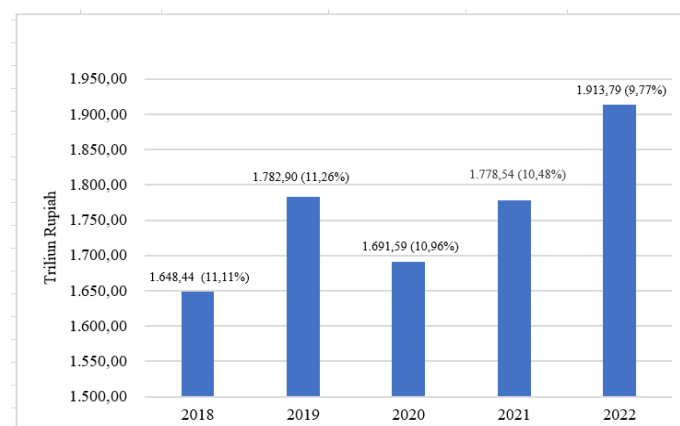


Figure 1. The value of national construction contribution to GDP in 2018-2022 according to BPS (2022)
Source: Central Statistics Agency (2022)

Figure 1 shows that in 2018 amounting to Rp 1,648.44 trillion or 11.11% was the contribution value of the national construction sector to Indonesia's total GDP. Similarly, in 2019 the contribution value given was Rp 1,782.90 trillion or 11.26%, while in 2020 it contributed Rp 1,691.59 trillion or 10.96% and was the fourth

sector as the sector that contributed the most. Furthermore, in 2021 it contributed IDR 1,778.54 trillion or equivalent to 10.48% of the total GDP at that time. In 2022, it is in fifth place as the sector that contributes the most to GDP, with a total of 9.77% or IDR 1,913.79 trillion. This data shows that the construction sector has a fairly high contribution to Indonesia's GDP growth every year.

Projects that are not completed will cause a domino effect in the future and this can be caused by several factors, one of which is cost overrun, which is if the realization cost exceeds the initial plan cost. This condition can occur due to poor cost management and lack of knowledge of the impact of risks that will occur. Completion of construction projects requires a large cost and takes a long time until finally it can be used according to its function. The length of the development process causes construction projects to be very vulnerable to changes in production costs in the middle of the implementation process, so there is a great potential for cost overrun. The construction sector has an important role in driving the real estate sector and increasing economic growth by creating jobs and increasing productivity and competitiveness of construction (Stone et al., 2017). The importance of the role of the construction sector makes its contribution have a great influence on GDP, but this only applies to projects that can be completed at the right cost, on time and in accordance with quality standards. In contrast to projects that are not completed or projects that are stalled, according to Anwar (2013) that projects that are stalled clearly cannot produce output (GDP) that is calculated as part of economic growth. This is because the project cannot be used according to its target so that the investment objectives for this project do not go according to plan. Sajiah (2022) also explained that government infrastructure projects face cost overruns that can cause negative economic growth, waste of limited resources, extend project completion time, cause negative public perceptions, disputes, litigation, and abandonment of a project.

Cost overrun has the potential to be a risk factor that has a negative impact on project goals ranging from time estimates, cost estimates to quality goals. Projects that experience cost overruns have a huge impact, not only on the construction company itself but also on owners, clients and consumers and all related parties. According to Ikechukwu et al. In 2017, his research found that the impact on client cost overrun implies that additional costs exceed the initially agreed costs, resulting in a smaller return on investment. For end users, the additional cost is passed on as a higher rental fee or price. For professionals, cost overrun implies an inability to provide value for money and can tarnish their reputation and result in a loss of trust that clients place in them. For the contractor, this implies a loss of profit because the project is not completed appropriately at cost, and defamation that can jeopardize his chances of winning the next project, if proven guilty. Meanwhile, for the industry as a whole, cost overruns can lead to project abandonment and a decline in development activities, with a bad reputation. It also gives the impression that the contractor's inability to secure project financing, damages their reputation and results in a loss of trust placed in them by the client.

Cost overrun for public clients with scarce financial resources has many effects and it will be a source of friction between clients and consultants (Nega, 2008). When cost overruns are due to clients' financial constraints, construction projects bear many problems that further exacerbate cost overruns. For public projects cost overrun will cause delays because public clients do not have enough financial resources ready to be added to the construction project, they need new approval for these additional costs from higher public officials or the Ministry of Finance and Economic Development (MoFED), in doing so time will continue to run and consequently project delays will arise thus causing further cost overruns as construction projects delayed for a long period of time will experience inflationary pressure and interest will accumulate. Bentil et al. (2017) also explained that the impact of cost overrun on his research on building construction projects in Ghana, namely the waste of construction project costs and time, has become a social and economic cancer in Ghana, which has a negative impact on the construction industry and its stakeholders. Fifteen effects/impacts were identified, there were ten most significant effects/impacts identified, namely the abandonment of building construction projects, the inability to secure project financing, the high cost of securing project financing due to additional risks, additional investment risks, loss of reputation of contractors and consultants, reduced return on investment, loss of investment in the construction industry, industrial unsustainability, slow national growth rate, and inability to provide value to clients.

Cost overruns in construction projects have a huge impact so it is important to analyze the causes and implement risk mitigation. Several studies have shown various factors causing cost overruns: Darmanto et al. (2020) identified eight main factors including inaccurate cost estimates and material issues; Puteri et al. (2022) highlighted the error of estimation and variation order (VO); Hadinata et al. (2013) found four classes of factors with the selection of heavy equipment as the dominant factor; Remi (2017) identified 52 factors in ten groups such as aspects of project documents and the environment; Sahusilawane et al. (2011) stated that the dominant factor in Ambon is the implementation of labor relations; and Maddeppungeng et al. (2013) highlighted delays due to equipment and supply chains.

From several studies that have been conducted by previous researchers, it can be concluded that cost overrun is a phenomenon that often occurs in the construction of a construction project, so it is also important

to analyze the causes. Indications of a project that has experienced cost overrun can also be known from the acquisition of a smaller percentage of profit at the end of the project or not in accordance with the original plan.

The XYZ project carried out by PT X has 17 towers with different RAP values on each tower. In general, the shape of the building is relatively almost the same even though there are some design differences, but each tower has different functions, facilities and sizes. With these differences, the RAP value to complete the work of each tower is not the same. Based on their functions, facilities and size, the 17 towers of the XYZ project are divided into 2 types, namely typical and interchange. The interchange type has a larger size, more functions and more complete facilities than typical towers. The interchange type consists of 3 floors, namely 1 operational floor and the other 2 floors function for commercial and public facilities. The typical type is a tower consisting of 2 floors, namely 1 operational floor and 1 commercial floor and public facilities. Of the 17 towers of the XYZ project, tower 5 is the only one that is an interchange type tower, and the other 16 towers are typical types. This causes tower 5 to be a tower that has a much larger RAP value than other towers. The difference in RAP values in each other tower which is a typical type tower is caused by several factors, including the location of the project, the level of difficulty of work in the field which results in a change in the work method, changes in the unit price of work items and the possibility of errors in the initial calculation of the project.

Project XYZ started in October 2017 and has reached more than 90% progress by the time this research was conducted. At the tender submission stage, the XYZ project is planned to be completed with an Implementation Budget Plan (RAP) of 86% of the total Contract Value (NK) obtained, so it is estimated that the company will earn a profit of 14%. RAP is the amount of cost budgeted to be able to complete a project based on the calculation of a cost budget analysis. Along with the construction implementation process from October 2017 to December 2022, there were many work items that experienced cost overruns. However, there are also some work items that achieve greater cost efficiency than targeted. The realization of the RAP cost of project XYZ can be seen in the following figure 2:

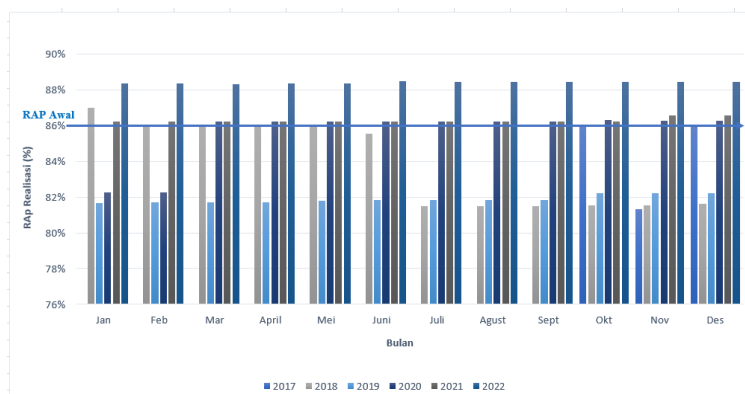


Figure 2. Budget plan for the implementation of the XYZ project in 2017-2022

Source: Enterprise information system

Figure 2 shows that from 2017 to 2019 the RAP was not far from the initial plan, and some were even below the initial RAP. However, from 2020 to 2022, the average RAP project realization was above the initial plan of 86%. The fluctuating project cost realization condition causes the remaining cost to be insufficient to complete the remaining work, it is assumed that the cost needed to be able to complete the XYZ project as a whole is 88.46% of the total contract value owned. With a work completion RAP greater than 2.46% or more than Rp 40 billion from the initial RAP, this project is assumed to experience cost overrun.

In this study, a risk analysis was carried out to cause cost overrun in project XYZ based on the results of sensitivity analysis to the variables that form RAP. The variables that form the RAP of project XYZ consist of direct costs, namely wage costs, material costs, subcontractor costs and equipment costs, as well as indirect costs that are included in the general cost of the project or overhead costs. Finding the most dominant factor as the cause of the cost overrun and then recommending managerial implications to minimize the repetition of the same risk factor in the next project.

The purpose of this study is to analyze the main factors causing cost overrun in project XYZ, evaluate the influence of cost overrun on the success rate and probability of project XYZ, and formulate a follow-up plan for managerial implications to minimize cost overrun in future projects. The benefit of this research for PT X is as a reference for future projects with similar circumstances so that it can be used as a reference in decision-making. In addition, the results of this research are expected to be a reference, source of information, and reference material for future researchers.

METHOD

The location of this research was carried out on the XYZ project which is one of the projects carried out by PT X located in Greater Jakarta. The research was conducted from September 2023 to October 2023.

The data used in this study is sequential data, namely data collected through primary sources by previous research and available for use in this study. The data collected based on the time series was obtained from PT X's company system, which is the actual data for the period October 2017 to December 2022.

For the data processing and analysis method, the researcher used:

- 1) Sensitivity Analysis: Sensitivity analysis is used to evaluate the influence of certain variables on the initial decision, determining which variables most significantly affect the production cost and selling price of the product. The purpose of this analysis is to assess the consequences of changes in cost calculations, analyze business probabilities based on uncertain projections, and find critical variables that can cause cost overruns that affect profits. This analysis was carried out using Crystal Ball software and the results were displayed in the form of a Tornado diagram, which examined input variables such as wage costs, material costs, subcontractor costs, tool costs, and overhead costs to determine the greatest impact on output variables in influencing cost changes that caused cost overruns.
- 2) Risk Identification with Monte Carlo Simulation (MCS): The MCS method is used to calculate or integrate building costs by using randomly selected values from the probability distribution of possible costs, aiming to calculate the possible distribution of the total cost of the project. According to Fadjar (2008), MCS is a reliable tool for project managers in analyzing risks and uncertainties in project financing, helping to determine more realistic financing expectations. MCS is generally used to calculate costs and time with random data from its probability distribution to calculate the total cost and time needed. The sensitivity analysis test determined the cost variables that had the most influence on cost overrun, which was then further analyzed with MCS. The MCS steps include determining the simulated variables, calculating random numbers, standard deviations, absolute errors, determining the number of iterations in the simulation, as well as analyzing and concluding the simulation results.

RESULTS AND DISCUSSION

Analysis of the Main Factors Causing Cost Overrun in Project XYZ

Each project has potential risks in each work item to be carried out. Potential risks that often occur in the formation of the project Implementation Budget Plan (RAP) can occur due to internal and external factors. Some of the reasons include an increase in the price of work units which can be caused by a difference in costs, both material and service prices at the time of tender calculation and prices at the time of implementation in the field. There is a change in work items or commonly called Variation Order (VO) which can be in the form of additional work or less work on the initial plan caused by changes in planning by related parties and generally occurs due to the request of the owner or project owner. In addition, changes in working methods in the field can also be a potential risk to the project's RAP, as this can lead to changes in realization costs. Another factor that also often occurs is rework due to errors in reading design drawings by the subcontractor and or there is a quality inconsistency with the work item.

There are 5 elements of the cost that form the RAP of the project, namely wage costs, material costs, subcontractor costs, tool costs and general costs. Each of these cost elements has a potential risk of cost overrun on the total RAP of the project with different levels of sensitivity. In the RAP of project XYZ, sensitivity analysis was carried out to find the variables that have the most influence on the total RAP. The sensitivity analysis is displayed in the form of a Tornado chart, which shows the sensitivity level of each element causing the cost overrun. Cost overruns affect the profitability of projects in particular and companies in general. The results of the sensitivity analysis show that the cost elements ranging from the highest to the lowest affect the RAP, so that a priority scale can be made in risk mitigation. By knowing this, managerial implications can be formulated to minimize cost overrun in the next project.

Table 1. Implementation Budget Plan (RAP) of project XYZ

No	Project Cost Elements	Initial RAP (Rp Million)	Current RAP (Rp Million)
1	Wages	47.054	91.696
2	Materials	45.786	129.364
3	Subcontractor	629.444	1.042.846
4	Equipment	14.806	48.725
5	General Costs	54.346	134.882
Total		791.436	1.447.514

Source: PT X

The RAP of project XYZ was used to build a total of 17 Towers, with each Tower having a RAP that had been estimated to complete all the work on the Tower.

Table 2. Tower Implementation Budget Plan (RAP)

Tower Name	Initial RAP (Rp Million)	Current RAP (Rp Million)
Tower 1	45.966	71.973
Tower 2	47.257	73.916
Tower 3	50.121	86.624
Tower 4	45.745	80.515
Tower 5	67.376	148.508
Tower 6	53.637	75.742
Tower 7	48.953	77.182
Tower 8	48.075	73.664
Tower 9	49.195	105.437
Tower 10	51.182	103.067
Tower 11	53.699	76.636
Tower 12	45.808	84.991
Tower 13	47.698	72.559
Tower 14	45.416	76.433
Tower 15	45.516	72.846
Tower 16	45.791	81.14
Tower 17	-	86.282
Total	791.436	1.447.514

Source: PT X

The value that forms the RAP of project XYZ on each of the cost elements consists of the initial RAP of the project and the current RAP. The initial RAP of the project is the value obtained at the time of tender calculation and is used as the basis for the initial cost. The initial RAP analysis is calculated based on the tender drawings (initial design) and the unit price of materials at that time. The current RAP value is the last RAP value at the time this data was taken after the VO, the current RAP is a RAP that is used as a reference for the most updated implementation costs until the project can be handed over to the owner. In the current RAP value, a sensitivity analysis simulation is carried out to find the most critical cost element as the cause of cost overrun.

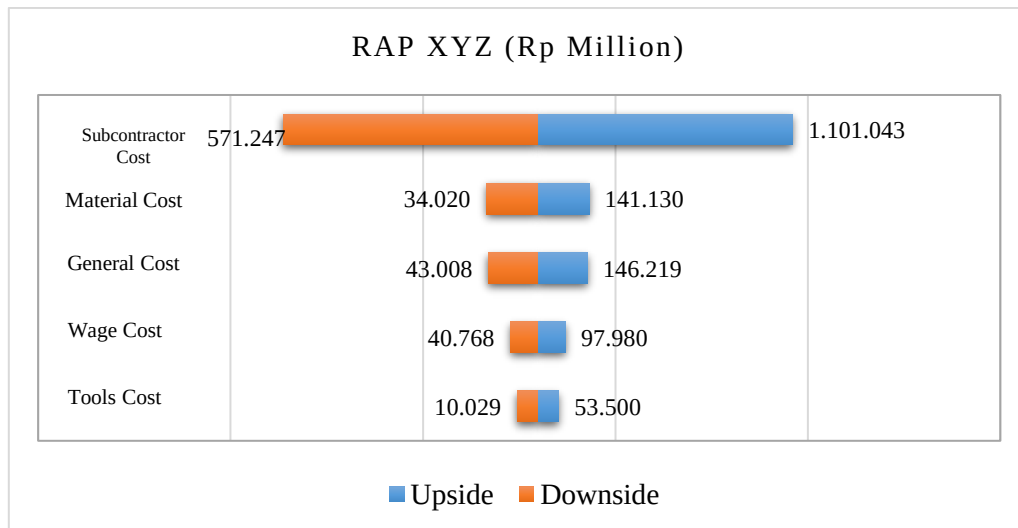


Figure 3. Tornado diagram

Source: PT X, processed

Preliminary

Table 3. Results of analytical sensitivity

Input Variable	Downside	Upside	Base Case
Subcontractor Costs	571,247.52	1,101,043.22	836,145.37
Material Costs	34,020.28	141,130.23	87,575.25
General Costs	43,008.61	146,219.84	94,614.23
Wages	40,768.94	97,980.52	69,374.73
Equipment Costs	10,029.42	53,500.11	31,764.77

Source: Data processing

The analysis was carried out on the 5 elements that form the RAP of the project consisting of wage costs, material costs, subcontractor costs, equipment costs and general costs with a range test of 10% and 90%. The Tornado diagram shows that the cost element that affects the RAP of project XYZ the most is the cost of the subcontractor and the least affects the cost of the tool. Of the 5 cost elements that form the RAP of project XYZ, subcontractor costs are the cost elements that should be the main focus of PT X's management because they have a very large influence but without ignoring the other 4 cost elements. The cost element of subcontractors is estimated to have the greatest potential cost overrun risk if not managed properly, so it will have a significant effect on the project's RAP. To find out the most dominant towers and items in influencing the RAP of project XYZ on the cost element of subcontractors, in this study an MCS analysis was carried out so that the influence of cost overrun on the success rate and probability of the project can be known.

Evaluation of the Effect of Cost Overrun on the Success Rate and Probability of Project XYZ

Each tower has a different sensitivity to the success rate and probability of the XYZ project as a whole, this is also influenced by the amount of RAP value of the subcontractor on each tower. The RAP value of subcontractors in the project implementation process is dynamic or can change, this is due to several factors, but the most dominant is the VO (Variation Order) factor. VO items can be in the form of additions or reductions in work that are adjusted to the needs and demands of the owner as the project owner or can also be adjusted to the ability of the contractor. Here are the initial costs of the subcontractors and the current costs of the subcontractors of each tower of the XYZ project:

Table 4. XYZ project subcontractor costs

Tower Name	Initial RAP Subcontractor (Rp Million)	Current RAP Subcontractor (Rp Million)
Tower 1	36.073	51.399
Tower 2	37.338	52.277
Tower 3	40.119	63.354
Tower 4	35.984	58.473
Tower 5	54.991	113.583

Tower 6	43.512	55.128
Tower 7	38.845	56.602
Tower 8	38.100	53.445
Tower 9	39.173	77.042
Tower 10	41.120	74.813
Tower 11	43.518	54.495
Tower 12	35.925	61.101
Tower 13	37.806	51.492
Tower 14	35.534	55.415
Tower 15	35.622	50.861
Tower 16	35.905	57.901
Tower 17	-	55.463
Total	629.444	1.042.846

Source: PT X

MCS analysis produces random numbers in each iteration carried out following the probability of the variable being tested, if it is tested again, the probability generated will not be the same as the previous test result. The more trials are carried out, the more precise the results will be. The test analysis in this study was carried out as many as 100,000 iterations. The effect of cost overrun on the success rate and probability of the project was analyzed in several reviews.

Analysis of the Success Rate and Probability of the Project Against the Total Value of the Current RAP of the Subcontractor, as Well as the Sensitivity of the Tower Affecting It

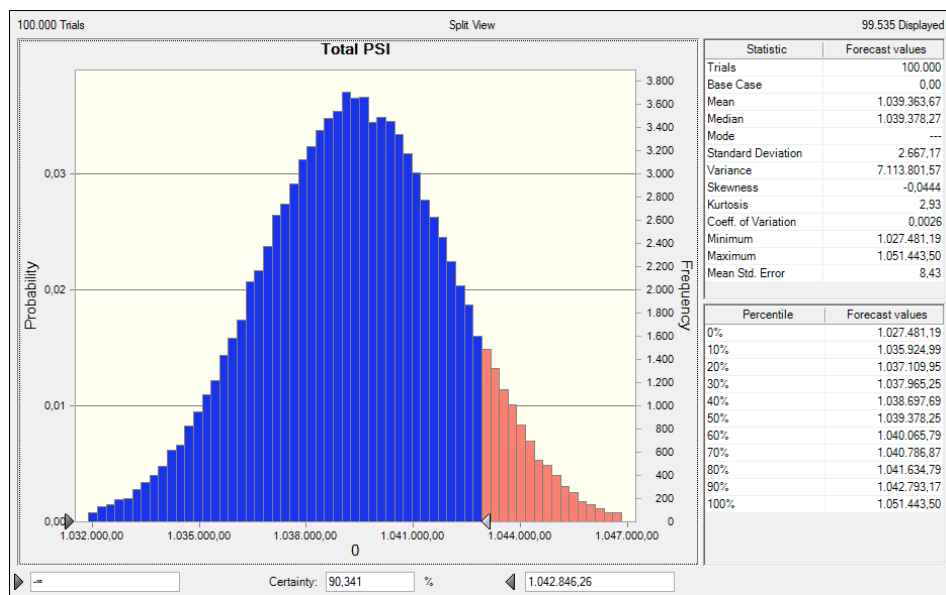


Figure 4. Total distribution of RAP subcontractors

Source: processed from MCS

In the analysis of the current RAP distribution of subcontractors, which is IDR 1,042,846 million which has been tested for 100,000 iterations, has a confidence level of 90.34% to be able to complete all work on the subcontractor items of the XYZ project. With such a large probability, there is a potential loss of 9.66% if it is still implemented with the existing RAP value. If you want the XYZ project to be completed with a 100% success rate, based on the results of the MCS analysis, it is estimated that the cost needed is IDR 1,051,443 million with a mean value of IDR 1,039,363 million. There is a potential cost overrun if the project is still carried out with the existing subcontractor's RAP value, which is Rp 8,597 million.

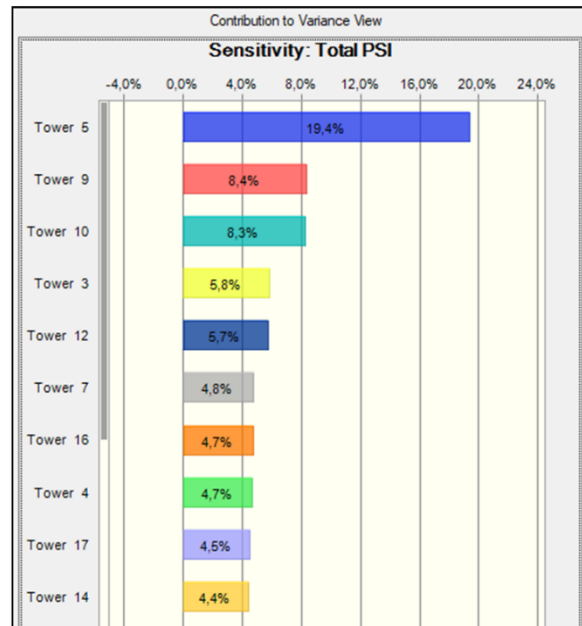


Figure 5. RAP sensitivity of subcontractor realization
Source: processed from MCS

The results of the MCS analysis on the RAP of the subcontractor tower 5, the result was that this tower has a sensitivity or influence of 19.4% on the success rate of completion of the work of the subcontractor of the XYZ project. Meanwhile, the RAP of tower 9 and tower 10 subcontractors has a sensitivity of 8.4% and 8.3%, respectively. In this analysis, it is found that the sensitivity of the tower to the success rate of the work of the subcontractor of project XYZ tends to be influenced by the amount of RAP value of the subcontractor in each tower. It can be seen in table 4.5 that the greater the RAP value of the subcontractor on the tower, the higher the sensitivity level of the tower. The following is the correlation value of the sensitivity level of the tower to the RAP value.

Table 5. Correlation of tower sensitivity level to RAP value

No	Tower Name	Initial RAP Subcontractor (Rp Million)	Current RAP Subcontractor (Rp Million)
1	Tower 1	36,073	51,399
2	Tower 2	37,338	52,277
3	Tower 3	40,119	63,354
4	Tower 4	35,862	58,473
5	Tower 5	54,991	113,583
6	Tower 6	43,512	55,128
7	Tower 7	38,845	56,602
8	Tower 8	38,100	53,445
9	Tower 9	39,173	77,042
10	Tower 10	41,120	74,813
11	Tower 11	43,518	54,495
12	Tower 12	35,925	61,101
13	Tower 13	37,806	51,492
14	Tower 14	35,534	55,415
15	Tower 15	35,622	50,861
16	Tower 16	35,905	57,901
17	Tower 17	-	55,463
Total		629,444	1,042,845

Source: processed from MCS

Analysis of the Success Rate and Probability of Each Tower's Subcontractor's RAP Value, as Well as the Sensitivity of the Forming Items Affecting It

There are 3 towers that have a very large influence on the success rate of the completion of the work of the subcontractor of the XYZ project, namely tower 5, tower 9 and tower 10, while the other 14 towers have a relatively close influence on each other. Each tower was analyzed using the MCS method for 100,000 iterations to see the sensitivity of the subcontractor's RAP forming items in each tower. The subcontractor's work items in each tower are generally the same, this is because towers 1 to 17 have almost the same function and shape except for tower 5. Tower 5 has a larger size, more functions and is different from other towers, besides that the construction location is quite difficult because it is in the center of the city and very heavy traffic, this is one of the factors for the high RAP in tower 5.

Table 6. RAP forming works of tower subcontractor

Kode	Nama pekerjaan	Kode	Nama pekerjaan
X 1	Pekerjaan baja 1	X 46	Manhole plafond
X 2	Pekerjaan expansion joint 1	X 47	Drop ceiling metal h=0,3-0,5m
X 3	Atap skylight (solar flat)	X 48	Shadow line
X 4	Solar flat dengan rangka	X 49	Plafond fire rated 1 jam (promatect 12 mm)
X 5	Solar flat - office	X 50	Plafond fire rated 2 jam (promatect 12 mm)
X 6	Pekerjaan solar flat	X 51	Railing tangga darurat (fin. duco)
X 7	Pekerjaan sandwich panel	X 52	Railing tangga (handrail ss; tiang fin. duco)
X 8	Pekerjaan plat hairline	X 53	Railing batas paid dan unpaid tinggi 100cm
X 9	Cat acrylic emulsion	X 54	Guard rail fasade (handrail ss; tiang fin. Duco)
X 10	Cat daun pintu	X 55	Tangga ladder
X 11	Cat kusen	X 56	Waterproofing coating
X 12	Cat ekterior	X 57	Waterproofing integral
X 13	Cat weathershield	X 58	Waterstop w = 20 cm
X 14	Pekerjaan partisi kubikel toilet	X 59	Floor hardener 3 kg/ m2
X 15	Aluminium composit panel	X 60	Proteksi floorhardener
X 16	Louvre aluminium	X 61	Pekerjaan sheet pile baja
X 17	Jendela tipe lv-2 uk. 1200 x 500 mm	X 62	Minipile (25 x 25 cm) panjang 12m/titik
X 18	Jendela tipe lv-3 uk. 500 x 500 mm	X 63	Pemancangan minipile (25x25cm) ,t = 11m/titik
X 19	Jendela tipe lv-4 uk. 2000 x 500 mm	X 64	Penyambungan minipile (25 x 25)
X 20	Jendela tipe lv-5a uk. 2500 x 500 mm	X 65	Pemotongan minipile
X 21	Jendela tipe lv-5b uk. 2500 x 500 mm	X 66	Pembuangan minipile
X 22	Jendela tipe lv-6 uk. 1800 x 500 mm	X 67	Lantai trap tangga granit (desert brown)
X 23	Jendela tipe lv-7 uk. 5000 x 500 mm	X 68	Tanggulan tangga finish granit
X 24	Rolling door uk. 2,7x3m	X 69	Stepnosing tangga utama granite
X 25	Pintu <i>single</i> tahan api a2 uk. 80x210 Cmm	X 70	Meja wastafel finish granite
X 26	Pintu <i>single</i> tahan api a2 -a uk. 100x210 Cmm	X 71	Top table finish granit
X 27	Pintu <i>single</i> tipe a1 uk. 80x210cm (UPVC Panel)	X 72	Pekerjaan signage
X 28	Pintu <i>single</i> tipe a1-a uk. 100x210cm (UPVC Panel)	X 73	Pekerjaan instalasi mep
X 29	Pintu <i>single</i> tipe a2-a uk. 110x210cm	X 74	Pekerjaan instalasi air conditioning
X 30	Pintu <i>single</i> tipe b1 uk. 110x210cm	X 75	Pekerjaan instalasi plumbing
X 31	Pintu <i>single</i> tahan api b1 uk. 110x210 Cmm	X 76	Pekerjaan sistem air hujan
X 32	Pintu <i>double</i> tahan Api c1-a uk. 200x210 Cmm	X 77	Pekerjaan instalasi fire hydrant
X 33	Pintu <i>single</i> tipe c1 uk. 100x210cm	X 78	Pekerjaan instalasi fire suppression
X 34	Pintu <i>double</i> tahan api dengan louvre c2	X 79	Pekerjaan lift & escalator
X 35	Pintu <i>double</i> tahan api dengan louvre c2-a	X 80	Pekerjaan instalasi listrik
X 36	Pintu <i>single</i> tipe d uk. 90x210cm	X 81	Pekerjaan generator set
X 37	Pintu shaft	X 82	Pekerjaan penyambungan daya
X 38	Plint aluminium	X 83	Pengadaan pompa pemadam
X 39	Pemasangan lantai granit sistem basah	X 84	Pekerjaan instalasi ruang pompa
X 40	Raise floor	X 85	Pekerjaan grounding stasiun
X 41	Pekerjaan raised floor	X 86	Pengadaan fire alarm r. pompa
X 42	Plafond gypsum t = 9 mm	X 87	Pekerjaan escalator & elevator jembatan
X 43	Plafond gypsum water resistant t = 12 mm	X 88	Penambahan alat berat untuk pemasangan escalator jen
X 44	Plafond metal panel	X 89	Papan nama proyek
X 45	Plafond metal perforated	X 90	Rangka kekuatan penggantung plafond

Kode	Nama pekerjaan	Kode	Nama pekerjaan
X 91	Plafond fire rated 1 jam (promatect 12 mm) 2	X 136	Pekerjaan baja pre-assembly
X 92	Plafond fire rated 2 jam (promatect 12 mm) 2	X 137	Partisi kubikal toilet
X 93	Tangga akses roof tank	X 138	Tescom plumbing air bersih
X 94	Insulated membrane	X 139	Pekerjaan jembatan 1
X 95	Fitting instalasi plumbing air bersih ground level	X 140	Pekerjaan jembatan 2
X 96	Pekerjaan baja endwall	X 141	Pekerjaan solar flat jembatan
X 97	Mob & demob mini pile	X 142	Tangga akses roof tank 3
X 98	Mini Pile 25x25	X 143	Insulated membrane 2
X 99	Pemancangan mini pile 25x25	X 144	Tescom plumbing air bersih 2
X 100	Pda test	X 145	Pekerjaan baja endwall 3
X 101	Penyambungan tiang pancang 25x25	X 146	Pekerjaan baja pre-assembly 3
X 102	Potong dan buang kepala pile 25x25	X 147	Pekerjaan baja endwall 2
X 103	Baja pipa chs dia 457	X 148	Partisi kubikal toilet 3
X 104	Baja pipa chs dia 283	X 149	Rangka perkutan penggantung plafond 2
X 105	Baja pipa 8"	X 150	Partisi kubikal toilet 2
X 106	Baja pipa 5"	X 151	Rangka perkutan penggantung plafond 3
X 107	Baja pipa 3"	X 152	Tangga akses roof tank 2
X 108	Baja pipa 2,5"	X 153	Pekerjaan sumur resapan
X 109	Baja H350	X 154	Pekerjaan baja jembatan 2
X 110	Baja H200	X 155	Pekerjaan railing jembatan 2
X 111	Baja H150	X 156	Pekerjaan sandwich panel & acp jembatan 3
X 112	Baja H125	X 157	Pekerjaan waterproofing jembatan 2
X 113	Baja WF200	X 158	Pekerjaan instalasi mep jembatan 2
X 114	Pekerjaan baja jembatan	X 159	Pekerjaan lampu jembatan 2
X 115	Pekerjaan sandwich panel & acp jembatan	X 160	Pengadaan panel & pompa sumpit jembatan 2
X 116	Pekerjaan railing jembatan	X 161	Pek. chemical angkur 2
X 117	Pekerjaan pintu jembatan	X 162	Pekerjaan baja 2
X 118	Pekerjaan instalasi mep jembatan	X 163	Pekerjaan baja pre-assembly 2
X 119	Pekerjaan lampu jembatan	X 164	Pekerjaan sandwich panel 2
X 120	Pengadaan panel & pompa sumpit jembatan	X 165	Pekerjaan solar flat & rangka end wall
X 121	Pek. chemical angkur	X 166	Pekerjaan expansion joint
X 122	Boombox	X 167	Terali louvre aluminium
X 123	Limestone	X 168	Pekerjaan cat
X 124	Macadam	X 169	Pekerjaan pintu dan jendela
X 125	Pekerjaan sandwich panel & acp jembatan 2	X 170	Pekerjaan pintu besi
X 126	Pekerjaan waterproofing jembatan	X 171	Plafond fire rated 2 jam area mep & boh
X 127	Pekerjaan baja track level	X 172	Plafond gyp tile 60x120
X 128	Pekerjaan expansion joint 2	X 173	Cove lampu
X 129	Pekerjaan sandwich panel track level	X 174	List plafond
X 130	Pekerjaan safety track & safetyline	X 175	Manhole plafond 2
X 131	Dinding panel ringan (sandwich panel) t : 75 mm	X 176	Boombox 2
X 132	Single swing door manual uk. 90 x 210 cm	X 177	Bangku stainless steel pipe d 4
X 133	Window uk 100x192 cm	X 178	Railing T=100cm
X 134	Plafond panel ringan (sandwich panel) t : 75 mm	X 179	Railing T=100cm tangga darurat
X 135	Pekerjaan acp eksterior	X 180	Tangga Aluminium Platform

Source: PT X

There are 180 subcontractor work items that must be done on project XYZ. The subcontractor's work items in the XYZ project are not carried out on all towers, this is because they adjust the needs, shape and function of each tower. Although the function and form are relatively almost the same, the work of the subcontractor in each tower still has differences.

MCS tower 5 analysis

In the results of the MCS analysis on the total RAP of the current subcontractors, tower 5 is the most dominant tower in influencing the success of the work of the subcontractors of the XYZ project among other towers. The following are the results of the MCS analysis of the RAP probability distribution of subcontractors in tower 5 (figure 5):

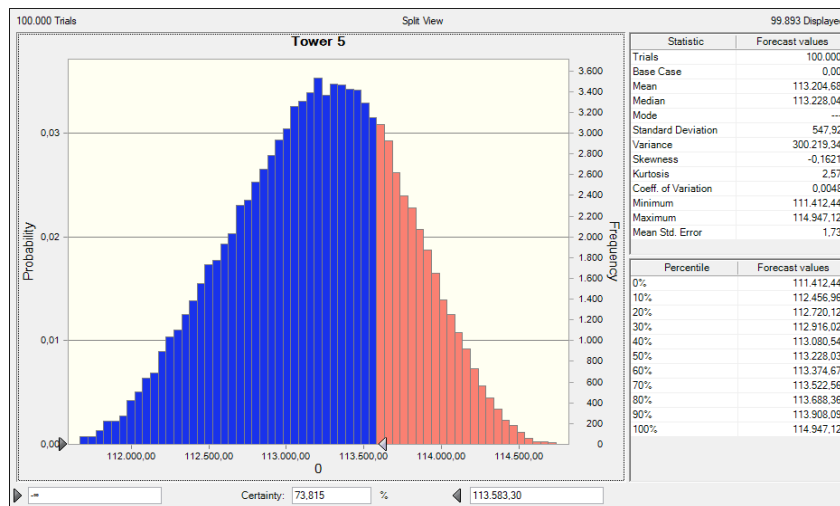


Figure 5. RAP probability distribution Tower 5 Subcontractor
Source: processed at MCS

Tower 5 with a subcontractor RAP of IDR 113,583 million, based on the results of the MCS analysis, this tower has the lowest probability of completing the work compared to other towers. The results of the analysis show that the current RAP of subcontractors is only able to complete the work by 73.8%. To be able to complete the subcontractor's work 100% of the cost needed is IDR 114,947 million. If forced to complete with 100% progress, it is estimated that tower 5 will experience a cost overrun of Rp 1,364 million, this potential loss is quite large. The results of the sensitivity carried out on all towers to the success of the work of the subcontractor of the XYZ project, tower 5 had the greatest influence of 19.4%. RAP subcontractor tower 5 is the highest value compared to 16 other towers.

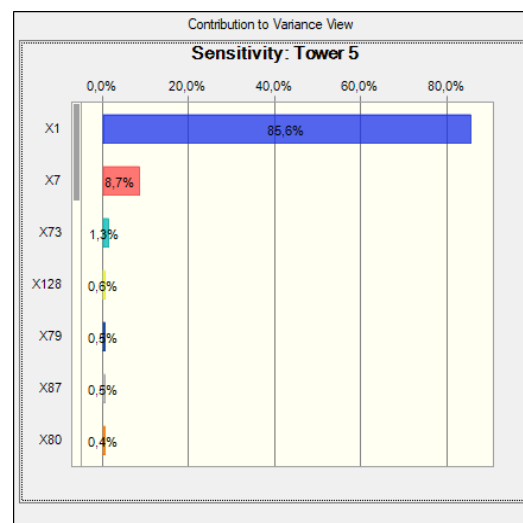


Figure 6. Sensitivity of subcontractor work tower 5
Source: processed at MCS

Steel work (x1) is very dominating in influencing the success of subcontractor work in tower 5 with a value of 85.6%. This value is the greatest compared to the influence of steel work (x1) on other towers. The next item that has a considerable contribution in influencing the success of tower 5 is the sandwich panel work (x7) which is 8.7%. The influence of sandwich panel work (x7) compared to steel work (x1) has a very large value difference, but if not managed properly, the potential for losses is still fairly high due to the current RAP value of the subcontractor tower 5 is very large. The MCS analysis as carried out on tower 5 is repeated on each tower to analyze the success rate and probability of the RAP value of each tower's subcontractor, as well as the sensitivity of the influencing forming items. The following is a summary of the results of the MCS analysis on all towers.

Table 7. RAP forming works of tower subcontractor

Tower	RAP subcontractor (Rp billion)	Subcontractor RAP confidence level (%)	RAP Estimate at 100% confidence level (Rp Billion)	Estimated Potential Cost Overrun (Rp Billion)	The most influential jobs
Tower 1	RP 51,398.88	76%	RP 51,935.00	-Rp 536.12	x1 Steel Works
					x7 Panel Sandwich Work
					x80 Electrical Installation Work
Tower 2	RP 52,276.86	77%	RP 52,799.00	-Rp 522.14	x1 Steel Works
					x7 Panel Sandwich Work
					x79 Elevator & Escalator Jobs
Tower 3	RP 63,354.19	80%	RP 63,940.00	-Rp 585.81	x1 Steel Works
					x7 Panel Sandwich Work
					x11 4 Jpo Steel Jobs
Tower 4	RP 58,472.83	79%	RP 59,006.00	-Rp 533.17	x1 Steel Works
					x7 Panel Sandwich Work
					x11 4 Jpo Steel Jobs
Tower 5	Rp 113,583.30	74%	Rp 114,947.00	-Rp 1,363.70	x1 Steel Works
					x7 Panel Sandwich Work
					x73 MEP Installation Work
Tower 6	RP 55,128.44	77%	RP 55,679.00	-Rp 530.56	x1 Steel Jobs 1
					x7 Panel Sandwich Work
					x73 MEP Installation Work
Tower 7	RP 56,602.43	77,40%	RP 57,172.00	-Rp 569.57	x1 Steel Jobs 1
					x7 Panel Sandwich Work
					x79 Elevator & Escalator Jobs
Tower 8	RP 53,445.31	75,8%	RP 54,005.00	-Rp 559.69	x1 Steel Jobs 1
					x7 Panel Sandwich Work
					x73 MEP Installation Work
Tower 10	RP 74,813.37	83,5%	RP 75,435.00	-Rp 621.63	x1 Steel Jobs 1
					x11 4 Jpo Steel Jobs
					x7 Panel Sandwich Work
Tower 11	RP 54,495.34	76,5%	RP 55,094.00	-Rp 598.66	x1 Steel Jobs 1
					x7 Panel Sandwich Work
					x73 MEP Installation Work
Tower 12	RP 61,101.31	78,9%	RP 61,732.00	-Rp 630.69	x1 Steel Jobs 1
					x7 Panel Sandwich Work
					x11 4 Jpo Steel Jobs
Tower 13	RP 51,491.54	75,0%	RP 52,069.00	-Rp 577.46	x1 Steel Works
					x7 Panel Sandwich Work
					x80 Electrical Installation Work
Tower 14	RP 55,415.11	77,2%	RP 55,983.00	-Rp 567.89	x1 Steel Works
					x7 Panel Sandwich Work
					x79 Elevator & Escalator Jobs
Tower 15	RP 50,861.16	76,9%	RP 51,401.00	-Rp 539.84	x1 Steel Works

					x7	Panel Sandwich Work
					x79	Elevator & Escalator Jobs
Tower 16	RP 57,901,33	79,0%	RP 58,438.00	-RP 536.67	x1	Steel Works
					x7	Panel Sandwich Work
					x11 4	Jpo Steel Jobs
Tower 17	RP 55,462.76	76,5%	RP 56,074.00	-RP 611,124	x16 5	Steel Jobs 2
					x16 7	Panel Sandwich Work 2
					x16 9	Expantion Joint Work

Evaluation of the Amount of Work RAP Weight that Affects the Total RAP of Subcontractors

This evaluation was carried out to see how much RAP weight the item had the most dominant influence on completing the subcontractor's work on each tower. This is important to do, because if the work item that has the most dominant influence and has a large RAP weight value is identified from the beginning, the company can immediately mitigate the risk so that the potential cost overrun can be minimized or even eliminated. If the weight of the work item has a value that is not too large for the total RAP, it is still important to conduct further evaluation. This needs to be a concern because in a project that has more than one tower and relatively the same work items as the XYZ project, it will have a very significant influence on the total project cost realization as a whole. The condition has the potential to experience a repeat of risks that cause cost overruns to be higher.

Table 8. Recapitulation of items with the greatest level of influence

Nama Tower	RAP subkontraktor	Urutan sensitifitas	Kode	Nama pekerjaan	RAP pekerjaan	Bobot RAP pekerjaan	Sensitivitas terhadap tower
a	b	c	d	e	f	g = (f/b)*100	h
Tower 1	Rp	51.398,88	1	x1 Pekerjaan Baja	Rp 18.694,12	36,37%	71,80%
			2	x7 Pekerjaan Sandwich Panel	Rp 10.587,73	20,60%	21,80%
			3	x80 Pekerjaan Instalasi Listrik	Rp 2.424,75	4,72%	1,00%
Tower 2	Rp	52.276,86	1	x1 Pekerjaan Baja	Rp 18.129,73	34,68%	69,80%
			2	x7 Pekerjaan Sandwich Panel	Rp 10.570,63	20,22%	22,10%
			3	x79 Pekerjaan Lift & Escalator	Rp 3.381,61	6,47%	2,20%
Tower 3	Rp	63.354,19	1	x1 Pekerjaan Baja	Rp 19.190,63	30,29%	69,30%
			2	x7 Pekerjaan Sandwich Panel	Rp 10.440,93	16,48%	18,40%
			3	x114 Pekerjaan Baja Jpo	Rp 5.461,42	8,62%	5,00%
Tower 4	Rp	58.472,83	1	x1 Pekerjaan Baja	Rp 18.006,14	30,79%	65,30%
			2	x7 Pekerjaan Sandwich Panel	Rp 11.432,14	19,55%	25,00%
			3	x114 Pekerjaan Baja Jpo	Rp 3.159,78	5,40%	1,80%
Tower 5	Rp	113.583,30	1	x1 Pekerjaan Baja	Rp 49.289,33	43,39%	85,60%
			2	x7 Pekerjaan Sandwich Panel	Rp 16.461,66	14,49%	8,70%
			3	x73 Pekerjaan Instalasi MEP	Rp 6.455,70	5,68%	1,30%
Tower 6	Rp	55.128,44	1	x1 Pekerjaan Baja 1	Rp 20.171,68	36,59%	76,90%
			2	x7 Pekerjaan Sandwich Panel	Rp 9.126,27	16,55%	14,70%
			3	x73 Pekerjaan Instalasi MEP	Rp 3.028,14	5,49%	1,70%
Tower 7	Rp	56.602,43	1	x1 Pekerjaan Baja 1	Rp 20.171,68	35,64%	77,00%
			2	x7 Pekerjaan Sandwich Panel	Rp 9.126,27	16,12%	14,30%
			3	x79 Pekerjaan Lift & Escalator	Rp 2.750,55	4,86%	1,40%
Tower 8	Rp	53.445,31	1	x1 Pekerjaan Baja 1	Rp 20.407,17	38,18%	78,10%
			2	x7 Pekerjaan Sandwich Panel	Rp 9.126,27	17,08%	14,70%
			3	x73 Pekerjaan Instalasi MEP	Rp 3.053,48	5,71%	1,50%
Tower 9	Rp	77.042,09	1	x1 Pekerjaan Baja 1	Rp 20.900,63	27,13%	57,00%
			2	x114 Pekerjaan Baja Jpo	Rp 13.376,43	17,36%	22,20%
			3	x7 Pekerjaan Sandwich Panel	Rp 9.126,27	11,85%	4,60%
Tower 10	Rp	74.813,37	1	x1 Pekerjaan Baja 1	Rp 17.089,73	22,84%	49,10%
			2	x114 Pekerjaan Baja Jpo	Rp 12.630,76	16,88%	25,80%
			3	x7 Pekerjaan Sandwich Panel	Rp 9.126,27	12,20%	13,40%
Tower 11	Rp	54.495,34	1	x1 Pekerjaan Baja 1	Rp 20.171,68	37,02%	77,30%
			2	x7 Pekerjaan Sandwich Panel	Rp 9.126,27	16,75%	14,70%
			3	x73 Pekerjaan Instalasi MEP	Rp 3.087,36	5,67%	1,60%
Tower 12	Rp	61.101,31	1	x1 Pekerjaan Baja 1	Rp 19.554,77	32,00%	69,30%
			2	x7 Pekerjaan Sandwich Panel	Rp 10.788,27	17,66%	19,60%
			3	x114 Pekerjaan Baja Jpo	Rp 4.842,23	7,92%	4,00%
Tower 13	Rp	51.491,54	1	x1 Pekerjaan Baja	Rp 20.390,63	39,60%	77,70%
			2	x7 Pekerjaan Sandwich Panel	Rp 9.732,86	18,90%	16,40%
			3	x80 Pekerjaan Instalasi Listrik	Rp 2.424,75	4,71%	1,00%
Tower 14	Rp	55.415,11	1	x1 Pekerjaan Baja	Rp 19.509,77	35,21%	72,60%
			2	x7 Pekerjaan Sandwich Panel	Rp 10.529,51	19,00%	20,00%
			3	x79 Pekerjaan Lift & Escalator	Rp 2.618,42	4,73%	1,20%
Tower 15	Rp	50.861,16	1	x1 Pekerjaan Baja	Rp 18.157,17	35,70%	73,30%
			2	x7 Pekerjaan Sandwich Panel	Rp 9.741,95	19,15%	19,60%
			3	x79 Pekerjaan Lift & Escalator	Rp 2.618,42	5,15%	1,30%
Tower 16	Rp	57.901,33	1	x1 Pekerjaan Baja	Rp 18.731,93	32,35%	72,30%
			2	x7 Pekerjaan Sandwich Panel	Rp 9.741,95	16,83%	18,40%
			3	x114 Pekerjaan Baja Jpo	Rp 2.902,50	5,01%	1,50%
Tower 17	Rp	55.462,76	1	x165 Pekerjaan Baja 2	Rp 20.026,96	36,11%	72,40%
			2	x167 Pekerjaan Sandwich Panel 2	Rp 10.694,89	19,28%	19,10%
			3	x169 Pekerjaan Expantion Joint	Rp 3.821,74	6,89%	2,40%

Source: processed at MCS

From the results of the evaluation carried out on the items that have the most dominant influence on each tower as a whole, it has the greatest weight of work among other items. The most dominant item affecting is steel work with weights ranging from 22.84% to 43.39%. The second dominant item in the sensitivity order was dominated by panel sandwich work as many as 15 items with a RAP weight range between 14.49% to 20.60%. The third sensitivity sequence consists of several influential work items, including electrical

installation work, elevator and escalator work, MEP installation work, expansion joint work. In the work that falls into the third sensitivity order, the weight range is between 4.71% to 12.20%.

Managerial Implications Follow-up Plan to Minimize Cost Overrun on Future Projects

From the results of the sensitivity analysis and Monte Carlo Simulation (MCS), it was obtained that the RAP forming items should be a concern for PT X, especially in the construction of the XYZ project. The results of this study show that the cost element of subcontractors has a very large effect on the total RAP of project XYZ and the most dominant work affecting is steel work and panel sandwich work. The things that need to be done by PT X to minimize the risk of cost overrun in the next project are:

Table 9. Managerial Implications Follow-up Plan to Minimize Cost Overrun on Future Projects

Managerial Implications	Follow-Up Plans	Bureau
Increase accuracy at the time of tender volume calculation	Mitigate the risk of cost overrun due to miscalculation of volume and work items	Estimating dan Engineering (Tender Team)
Improving accuracy when reading tender drawings	Mitigation of the risk of cost overrun due to misreading of work drawings resulting in rework in the field	Estimating dan Engineering (Tender Team)
Pay attention to the project location and the conditions around the project	Mitigation of the risk of cost overrun due to changes in work methods	Estimating dan Engineering (Tender Team)
Taking into account fluctuations in the price of a unit of work	Mitigation of the risk of cost overrun due to the increase in the price of work units due to the price difference between the calculation time and the time of ordering materials	Estimating dan Engineering (Tender Team)
Pay attention to the production status of local or imported materials	Mitigation of the risk of cost overrun due to price increases affected by foreign currency values	Estimating dan Engineering (Tender Team)
Taking into account shipping process obstacles due to unforeseen circumstances	Mitigation of cost overrun risk due to overtime delivery to the project due to the length of the expedition process, geographical conditions of material delivery routes	Estimating dan Engineering (Tim Tender)
Estimating material delivery travel time	Mitigation of the risk of cost overrun due to overtime delivery to the project due to late ordering and not taking into account national holidays in each country	Estimating dan Engineering (Tender Team)
Pay attention to the condition of the importing country	Mitigation of the risk of cost overrun due to political stability and economic performance of importing countries and those that affect them	Estimating dan Engineering (Tender Team)

Source : processed data

CONCLUSION

The most dominant factor causing cost overruns in project XYZ is subcontractor costs, followed by general costs, wage costs, material costs, and tool costs, with this sequence influenced by the RAP value of each element. The RAP PSI subcontractor budget for the XYZ project is Rp 1,042,846 million with a completion success rate of 90.34%, indicating a potential failure rate of 9.66% or Rp 8,597 million. The certainty of subcontractor work success varies across different towers, with Tower 1 having a 76.0% certainty and a potential cost overrun of IDR 537 million, while Tower 7 has a 77.4% certainty and the highest potential cost overrun of IDR 1,570 million. The RAP weight analysis shows that steelwork, with a dominant weight ranging from 22.84% to 43.39%, followed by panel sandwich and bridge steel work, significantly affects the total RAP of the subcontractor. To address these issues, eight strategic plans for managerial implications have been developed based on sensitivity analysis and Monte Carlo Simulation (MCS), including increasing accuracy in calculating tender volumes, reading tender drawings, considering project locations, and accounting for fluctuations in unit prices and material supply chain constraints. These measures aim to minimize the risk of cost overruns in future projects and enhance project success. It is recommended that PT X evaluate the performance of estimating and engineering bureaus, focusing on long-term risks, and increase awareness among the tender and project teams to mitigate potential risks that could lead to cost overruns. Future research could further investigate the specific factors contributing to subcontractor-related cost overruns and the effectiveness of various cost management strategies, particularly in high-risk areas like steelwork, and apply

advanced risk assessment techniques such as Monte Carlo Simulation to better predict and mitigate cost overruns across different project types.

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