Eduvest – Journal of Universal Studies
Volume 5 Number 7, July, 2025
p- ISSN 2775-3735- e-ISSN 2775-3727

THE EFFECT OF SOIL SURVEY ADEQUACY ON ENGINEERING DESIGN DETAILS (DED) ON POTENTIAL COST AND CONSTRUCTION TIME SAVINGS

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ABSTRACT

The construction of the Kadusirung Dua Underpass Project in Banten aimed to improve access routes but encountered landslides during execution, necessitating design changes and additional soil investigations. This study examined the impact of inadequate soil surveys on engineering design, focusing on cost and time efficiency. The research objectives were to analyze the effects of design changes during construction, compare initial and revised designs, and evaluate savings potential if proper soil investigations were conducted initially. Using secondary data from the project, the study employed Microsoft Project for time-cost analysis and applied the Cost of Change vs. Opportunity to Influence theory. Findings revealed that design changes during construction increased costs by Rp 43.6 billion and extended the timeline by 566 days. Conversely, comprehensive soil surveys at the planning stage could have saved 25% of the time (237 days) and 18% of costs (Rp 38.9 billion). The implications highlight the critical need for thorough geotechnical investigations early in projects to mitigate delays and cost overruns. The study underscores the importance of adhering to soil testing standards (SNI 8460:2017) and optimizing design decisions during planning to enhance project efficiency.

KEYWORDS *Design Change, Construction Cost and Time, Cost of Change vs Opportunity to Influence.*

INTRODUCTION

The BSD underpass work for the Serpong–Balaraja Toll Road crossing was constructed as an 8x4 m culvert box with the Cijantra main drain superimposed on the box underpass structure. Project management is an effort or method to achieve a goal, namely completing a project on target in implementation time, cost, and quality, according to Ervianto (2002). Construction management itself aims to

How to cite: Ilham Akbar Mulya Wibawa, et al (2025). The Effect of Soil Survey Adequacy on Engineering Design Details (DED) on Potential Cost and Construction Time Savings. Journal Eduvest. *Vol 5* (7): 9047-9063
E-ISSN: 2775-3727

regulate the implementation of a project so that it is well planned in order to achieve optimal results in accordance with time, cost, and quality (Chitkara, 2014). Construction management basically consists of three basic parts: time scheduling, which can be planned using a work breakdown structure (WBS) (Mosey, 2019); cost control (McGeorge & Palmer, 2015); and quality management (Mokhtar, 2020). In general, project activities are divided into four main stages, namely planning, organizing, scheduling, and controlling (Alvarado & Larios, 2018).

A Contract Change Order is a condition in which the value of the work contract document between the owner and the service provider/contractor that has been agreed upon experiences changes in the plan and changes in the value of costs, whether due to additional or reduced work that occurs during implementation. According to Levy (2002), a contract change order is a written request signed by the architect, contractor, and owner made after the contract is issued, who has the authority to change the scope of work or make adjustments to the contract value and completion time.

The project control method uses Microsoft Project to determine early whether the design change can solve the problem more efficiently in terms of time and cost (Nusen et al., 2021; Shoar & Chileshe, 2021). According to Buluatie (2013), the Time-Cost Trade-Off method provides an alternative to project planners to prepare the best plan so that they can optimize time and cost in completing a project and assign resources to streamline resource allocation, thereby obtaining the desired resources with the most optimal cost increase. Adde Currie Siregar said that in the project control method using Microsoft Project, there is also a critical path that can be seen, namely the path that has a series of activity components with the longest total duration. The critical path consists of a series of critical activities, starting from the first activity to the final activity of the project.

The construction of the Kadusirung Dua Underpass Project, Banten, is expected to increase access points for residents around Pagewith Legok Banten, who will travel to the BSD area, as well as those going to Jakarta through the Serang-Balaraja toll road, which is connected to the Kadusirung Dua underpass (O'Brien, 2019). The transverse underpass project under the Serang-Balaraja Toll Road is planned to be completed in 380 working days with a cost budget of Rp. 174,012,734,021 (Shen & Xu, 2020). The construction of this project is estimated to be completed as planned within a duration of 32 months, provided that there are no significant delays in the construction schedule (Yang & Wang, 2018). Along with the target of completing the all-round toll road that must cross this underpass, with this very strict target, an analysis is carried out so that the acceleration of this underpass work can run according to the schedule for the opening of the all-round toll road (Li et al., 2021). Therefore, several acceleration analyses were conducted by comparing the initial plan design with the new design as a result of the development of several additional land investigation results (Zhao & Wu, 2017). These studies aim to optimize project completion time and cost reduction by refining the design based on unforeseen factors (Peng, 2019). The completion time was faster, and the cost could be reduced due to the reduction of several designs, which illustrates the importance of proactive management in large-scale infrastructure projects (Tan & Lee, 2018).

The construction industry frequently faces challenges related to design changes, particularly when inadequate soil investigations lead to unforeseen geotechnical issues during project execution. Despite established standards such as *SNI 8460:2017* for soil testing, many projects still encounter costly and time-consuming redesigns due to insufficient initial surveys. This research addresses a critical gap in the literature by examining the direct impact of soil survey inadequacy on engineering design changes, cost overruns, and delays, using the Kadusirung Dua Underpass Project as a case study. While previous studies have explored design change management, few quantify the financial and temporal consequences of geotechnical oversights in the planning phase, highlighting the need for this investigation.

The urgency of this research stems from the escalating costs and delays plaguing infrastructure projects in Indonesia and similar regions, where rapid urbanization demands efficient construction practices. The Kadusirung Dua Underpass Project exemplifies these challenges, as landslides necessitated redesigns, inflating costs by Rp 43.6 billion and extending timelines by 566 days. Such inefficiencies undermine economic growth and public trust in infrastructure development. By analyzing this case, the study provides actionable insights for policymakers and engineers to prioritize thorough geotechnical assessments, thereby minimizing disruptions and optimizing resource allocation in future projects.

The novelty of this research lies in its integration of the *Cost of Change vs. Opportunity to Influence* theory with empirical data to demonstrate how early-stage design precision can yield significant savings. Unlike prior studies focusing solely on contractual or managerial aspects of design changes, this work quantifies the benefits of proactive soil investigations, revealing potential savings of 25% in time and 18% in costs. The implications extend beyond the case study, offering a framework for global construction practices to enhance planning rigor, reduce risks, and align with sustainable development goals. This research thus bridges theory and practice, advocating for a paradigm shift in geotechnical preparedness to ensure project resilience.

RESEARCH METHOD

This research was conducted on the project object located in Banten Province, specifically on the Kadusirung 2 BSD City Underpass project. This study uses secondary data obtained from the project and is divided into two conditions: the first condition occurs when there is an error in determining the type of soil at the initial planning stage, causing the design to be changed while the project is ongoing; the second condition occurs when the design change is made before the construction stage begins.

The main purpose of the study is to obtain data on additional work items required to overcome the landslide problem. Through this data processing, the researcher will obtain data that meets the set standards. Secondary data in condition 1 allows estimation of work items, construction costs, and execution duration if design changes occur during the construction period. Meanwhile, in condition 2, estimates can be made for work items, construction costs, and implementation time optimization if design changes are made before the construction phase begins.

RESULT AND DISCUSSION

Chronology of Changes in Underpass Construction Design

In the initial planning of the Kadusirung 2 Underpass project, the underpass design used a box structure and used a minipile foundation, while the design was obtained from the initial soil investigation with the drill soil investigation report in the SPT carried out as many as 28 points.

Underpass structure plan design

Based on the results of the land investigation, the consultant designed a drawing of the Box Underpass plan located on the Serbaraja BSD Barat toll road phase II-3, BSD City, Tangerang is planned to have a height and width in a box of 12,075 x 5.3 meters 2 Cell, designed with concrete (cast in-situ) consisting of each cell of pedestrian lane (1.0 m) + traffic lane (3 x 3.5m) and pedestrian lane (0.575 m) = 12,075 m. toll roads with a total of 2x2 lanes in each direction and added with plans to widen or add lanes in the future.

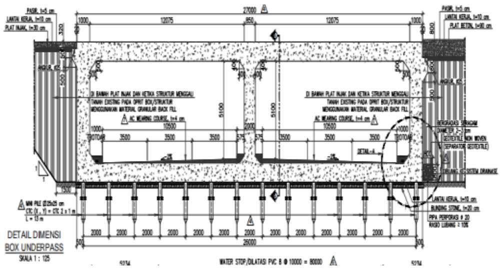

Figure 1. Underpass Structure

The initial cause of the Underpass Construction Redesign

During the construction period, by following the plan design, when excavating for the Maindrain location, where the excavated location is almost 6-7 meters deep, and when carrying out the preparation for casting the working floor, the soil condition is in accordance with the plan level, the soil undergoes an uplift or a condition where the soil has a significant increase of 60cm, within 1 hour, and the condition of the soil retaining sheet pile has shifted to 3m from the starting point, can be seen in the picture below.

Figure 2. Underpass Construction Design

Seeing these conditions, the owner instructed to postpone all work in the underpass area.

Comparative Comparison of Soil Testing and Initial Design Work and New Design

Based on SNI 8460 of 2017, it is stated that soil investigation standards for transportation tunnels and for soil construction that have soft clay properties have the following soil investigation standards.

1. Soil Log Drill Test (Boring Test)
2. Standard penetration test (SPT) is carried out every 2m interval
3. Sondir Test
4. Testing of electrified sondirs with potty water stress measurement (CPTU)
5. Laboratory testing
   . Testing of Soil Index Properties
   . Testing of triaxial undrained unconsolidation (UU), Consolidated Undrained (CU)
   . Direct shear test
   . Condolid Test.

With the soil testing standards for transportation tunnels and soft clay soils above, it can be concluded that the initial soil testing in the Kadusirung Underpass Project does not meet the soil testing requirements to design an underpass construction, so in the construction process of the Kadusirung Underpass Project after the landslide, an additional soil investigation is carried out to ensure the strength of the plan design but after the additional soil investigation is carried out with the following data.

Table 1. Initial and New Design Data

Initial Design	New Design
Initial soil data 1. Sondir Test (CPT) 10 points 2. Boring Test 18 points	Additional soil data for construction implementation: 1. Drilling (deep boring) 2 points @ 40 m 2. SPT interval SPT interval 2.0 m 3. Undisturbed 4. Piezocone Test (CPTu) Laboratory Work: 1. Natural Moisture Content 2. Bulk Density 3. Specific Gravity 4. Grain Size Analysis 5. Unconfined Compression Test 6. Triaxial UU Test 7. Triaxial CU Test 8. Direct Shear Test

Additional Soil Investigation During Construction

The soil investigation was carried out after there was a landslide/landslide in the area of the main drain location that was excavated, where when the excavation occurred, the surrounding soil experienced a landslide, and project activities were stopped to re-carry out the soil investigation, and the output of the planner hoped that it could be applied to become a safe building. at the time the Kadusirung Underpass project located in BSD is underway to provide information about the actual soil condition at the location to interested parties and consultants so that the analysis carried out can be carried out thoroughly, accurately and economically. The results of this data will be processed and become a new design as well as to obtain a new design for the protection of soil retaining walls. Soil investigation work is carried out in the area of the project site where the landslide is very significant, but other areas are also taken to determine the subsoil structure, work done in the field and laboratories can be seen in the table below.

Table 2. Project Workers

Type of Work	Quantity
Field Geotechnical Work: 1. Drilling (deep boring) 2 points @ 40 m 2. SPT interval SPT interval 2.0 m 3. Undisturbed 4. Piezocone Test (CPTu) **Laboratory Work:** 1. Natural Moisture Content 2. Bulk Density 3. Specific Gravity 4. Grain Size Analysis 5. Unconfined Compression Test 6. Triaxial UU Test 7. Triaxial CU Test 8. Direct Shear Test 9. One Dimensional Consolidation	80 m 40 pieces 2 pieces 3 points Laboratory Work: 2 tests 2 tests 2 tests 2 tests 2 tests 2 tests 2 tests 2 tests 1 test

The conclusions from the results of soil yield data collection are:

1. Drilling data is known that the soil layer from the beginning of the test to a depth of 5-7 m is dominated by silt clay soil with soft conditions.
2. The layer of 8-20 m is known to contain a very soft silt layer.
3. The 18-24 m layer is dominated by silt sand and is very hard
4. Layer 30-37 m of very hard sand layer with hard consistency
5. The yield of soil face was obtained at a depth of 4-7 m from the existing elevation
6. From a depth of 10-18 m, the soil is estimated to still experience consolidation and the possibility of a landslide field where further analysis is needed.

Underpass Structure Redesign

Soil surveys are carried out in the field and in the laboratory so that the consultant issues a new underpass design, which can be seen in the picture below. Where the latest design there are significant changes in the thickness of the upper slab is larger and the Underpass wall on all sides is eliminated and uses secant pile as the Underpass wall.

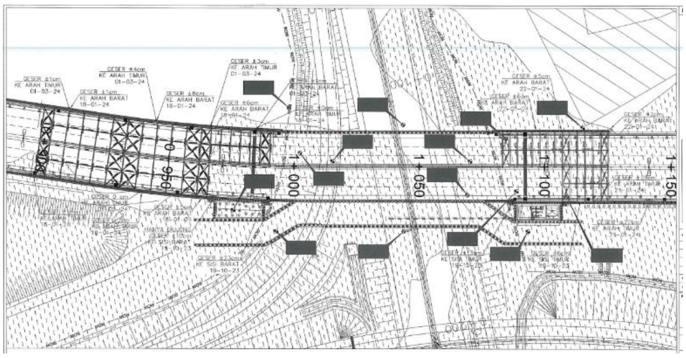

Figure 3. Underpass Design

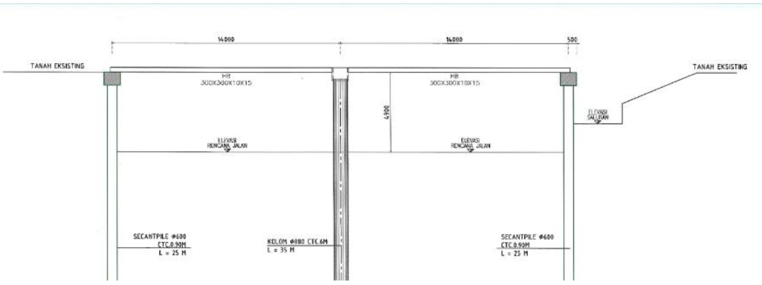

Figure 4. Underpass Design

Landfill work

The stockpile work is carried out only in the area of heavy equipment that works as a platform for the establishment of drilling tools, piling tools and material supply road access. The backfill work using good soil and compacted for soil improvement is replaced with another soil improvement method, namely using bamboo piles with geotextile as a locking material for class B aggregate material.

Mini Pile Work

The minipile work on the underpass is still carried out, but the minipile work on the Maindrain is eliminated, so that the mini pile work is faster than the implementation, and it is less work on the owner's side. However, it is an additional work on the lower slab by adding concrete corbels and chemical anchors.

Secant Pile Underpass and Maindrain Works

The work of adding secant piles in the Underpass and maindrain is carried out simultaneously and by utilizing the borepile as a substitute for the concrete wall of the Underpass, so that the work uses less iron for the underpass and maindrain walls. With the method of integral concrete pile waterproofing, the underpass and maindrain are side by side.

Top-Down Underpass and Maindrain Excavation.

The implementation of the top slab is done first, the advantage is that the all-round toll road work can be done at the same time as the Underpass work is carried out, and excavation with *a Top-Down* system takes a long time, but if it is done from both sides by adding heavy equipment, then *the Top-Down* excavation work can be done faster

Ramp Excavation Work

Good soil replacement work is eliminated so that excavation and replacement work is replaced with bamboo piles, so that the work is faster and the quality is better.

Data Analysis of Initial Design Costs and New Designs

The initial design of the Underpass project could not be implemented due to landslides, so additional soil investigations were carried out which resulted in the emergence of new designs. In the implementation of the construction work of the Kadusirung 2 Access Underpass, there are two types of costs, namely the cost of work before the landslide occurs, and the cost of work after the landslide occurs.

Work Costs Before Landslides

In the data on the planned cost budget for the construction of the Kadusirung 2 Access Underpass, the total amount of the project cost budget for soil work, soil retaining wall structures and minipiles is Rp 38,893,949,186. Can be seen in the table below

Initial Design Soil Data Testing Cost

In the initial design land data testing, a cost of Rp. 45,500,000 (Forty-five Million Five Hundred Thousand Rupiah) was incurred with a soil survey time of 20 days.

Work Costs After Landslides

From the results of the calculation of the change in design due to landslides, the budget cost after the landslide can be detailed with the following calculation of Rp. 43,641,840,000.

Additional Land Survey Fees

In the additional soil testing inspection due to the occurrence of landslides, a fee of Rp. 84,375,000 (Eighty-four million three hundred and seventy thousand rupiah) is required with a soil investigation time of 45 days.

As a result of the failure of the land, namely landslides, there was an additional cost of Rp. 43,641,84,000, and made the contract value increase with details. Initial Contract Value + Supplementary Contract Value: Rp. 174,012,734,021 + Rp. 43,641,84,000: Rp. 217,654,574,021. The contract cost after there is work increases to Rp 217,654,574,021, and if from the beginning the design has used appropriate land data, the construction cost that should not have been carried out is Rp 38,893,949,186. With this design change, the total work of this change has obtained several points, including:

1. The cost of the work plan increased due to design changes caused by landslides, which amounted to Rp. 43,641,84,000
2. The total initial design work amounted to Rp. 174,012,734,021 and then increased by Rp. 43,641,84,000, so that the contract value increased after experiencing a design change to Rp. 217,654,574,021
3. If from the initial design it has used appropriate and appropriate soil data, then the construction cost that should not be carried out is Rp 38,893,949,186
4. If from the beginning you have carried out a soil inspection at a cost of Rp. 84,375,000, then you can save costs of Rp. 38,893,949,186.
5. If from the beginning you have used an improved design, the optimal cost is obtained as follows.
   = Contract value after added work – Value of unnecessary costs incurred
   = Optimal Cost
   = IDR 217,654,574,021 - 38,893,949,186
   = IDR 178,760,624,835

Time Performance

The performance of the implementation time can be determined by applying a fast and efficient work method between the plan design and the new design, and additional items to speed up the work.

Microsoft Project Design Plan Analysis

To analyze the project condition in terms of time, I tried to analyze the critical areas of the Kadusirung Underpass project through Network Planning. The results of critical activities from the analysis using Microsoft Project that have been summarized can be seen in the table below.

Table 3. Plan Design

NO	WORK DESCRIPTION	DURATION (Days)
1	Embankment work	120
2	Secant pile work	240
3	Mini pile work	116
4	Underpass and ramp excavation work	60
5	Secant pile capping beam structure work	270
6	Pump house structure work	90
7	Pump house M&E work	50

In the Microsoft project above, it can be seen that the initial schedule of the work, if it is in accordance with the initial contract and additional time due to additional work caused by landslides, the work will start on September 1, 2022 and the work is planned to be completed on April 16, 2026 with a work duration of 946 days. The time schedule of Ms Project above can be simulated using the S Curve

Microsoft Project Redesign Analysis

To analyze the existing conditions in terms of cost and time, the same method is used, but there are some changes in design and working methods, which can be seen in Redesian network planning. In the analysis of time optimization with the new design using the Microsoft project above, it can be seen that the duration of work using the new design can be completed in 709 days, if the work starts on September 1, 2022, then the work of the Kadusirung 2 Underpass can be completed on April 20, 2025. The time schedule of Ms Project above can be simulated using the S Curve.

Table 4. Project Redesign

NO	PLANNED WORK DESCRIPTION	REDESIGN WORK DESCRIPTION
1	Embankment work 60 days	Volume reduced by 30 days
2	Reduced Underpass wall structure work 120 days Open cut	Added secant pile top-down excavation Underpass work 240 days
3	Reduced mini pile Maindrain work 68 days	Becomes reduced work due to method change
4	Underpass and ramp excavation work	Work method changed
5	Secant pile capping beam structure work	Volume added
6	Pump house structure work	Method changed and work method added
7	Pump house M&E work	Volume added and work method changed

Data Analysis on Cost and Time

Project time and cost efficiency is the comparison between the time and cost of the project plan and the time and cost of the project after acceleration is carried out using a new design and method of accelerating the addition of work items (redesian). Based on the calculation of the time and cost of the project with the initial design and increased due to the new design is 946 days of the plan implementation contract at a cost of Rp 217,654,574,021, and the work results according to the redesign of the optimal time and cost are 709 days with an optimal cost of RP. 178,760,624,835, then the percentage of project time and cost efficiency can be calculated as follows.

Time efficiency

= (((946 – 709) / 946) x 100%)

= 25.05%

Cost efficiency

=((IDR 217,654,574,021– 178,760,624,835) / IDR 217,654,574,021) x 100%)

= 17.87 %

Furthermore, from the cost data above, the additional cost is recapitulated according to the data in the table below:

Table 5. Cost Data

No	Item	Value
1	Initial Contract	174,012,734,021
2	Additional Work Cost	43,641,840,000
3	Initial Contract + Addendum	217,654,574,021
4	Cost If using optimal design	178,760,624,835
5	Savings Value	38,893,949,186
6	Additional Soil Testing Cost	84,375,000
7	Initial Soil Testing Cost	45,500,000

The total cost incurred is IDR 217,654,574,021, with details of IDR 174,012,734,021 of the initial contract value and IDR 43,641,840,000 of additional costs due to the landslide.

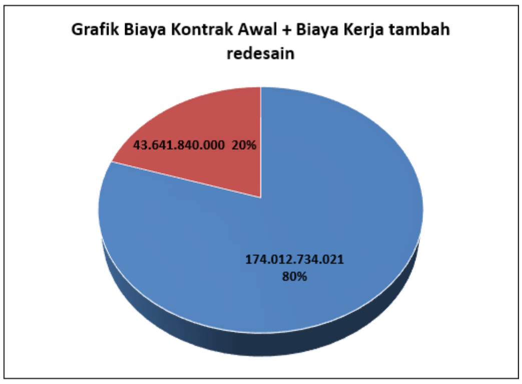

Figure 5. Cost Chart

If the land investigation is perfected from the beginning with a land investigation cost of Rp.84,375,000, then from the total cost incurred of

Rp.217,654,574,021, savings of Rp.38,893,949,186 can be made and the optimal cost is Rp.178,760,624,835.

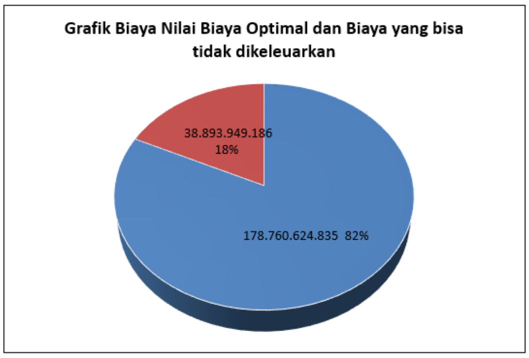

Figure 6. Cost Chart

Furthermore, from the data of the subtraction time table, the table can be recapitulated below:

Table 6. Data Recapitulation

No	Item	Time
1	Initial Contract Duration	380
2	Time Extension Duration	566
3	Addendum Contract Duration	946
4	Duration that can be eliminated	237
5	Optimal Duration	709

The total time carried out is 946 days with details of 380 days of initial contract duration and 566 days of additional duration due to landslides.

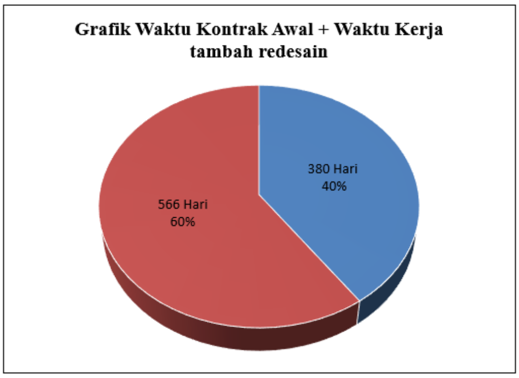

Figure 7. Cost Chart

If the land investigation is perfected from the beginning with a land investigation cost of Rp.84,375,000 and a soil investigation time of 45 days.

Therefore, from the duration of the final contract for 946 days, an efficiency of 237 days can be carried out with an optimal duration of 709 days.

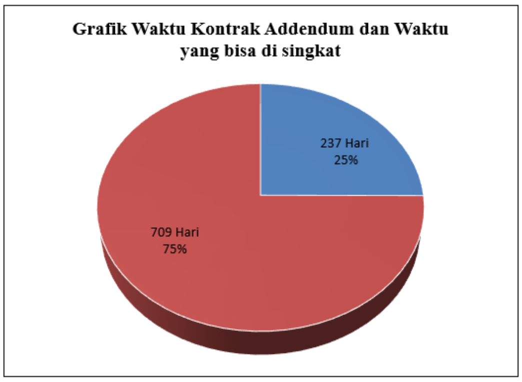

Figure 8. Cost Chart

Summary of Analysis Results

From the results of the research that has been carried out, the following analyst results are obtained.

1. In the initial construction planning, the soil data only used sondir test data of 10 points and log drill testing as many as 18 points and caused work that should not be done, namely Landfill work, Excavation work, Replacement of maindrain soil, Minipile maindrain work, Maindrain wall work, Underpass wall work, Re-landfill work, Underpass soil replacement work. Then if the soil data from the beginning is carried out comprehensively, namely Drilling (deep drilling) 2 points @ 40 m SPT interval SPT interval 2.0 m Undisturbed, Piezocone Test (CPTu), Natural Moisture Content, Bulk Density, Specific Gravity, Grain Size Analysis, Unconfined Compression Test, Triaxial UU Test, Triaxial CU Test, Direct Shear Test. Then a design that has met the strength for the underpass project will be designed, namely with the design of soil improvement work with piles, anchor chemical work, maindrain cable ironing work, underpass cable ironing work, secant pile work, lower slab pile work, underpass excavation work (top down), maindrain excavation work (top down), soil reinforcement work with geotextile.
2. Based on the calculation of time and costs, the time needed is 946 days at a cost of IDR 217,654,574,021 due to new design changes.
3. Based on the results of the analysis using the theory of Cost of Change vs. Opportunity to Influence obtained similar results, namely design changes if carried out from the beginning of the planning period will reduce the cost of additional construction and increase the implementation time, if the design change is only known after the construction period has been running, resulting in greater construction costs and implementation time. This is in

line with the previous theory which stated that design changes should be made at the planning stage. Design changes during the construction phase should be avoided as much as possible, as they can lead to a more significant increase in costs than if the changes were made during the planning phase.

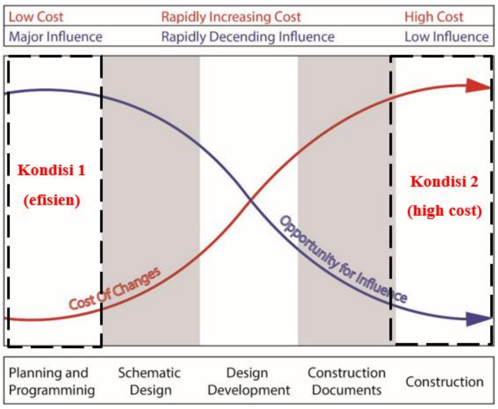

Figure 9. Teori Cost of Change vs. Opportunity to Influence

Thus, the optimal time and cost due to the change in design and optimal cost (Condition 1) was obtained with a project time duration of 709 working days with a total project cost of Rp.178,760,624,835 with a project time efficiency of 237 days (25.05%) and project cost efficiency of Rp.38,893,949,186 (17.86%). And based on the results of the study (Condition 2), it was obtained that the project implementation time was 904 days with details of 60% (566 days) of the initial contract duration and 40% (380 days) of the duration of the additional contract due to the landslide, and the total cost incurred was Rp 217,654,574,021, with details of 80% (Rp. 174,012,734,021) of the initial contract value and 20% (Rp.43,641,840,000) of the additional costs due to the landslide.

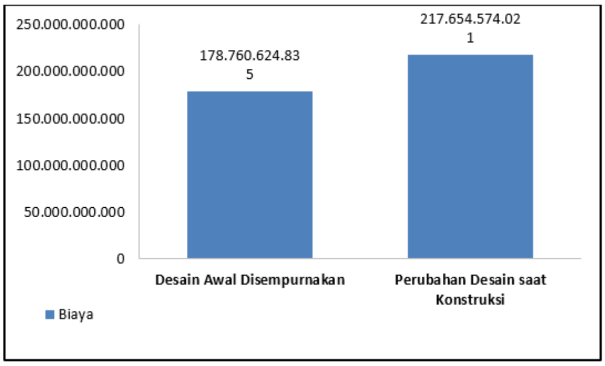

Figure 10. Cost Recapitulation Data

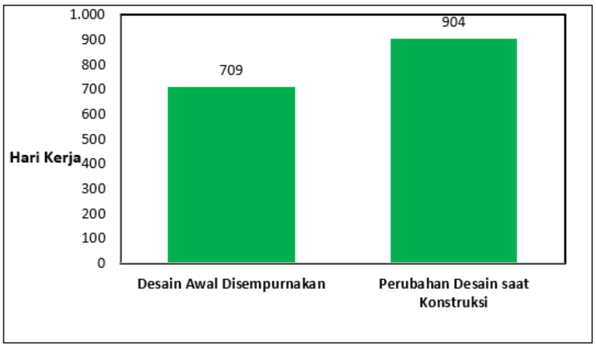

Figure 11. Cost Recapitulation Data

4. The initial soil investigation was carried out at a cost of Rp 45,500,000 for 20 days. If the land investigation is continued with improvements that require a cost of Rp 84,375,000 and an implementation time of 45 days, and the investigation is carried out from the beginning, then a cost savings of Rp 38,893,949,186 and a time savings of 237 days can be obtained.
5. The use of Microsoft Project can determine critical areas at the location of the underpass for land preparation work, the structure of the underpass and the maindrain cost of the work can be substituted with the presence of additional and less work.

CONCLUSION

Design errors identified during the construction phase can lead to increased costs and significant time delays. This is in accordance with the theory of *Cost of Change vs. Opportunity to Influence*, which indicates that design changes should be made at the planning stage. Design changes during construction should be avoided as much as possible, as the impact on costs will be much greater than if the changes were made at the planning stage. Based on *SNI 8460 of 2017*, the soil investigation carried out to design the Kadusirung 2 underpass was not sufficient to meet the soil inspection standards for transportation tunnels with soft soil conditions. If design errors are detected at the planning stage or at the beginning of construction with a soil investigation in accordance with *SNI 8460 of 2017*, the savings that can be obtained can reach 25% of the total time implemented and 18% of the total cost.

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