Estimation of earthwork volume for Klarik-Teluk Buton road construction in Natuna Regency, Riau Island

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Abstract. Earthworks (land cutting and filling) are crucial initial stages before undertaking the road and bridge projects. These work processes are carried out to achieve the road's desired elevation and soil density according to the project plan. Land's cutting and filling volumes in the road projects can be calculated based on topographic mapping. Further, the data on land's cutting and filling volumes can be used to determine the total required soil for construction work. This study attempts to estimate the total volumes of excavation and landfilling works along the Klarik-Teluk Buton road development in Natuna Regency, Riau Islands Province. The method employed to calculate excavation and landfilling volumes for the Klarik-Teluk Buton Road Development is the composite volume method, which involves calculating the difference in elevation between the original and planned surface contours using AutoCAD Land Desktop 2009 software. The calculations show an excavation volume of 40.112 m^3 and a landfill volume of 142.867 m^3 for the area of the Klarik-Teluk Buton Road. Based on the calculations, it is found that there is a shortage of 102.755 m^3 of landfilling soil for the Klarik-Teluk Buton road development.

1 Introduction

Roads and bridges constitute foundational infrastructure elements that are paramount to human societies. Their pivotal role is enabling seamless movement between disparate locations, effectively addressing a spectrum of human needs [1-3]. In alignment with the stipulations of Law Number 38 of 2004, roads and bridges assume pivotal roles across diverse domains encompassing economics, socio-cultural dimensions, environmental considerations, politics, defence, and security [4].

These transportation conduits fundamentally underpin the vitality of communities, nations, and states, imparting significant impetus to developmental endeavors, particularly in regional expansion [5-7]. Roads, functioning as communication arteries, interconnect disparate locales, facilitating the movement of individuals and commodities. As primary vehicular conduits, roads foster economic growth by augmenting accessibility to markets and resources [8]. Furthermore, they foster socio-cultural cohesion by fostering interactions across diverse demographic origins. Conversely, bridges, possessing foundational significance, facilitate the traversal of natural impediments such as rivers, valleys, and variances in terrain, thereby engendering economic and social enhancement in previously isolated areas.

Their establishment establishes efficient linkages between regions segregated by geographical barriers. The contemporary landscape witnesses' notable strides in construction and development within Riau Island. This progress crescendo has engendered a pressing need for road establishment to facilitate community mobility and engagement. Among ongoing endeavors, the Klarik-Teluk Buton road project garners attention, currently navigating the path toward realization. Within the composite construction framework, the earthwork phase emerges as an elemental enabler, primarily in quantifying the volume of soil requisite for project materialization [9].

Road development constitutes a pivotal stride in the broader spectrum of infrastructural expansion within Riau Island. Novel roadways are poised to unlock hitherto inaccessible domains, fostering interurban and intervillage linkages and catalyzing economic dynamism within the locale [10]. The ongoing Klarik-Teluk Buton road construction seeks to amplify and extend the transportation grid, rendering essential services and facilities easily accessible to residents. This mission is paramount in surmounting the mobility challenges intrinsic to island territories, characterized by maritime and topographical complexities. The strategic design of this road aims to yield pronounced advantages, including heightened travel efficiency, augmented accessibility, and the facilitation of routine pursuits.

Across the spectrum of road erection, earthwork emerges as the fulcrum for determining the quantum of earth required. Accordingly, a methodically structured inquiry and precise quantification are indispensable

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prerequisites for realizing optimal and sustainable outcomes. Earthwork constitutes a seminal precursor stage preceding the initiation of construction proper, prominently in securing the stipulated elevation. This is particularly consequential because field-measured elevations might diverge from preconceived intentions. Hence, excavation and landfilling maneuvers assume quintessential roles in realigning these contours with stipulated blueprints [11].

Symmetrically calibrated in measurement and computation, excavation and landfilling phases entail a sequential operational logic. Excavation commences antecedently, clearing the terrain and yielding soil resources earmarked for landfilling formation. Subsequently, the landfilling phase rectifies elevation disparities in specified sectors, culminating in attaining intended benchmarks [12].

Lapses in computation or execution during the earthwork phase have the potential to exert substantial ramifications upon the ultimate outcomes of road creation. Thus, a meticulously conceived prelude, precise metrics acquisition, and fidelity to executing earthwork emerge as the cornerstones underpinning the viability and caliber of secure and sustainable road infrastructure. The earthwork optimization constitutes a propellant for overarching road projects, concomitantly nurturing efficiency, safety, and user amenities.

Numerous methodologies are amenable for quantifying excavation and landfilling volumes in road initiatives, with the Composite Volume technique emerging as the chosen modus operandi in this investigation. This methodology predates excavation and landfilling volumes upon differential contour elevations between the native terrain and schematics harnessed via AutoCAD Land Desktop 2009 software. Integrating software utilities such as AutoCAD Land Desktop 2009 and Microsoft Office Excel confers operational expediency upon volumetric quantification tasks, accentuating efficiency and precision.

The study's intent resides in the precise computation of excavation and landfilling volumes within the Klarik-Teluk Buton Road in Natuna Regency, Riau Island. Through the lens of the Composite Volume method, encapsulated within the Autocad platform, derived volumetric indices prognosticate excesses or deficiencies in soil quantum pertinent to the road construction initiative. Consequently, the research's thrust materializes as a substantive and contributory facet in orchestrating the unobstructed and prosperous four development of road infrastructure, consonant with stipulated blueprints and extant technical benchmarks. Rigorous excavation and landfilling volume calculations serve as the lynchpins to obviate potential resource wastage, ensuring both efficiency and the caliber of the road construction endeavor.

2 Research methodology

2.1 Research location

This study was predominantly conducted along the Klarik-Teluk Buton Road in the Natuna Regency, Riau Island Province. The road spans a total length of approximately 10.902 km. The sketch of the research location is depicted in Figure 1, with starting coordinates at 4°03'05" N and 108°01'47.3" E. Meanwhile, Figure 2 illustrates the original condition of the road before measurement and construction.

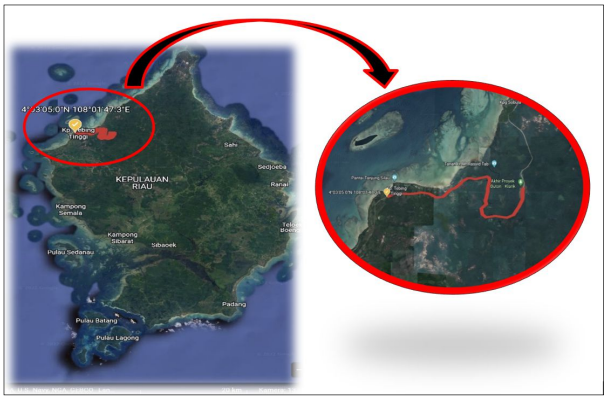


Fig. 1. The sketch of research location.

Fig. 2. Original condition of klarik-teluk buton road.

2.2 Research flow

The research initiates with an intensive literature review phase, serving as the preliminary groundwork. During this stage, an exhaustive exploration, compilation, and analysis of pertinent literature about the research subject are undertaken to gain a profound comprehension of the topics under investigation. Subsequently, field data is amassed by employing a total station instrument to measure the surface elevation along the Klarik-Teluk Buton Road. This meticulous measurement procedure ensures the acquisition of accurate and pertinent data for subsequent analysis.

Once the field data collection phase is concluded, it progresses to the data processing stage, where the Klarik-Teluk Buton Road's topographic map is generated. This topographic map functions as an intricate visual portrayal of the road's topographical features and terrain conditions, rendering a detailed insight into the characteristics of the land.

In this study, Figure 3 is an illustrative representation of the research sequence, embodied in a flowchart. This depiction provides a comprehensive and organized visual portrayal, effectively encapsulating the successive stages of the research process.

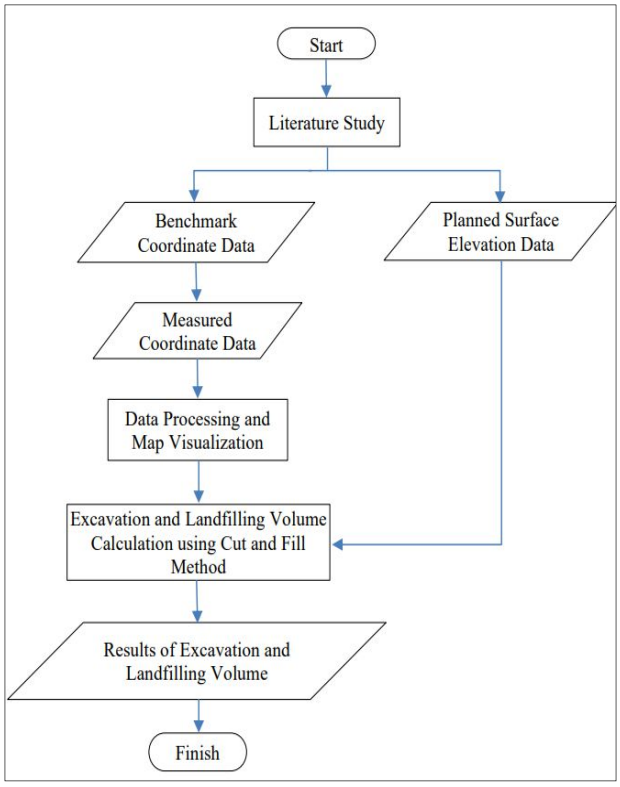


Fig. 3. Research flowchart.

The ensuing phase of data processing encompasses the quantitative assessment of excavation and landfilling volumes, executed through the application of the composite volume method, aligning with the projected elevations of the project. The selection of this method is attributed to its efficiency in computing excavation and landfilling volumes by accounting for variations in elevation between the natural terrain and the envisioned design. The derived excavation and landfilling volume outcomes are pivotal, offering indispensable insights into the soil requisites for undertaking the Klarik-Teluk Buton Road construction.

2.3 Method of data collection

Throughout this research compilation, the data utilized encompasses both primary and secondary sources. Primary data is procured through direct field measurements. Concurrently, secondary data is obtained through collaboration with PT Maju Bersama Jaya Group and PT. Astadipati Duta Harindo. To acquire primary data, survey techniques are employed in the field to obtain topographical data pertinent to this study. In this data collection technique, the Total Station CX-105 instrument is employed to conduct measurements along the Klarik-Teluk Buton Road.

The measurements undertaken along the road yield data in the form of original surface coordinates, furnishing detailed insight into the topography and elevation of the land at the research location. The primary data obtained from these direct measurements are pivotal and serve as the foundation for further analysis, including the computation of excavation and landfilling volumes and the creation of the topographic map of the Klarik-Teluk Buton Road. Meanwhile, secondary data acquired from PT Maju Bersama Jaya Group and PT. Astadipati Duta Harindo contribute relevant supplementary information, bolstering and supporting this research. Integrating both primary and secondary data is a crucial step, ensuring data completeness and accuracy within this study.

2.4 Method of data processing

Computational calculations are conducted using Autocad Land Desktop 2009 software during the data processing phase. The chosen method is the composite volume technique, which necessitates the generation of two types of surfaces: the existing surface and the planned surface, based on the establishment of a Digital Terrain Model (DTM). This DTM furnishes a digital representation of the ground surface topography.

Following the creation of both surfaces, the computation of excavation and landfilling volumes ensues by importing the established surfaces into Autocad software. Subsequently, the software performs analysis using the Terrain – Volume Calculation – Composite Volume feature. The composite volume method is selected for its capacity to calculate excavation and landfilling volumes based on the elevation differential between the existing surface and the planned project surface. The outcomes of these volume calculations are pivotal for comprehending soil volume requirements within the Klarik-Teluk Buton Road construction project. With computerized data processing techniques and the utilization of sophisticated software, such as Autocad Land Desktop 2009, it is envisaged that data analysis will be conducted more efficiently and accurately, thereby significantly contributing to the smooth progression of this research.

3 Result and discussion

The culmination of this study lies in the interpretation and deliberation of the outcomes obtained through meticulous data collection and processing. The results encapsulate valuable insights that shed light on the research's practical implications, particularly in the Klarik-Teluk Buton Road construction project context.

3.1 Topographic mapping and visualization

Figure 4 presents the topographic map of the original state of the Klarik-Teluk Buton Road. This map is not merely a graphical representation; it encapsulates information about the road's natural topography and terrain characteristics. This map offers a panoramic insight into the elevation contours and variations along the road by employing a total station instrument for field measurements. Consequently, it serves as a cornerstone in understanding the groundwork for the road construction project. Visualizing the road's topography not only aids in appreciating its existing state but also acts as a basis for further evaluations and calculations.

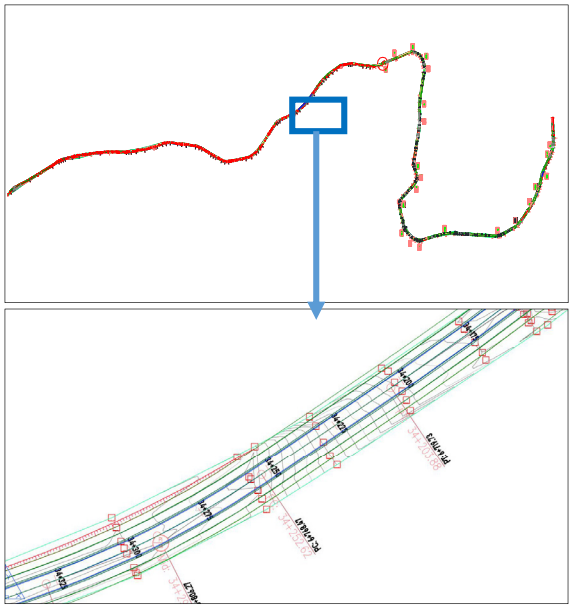
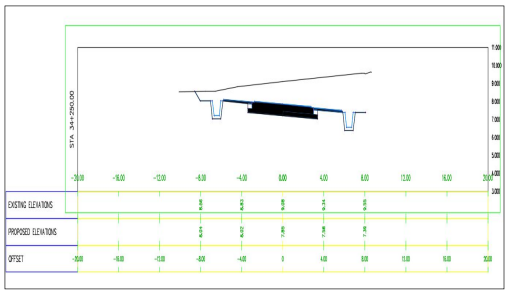


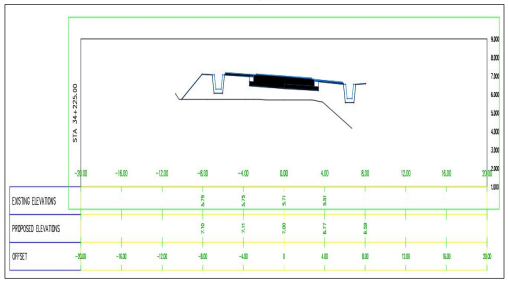
Fig. 4. Topographic map of Klarik-Teluk Buton road.

3.2 Cross-Sectional profiles

The cross-sections depicted in Figure 5 provide an added layer of comprehension of the road's elevation profile. Specifically, these profiles contrast the original state with the planned elevation/cross-section for select locations, exemplified by STA 34+250 (cutting location) and STA 34+225 (filling location). These cross-sections highlight the elevation differences and variations between the existing topography and the proposed road design. This visualization aids engineers and project managers identify areas where elevation adjustments are required to achieve the desired road layout. Considering these profiles, the construction team can strategize handling elevation discrepancies, ensuring a smooth and well-aligned road surface.



(a)



(b)

Fig. 5. Cross-section/Elevation for STA 34+250 (a) and STA 34+225 (b).

3.3 Excavation and landfilling volumes

Applying the Composite Volume method yields crucial insights into the required soil volumes for the Klarik-Teluk Buton Road construction. The computation reveals that an excavation volume of 40.112 m3 is necessary to create the road's formation. This excavation determines the earthwork requirements and offers insights into the landscape's composition and characteristics. On the other hand, a landfilling volume of 142.867 m3 is essential to raise the road's elevation to the desired level. These volume calculations directly impact material sourcing, logistics planning, and budget considerations. Furthermore, they offer engineers and construction teams a tangible metric to ensure the project's feasibility and to align execution with project goals.

3.4 Addressing the landfilling volume deficit

One of the significant revelations from the results is the apparent deficiency of approximately -102.755 m3 in landfilling volume. This deficit indicates a critical challenge that must be addressed to ensure the successful completion of the road construction. The practical implications of this shortage are twofold. Firstly, it emphasizes the importance of accurate volume calculations and material management during construction planning. Neglecting these calculations could lead to delays, resource shortages, and budget overruns. Secondly, it underscores the need for strategic solutions to source soil volume from external locations. This prompts a comprehensive evaluation of alternative areas for soil procurement while factoring in logistical considerations, environmental regulations, and transportation feasibility.

3.5 Important of sustainable development

Integrating environmental considerations within construction projects is increasingly critical in modern infrastructure development. The results of this study underline the need for sustainable development practices. While addressing the landfilling volume deficit, exploring supplementary soil resources while maintaining environmental balance becomes essential. By conducting thorough analyses of potential soil sources, the project can adhere to sustainable practices that safeguard local ecosystems and resources.

In sum, the results and discussion chapters provide a comprehensive understanding of the practical implications of the research. They emphasize the significance of accurate topographic data, precise calculations, and sustainable development practices in ensuring the successful completion of the Klarik-Teluk Buton Road construction project. The deficiencies highlighted underscore the importance of meticulous planning, resource management, and coordination with stakeholders and external entities. By addressing these challenges head-on and adhering to best practices, the road project can achieve its goals while minimizing environmental impact and ensuring long-term viability.

4 Conclusion

Based on the outcomes outlined and discussed within this study, we can deduce that the utilization of the Composite Volume method in the Klarik-Teluk Buton Road construction project yields an excavation volume of 40.112 m3 and an embankment volume of 142.867 m3 for a road length of approximately ±11.000 km. This information proves invaluable in comprehending the soil volume requirements for this project and provides a more detailed insight into the soil characteristics at the research site. However, we have identified a deficit of approximately 102.755 m3 of soil volume in the embankment creation process, necessitating procurement from alternative construction sites to fulfil optimal embankment requirements.

The significance of this soil volume deficiency underscores the necessity for careful consideration during project planning and implementation stages to ensure the availability of sufficient materials to achieve the intended elevation and soil density following the design. In this context, the stakeholders involved in the Klarik-Teluk Buton Road construction project must further evaluate soil resources that can be utilized as supplementary embankment material.

This step ensures material adequacy and project smoothness. Moreover, the project's success is contingent upon effective coordination with relevant entities at other construction sites to obtain additional soil resources in line with prevailing technical standards and environmental regulations. Consequently, appropriate strategic measures to meet embankment requirements stand as pivotal factors in the success and sustainability of this road construction venture.

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