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Time and Cost Analysis of Walls (Load-bearing and Non-load-bearing) for Multi-family Houses

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Abstract
In the construction industry, the budget and completion time of a project are the most critical factors determining its success or failure? Exceeding these parameters can result in substantial financial losses for investors. Therefore, this research aims to emphasize the significance of accurate and detailed cost estimations and scheduling in residential projects, with a specific focus on wall elements. By synthesizing the theoretical frameworks of various literature pieces, this study identifies the most effective methods for cost and time estimation. The S-curve model generated from these estimations enables project monitoring and control, mitigating the risk of cost overruns. Furthermore, this research presents a Building Information Modelling (BIM) model of multi-layered wall elements created using ArchiCAD software. The findings of this study demonstrate that the calculation results can be reliably applied in real-world projects, providing investors with accurate and reliable information in the early stages of project development.

Keywords: Cost estimation, Scheduling, S-curve model, BIM, Residential buildings.

Introduction

Background

The construction of multi-family houses requires careful planning and consideration of various factors, including the type of walls used. Load-bearing walls and non-load-bearing walls are two common types of walls used in building construction, and they have different functions, advantages, and disadvantages.

Load-bearing walls support the weight of the building and transfer the loads to the foundation, while non-load-bearing walls only support their own weight and do not carry any additional loads. Understanding the time and cost implications of using these types of walls is essential for contractors, builders, and developers to make informed decisions and optimize their construction projects.

Time and cost analysis of walls for multi-family houses involves evaluating the materials, labor, equipment, and other resources required for construction, as well as the duration of the construction process. This analysis can help identify areas for cost savings, efficiency improvements, and optimization of the construction process.

In construction literature, the study on project cost and time calculations using mathematical and computerised methods got more attention. However, a single construction activity like the different wall elements for a whole multi-family housing (MFH) is never studied. The types of walls in an MFH building varies according to its position and nature. In order to understand the cost and time parameters of different wall elements of an MFH building, a well-detailed cost and time calculations are taken into account. The resulting values of cost and time calculations help to plot a progressive curve (S-curve). The S-curve is a tool that helps to plan and control the construction progress.

Research Aim

This study endeavors to create a comprehensive Building Information Modelling (BIM) model utilizing ArchiCAD software, which delineates the intricate details of various wall elements comprising a load-bearing masonry wall. This model provides a visual representation of the diverse materials and layers employed in the construction of these wall elements. Furthermore, the cost and schedule calculations for the wall activities are graphically represented as a progressive S-curve, which serves as a valuable tool for planning and managing construction projects in their early stages. The S-curve enables the tracking of activities and the prediction of future project progression, facilitating informed decision-making and effective project management.

Research Objectives

The key objectives of this study are:

1. To understand the different construction practices and needs of the residential housing sector in Germany.

2. To identify the different wall types (load-bearing and non-load-bearing) for further evaluation.

3. To evaluate the cost and time estimation of the building activities corresponding to wall elements in the early stage.

Research Methodology

The approaches employed for cost estimation vary depending on the project manager's requirements and preferences. Nevertheless, in the detailed estimation process, costs are calculated using labor rates, material rates, and wall areas on each floor, taking into account different wall types and functions. This calculation is facilitated through the use of Excel spreadsheets. Moreover, the most comprehensive and accurate method for calculating the construction schedule is through the utilization of Vico Schedule Planner, a feature provided by Vico Office. Vico Office is a Building Information Modelling (BIM) tool that offers a wide range of functionalities, including cost calculations, cost optimization, project scheduling, quantity take-offs, and more. Its extensive capabilities make it an invaluable resource for construction project management.

Research Methodology

Cost estimation methods differ based on project manager preferences and requirements. Detailed estimation involves calculating labor and material rates, and wall areas by floor, considering various wall types and functions, using Excel. For construction scheduling, Vico Schedule Planner (Vico Office) is a more comprehensive and accurate tool. Vico Office is a BIM software that offers cost calculation, optimization, scheduling, quantity take-off, and other features.

Literature Review

Dipasquale et al. (2019) investigate the effect of retrofitting solutions on the energy efficiency of European residential building stocks, highlighting the influence of building typology and climatic factors on their implementation. The authors propose a methodology for developing effective retrofit solutions tailored to building blocks in various climatic regions. The results are systematically cataloged in a database and compared against a comprehensive dataset of over 250,000 entries, encompassing building types, ages, climatic conditions, and energy performance metrics.

Pohoryles et al. (2020) highlight the imperative need for renovating Europe's ageing building stock, as retrofitting enhances both energy performance and structural safety. The existing building stock is responsible for substantial CO_2 emissions, given that most European buildings are over 50 years old. The residential sector accounts for a significant proportion (75%) of the European building stock. The authors propose combined retrofitting methods, such as exoskeleton or double-skin solutions, which simultaneously improve energy performance and structural strengthening of buildings (Pohoryles et al., 2020).

Rodrigues et al. (2018) examine the crucial role of European regulations in enhancing building energy efficiency through the implementation of low thermal transfer envelopes. To achieve reduced U-values, the authors conducted a comprehensive analysis of thousands of residential buildings across various European countries, considering diverse U-values and geometries. The buildings were categorized based on thermal envelope transfer, and six geometry indexes were correlated with energy performance. The study reveals that climatic regional variations in U-values diminish the significance of geometry-related effects on energy performance.

Cost and schedule integration

Rashmi J V et al. (2017) investigated the application of project management techniques and tools to optimize the time and cost requirements for a multi-family residential building. These tools facilitate the rapid development of a schedule plan, enable the establishment of connections between various activities, define necessary resources, and track work progress. Through a comparative case study analysis, Rashmi J V demonstrated that the project management approach surpasses the conventional approach, yielding reduced total cost and construction time without compromising the quality of construction activities, thereby enhancing the reliability of the project outcome.

Konior and Szóstak (2020b) leveraged the S-curve as a vital tool for construction progress control and planning. By graphically depicting financial expenses against the activity timeline, the authors illustrated the characteristic "S" shape of the progressive curve, wherein the initial and final stages exhibit a flatter slope, while the middle stage displays a steeper incline. This nonlinear pattern is attributed to the increased resource allocation and corresponding cost escalation during the intermediate phase, relative to the slower initial stages. The authors subsequently adapted the classic S-curve method to develop modified approaches for planning applications.

Standards, norms and minimum requirements

According to established guidelines, the minimum recommended thickness for exterior load-bearing walls of buildings up to 35 feet (10.67m) in height is 12 inches (304.8 mm). For every additional 35 feet in height, a supplementary 4 inches (101.6 mm) in thickness is suggested. In the case of single-storey buildings with an unsupported height not exceeding 12 feet (3.65 m), a wall thickness of 8 inches (203.2 mm) is recommended. Notably, the standardization of brick sizes has led to the widespread adoption of wall thicknesses expressed in increments of 8, 12, and 16 inches, as documented by Woolson (1924).

Methodology and validation of data

A comprehensive review of the literature reveals diverse methods employed by various authors for construction cost estimation, providing a broad understanding of the estimation techniques. Notably, the detailed cost estimation method stands out as a meticulous and time-consuming process that yields relatively high accuracy and minimal error margins. This method is widely adopted by contractors for bidding purposes due to its precision. In this thesis, the detailed cost estimation method is utilized, facilitated by an Excel spreadsheet, to ensure rigorous and accurate cost calculations. To achieve precise cost estimation, a thorough understanding of building parameters and relevant information is essential, which has been duly considered in this study.

Cost estimation steps

Accurate project initiation data plays a crucial role in preliminary cost estimation, and its significance extends throughout the project lifecycle, enabling increasingly detailed cost calculations. To achieve precise cost estimation for walls, a comprehensive analysis of the following factors is essential:

1. Development of a suitable project plan
2. In-depth examination of floor plans and flat sizes
3. Quantification and classification of walls
4. Detailed cost calculations for walls

By meticulously evaluating these factors, a robust foundation for accurate cost estimation is established.

Schedule using Vico schedule planner

Scheduling, as extensively discussed in the literature, constitutes a vital aspect of project management. However, project managers often encounter challenges in creating accurate schedules due to unforeseen delays arising from natural phenomena and human errors. Scheduling is a complex and time-consuming process, akin to cost estimation, requiring meticulous evaluation. To facilitate scheduling, specialized tools like the Vico Schedule Planner, which leverages Building Information Modelling (BIM) technology, are employed to ensure precise project timelines.

The calculated quantities are integrated into the Vico software, enabling the scheduling of wall elements. The Work Breakdown Structure (WBS) of the project provides a detailed list of activities, facilitating precise scheduling. The Vico Schedule Planner estimates the construction time based on the specified resources and quantities. Furthermore, the schedule planner allows for the adjustment of resources and work shifts to prevent activity conflicts and optimize the construction timeline.

Results & Findings

Final cost calculations

The outcomes of the comprehensive cost calculation for wall elements are summarized as follows. The total wall quantities derived from the Excel spreadsheet are subsequently applied to the "Abstract of Cost" spreadsheet, as outlined in the methodology. Through a systematic approach, all requisite data and calculations were prepared to achieve the ultimate objective of precise cost calculations. The DIN 276 and BKI standards provide the necessary information for accurate estimation, ensuring a reliable and informed cost assessment.

Precision in wall cost calculation is crucial for achieving accurate results. The Work Breakdown Structure (WBS) facilitates the costing of various wall elements by listing relevant activities. The BKI medium costs (Tab. 10) are applied to different activities for distinct wall elements. The comprehensive cost calculations for walls are presented in Tab. 12. The final column utilizes the DIN 276 cost group classification, providing a clear categorization of wall elements. The total cost of wall construction, inclusive of insulation, base coat, finishing render, gypsum board installation, and inner plastering, for a 5-story multi-family house (MFH) amounts to €655,855.

Detailed wall elements – ArchiCAD Model (BIM)

The utilization of ArchiCAD 22 software enables the transformation of two-dimensional plans into three-dimensional models, facilitating the application of various materials to distinct construction elements, including columns, beams, slabs, and wall elements. This advanced visual representation allows for the accurate depiction of diverse materials and layers employed in external walls, which may not be readily apparent in real-life scenarios. The three-dimensional model provides a comprehensive and detailed illustration of multi-layered wall elements, enhancing understanding and facilitating practical applications in the design and construction of new buildings.

Cost – Time progressive model (S-curve)

Numerous authors in the literature have employed the S-curve as a valuable tool for monitoring project progress, predicting project completion dates, tracking resource allocation, and managing construction activities. Utilizing a schedule planner, the wall activities for the MFH building were scheduled to be completed within a duration of 10 weeks. The S-curve was generated using an Excel spreadsheet, which plotted the cumulative expenditure against various stages of construction work. As previously discussed, the initial stages of construction exhibit a slow pace, followed by an accelerated phase in the middle, ultimately forming an S-shaped curve when graphically represented.

Conclusion & Recommendation

Here's a rewritten version of the text in a more formal and academic tone:

"This research endeavored to determine the cost and time calculations for wall elements in a multi-family housing building, leveraging both qualitative and quantitative analyses of housing needs, cost estimation methods, and time duration. The findings indicate accurate and reliable results, providing valuable insights for investors. The detailed information obtained in the early stages can facilitate informed consultations among stakeholders. The results can be applied to real-life projects with similar geometries, ensuring maximum accuracy. The generated S-curve models offer utility in project tracking, resource planning, and cost monitoring. Future studies could explore more complex projects utilizing BIM tools for quantity take-offs, 4D scheduling, and cost estimation. Additionally, investigating carbon footprint calculations for wall elements, in conjunction with energy retrofitting, could provide further insights.

Reference :

1. Rashmi J V et al. (2017) employed project management techniques and tools to assess the overall time and cost requirements for a multi-family residential building.
2. Pohoryles et al. (2020) highlighted the necessity of renovating Europe's ageing building stock, emphasizing the benefits of retrofitting in enhancing energy performance and structural safety.
3. Dipasquale et al. (2019) examined the impact of retrofitting solutions on the energy efficiency of European residential building stocks, considering building typology and climatic factors.
4. Rodrigues et al. (2018) discussed the importance of European regulations in promoting energy efficiency in buildings through the use of low thermal transfer envelopes.
5. Konior and Szóstak (2020b) utilized the S-curve as a tool for construction progress control and planning.
6. Niemelä et al. (2017) emphasized the need for deep renovation in Finnish brick apartment buildings and explored the effects of various renovation methods on energy performance.
7. Van Gulck et al. (2020) addressed the issue of outdated building stocks in Belgium and their impact on energy standards and the environment.
8. Lee et al. (2020) stressed the importance of preliminary estimation during the initial project stage for decision-making and progress determination.