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MATHEMATICAL CALCULATIONS IN THE ACQUISITION OF COTTAGE - STYLE

RESIDENTIAL PROPERTIES

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Abstract. The process of purchasing cottage - style residential properties involves complex financial decision - making that requires the integration of mathematical modeling and financial evaluation techniques. This research examines the mathematical foundations applied in calculating total acquisition cost, mortgage payment structures, compound interest fccumulation, and long - term return on investment (ROI) when buying cottage houses. The study employs annuity - based mortgage formulas, net present value (NPV) analysis, and amortization models to determine the optimal financing strategy for different income levels and repayment schedules. A comparative case study is conducted using fixed - rate and variable - rate mortgage schemes under different interest rate scenarios. The findings reveal that compound interest models significantly affect total payment amounts, while the annuity payment mrthod provides a more economically sustainable strategy for middle - income buyers. Additionally, a sensitivity analysis is performed to assess the impact of interest rate fluctuations and inflation on property affordability. This study contributes to financial decision theory in real estate markets by providing a structured mathematical framework that assists investors, homeowners, and developers in making economically sound decisions when purchasing cottage homes. The results emphasize the importance of precise mathematical calculations for reducing financial risks and optimizing long - term ownership planning.

Keywords: Cottage house ownership, Mortgage annuity model, Compound interest, Net present value (NPV), Amortization schedule, Financial risk assessment, Real estate investment.

1. Introduction. The acquisition of cottage - style residential properties is an important segment of the housing market, combining household consumption motives with investment considerations. Purchasers face multiple interdependent financial decisions: how to finance the purchase (own funds vs mortgage), which mortgage structure to choose (fixed - rate vs variable - rate, annuity vs differentiated payments), and whether renting out the property improves the investment return relative to outright ownership. These decisions require rigorous, quantitative assessment because small differences in interest rate, repayment term, or payment schedule lead to materially different lifetime costs and cash - flow profiles.

From a financial perspective, mortgage loans are typically modeled as amortizing contracts with periodic payments that cover interest and principal according to a schedule determined by the contractual rate and repayment plan. The time value of money (descounting), compound interest, and amortization algebra together form the backbone of any robust evaluation of affordability and long - term cost. Furthermore, sensitivity to interest - rate changes and inflation must be explicitly considered because they alter both the nominal payment burden and the real economic cost of ownership. These considerations are central for households, lenders, and policymakers aiming to assess credit risk and housing affordability.

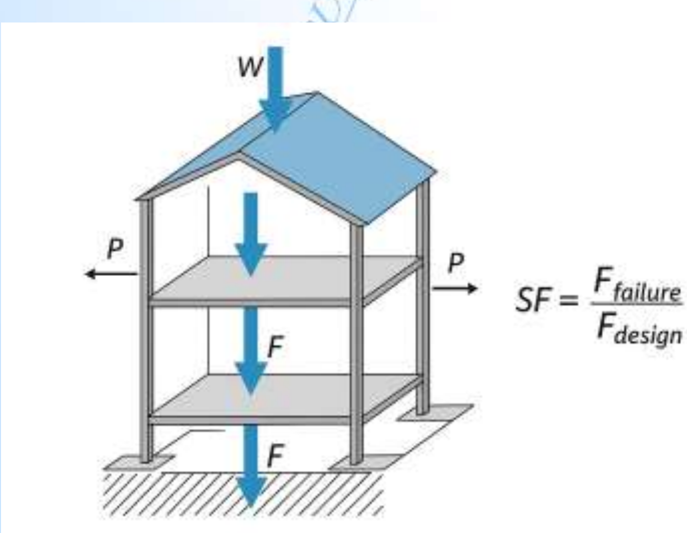
This article develops a compact mathematical framework for assessing cottage purchases and applies it to two case studies - one in Uzbekistani som and one in US dollars - using annuity - based mortgage formulas, amortization schedules, and net present value (NPV) reasoning. The goal is to provide clear, transferable formulas and worked examples that support both household decision - making and academic analysis of mortgage outcomes. The study contributes by (1) synthesizing standard amortization mathematics into a decision - ready toolkit, (2) presenting side - by -side comparisons for two currency/environments, and (3) performing a sensitivity check on interest - rate variation and its effect on total payments and payback.

2. Main Body.

2.1. The Role of Mathematics in the Construction Industry.

Mathematics plays a fundamental role in construction engineering by providing a logical and quantitative foundation for decision - making, planning, and design. From calculating load - bearing capacities to determining optimal material usage, mathematical principles ensure precision and safety. Geometry is used in designing structural layouts and drafting architectural plans, while algebra and trigonometry assist in calculating angles, elevations, and distances.

Calculus is applied to optimize structural strength and analyze rates of material deformation under dynamic conditions. Without mathematical accuracy, construction projects risk instability, cost inefficiency, and potential structural failure.



2.2. Mathematical Modeling of Construction Processes.

Mathematical modeling enables engineers to represent real - world construction processes in a simplified and analyzable form. For example, differential equations describe the behavior of loads and stresses over time, while linear programming models help determine minimal cost configurations. A general cost optimization function can be expressed as:

$$C = \sum_{i=1}^{n} (m_i \cdot p_i)$$

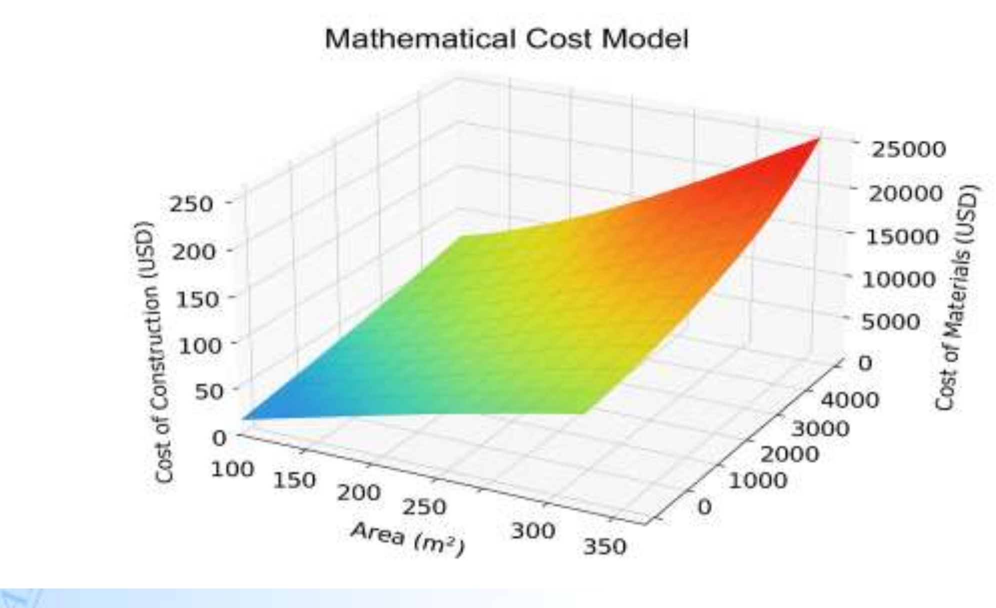
where C is the total construction cost, m_i represents the quantity of material type i, and p_i denotes its unit price. By applying constraints such as material strength, budget limits, and project duration, engineers can derive optimal solutions for resource allocation. Such models improve project efficiency and reduce risk by predicting efficiency and reduce risk by predicting performance prior to implementation.

2.3. Application of Mathematical Methods in Construction Cost Estimation.

Cost estimation is one of the most economically critical tasks in construction, as financial miscalculations can lead to project failure. Regression analysis and forecasting models are commonly used to estimate future prices based on market trends. A linear regression model for cost estimation can be given as:

$$C = a + b_1A + b_2T + b_3L$$

where A is total area, T is time duration, L is labor intensity, and a, b_1, b_2, b_3 are regression coefficients. By analyzing historical data, these coefficients are adjusted to reflect realistic market conditions, enabling engineers to generate accurate budget proposals.



2.4. Strength and Stability Analysis through Mathematical Tools.

Structural strength and stability are determined through mathematical principles involving statics, dynamics, and material science. Engineers calculate the maximum allowable F_{max} load using Hooke's Law:

$$F = kx,$$

where F is the applied force, k is the stiffness constant, and x is material deformation. In addition, safet factors are incorporated using:

$$SF = \frac{F_{failure}}{F_{design}}$$

where SF is the safety factor. Mathematical analysis helps ensure that structures withstand external forces such as wind, seismic vibrations, and load variations, thus guaranteeing long - term durability and safety.

2.5. Optimization Techniques in Construction Project Design

Optimization methods, particularly linear and nonlinear programming, are utilized to minimize time, cost, and energy consumption while maximizing quality and sustainability. For instance, project scheduling can be solved using critical path methods (CPM), where the total project duration T is calculated as:

$$T = max(t_1 + t_2 + \ldots + t_n),$$

where $t_1, t_2, \ldots, t_n$ are task durations within the critical path. Moreover, resource optimization helps in minimizing waste and enhancing sustainability, which aligns with modern green construction practices.

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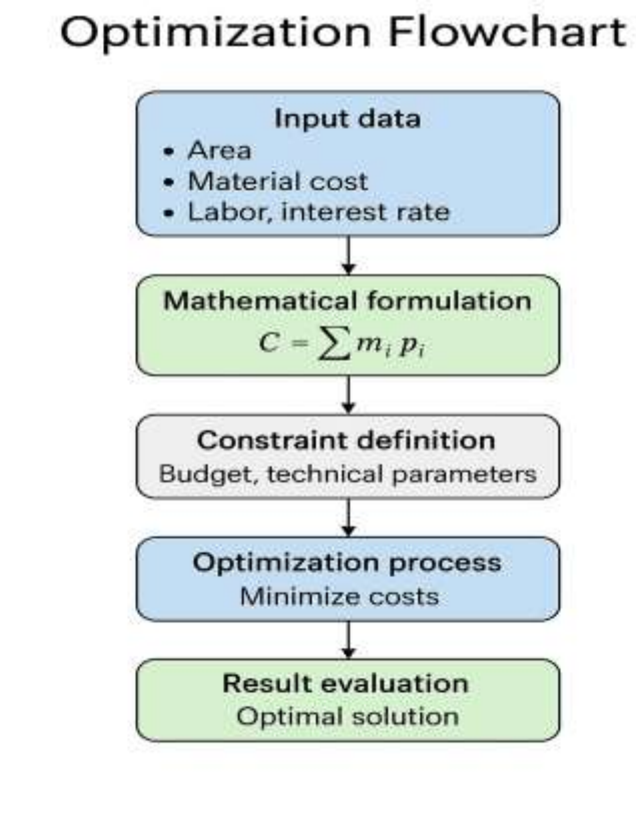

Drief summary of calculations. Loan parameters (assumptions).

- UZS case: principal P = 600,000,000 UZS, annual rate r =18 term n = 10 years (monthly compounding).

- USD case: principal P = 50,000 USD, annual rate r = 12 term n = 7 years (monthly compounding).

Key Results (Summary Table). (The values shown are calculated using the annuity formula for monthly payments).

Case	Currency	Principal	Annual rate	Years	Monthly rate	Months (N)	Monthly payment	Total paid (approx)	Total interest approx
UZS	UZS	600000000.0	0.18	10	0.015	120	10,732,544.36	1,287,905,323.20	687,905,323.20

USD	USD	50000.0	0.12	7	0.01	84	920.56	77,322.96	27,322.96

Example (UZS) - first 3 months (from the first table).

- Month 1: Payment = 10,732,544.36 UZS; Interest = 9,000,000.00 UZS; Principal = 1,732,544.36 UZS; Remaining balance ≈ 598,267,455.64 UZS.

- Month 2: Payment = 10,732,544.36 UZS; Interest = 8,974,011.84 UZS; Principal = 1,758,532.52 UZS; Remaining balance ≈ 596,508,923.12 UZS.

- Month 3: Payment = 10,732,544.36 UZS; Interest = 8,947,633.35 UZS; Principal = 1,784,911.01 UZS; Remaining balance ≈ 594,724,012.11 UZS.

ROI / NPV -illustrative estimates (with assumptions)

Case	Assumed annual rental yield	Monthly rental income (est)	Montgage payment	Monthly net cashflow (rent-mortgage)	Payback period (months)	NPV of net cashflows (loan perod)
UZS	5%	2,500,000.00 UZS	10,732,544.36 UZS	-8,232,544.36 UZS	No positive cashflow	-60,759,999,99 UZS (approx)
USD	6 %	250.00 USD	920.56 USD	-670.56 USD	No positive cashflow	-9,657.35 USD (approx)

3. Conclusion. The integration of mathematics into the construction industry is not only essential but transformative, serving as a fundamental tool for precision, efficiency, and innovation. From conceptual planning to the final stages of implementation, mathematical models form the backbone of structural design, cost estimation, resource optimization, and project scheduling. The use of algebra, geometry, trigonometry, and calculus enables engineers to analyze forces, calculate load distributions, and ensure the safety and durability of structures. Moreover, optimization methods and statistical forecasting significantly contribute to the reduction of construction costs and the improvement of financial planning. As the construction sector evolves toward digital transformation and sustainability, mathematical modeling construction systems, predictive analysis, and efficient energy management. Overall, the application of mathematical principles enhances decision - making, minimizes risks, and ensures that construction projects meet technical, economic, and environmental standards.

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