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Mathematical modeling of fixed and declining amortization schemes in Indonesian cooperative loan systems

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ABSTRACT

Village cooperatives play a crucial role in promoting rural economic development by providing accessible microfinance services. This research focuses on Indonesian cooperative microfinance systems, providing insights for both local policymakers and cooperative managers. The urgency of this study lies in the growing need for resilient and fair lending systems in Indonesian cooperatives amid economic uncertainty. The novelty of this research is the integration of mathematical modeling with sensitivity analysis, an approach that has rarely been applied to cooperative microfinance contexts. This research evaluates two widely applied loan amortization schemes—fixed installment (annuity) and declining balance—within the framework of cooperative finance. By simulating a twelve-month loan of IDR 10,000,000 at a one percent monthly interest rate, the paper models and examines the allocation of principal and interest payments under both approaches. The results indicate that although fixed installments ensure stable monthly obligations, they generate higher total interest costs compared to declining balance schemes, which more closely align repayment amounts with the outstanding loan balance. A sensitivity analysis of varying interest rates and loan tenures further offers insights into financial risk management and borrower affordability. These findings provide cooperative managers with data-driven guidance for developing more effective and transparent lending strategies.

Keywords: amortization, cooperative finance, declining balance, fixed installment, microloan

PLAIN LANGUAGE SUMMARY

Village cooperatives in Indonesia provide small loans to rural communities, but choosing the right repayment structure is challenging. This study compared two common loan repayment methods: fixed installments (same payment each month) and declining balance (payments decrease over time). Using computer simulations of a typical 12-month loan, we found that fixed installments are easier to budget but cost more in total interest. Declining balance loans save money overall but require higher initial payments. The study tested different interest rates and loan lengths, showing cooperative managers how to design better loan products that balance fairness for borrowers with financial sustainability for cooperatives.

Introduction

Village cooperatives play a pivotal role in promoting rural economic development by providing accessible microfinance services to marginalized communities. In Indonesia, more than 64 million micro, small, and medium enterprises form the economic backbone, with microfinance institutions reaching approximately 15 million customers through various lending models [1, 2]. These cooperatives function as essential financial intermediaries in regions where formal banking infrastructure remains limited, offering savings and loan services responsive to local economic cycles, particularly in agricultural and informal sectors [3]. Research has consistently demonstrated that microfinance improves welfare outcomes among rural households in Indonesia when loan products appropriately match borrowers' repayment capacity, with factors such as loan purpose, interest rates, and monthly income significantly affecting the probability of increasing borrowers' welfare after accessing microcredit [4]. The role of cooperatives in fostering economic resilience is particularly critical in rural populations that rely on microfinance to support livelihoods and small-scale enterprises [5].

One primary operational challenge facing these cooperatives is structuring effective loan repayment systems that balance borrower affordability with institutional sustainability. The choice of amortization scheme significantly affects borrower affordability, cooperative liquidity, and the risk of loan default [6]. Among commonly adopted approaches are the fixed installment (annuity) model and the declining balance method. The fixed installment model ensures equal monthly payments throughout the loan term, although a larger portion of early payments is

typically allocated to interest, resulting in higher total interest costs [7, 8]. The declining balance method gradually lowers payment amounts as the principal owed decreases, bringing repayments closer to the remaining loan balance and reducing total interest expenses. However, this structure demands higher initial payments that may pose challenges for borrowers with limited or irregular income sources.

The financial and behavioral effects of amortization models have attracted increasing scholarly attention within microfinance literature. Studies on repayment flexibility have revealed that rigid debt structures are not suitable for borrowers with unstable, seasonal income, which is particularly common among microentrepreneurs in developing countries [9]. Field experiments in Bangladesh demonstrated that providing repayment flexibility through alternative contract designs leads to substantial improvements in business outcomes, with treated microfinance clients showing increases in borrowing, business assets, revenues, and profits, while default rates actually decreased [10]. Research has established that multiple factors influence default rates in microfinance institutions, including creditworthiness, economic conditions, loan characteristics, and geographic differences, with rural regions experiencing higher default rates due to limited economic opportunities and seasonal income fluctuations [11, 12]. Despite these insights, the existing literature has predominantly concentrated on commercial microfinance institutions and banking systems, with relatively limited attention to cooperative-based lending practices in rural Indonesia, where more than 129,000 microfinance institutions operate [13].

A critical gap remains in understanding how amortization structures respond to variations in interest rates and loan tenors, despite these factors being essential to the financial resilience of cooperatives. Studies emphasize that financial literacy and governance play important roles in the sustainability of rural microfinance institutions, yet the performance of cooperatives depends on financial literacy and effectiveness of financial management in responding to economic conditions [14]. Assessment frameworks for microfinance lending processes highlight that product design elements, including loan maturity, effective interest rate, and payment schedules, create risks when not properly matched to local culture and institutional constraints [15]. Evidence-driven loan design requires actionable insights from simulation-based modeling, enabling cooperatives to evaluate how repayment plans adapt to various lending scenarios and economic conditions [16]. This research addresses these gaps by using mathematical modeling combined with sensitivity analysis to provide novel insights into the sustainability and affordability of cooperative loan systems in Indonesia.

This study simulates and assesses both fixed and declining amortization schedules using a financial mathematics approach applied to a standardized twelve-month microloan scenario of IDR 10,000,000 at a one percent monthly interest rate, representing typical cooperative microfinance products in rural Indonesia. We examine payment distribution, interest accrual, and loan balance evolution over time under both approaches. The sensitivity analysis systematically varies monthly interest rates between 0.5 percent and 2 percent and loan tenures between six and twenty-four months to assess each model's resilience to changing economic conditions. These ranges reflect lending conditions commonly found in Indonesian cooperative finance, capturing the influence of inflation, monetary policy shifts, and varying borrower risk profiles. The findings provide cooperative managers with data-driven guidance for developing more effective and transparent lending strategies that balance institutional sustainability with borrower affordability, while offering policymakers a replicable framework to evaluate the fairness and transparency of community-based lending structures in promoting financial inclusion.

Methods

This research used a structured quantitative methodology to evaluate the effectiveness and impact of two common loan amortization models in the context of cooperative microfinance: the fixed installment (annuity) approach and the declining balance method. These models differ mathematically in how they distribute principal and interest throughout the loan term, with distinct implications for borrower cost, institutional liquidity, and credit risk exposure. This methodological

approach aimed to simulate realistic lending conditions commonly found in Indonesian rural cooperatives, where participants frequently face irregular income sources and limited financial knowledge. The research applied a standardized set of loan parameters to simulate and compare amortization profiles under each scheme using established financial mathematical models. To assess the resilience of each repayment structure to changes in critical variables such as interest rates and loan durations, we conducted sensitivity analysis.

Fixed installment (annuity) model

The fixed installment model, commonly called the annuity-based amortization approach, represented a widely adopted structure in both traditional and cooperative microfinance systems [7, 8]. Under this method, borrowers make uniform monthly payments throughout the entire loan term. Each payment consists of two components: an interest charge and a principal reduction. While the total monthly payment remains constant, the allocation between these components shifts over time. The proportion applied to interest decreases gradually, while the amount allocated to principal repayment increases accordingly as the outstanding loan balance decreases. The fixed monthly installment was calculated using the following formula:

$$A = P\,\frac{r(1+r)^{n}}{(1+r)^{n-1}} \qquad \text{(i)}$$

where A represents the fixed monthly installment, P denotes the initial loan amount (principal), r indicates the monthly interest rate expressed as a decimal, and n specifies the total number of monthly payments (loan tenure). This formula ensured equal distribution of the total repayment obligation across the loan lifecycle. However, because interest was calculated on the remaining balance and the balance decreased more slowly in early periods, a greater portion of initial payments was directed toward interest charges. This characteristic resulted in higher total interest costs compared to alternative amortization models, particularly for long-term loans or those with high interest rates [8, 9].

From the borrower's perspective, the main advantage of the annuity model lies in payment predictability and consistency. This stability makes household budgeting and financial planning easier. Nevertheless, this structure can present challenges for borrowers experiencing significant income variability, as the fixed payment obligation may become burdensome during periods of reduced earnings. From the institutional viewpoint, cooperatives benefit from predictable cash flows that support liquidity planning and risk management, although the model results in slower principal recovery during the early stages of the loan term. In cooperative microfinance contexts, particularly in rural areas, this model is frequently selected for its simplicity and clarity [1]. However, cooperative managers must ensure transparent communication regarding the true cost of credit, including total interest paid, enabling members to make informed borrowing decisions.

Declining balance model

The declining balance model, also known as the reducing balance method, represented an alternative amortization structure commonly used in microfinance institutions and cooperative lending schemes [9, 13]. Unlike the annuity model, this approach generated gradually decreasing installment amounts throughout the loan term. Each monthly payment consisted of a fixed principal component and a declining interest component, where interest was calculated only on the outstanding loan balance at each payment period.

During the initial phase of the loan, borrowers pay higher total amounts because interest is charged on the full principal. As repayments continue and the principal balance decreases gradually, the interest portion decreases proportionately, resulting in gradually lower total payments. This structure yielded lower total interest costs, making it particularly attractive to borrowers who prioritize long-term affordability [7, 13]. The monthly interest for period t was calculated using the following formula:

$$Interest_t = \left(P - \sum_{i=1}^{t-1} Principal_i\right) \cdot r \qquad (2)$$

where P represents the initial loan principal, r denotes the monthly interest rate in decimal form, $Principal_i$ indicates the portion of principal repaid

in month i, and$Interest_t$ specifies the interest due in month t. The total installment for month t is then determined by:

$$Installment_t = Principal\ portion + Interest_t \quad (3)$$

The combination of a fixed principal component across all months with a decreasing interest portion causes the total installment to decline over time. This characteristic makes the declining balance model particularly suitable for borrowers who expect their income to increase or who prefer to minimize total interest by repaying more aggressively during early stages [14].

Adopting this model introduces operational challenges for cooperatives, including fluctuating cash inflows and more complex liquidity planning requirements. However, the repayment structure aligns more closely with the actual loan balance, improving transparency and enabling borrowers to understand their repayment progress more easily. This feature is especially beneficial in rural cooperative contexts where financial literacy may be limited. The declining balance method also promotes repayment discipline, as borrowers experience tangible reductions in monthly obligations. Due to its relative simplicity and inherent fairness in interest calculation, this model has become a preferred approach in community-based microfinance programs, particularly in developing economies.

Simulation parameters

This research evaluated the financial behavior of two amortization schemes through a deterministic simulation using standardized parameters. The simulation design mirrored typical microloan structures adopted by rural cooperatives in Indonesia, particularly those serving low- to middle-income borrowers with limited access to formal financial services. The baseline scenario specified a principal amount of IDR 10,000,000, a loan tenure of twelve months, and a monthly interest rate of one percent, equivalent to twelve percent annually. It is important to acknowledge that the present analysis relied on simulated data rather than empirical loan records from cooperatives. Therefore, the results should be interpreted as showing the financial dynamics in amortization models, rather than as direct evidence of actual cooperative lending practices. This represents a methodological limitation that highlights the need for future research to validate these findings using real-world borrower-level datasets in order to strengthen external validity and policy relevance.

Both the fixed installment (annuity) and declining balance models were computed using the respective mathematical formulations described previously. The calculations were implemented in Microsoft Excel, using built-in financial functions to generate amortization tables that reflected realistic repayment behavior. The simulation yielded detailed monthly insights by capturing several key metrics: the allocation of interest and principal components in each installment, the total interest accrued throughout the loan period, the remaining loan balance after each monthly payment, and the total repayment obligations associated with each amortization scheme. These parameters illustrated the differences in cash flow dynamics and overall financial costs from both the borrower's and cooperative's perspectives. The selected loan size and tenure represented typical microfinance products offered by Indonesian village cooperatives [1, 2].

The simulation framework also included a sensitivity analysis feature that systematically varied key parameters such as interest rates and loan duration to assess the robustness and flexibility of each amortization model under different economic and lending scenarios. The simulation results served several important purposes: enabling borrowers to understand repayment progression and the implications of interest costs clearly, supporting cooperatives in improving liquidity planning, reducing financial risks, and designing tailored loan products, and providing policymakers with a replicable model to evaluate the fairness, affordability, and transparency of community-based lending structures. By aligning its structure with real-world cooperative practices, the simulation ensured both policy relevance and practical applicability for decision-makers in microfinance. To ensure robustness, the simulation used established financial mathematics principles that have been validated in prior microfinance studies [16]. Additionally, the use of deterministic models enabled precise comparisons across scenarios, aligning with best practices in financial modeling for microcredit systems [17].

Sensitivity analysis

Sensitivity analysis is a vital tool for evaluating the robustness and responsiveness of amortization schemes under fluctuations in key loan parameters. In cooperative microfinance, variations in interest rates and loan tenures can significantly influence repayment burdens, borrower affordability, and the effectiveness of institutional cash flow planning. Prior research has emphasized the importance of such analyses in microcredit programs, demonstrating that loan design outcomes show high sensitivity to changes in cost structures, directly affecting repayment dynamics and default probabilities [12]. Similarly, studies have shown that the sustainability of microfinance institutions is strongly influenced by variations in interest rates and repayment conditions, illustrating the importance of sensitivity testing in evaluating financial resilience [14].

This research extended the baseline simulation through systematic variation of two primary variables: the monthly interest rate and the loan tenure. Interest rates were tested across a range from 0.5 percent to 2 percent per month, while loan durations varied between six and twenty-four months. These ranges reflected lending conditions commonly found in Indonesian cooperative finance, capturing the influence of inflation, monetary policy shifts, and varying borrower risk profiles. Each scenario involved a recalculation of repayment schedules based on the mathematical structures presented earlier. Key evaluation metrics included total interest paid, monthly installment variation, and fluctuations in payment stability. Comparisons across scenarios revealed the sensitivity levels of each amortization model and identified which structure offered greater predictability or cost efficiency for different borrower types.

Consistent with earlier evidence, the findings demonstrated that higher interest rates and longer repayment periods substantially increased the total interest burden. This research further contributed by demonstrating that declining balance structures adapted more effectively than fixed installment schemes under such conditions, thereby offering improved cost efficiency and borrower affordability in volatile financial environments. This analysis extended the existing literature by applying sensitivity testing specifically to cooperative-based lending in Indonesia, a context that has received limited scholarly attention. Moreover, while prior studies have primarily examined the sustainability of microfinance institutions at a macro level, this study provided a micro-level perspective on loan repayment structures, generating actionable insights for cooperative managers and policymakers.

The analysis revealed that the fixed installment model ensured consistent monthly payments but tended to generate higher total interest in long-tenure or high-interest environments. In contrast, the declining balance model offered increased flexibility and resulted in lower total interest payments, although it introduced greater variability in installment amounts, posing challenges for borrowers with irregular income streams. Quantifying the economic effects on loan repayment structures enabled cooperatives to develop more adaptive and borrower-centered financial products. Moreover, evidence from this analysis supported policy evaluations concerning interest rate caps, credit restructuring mechanisms, and subsidy programs aimed at promoting financial inclusion in rural economies.

Results

Baseline simulation results

To illustrate the practical implications of amortization structures, a baseline simulation was conducted using a microloan of IDR 10,000,000 with a loan tenure of twelve months and a monthly interest rate of one percent, equivalent to twelve percent annually. This scenario reflects a typical cooperative microfinance product offered in rural Indonesia, representing the lending conditions commonly found in village cooperatives serving low- to middle-income borrowers.

Fixed installment (annuity) model

The amortization schedule presented in Table 1 demonstrates the fixed installment repayment structure over the twelve-month period. Under this model, the borrower makes consistent monthly payments of IDR 888,487.89 throughout the loan duration, although the composition of each payment shifts over time. During the initial months, the majority of each installment services interest charges,

with IDR 100,000 allocated to interest in the first month while only a smaller portion reduces the loan principal. As the loan continues, the interest component decreases because the outstanding balance decreases continuously, while the principal repayment portion increases accordingly. In the final month, the interest charge decreases to IDR 8,796.91, with the principal repayment of IDR 879,690.98 fully settling the remaining loan balance. This fixed installment structure creates a predictable payment pattern where the borrower's debt obligation remains constant monthly while the underlying allocation between interest and principal changes systematically.

The results from Table 1 are visualized in Figure 1, which illustrates the composition of principal, interest, and total installment payments across the twelve-month period. The visualization demonstrates how the allocation of fixed installment payments changes throughout the loan duration. The total installment appears as a horizontal dashed line, confirming that the payment amount remains constant across all periods. The orange line representing interest payments shows a steady decline over successive months, while the red line depicting principal repayment shows a corresponding increase. This inverse relationship demonstrates that although the total payment amount remains fixed,

Tabel 1. Fixed installment amortization

Month	Total payment	Interest	Principal	Balance
1.0	888487.89	100000.0	788487.89	9211512.11
2.0	888487.89	92115.12	796372.77	8415139.35
3.0	888487.89	84151.39	804336.49	7610802.85
4.0	888487.89	76108.03	812379.86	6798423.0
5.0	888487.89	67984.23	820503.66	5977919.34
6.0	888487.89	59779.19	828708.69	5149210.65
7.0	888487.89	51492.11	836995.78	4312214.87
8.0	888487.89	43122.15	845365.74	3466849.13
9.0	888487.89	34668.49	853819.4	2613029.73
10.0	888487.89	26130.3	862357.59	1750672.14
11.0	888487.89	17506.72	870981.17	879690.98
12.0	888487.89	8796.91	879690.98	0.0

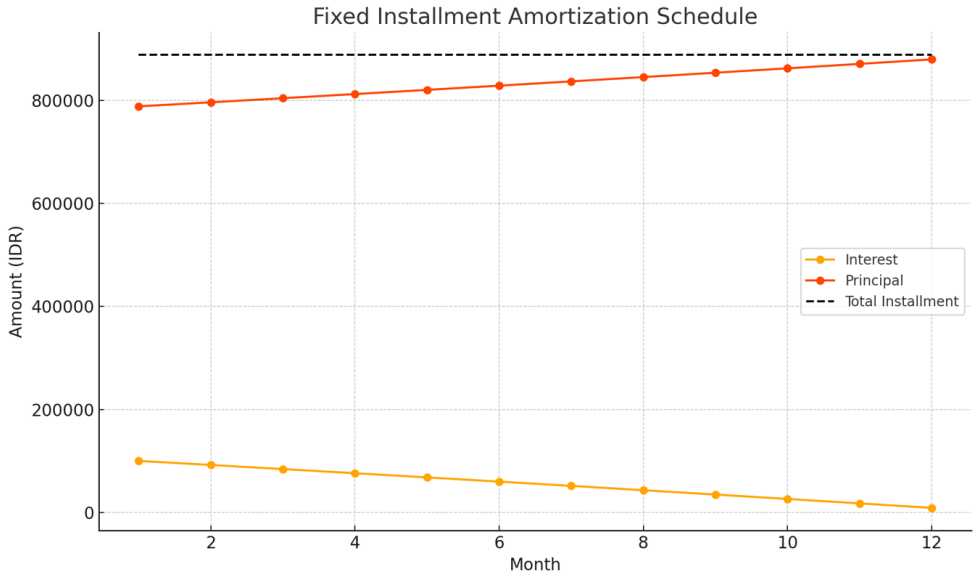

Figure 1. Fixed installment amortization schedule. Monthly composition of principal (red line), interest (orange line), and total payment (dashed line) for a 12-month loan of IDR 10,000,000 at 1% monthly interest rate under the fixed installment model

the borrower gradually shifts from primarily servicing interest to repaying principal in later months. The chart illustrates both the convenience of fixed installment payments for predictable budgeting and the systematic reduction in the outstanding loan balance throughout the loan term.

This framework facilitates budgeting and reduces the burden on borrowers by maintaining predictable monthly payment obligations. However, principal reduction occurs more slowly during the early months because a larger proportion of each payment services interest charges. From the cooperative's perspective, the fixed installment model guarantees steady monthly cash inflows, which simplifies financial planning and improves liquidity management. The stability of cash flows enables cooperatives to better match their assets and liabilities while maintaining adequate reserves for operational requirements.

Declining balance model

The amortization schedule presented in Table 2 illustrates the declining balance loan structure over the twelve-month period. Under this model, the principal repayment remains fixed at IDR 833,333.33 each month, while the interest component varies

Table 2. Declining balance amortization table

Month	Total payment	Interest	Principal	Balance
1.0	933333.33	100000.0	833333.33	9166666.67
2.0	925000.0	91666.67	833333.33	8333333.33
3.0	916666.67	83333.33	833333.33	7500000.0
4.0	908333.33	75000.0	833333.33	6666666.67
5.0	900000.0	66666.67	833333.33	5833333.33
6.0	891666.67	58333.33	833333.33	5000000.0
7.0	883333.33	50000.0	833333.33	4166666.67
8.0	875000.0	41666.67	833333.33	3333333.33
9.0	866666.67	33333.33	833333.33	2500000.0
10.0	858333.33	25000.0	833333.33	1666666.67
11.0	850000.0	16666.67	833333.33	833333.33
12.0	841666.67	8333.33	833333.33	0.0

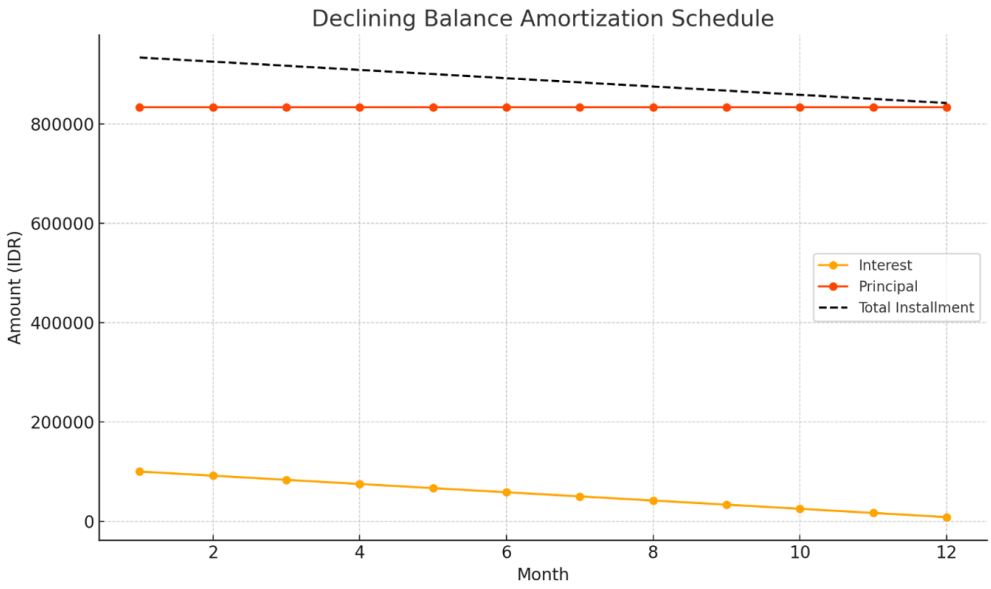

Figure 2. Declining balance amortization schedule. Monthly composition of principal (red line), interest (orange line), and total payment (dashed line) for a 12-month loan of IDR 10,000,000 at 1% monthly interest rate under the declining balance model

based on the outstanding balance. As the loan balance decreases gradually, the interest portion of each installment declines proportionally, from IDR 100,000 in the first month to only IDR 8,333.33 in the final month. As a result, the total monthly payment decreases steadily throughout the loan term, starting from IDR 933,333.33 in the first month and reducing to IDR 841,666.67 by month twelve. This structure enables more efficient loan repayment because a fixed portion of each payment consistently reduces the principal, resulting in lower total interest costs over the loan period compared to the fixed installment scheme.

The results from Table 2 are visualized in Figure 2, which displays the composition of principal, interest, and total installment payments under the declining balance system. The visualization clearly demonstrates the amortization behavior characteristic of this approach. The dashed black line shows a downward-sloping total installment trajectory, indicating that the borrower's payment obligation decreases each month as the interest portion decreases. The orange line representing interest slopes downward consistently, while the red line depicting principal remains horizontal across all months, confirming that the borrower pays a constant principal amount throughout the loan term. This structure provides gradual interest savings but requires higher initial total payments, which may present affordability challenges during the early loan period. The visualization reflects a payment structure that aligns with a decreasing financial burden over time.

This framework reduces total interest expenses by allocating a fixed amount to principal repayment each month, thereby speeding up the reduction of the loan balance. However, the total monthly payment is higher at the beginning of the loan term and gradually decreases over time, which may pose challenges for borrowers with limited or unstable income during the initial repayment period. From the cooperative's perspective, this model results in declining monthly cash inflows, requiring more active cash flow management and careful liquidity planning. Nonetheless, it offers greater transparency and fairness by linking the interest charge directly to the outstanding balance, thereby aligning repayment obligations with the borrower's decreasing debt burden.

Comparative analysis of payment profiles

A comparative summary of the two amortization models is presented in Table 3 to highlight their key financial and structural differences across several dimensions. The fixed installment model offers a constant monthly payment of IDR 888,487 throughout the twelve-month term, which simplifies budgeting for borrowers but results in a slightly higher total interest of IDR 661,846. In contrast, the declining balance model begins with a higher first-month installment of IDR 933,333 but gradually decreases to IDR 841,667 by the final month, leading to a lower total interest burden of IDR 650,000. Although both models result in nearly similar total amounts paid, their affordability profiles differ substantially across the loan lifecycle. The fixed installment model is more affordable during the early months due to lower initial payments, whereas the declining balance model becomes gradually more manageable toward the end of the loan term as payment obligations decline. The choice between these models should consider the borrower's cash flow patterns, income stability, and risk tolerance.

Table 3. Comparative fixed Installment model and declining balance model

Feature	Fixed installment model	Declining balance model
First-month installment	888,487	966,667
Final-month installment	888,487	841,667
Cumulative interest	661,846	650,000
Total amount paid	10,661,846	10,650,000
Payment structure	Constant	Decreasing
Affordability early in term	Easier	More difficult
Affordability late in term	Constant	Easier

The comparison is further visualized in Figure 3, which displays the total monthly payments for both the fixed installment (annuity) model and the declining balance model over the twelve-month loan period. The annuity model is represented by a flat orange line, indicating that the borrower makes constant payments each month regardless of the loan balance. In contrast, the declining balance model, shown by the descending red-orange line, starts with a higher payment in the first month and decreases gradually over time as the outstanding balance decreases. This visualization demonstrates the stability offered by the annuity model, which is beneficial for borrowers who prioritize predictable budgeting and payment certainty. In contrast, the declining balance scheme reduces the borrower's payment burden in later months, making it more suitable for those expecting rising income or reduced financial pressure over time. The main tradeoff lies between early affordability and long-term interest savings, as the declining balance model produces slightly lower total interest despite requiring steeper initial payments.

The visualization highlights a main tradeoff between the two amortization schemes. Although the declining balance model provides lower total interest payments across the loan tenure, it demands higher initial installments, which may pose challenges for borrowers facing limited income or tight liquidity constraints during the early loan period. In contrast, the fixed installment model offers payment stability and early affordability at the cost of higher total interest over the loan lifecycle. These insights are important for cooperative decision-makers in designing amortization products that align with both institutional sustainability objectives and borrower affordability requirements, thereby ensuring that financial inclusion goals are achieved without compromising the financial strength of the cooperative institution.

Sensitivity analysis results

The sensitivity analysis examines how variations in interest rates and loan tenures affect the total interest burden for both amortization models. This analysis is important for evaluating how external economic factors, including inflation and monetary tightening, influence borrower affordability and cooperative liquidity in community-based lending systems. This section presents results demonstrating the effect of interest rate variations on total interest paid, as illustrated in Figure 4, and the effect of loan tenure variations on total interest paid, as shown in Figure 5.

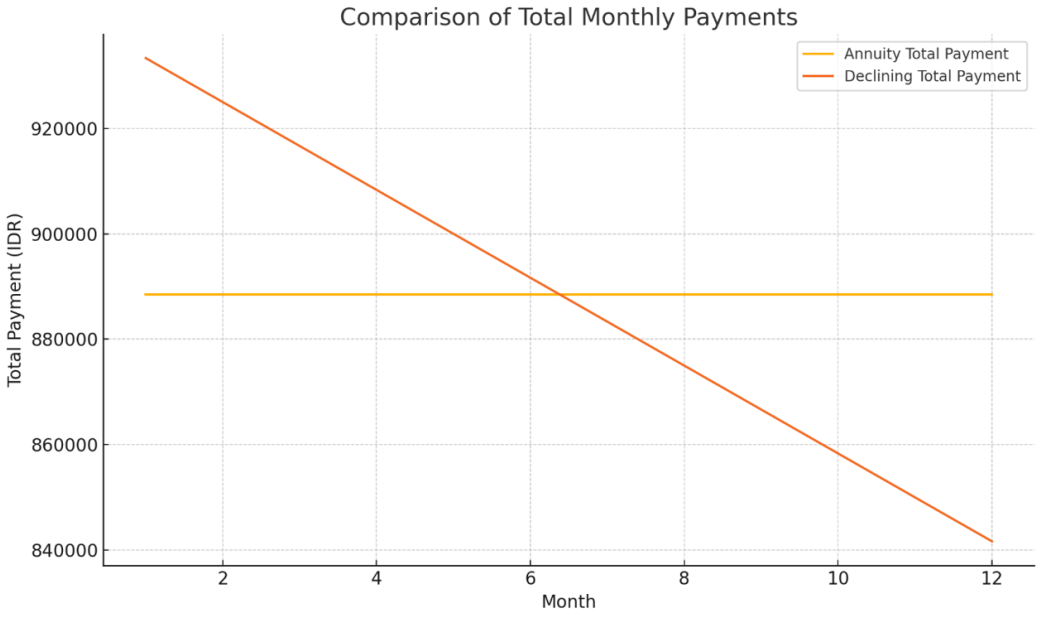

Figure 3. Comparison of total monthly payments between fixed installment and declining balance models. The fixed installment model (orange line) maintains constant payments, while the declining balance model (red-orange line) shows progressively decreasing payments over the 12-month period

Figure 4 illustrates the relationship between monthly interest rates, ranging from 0.5 percent to 2 percent, and the total interest paid over the loan period. A proportional increase in total interest is observed across both amortization models as interest rates rise. The fixed installment (annuity) model consistently generates slightly higher total interest compared to the declining balance model across all interest rate scenarios tested. The gap between the two models becomes larger at higher interest rates, highlighting the relative cost efficiency of the declining balance model under expensive borrowing conditions. This finding suggests that when interest rates are high, borrowers can achieve

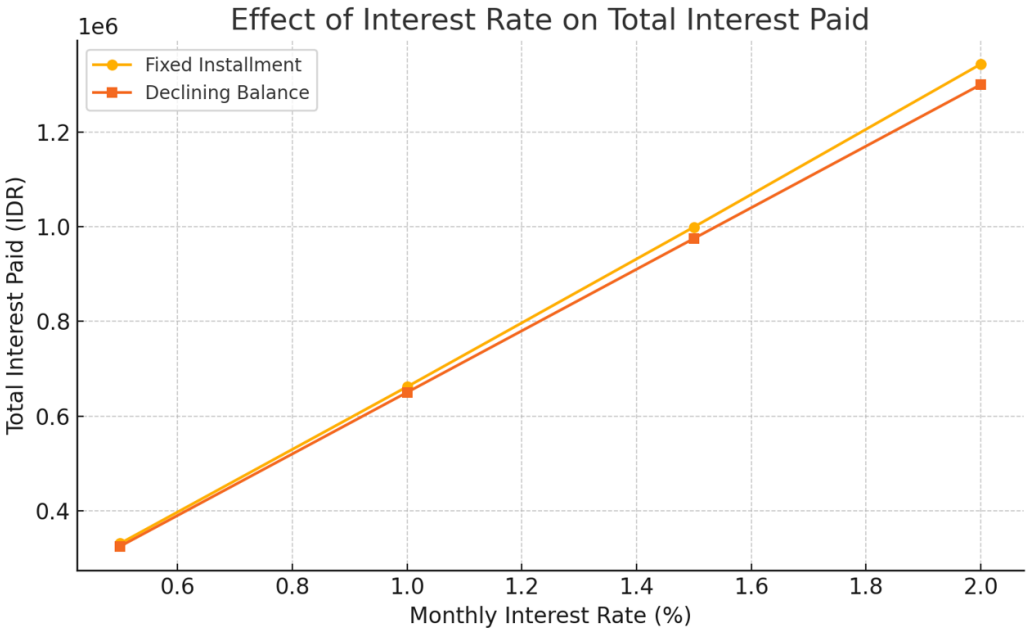

Figure 4. Effect of interest rate on total interest paid. Total interest costs for both amortization models across monthly interest rates ranging from 0.5% to 2%, demonstrating that the fixed installment model generates consistently higher interest costs, with the gap widening at elevated interest rates

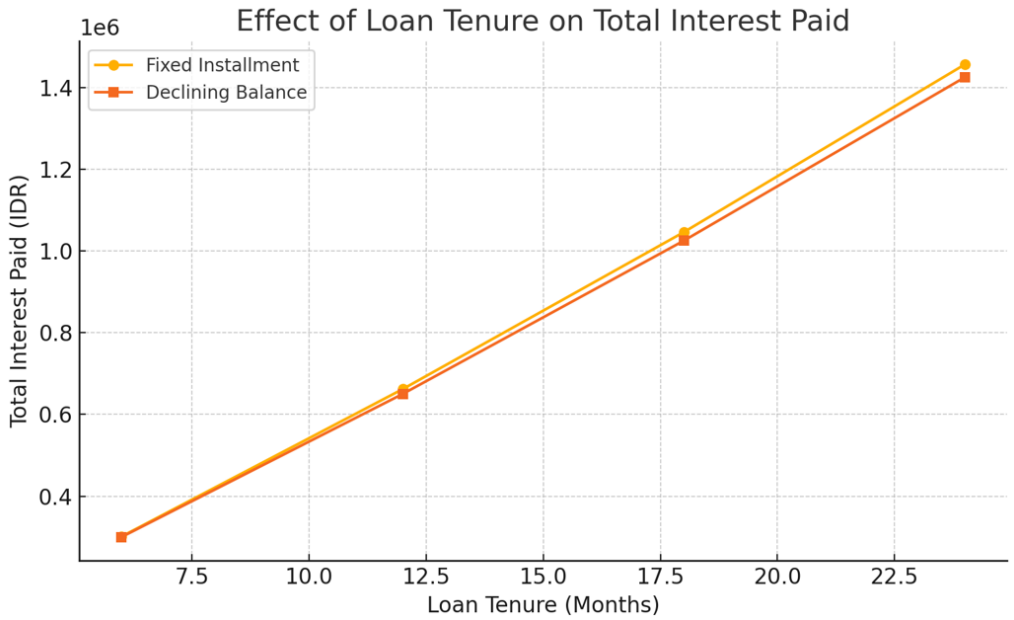

Figure 5. Effect of loan tenure on total interest paid. Total interest costs for both amortization models across loan tenures ranging from 6 to 24 months, showing that longer loan durations significantly increase cumulative interest, with the fixed installment model remaining consistently more expensive

meaningful interest savings by selecting the declining balance approach, although they must accept greater payment variability.

Figure 5 demonstrates the impact of loan tenure extensions, tested across a range from six to twenty-four months, on the total interest paid under both models. For both amortization approaches, longer loan durations lead to significantly higher total interest costs. However, the fixed installment structure remains consistently more expensive than the declining balance method throughout the entire tenure range examined. This outcome becomes increasingly clear with longer repayment periods, confirming the suitability of the declining balance scheme for borrowers focused on minimizing interest costs over extended time horizons. The analysis reveals that as loan tenure doubles from twelve to twenty-four months, the interest difference between the two models widens substantially, emphasizing the importance of tenure considerations in loan product selection.

These results demonstrate that while the fixed installment model ensures consistent monthly obligations, it is less favorable under prolonged or high-cost lending scenarios. The declining balance model, despite involving more variable payments, adapts better to shifts in loan parameters and offers lower overall financial burden for borrowers. Cooperative institutions may use these findings to align their credit product designs with changing economic conditions and diverse borrower profiles. For instance, declining balance loans could be prioritized during periods of high interest rates or assigned to members with increasing income potential or greater financial literacy. Meanwhile, fixed installment schemes may remain appropriate for clients who highly value predictability and possess stable cash flow profiles, particularly those employed in formal sector positions with regular monthly salaries. Understanding how loan performance shifts under varying financial conditions is important for effective lending decisions that balance institutional sustainability with borrower welfare objectives.

Discussion

The simulation and sensitivity analyses reveal several important findings that are particularly relevant for stakeholders in cooperative microfinance. The fixed installment model ensures consistent monthly payments, providing predictability that is valuable for both borrowers and cooperatives. However, this payment stability comes at the cost of slightly higher total interest expenses over the loan period. This tradeoff may be acceptable for borrowers who value payment certainty and for cooperatives that need steady cash flows to maintain operations. Furthermore, the model's simplicity makes it easier for borrowers to understand, which is especially beneficial in rural areas where financial literacy may be limited. The predictable nature of fixed payments reduces confusion and enables borrowers to plan household budgets more effectively, which can reduce the likelihood of missed payments.

In contrast, the declining balance model offers better long-term affordability through lower total interest costs. This structure is particularly suitable for borrowers who can manage higher initial payments or those who expect their income to increase over time. The model's transparency, where interest charges directly reflect the decreasing loan balance, can build borrower trust and encourage consistent repayment behavior in cooperative lending settings. By clearly linking interest costs to the outstanding principal, this approach helps borrowers understand their debt reduction progress, which may motivate them to maintain regular payments. Additionally, the visible decrease in monthly obligations provides psychological benefits, as borrowers can see tangible evidence of their progress toward becoming debt-free, which may reinforce positive financial behaviors.

The sensitivity analysis shows clearly that changes in interest rates have substantial effects on total interest costs, especially over longer loan periods. Under these conditions, the declining balance model is more flexible because it recalculates interest monthly based on the remaining balance, while the fixed installment model determines the payment schedule at the start. This flexibility is especially valuable during periods of high inflation or economic uncertainty, when interest rates are more likely to change. The analysis shows that as interest rates increase from 0.5 percent to 2 percent monthly, the cost difference between the

two models becomes larger, with the declining balance approach offering greater savings. Similarly, when loan periods extend beyond twelve months, the interest advantage of the declining balance model becomes more apparent, suggesting that this approach may be more appropriate for longer-term cooperative loans.

These findings suggest that using only one amortization structure may not be the best approach for rural cooperatives serving diverse members. Instead, offering multiple repayment options or adding flexible features, such as interest rate caps, payment deferrals during difficult periods, or income-based repayment adjustments, can reduce default risk and improve financial inclusion without harming institutional sustainability. Cooperatives might consider offering different products where borrowers with stable employment receive fixed installment loans, while those in agriculture or informal work with seasonal income access declining balance products. Such differentiation would require better borrower assessment procedures but could significantly improve repayment outcomes and member satisfaction.

Furthermore, training cooperative staff to conduct regular simulations and apply sensitivity analysis techniques would substantially improve decision-making and risk management. By developing the ability to quickly assess how different borrower profiles, loan structures, and economic conditions interact, cooperatives can better serve member needs while maintaining financial stability. This analytical capability becomes particularly important during economic downturns or policy changes that affect interest rates, enabling cooperatives to adjust lending terms proactively rather than responding to problems after they emerge. Training programs that equip cooperative managers with basic financial modeling skills could yield substantial benefits in terms of portfolio quality and institutional strength.

Implementing flexible loan structures requires cooperatives to invest in better management information systems that can handle more complex repayment schedules. While this represents an upfront cost, the long-term benefits in terms of lower default rates, improved borrower satisfaction, and better portfolio performance likely justify such investments. Moreover, digital financial platforms increasingly enable cooperatives to automate complex calculations and provide borrowers with real-time information about their loan status, repayment progress, and alternative payment options. Using technology in this way could reduce the operational burden of managing diverse loan products while improving transparency and borrower engagement.

From a policy perspective, these findings highlight the importance of evidence-based loan design in ensuring both borrower affordability and institutional sustainability. Regulatory frameworks governing cooperative microfinance should encourage rather than limit product innovation, allowing institutions to adapt offerings to local economic conditions and member characteristics. Policymakers might consider establishing interest rate guidelines rather than strict caps, recognizing that well-structured declining balance loans with slightly higher stated interest rates may actually be more affordable than fixed installment alternatives with lower nominal rates. Additionally, financial literacy programs targeting both borrowers and cooperative staff could significantly enhance the effectiveness of more sophisticated loan products.

The results align with broader microfinance research emphasizing the importance of evidence-based loan design in ensuring borrower affordability and institutional sustainability [9, 12]. The use of social credit scoring by cooperative credit banks demonstrates how transparency can enhance member trust and long-term institutional strength [13]. Moreover, achieving an appropriate balance between financial stability and accessibility has been identified as a key challenge in sustaining microfinance institutions [14, 16]. This study contributes to this discussion by providing quantitative evidence about the specific tradeoffs in different amortization approaches, enabling more informed decisions by cooperative managers and policymakers.

Overall, the findings support a data-driven, member-centered approach to designing cooperative loan products that carefully balances payment stability, cost transparency, long-term affordability, and operational strength. By moving beyond one-size-fits-all lending models toward more tailored product offerings informed by careful analysis,

cooperatives can better fulfill their dual mandate of serving member welfare while maintaining institutional sustainability. This evolution requires investment in analytical capacity, staff training, and potentially technology infrastructure, but the resulting improvements in portfolio quality and member outcomes justify such commitments. As rural Indonesia continues to develop economically and financially, cooperatives that adopt careful, evidence-based approaches to loan product design will be better positioned to serve their communities effectively while managing an increasingly complex financial landscape.

Conclusion

This research evaluates two widely adopted amortization models, fixed installment (annuity) and declining balance, within the context of cooperative microfinance. The simulation results indicate that the fixed installment model provides stable monthly payments, facilitating budget planning for borrowers and offering consistent cash flow for cooperatives, albeit with a higher cumulative interest cost. In contrast, the declining balance model yields lower total interest payments and aligns more closely with the reducing loan balance. However, its higher initial payments may pose challenges for borrowers with fluctuating incomes.

The sensitivity analysis reveals that increases in interest rates and loan durations substantially elevate the total interest burden. The declining balance model exhibits greater adaptability in response to changing financial conditions, making it more appropriate for volatile economic settings. Based on these results, we suggest that cooperatives adopt flexible loan structuring approaches and consider offering multiple repayment schemes. We also recommend policy measures such as setting interest rate ceilings, enhancing borrower financial literacy, and introducing adaptive loan terms to promote financial inclusion and strengthen institutional resilience.

Declaration of interest

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Author contributions

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References

1. Allen F, Demirguc-Kunt A, Klapper L, Peria M. The foundations of financial inclusion: Understanding ownership and use of formal accounts. J Financ Intermediation. 2016;27:1–30. https://doi.org/10.1016/j.jfi.2015.12.003
2. Adusei M. Interest rate and the social performance of microfinance institutions. The Quarterly Review of Economics and Finance. 2021;80(3):21-30. https://doi.org/10.1016/j.qref.2021.01.009
3. Durango-Gutiérrez P, Lara-Rubio J, Navarro-Galera A, Buendía-Carrillo D. Microcredit Pricing Model for Microfinance Institutions under Basel III Banking Regulations. International Journal of Financial Studies. 2024;12(3):88. https://doi.org/10.3390/ijfs12030088
4. Judijanto L, Sudiana U. The Role of Microfinance in Fostering Entrepreneurship and Economic Growth in Indonesia. The Es Economics and Entrepreneurship. 2025;3(03):347–354. https://doi.org/10.58812/esee.v3i03.536
5. Ledgerwood J. Microfinance Handbook: An Institutional and Financial Perspective. World Bank Publications; 1998.
6. Stein R. Measuring the Effect of Credit Risk on Loan Pricing: Evidence from the Small Business Market. J Bank Finance. 2020;113:105158. https://doi.org/10.1016/j.jbankfin.2020.105158
7. Mari C. Amortizing Loans under Arbitrary Discount Functions. J Risk Financ Manag. 2024;17(5):185. https://doi.org/10.3390/jrfm17050185
8. Geelen T, Hajda J, Morellec E, Winegar A. Asset life, leverage, and debt maturity matching. Journal of Financial Economics. 2024;154:103796. https://doi.org/10.1016/j.jfineco.2024.103796
9. Barboni G. Repayment flexibility in microfinance contracts: Theory and experimental evidence on take up and selection. Journal of Economic Behavior & Organization. 2017;142:425-450. https://doi.org/10.1016/j.jebo.2017.07.020
10. Field E, Pande R, Papp J, Rigol N. Does the Classic Microfinance Model Discourage Entrepreneurship among the Poor? Evidence from India. Am Econ Rev. 2013;103(6):2196–226. https://doi.org/10.1257/aer.103.6.2196

11. Koswara A, Taofik E, Andriana E, Gunawan J, Maria L. Prospects and Challenges of Multi-Stakeholder Cooperatives in Supporting Community-Based Economy in Indonesia. Review of International Economic, Taxation, and Regulations. 2025;1(1):1–10. https://ojs.proaksara.com/index.php/rietr/article/view/12
12. Banerjee A, Karlan D, Zinman J. Six Randomized Evaluations of Microcredit: Introduction and Further Steps. Am Econ J Appl Econ. 2015;7(1):1–21. https://doi.org/10.1257/app.20140287
13. Zedda S, Modina M, Gallucci C. Cooperative credit banks and sustainability Towards a social credit scoring. Research in International Business and Finance. 2024;68:102186. https://doi.org/10.1016/j.ribaf.2023.102186
14. Fersi M, Boujelbène M. Comparative Study of Microfinance Sustainability: Credit Risk-Taking and Capital Structure. International Journal of Management Economics and Social Sciences. 2023;12(3):184–216. https://doi.org/10.32327/IJMESS/12.3.2023.8
15. Lamrani Alaoui Y, Tkiouat M. Assessing the performance of microfinance lending process using AHP-fuzzy comprehensive evaluation method. SAGE Open. 2017;7(4):1-17. https://doi.org/10.1177/1847979017736692
16. Cull R, Demirgüç-Kunt A, Morduch J. Microfinance meets the market. Journal of Economic Perspectives. 2009;23(1):167–192. https://doi.org/10.1257/jep.23.1.167
17. Shah DY, Nandani S. Optimizing credit management for advancing financial inclusion: A study of microfinance institution. International Journal for Novel Research in Economics, Finance and Management. 2024;3(1):194–202.