



## Proposing a Novel System for Measuring the Effectiveness of Validating Customers of the Banking System based on the System Dynamics

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### Abstract

This study aims to develop a system for measuring the effectiveness of customer validation in the banking sector using a system dynamics approach. The proposed model illustrates how dynamic systems can optimize and stabilize financial unit operations by considering the interplay of various factors affecting credit risk. Simulation results over a two-year period demonstrate the significant impact of external pressures like sanctions and environmental conditions on the system. By implementing strategic policies and leveraging knowledge management, the study shows how banks can reduce default probabilities, enhance capital returns, and improve overall system quality. The research underscores the importance of preventive measures and efficient resource management in maintaining robust financial processes. Future recommendations include involving more experts, utilizing extensive quantitative data, and incorporating additional sub-parameters for more accurate predictions.

**Keywords:** System Dynamics, Customer Validation, Credit Risk, Banking Sector, Knowledge Management

### 1. Introduction

In the banking sector, effective customer validation is critical for ensuring security, regulatory compliance, and customer satisfaction [1]. Traditional validation methods often face challenges such as lengthy processing times, high operational costs, and vulnerability to fraud, which can negatively impact both the customer experience and the institution's reputation [2]. To address these challenges, a novel system dynamics-based approach is proposed to measure and enhance the effectiveness of customer validation processes [3]. This approach leverages the interconnectedness of key variables such as validation time, accuracy, operational costs [4], and customer satisfaction,



providing a comprehensive framework for continuous improvement and robust fraud prevention, ultimately leading to a more secure and efficient banking environment [5]. It should be noted that more research has been examined regarding the issue of banking system for loan so far. To mention a few, Ghodrati et al. [6] examined the impact of financial information quality on loan accreditation at Bank Mellat's East Azerbaijan branches, using a sample of 31 branches from 2010-2011. It employed a multi-variable linear regression technique and found that relevance, timeliness, and reliability significantly affected loan accreditation and bank contracts. The results highlighted the importance of high-quality financial information in banking decisions. Prieto et al. [7] revealed a significant correlation between the amount of loans granted to microenterprises and the number of individual CPAs.

It also found that banks and loan officers regarded audits by sole practitioners as high quality, comparable to larger firms. The research contributed to the literature by employing a mixed-method approach to assess audit quality. Beatty et al. [8] found that banks reducing lending during recessions mitigated future capital inadequacy concerns, particularly under stricter regulatory capital constraints. It revealed that banks with less delay in expected loss recognition reduced lending less during recessions compared to expansionary periods. Additionally, smaller delays in loss recognition diminished the recessionary capital crunch effect across different levels of management quality. Faure et al. [9] allocations under conditions of no uncertainty. It demonstrated that using the simpler loanable-funds approach did not compromise generality. Additionally, it indicated a restricted equivalence under aggregate risk with complete contracts and markets. Thamae et al. [10] reviewed the theoretical and empirical literature on the impact of bank regulation on bank lending. It found that the effects of regulation were ambiguous, with studies showing negative, positive, or inconclusive impacts.

Most studies only assumed first-round effects, with limited research on second-round effects using general equilibrium models. Tsai et al. [11] highlighted the critical importance of credit granting as both a primary job and main income source for banks. It examined various facets and cause-effect relationships in credit risk assessment, focusing on enhancing reliability and usefulness. Conclusions identified "optional capability" and "competitiveness" as highly influential dimensions, suggesting improvements in these areas would address major credit risk assessment issues. Robiyantoko et al. [12] examined the reluctance of Notaries and PPATs to issue deeds for cross-country mixed marriage couples seeking Sharia financing with mortgage rights. It analyzed relevant laws and regulations and identified opportunities and constraints for these couples in accessing such financing. The findings provided a comprehensive understanding of the legal conditions affecting their eligibility. In the digital age, the banking sector is undergoing a profound transformation, driven by technological advancements, evolving customer expectations, and increasingly stringent regulatory requirements. Central to the integrity and stability of the banking



system is the process of validating customers, ensuring their identities, and mitigating risks associated with financial transactions. However, traditional methods of customer validation are facing unprecedented challenges in keeping pace with the rapidly changing landscape. Amidst this backdrop, there is a pressing need for innovative approaches to measure the effectiveness of customer validation within the banking system. Such approaches must not only account for the intricacies of regulatory compliance but also adapt to the dynamic nature of customer behaviors and technological advancements. Ahmed et al. [13] enhanced banking risk management by introducing a novel risk ranking index and assessing the importance of various risk ratios.

Employing Mahalanobis Distance and an Adaptive Neuro-Fuzzy Inference System, the research analyzed data from 45 Gulf banks over 2016–2020. Results revealed a strong predictive power, with the Mahalanobis Distance effectively gauging banks' risk positions and identifying significant risk factors, notably emphasizing the importance of Net Interest Margin and Capital Adequacy Ratio in influencing financial stability. Chauhan et al. [14] delved into digital banking's impact on customer experience, identifying key factors like trust, convenience, website attributes, and gamification. It proposed a comprehensive framework linking technology, customer experience, satisfaction, loyalty, and financial performance, offering insights for banks to enhance their online presence strategically. By filling gaps in understanding and emphasizing the role of gamification, this research contributed significantly to the evolving landscape of digital banking literature. Menor et al. [15] presented a two-stage approach for developing and validating measurement scales for NSD competence, addressing the lack of psychometrically sound items. Through iterative item-sorting and confirmatory factor analysis, the study assessed reliability and validity, confirming the unidimensionality of five NSD competence dimensions. The research significantly advanced understanding in NSD and provided managers with a diagnostic tool for assessing and improving service innovation expertise. Yıldız et al. [16] developed a dynamic strategy map model by integrating scenario analysis and systems dynamics, addressing criticisms of traditional methods. Serial Group Model Building sessions were conducted with experts from a Turkish construction company, ensuring structural and behavioral validity. Simulation tests demonstrated that the model enhanced strategic decision-making by simulating the impacts of alternative strategies and future scenarios. This research offered a reliable methodology for scholars and industry practitioners on developing dynamic strategy maps for improved performance management. Laitinen et al. [17] presented a novel dynamic integrated performance measurement system (IPMS) based on a managerial perspective. It proposed seven main factors linked in a causal chain, echoing the principles of activity-based costing (ABC). Empirical evidence gathered from small Finnish technology firms highlighted the significance of factors such as employee motivation, customer satisfaction, and financial performance in performance measurement, with factor analysis categorizing companies into distinct groups. Irani et al. [18] explored augmented



reality's role in contextual marketing, analyzing key variables and their causal relationships. Mathematical functions were extracted to understand the behavior of each factor.

Various scenarios were simulated to demonstrate how AR technology could enhance contextual marketing. Overall, the study provided valuable insights into leveraging AR within dynamic marketing environments. Sha et al. [19] presented a novel System Dynamics (SD) approach, analyzing historical data and assessing the impact of fuel economy policies in Sri Lanka, including electric mobility. The authors utilized Vensim SD software for modeling and conducted expert-in-the-loop sensitivity analysis. Three strategic intervention scenarios were developed, showing potential improvements in fuel economy for Four-Wheeled Passenger Vehicles (FWPVs) by 2030, with hybrid and electric vehicles demonstrating significant gains.

Li et al. [20] integrated system dynamics and structural topic modelling to identify team behavior categories in data science open innovation. Results revealed that activities such as model evaluation and community support positively impacted team performance. The research underscores the significance of forum feedback in enhancing empirical understanding and offers insights for both researchers and practitioners involved in data science open innovation. Mao et al. [21] proposed a system dynamics model that analyzed factors such as trust, AV purchase willingness, and shared AV service accessibility. Indicated by the results was a significant decrease in private vehicle ownership, with shared AV fleets dominating after 2030. Found by the researchers was that attitudes towards ride-sharing influenced the adoption of shared AVs, impacting fleet sizes and congestion levels in Beijing. Favored by policymakers was the limitation of vehicle numbers through registration controls, but future adjustments may prioritize promoting ride-sharing for sustainable urban transport. Kotir et al. [22] reviewed the implementation of stakeholder-driven participatory modelling in understanding water and agri- food systems dynamics in the Volta River Basin, West Africa. It outlined eight key insights derived from various stages of the modelling process, highlighting stakeholders' active contribution and challenges encountered. The findings demonstrated stakeholders' involvement in parameter estimation, sensitivity analysis, and simulation experiments, despite challenges such as time constraints and consensus struggles. The paper contributes practical guidance for future participatory modelling efforts in regions facing sustainable development challenges in water and agri-food systems, emphasizing stakeholder engagement for effective policy interventions.

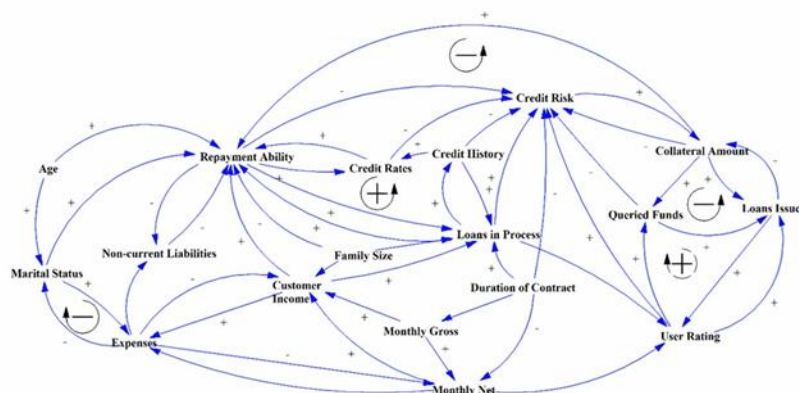
a holistic and dynamic perspective on customer validation in banking. By leveraging the principles of system dynamics, this study aims to model the complex interactions and feedback loops inherent in the customer validation process. It seeks to identify the critical variables influencing validation effectiveness, understand their interdependencies, and simulate different scenarios to assess the impact of various validation strategies. Through this approach, the study seeks to provide banks



with actionable insights to enhance their validation processes, improve compliance, and mitigate risks. In this study, we delve into the rationale behind adopting a system dynamics approach, highlight the significance of the study in the context of contemporary banking challenges, and outline the structure of the research endeavor. Through this exploration, we endeavor to contribute to the ongoing discourse on customer validation in banking, offering new perspectives and methodologies to address the complexities of modern financial ecosystems.

## 2. Methodology and dataset

A causal-effect diagram is a tool for drawing causal relationships within a system, which is divided into two general types [23]: reinforcing loops and balancing loops. Reinforcement loops are positive feedback systems that keep pace with the initial change. Balancing loops, contrary to the behavior of reinforcing loops, will take a movement opposite to the initial change. According to Figure 1, the causal and effectual loops related to the proposed dynamic hypotheses are presented.



**Figure 1. Causal-disability loop diagram based on systemic thinking about the balance and strengthening of the loops**

The graph made in this study has significant reinforcing or positive double loops that cause change in the same direction (growing) which are indicated by the + symbol (R) and indicate causality. On the other hand, the causal diagram of the model has three important balancing or letter "B". Figure 1 shows that the sudden disruption in credit risk depends on various reasons such as credit rates, collateral amount, repayment ability and other such factors, as a result, the amount and amount of credit risk will depend on these variables. An increase in the amount of collateral and the duration of the contract leads to a decrease in the probability of default, which will result in a decrease in credit risk for the financial unit, which will ultimately affect the performance of any event.



### 3. The state-flow model

Examining the behavior of the system over time requires the simulation of relationships and variables in Vensim software, which in the simulation, flow diagrams will be equivalent to causal loops. In the current state model, based on an interview conducted with experts, we selected variables that had a greater effect on the variables related to repayment and credit risk, and there was enough information about those variables for writing formulas in the software.

First, we defined the desired time period and also the relationship between the components of the system variables as a hypothesis in the Vensim software. that this hypothesis and formulas due to the fact that there is no precise definition of the relationships between variables, based on the opinion of experts; These relations are created and defined based on the logic and data at hand. Then, based on the input information, the software has simulated and drawn a behavior that can be seen in Figure 2. This model has been implemented for a period of 2 years (2021-2023) and the system's behavior shows the validity of these relationships. Therefore, the output behavior of the variables, based on the assumption defined according to Figure 2, will be examined in the following. After entering the information in the software and running the Vensim simulator software, causal (Figure 3) and negative (Figure 4) outputs are obtained.

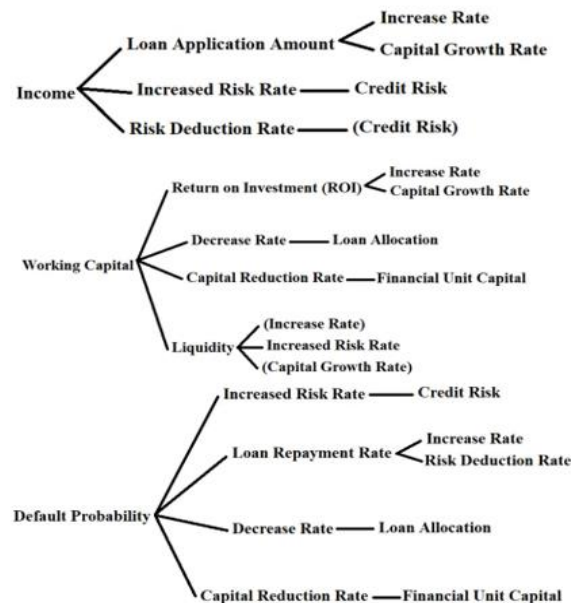


Figure 2. Causal relationships between the variables "income", "working capital" and "probability of default"



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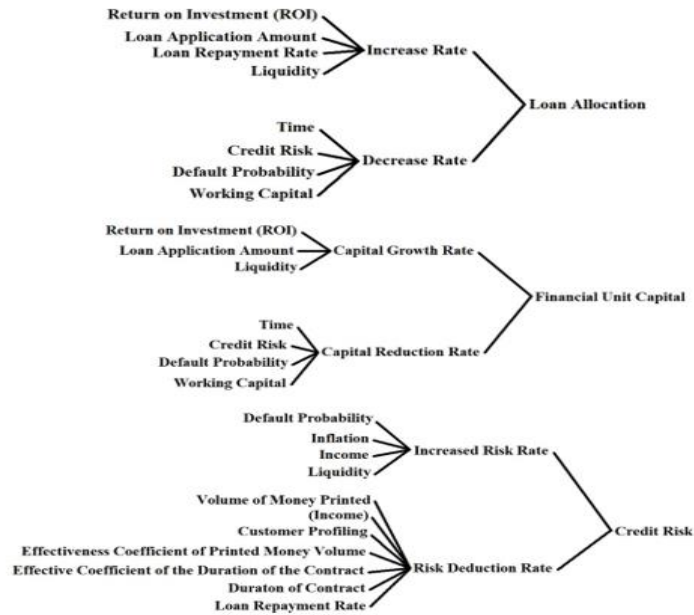


Figure 3. Corresponding relationships between the variables of facility allocation, financial unit capital and credit risk



Figure 4. Corresponding relationships between the variables of facility allocation, financial unit capital and credit risk



## 4. Model validation

Validation in the approach of dynamic systems emphasizes more on the behavior of data over time, which expresses the correctness of the relationship between the created structure and the production behavior. Model testing seeks to trust the model and its results and achieve a deeper understanding. In this test, by using the limit values of some variables, it is determined whether the equations and the model behave logically and in accordance with the physical laws. As indicated in Figure 5, the behavior of the system and the variables at their maximum possible value, which can be reached by changing the amount of input and output variables. It can be concluded that the behavior and relationships between the variables of the model are correct.

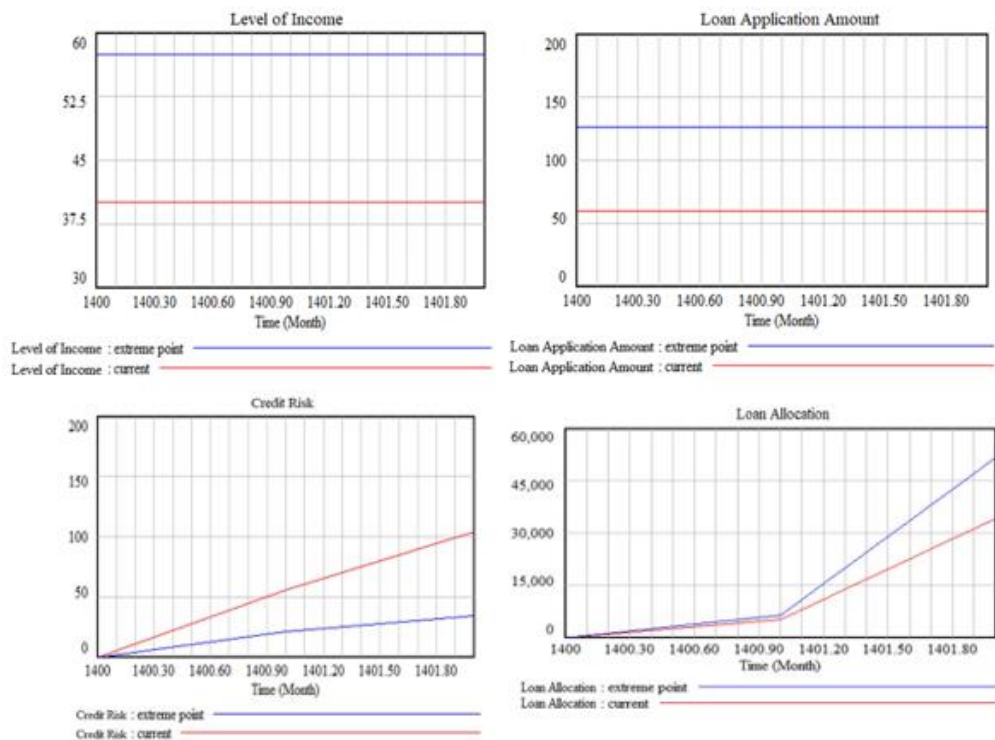


Figure 5. The behavior of the model in extreme point mode

This type of behavior by comparing the state of maximum input variables and the minimum value of output variables shows the effect of income on the rate of change of credit risk components and facility allocation (Figure 5). With the minimization of the variables that have a negative effect and the maximization of the variables that have a positive effect on the components, the values of





the components that are affected by this parameter (income level) also change. As you can see in the diagram above, you can see the effect of the maximum amount of this component on the amount of credit risk and other indicators. In this test, the required amount in each unit is possible in two states, minimum and maximum, so that it can be seen in Figure 4, if the sum of the input variables is equal to the sum of the output variables, the next loops are minimized, which indicates healthy relationships and behavior. It is among the variables of the model. In addition to determining the maximum and minimum value of the parameters, this test helps us to check the maximum or minimum effect of the main variables on the model and make appropriate decisions accordingly. The effect of maximizing the level of income: by increasing the amount of income to the maximum possible amount, as can be seen in the figure above, the amount of requests and allocation of facilities will also increase, which will be due to the reduction of credit risk and greater trust of financial units in repaying their customers which has a significant difference with its final value in the current state.

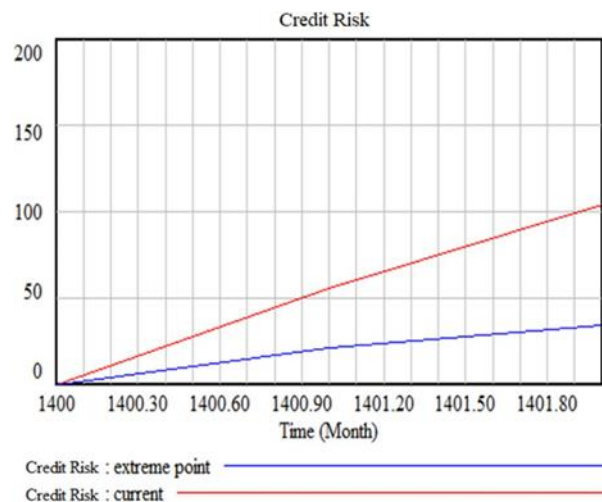


Figure 6. Behavior of credit risk variable in extreme point mode

According to Figure 6, the component of the allocation of facilities under the influence of the increase in income is 51.740 and the component of allocation of facilities in the current state is 34.170. With the improvement of living conditions, the probability of default will decrease, and subsequently the credit risk will also decrease.

## 5. Dimensional and structural testing of the model

This study proposes a novel system for measuring the effectiveness of customer validation in the banking sector through the application of System Dynamics (SD). By utilizing SD's components—feedback loops, stocks and flows, and delays—this model provides a comprehensive framework



to analyze and optimize the validation process. The core components of the model include validated customers, pending validation customers, and fraudulent customers as stocks, with corresponding flows such as validation rate, detection rate, and error rates (false positives and false negatives). This approach allows for the simulation of various scenarios and the evaluation of key performance indicators like accuracy, efficiency, and customer satisfaction.

The implementation involves gathering historical data, developing and simulating the SD model, and optimizing validation strategies based on simulation results. For instance, introducing an AI-based validation tool could significantly enhance the validation process by reducing false negatives and increasing the validation rate. The continuous feedback loop inherent in the SD approach ensures that the model can be updated with new data, facilitating ongoing improvements. Thus, the SD model not only enhances the understanding of the customer validation process but also supports strategic decision-making to improve security, compliance, and customer experience in banking.

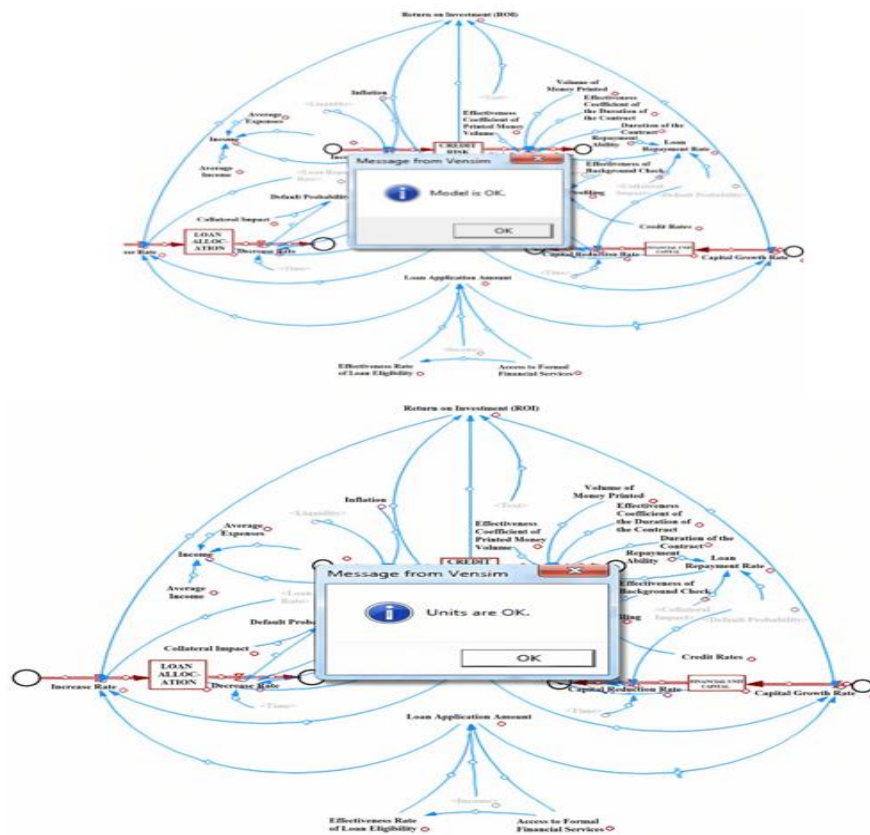


Figure 7. Confirmation of dimensional and structural relationships in Vansim



Based on Figure 7 in Vansim software, the presented model does not have any obvious errors and does not have any defects in the dimensions and structure of the defined variables, and further on, the compatibility of the model dimensions is confirmed, which means that the dimensions and structure variables used in the model are congruent with each other. According to the model's function, it can be concluded that the proposed dynamic hypotheses are confirmed.

## 6. Scenario Planning and Sensitivity Analysis

In this scenario, we examine the model's behavior over the review period without any changes to the current system processes. The aim is to understand the long-term impact of maintaining the status quo. Figure 8 illustrates the behavior of the credit risk component under normal conditions. The model predicts that, if current conditions persist, the credit risk will rise to approximately 110% by 1402. This significant increase highlights the urgent need for preventive measures to curb credit risk growth and enhance customers' repayment abilities. If the current policies continue unchanged, the allocation rates for facilities and working capital, along with other positively influential variables, will decline. Conversely, components such as the probability of default and other negatively impactful factors will rise. This trend will lead to reduced capital and return on capital for the financial unit. Over the long term, these outcomes can disrupt the financial unit's operations, underscoring the critical need for strategic interventions to maintain financial stability and performance.

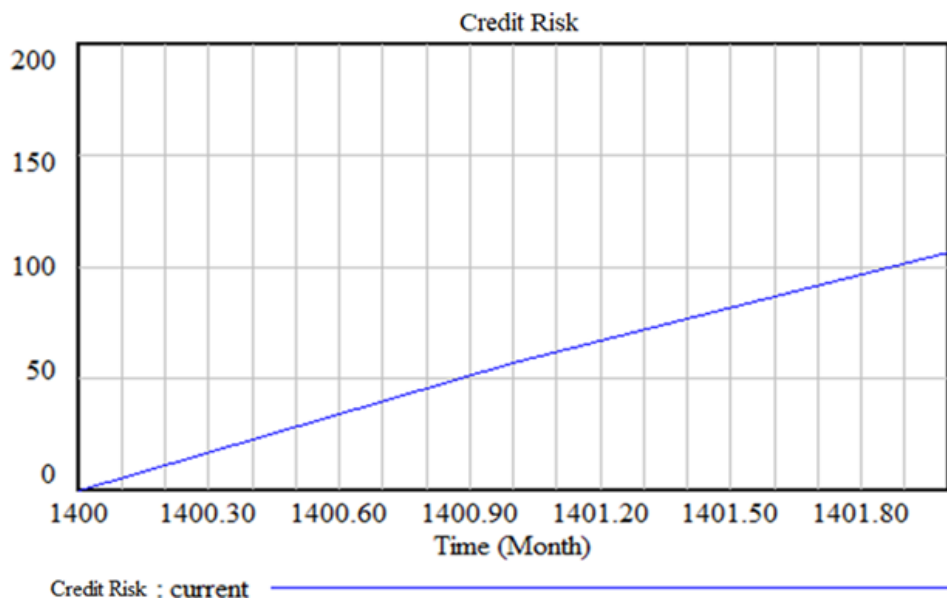


Figure 8. Behavior of credit risk component in normal state

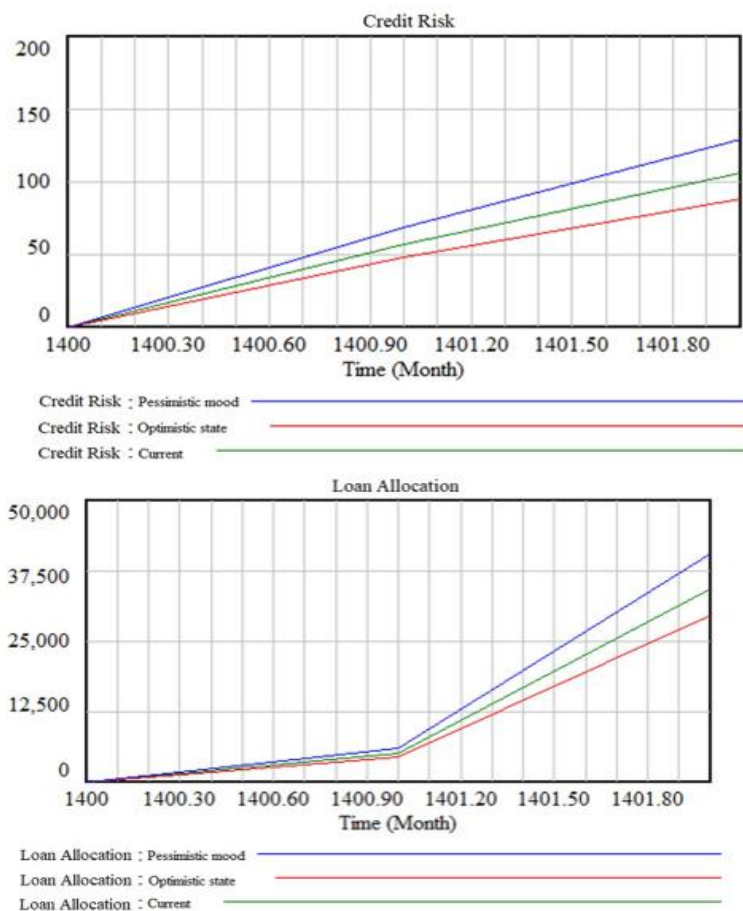


As discussed, maintaining the current conditions, regardless of positive parameters, will lead to an increase in variables that elevate credit risk, ultimately reducing capital return. The model suggests two primary solutions: avoiding the increase of these risk variables and strengthening positive parameters that can offset the negative effects. However, preventing the rise in risk variables is complex and challenging under normal conditions. Therefore, the more feasible approach involves enhancing factors such as income levels, collateral effectiveness, return rates on facilities, and policy improvements. By focusing on these areas, the negative impacts can be mitigated, helping to stabilize the financial unit's operations. Additionally, an optimistic-pessimistic scenario analysis, which involves altering key factors by  $\pm 10\%$ , can provide valuable insights into the model's sensitivity and potential outcomes under varying conditions. This approach allows us to understand how the system behaves under both favorable and adverse scenarios, aiding in strategic planning and decision-making. By preparing for a range of possible futures, financial units can develop more resilient strategies, ensuring better management of credit risk and overall financial stability

Optimistic state      Pessimistic mood      Credit risk  
10% reduction      10% reduction      Income level  
10% reduction      10% reduction      livelihood status  
10% reduction      10% reduction      Probability of default

**Table 1. Comparison of the credit risk states**

Optimistic state	Pessimistic mood	Credit risk
10% reduction	10% reduction	Income level
10% reduction	10% reduction	livelihood status
10% reduction	10% reduction	Probability of default



**Figure 9. Behavior of credit risk parameters and facility allocation under optimistic-pessimistic scenario**

Implementing the optimistic scenario results in a more favorable growth rate for the credit risk component over two years compared to both the current and pessimistic states as shown in Figure 9. This scenario shows a slower upward trend in credit risk, which helps maintain higher facility allocation rates and positively affects related components. Conversely, the pessimistic scenario leads to a significant increase in credit risk, exacerbating negative trends and impacting all related variables and model behavior. Given the interconnected nature of these variables, even minor adjustments can significantly alter the model's trajectory. By analyzing the simulated model, we can identify factors influencing credit risk and apply this



understanding to reduce the variable, as demonstrated in the optimistic scenario. According to the data, increasing factors that mitigate credit risk can halt its rise, aligning the financial unit closer to its goal of higher capital returns. Since default probability and credit risk negatively impact financial processes, policies targeting these reductions will enhance financial security.

Similarly, boosting components with positive effects on the system can counterbalance negative variables, promoting overall organizational stability. The aim of this research is to develop a system for measuring the effectiveness of customer validation in the banking sector using a system dynamics approach. The proposed model serves as an example of implementing dynamics in this field and suggests ways to prevent the deterioration of key components by considering optimization and sensitivity outputs. A major merit of dynamic system modeling is the comprehensive consideration of all related elements and the examination of their feedback effects on the entire system. By accurately identifying effective factors and simulating current conditions, the model can predict factors that influence credit risk through negative and positive feedback loops, resulting in improved forecasting and planning outcomes. The simulation results over a two-year period highlight that external pressures, such as sanctions and environmental conditions, significantly impact the system [24]. Appropriate policies leveraging existing capacities and encouraging customer behaviors to reduce default probabilities can partially mitigate these deficiencies. Knowledge management in rule formulation and continuous monitoring of project performance improves overall system quality and service delivery. Reducing default probability decreases credit risk, enhancing capital return. The system dynamics approach also enables preventive measures and error prediction, ensuring robust financial unit management. Efficient modeling of complex dependencies and relationships is critical for optimizing system performance, resource management, and minimizing credit risk. The proposed model evaluates different risk scenarios, demonstrating significant changes in system behavior with variations in key factors, ultimately guiding better resource management and strategic decision-making.

## 7. Conclusion

This research successfully demonstrates the application of a system dynamics approach to measure and enhance the effectiveness of customer validation in the banking sector. By developing a comprehensive model, we highlighted the importance of considering all related elements and their feedback effects on the system. The simulation results indicate that external pressures such as sanctions and environmental conditions significantly impact the system's performance. To mitigate these effects, implementing appropriate policies that leverage existing capacities and encourage customer behaviors to reduce default probabilities is essential. The study underscores the value of knowledge management in rule formulation and continuous monitoring to improve system quality and service delivery. The dynamic model allows for preventive measures and error prediction,



ensuring robust financial unit management and reducing credit risk, which naturally enhances capital returns. Evaluating different risk scenarios showed significant changes in system behavior with variations in key factors, providing valuable insights for better resource management and strategic decision-making. Future research should expand the model's scope by involving more experts and utilizing extensive quantitative data, focusing on strategies to reduce default probabilities, control inflation, and adopt updated productivity methods. Incorporating additional sub-parameters could further refine the model, offering more precise predictions and enhancing its overall effectiveness in the banking system.

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