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A Combination of Balanced Scorecard, System Dynamics and Game Theory to Design Performance Measurement System

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Abstract

Performance evaluation in organizations is a widely debated topic, drawing on numerous methods for optimal insights. While existing methodologies offer depth, there's a growing need for an integrated framework to better understand the intricate dynamics of relevant factors. This paper proposes a novel approach by combining the Balanced Scorecard with system dynamics, facilitating the establishment of causal relationships among indices. By applying game theory, we cluster expert decisions into coalitions, deriving a holistic performance assessment. To test the effectiveness of this innovative method, we conducted a real-world application study on "Bank Melli," Iran's premier bank. Engaging a panel of experts, we gathered data on key indices, causal relationships, scenario construction, and game theoretic analysis using both qualitative and quantitative questionnaires. The proposed method's efficacy is underscored by its validation through expert panels. Beyond offering a deeper comprehension of the nuanced influences on an organization's performance, our approach also introduces a scenario-building tool that opens avenues for exploring new managerial strategies.

Keywords: Banking Performance Measurement System; Balanced Scorecard; System Dynamics; Game Theory.

1. Introduction

In today's business landscape, marked by escalating complexity and diversity, managers are under increasing pressure to cultivate an environment of continuous and effective learning (Anjomshoae,2022). Such proactive learning fosters organizational adaptability, enabling a judicious blend of decision-making that resonates with the evolving needs of the marketplace. In these nuanced ecosystems, delineating the intricate interconnections between performance indicators becomes paramount, serving as navigational aids steering the organization toward its long-term objectives.

Historically, organizations leaned heavily on financial indicators as barometers of their performance. These metrics, rooted in tangible outcomes such as profit and loss, offered a unidimensional perspective, reflecting only the aftermath of managerial decisions. Such a narrow lens, while insightful, seldom catered to the holistic growth needs of organizations. Recognizing this vacuum, the 1980s witnessed a paradigm shift, ushering in a suite of performance management methodologies. These contemporary models pivoted toward perpetual evolution, imbibing fresh perspectives and ideologies. As Seal (2014) articulates, the essence of performance management lies in its integrative nature, weaving an organization's myriad threads into a cohesive tapestry aligned with its overarching goals and strategies.

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A beacon in this transformative journey has been the Balanced Scorecard. Garnering substantial scholarly attention over the past decade, the Balanced Scorecard amalgamates a quartet of perspectives: finance, customer orientation, internal processes, and growth and learning. This integrative approach empowers managers with a panoramic view, illuminating the multifaceted linkages and their subsequent ramifications. Such a broadened horizon encourages managers to transcend conventional silos, refining their decision-making and problem-solving prowess (Zhang and Li, 2009; Rigo et al., 2022).

Among the various methods that have been proposed so far to evaluate decisions and guide the performance of organizations, the interest of researchers in the influence and credibility of the Balanced Scorecard has increased in the last decade. A balanced scorecard combines the four perspectives of financing, customer, internal processes, growth and learning, leads managers to understand the myriad connections and their logical implications. This perception helps managers to think beyond traditional perceptions of task barriers and ultimately improve decision-making and problem solving (Zhang and Li, 2009).

While the Balanced Scorecard brings undeniable benefits to organizational evaluations, it is not devoid of limitations. Chiefs among these are the overlooking of delays between cause and effect, neglecting accumulations (Showing and Tu, 2004; Schoeneborn, 2003; Wolstenholme, 1998), one-dimensional causal relationships (Wolstenholme, 1998; Linard, 2000), an emphasis on linear associations (Lyell and McDonnell, 2011), the uncertainties clouding causal linkages (Glykas, 2013), and an inherent static nature (Bianchi and Montemaggiore, 2006; Zhang and Li, 2008). Such constraints can muddle the waters for management, complicating the processes of decision-making, strategy selection, and the forecasting of performance metric impacts. Recognizing these drawbacks, researchers have sought to bolster the Balanced Scorecard's efficacy by integrating it with other management tools.

Arguably, the most promising merger is with the system dynamics approach, an area where multifaceted interactions are meticulously analyzed and simulated. This approach does not merely identify factors but elucidates their interplay, modeling the dynamism intrinsic to the subject. Such a perspective provides insights into how individual factor targets, when achieved, coalesce to influence the overarching performance of an entity. The essence is to ascertain that when diverse targets converge, the global output is harmoniously realized. Moreover, the nuances of system dynamics foster the creation of scenarios—projected interactions of system elements adapting to environmental shifts. However, these scenarios, being rooted in predictive models and expert opinions, can birth varying, at times conflicting, perceptions, known as coalitions. Addressing these contrasting viewpoints necessitates a robust scientific method, a niche aptly filled by game theory. This mathematical framework captures the dynamics of these coalitions, analyzing them as distinct entities, a synergy validated by Zhang et al. (2021).

The applicability of this integrated model is aptly demonstrated through its implementation at the Melli Bank of Iran, a cornerstone in the nation's financial landscape. With its vast economic potential, strategic importance in financial service delivery, myriad training hubs, and sprawling public assets, the bank's performance is pivotal. In the banking sphere, customer attraction and satisfaction reign supreme. While services cater to both new and existing clientele, the latter holds greater weight due to the higher cost implications of the former. Consequently, the key to enduring market competition lies in sustained customer satisfaction. The present study crafts an optimal decision-making framework tailored to the Melli Bank of Iran, elucidating how an amalgamation of the Balanced Scorecard, system dynamics, and game theory offers a holistic performance assessment of the institution.

2. Literature review

The Balanced Scorecard, despite its widespread application, is not devoid of limitations. Shoving and Tu (2004) emphasized that these limitations stem from causal relationships' high dependency on time and space. They pointed to latency, direct communication, inadequate validation mechanisms, and excessive internal organizational focus as primary causal constraints. By employing Systemic Dynamics, they sought to address these constraints.

Rydzak et al. (2004) highlighted limitations like one-way communication, lack of latency, and static nature. They argued that a Balanced Scorecard often overlooks an organization's value chain position. To circumvent these drawbacks, they amalgamated system dynamics with the Balanced Scorecard, yielding benefits such as improved performance criteria selection, accurate sensitivity analysis, and diverse simulations. Their method's effectiveness was subsequently demonstrated in the electrical machinery sector.

Barnabe (2011) cataloged both the strengths and weaknesses of a Balanced Scorecard. While he acknowledged its merits—simplicity, integrated operational views, managerial capability enhancement, systematic organizational overview, non-financial evaluations, and strategic planning—he didn't shy away from its pitfalls. Barnabe particularly noted ambiguous causal relationships, static nature, errors in performance criteria selection, and excessive internal focus as challenges. Leveraging systemic dynamism, he proposed a model tailored for launching business-centric services.

Glykas (2013) highlighted that the Balanced Scorecard often overlooks aspects such as feedback loops, uncertainty in performance evaluations, time considerations in decision-making, and the need for a dynamic, flexible scorecard. As a remedy, he introduced the fuzzy cognitive mapping solution. Utilizing this software, he simulated two scenarios for each Balanced Scorecard perspective.

Zdenka et al. (2020) embarked on a robust empirical endeavor, first crafting a hypothetical model informed by global academic publications. They then applied the Structural Equation Model (SEM) across 223 companies. Their chief objective was assessing the Balanced Scorecard model's applicability for gauging innovation in small and medium-sized enterprises within the Slovak Republic and Serbia.

Ghannadpour and Zandiyeh (2020) devised a novel multi-objective game theory-based model aimed at bolstering cash transportation security. Their model, rooted in the real-world perils of theft and armed attacks, harnesses game theory to simulate the dynamics between thieves and cash carriers. The introduced model also features a periodic review mechanism, ensuring infrequently used routes are prioritized. To tackle the model, they crafted a new multi-objective hybrid genetic algorithm complemented by innovative operators and strategies. Their empirical tests underscored the algorithm's potency.

Sujitha and Vishnu (2020) postulated that tools from nonlinear dynamics and complex systems theory offer fresh, innovative methods for monitoring combustion systems. Their discourse covered the latest strides in unstable combustion dynamics, rooted in dynamic and complex systems theory.

In system dynamics applications, scenario creation is instrumental in decision-making. Yet, these scenarios, stemming from diverse vantage points, can sometimes clash. This discordance in scenarios and resultant coalitions underscore the need for a robust decision-making paradigm—here, game theory offers promise. While Federico (2011) championed system dynamics in performance metrics, he didn't provide solutions for scenario conflicts. Notably, Akermans and Oorschot (2018) delved deep into integrating the Balanced Scorecard with system dynamics, albeit without addressing the coalition conundrum. Furthermore, Guo et al. (2018) sought to meld game theory and system dynamics for construction engineering quality oversight. Yet, their methodology fell short in performance evaluations. As Fatima and Elbanna (2020) suggest, the Balanced Scorecard's broad evaluation potential must be harnessed effectively. Incorporating system dynamics and game theory into management science is gaining traction, as affirmed by Mehmanpzair et al. (2022). Thus, the hybrid methodology that used in this study fills the existing research gap.

3. Research method

The research methodology hinges on a performance measurement paradigm. It employs the Balanced Scorecard to identify and categorize indices, harnesses system dynamics to scrutinize causal interactions, and finally uses game theory to synthesize the most favorable outcome amidst contradictory scenarios emanating from system dynamics. This procedure is pictorially captured in Figure 1. The steps of the proposed method are explained in detail in the next sections.

3.1. Balanced Scorecard

The Balanced Scorecard, a brainchild of Robert Kaplan and David Norton in the 1990s, serves as a strategic performance metric. Encompassing both process metrics and end outcomes, it grants a holistic view of an organization's trajectory towards strategic targets. The Balanced Scorecard emphasizes the interconnectedness of financial and non-financial metrics, thereby catering to the diverse informational needs of stakeholders at various organizational tiers. Kaplan and Norton propound that any evaluation of organizational performance must span four dimensions: financial, customer, internal processes, and growth & learning. Successful enterprises craft clear objectives under each dimension, pinpoint relevant metrics, and establish performance benchmarks. This structure is illustrated in Figure 2.

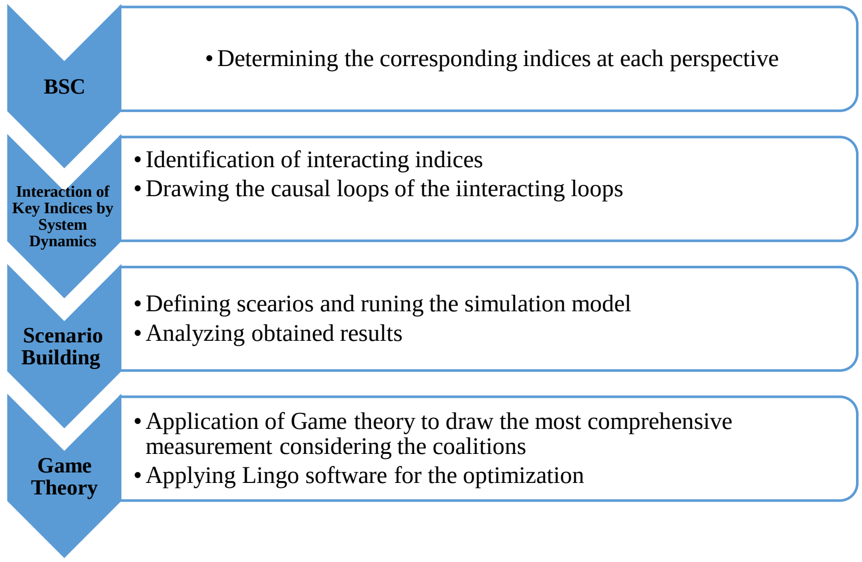

Figure 1. The flowchart of the proposed method

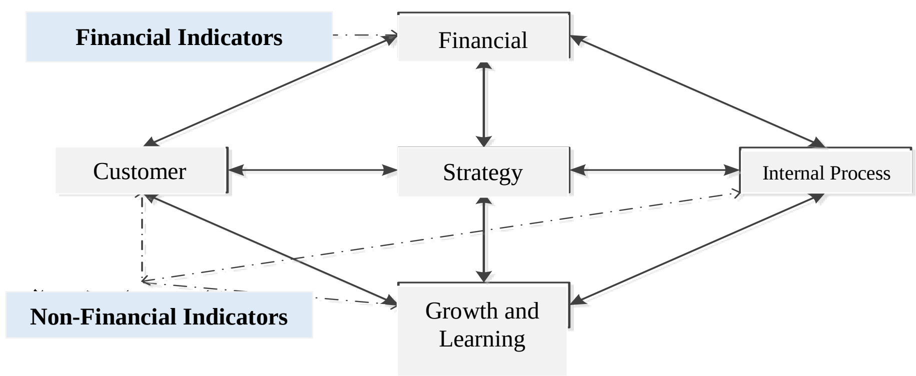

Figure 2. A Simplified Representation of the Balanced Scorecard (Kaplan and Norton, 1996)

3.2. System dynamics

System dynamics stands as a technique for scrutinizing, emulating, and refining dynamic socio-economic and managerial systems through a lens of feedback (Garces et at,2023). It provides a holistic approach to understanding complex systems by considering the interdependencies and feedback loops among various components. One of the key advantages of system dynamics is its ability to capture the dynamic behavior of a system over time. By modeling the causal relationships between different variables, system dynamics allows researchers to simulate and analyze how changes in one variable can affect the entire system (García,2023).

There are several benefits associated with employing system dynamics in decision-making processes:

1. Enhanced Understanding: System dynamics helps in gaining a deeper understanding of complex systems by visualizing the cause-and-effect relationships between different variables. This enables decision-makers to identify leverage points and potential unintended consequences.

2. Long-term Perspective: System dynamics models are particularly useful for long-term planning and policy analysis. They allow decision-makers to explore different scenarios and assess the long-term implications of their decisions.

3. Feedback Loops: System dynamics models explicitly incorporate feedback loops, which are often overlooked in traditional linear models. This enables decision-makers to understand how changes in one variable can create reinforcing or balancing feedback loops within the system.

4. Policy Testing: System dynamics models can be used as virtual laboratories for testing different policies and strategies before implementing them in real-world settings. This helps decision-makers evaluate the potential outcomes and risks associated with different policy options.

5. Communication Tool: System dynamics models provide a visual representation of complex systems, making it easier for decision-makers to communicate their insights and findings to stakeholders who may not have a technical background.

In summary, system dynamics offers a powerful approach for analyzing complex systems by considering their dynamic behavior and feedback mechanisms. By employing this technique, decision-makers can gain valuable insights into the behavior of socio-economic and managerial systems, leading to more informed decision-making processes. The simulation of system dynamics usually follows these stages:

1. Enunciation of the dynamic hypothesis and discernment of causal relationships.

2. Identification of state, level, and rate variables.

3. Establishment of dynamic relations and equations amongst elements.

4. Model deployment and scenario assessment.

3.3. Game theory

Rooted in applied mathematics, game theory has permeated various disciplines, from economics and engineering to marketing and philosophy. It seeks to unravel behaviors in strategic setups where an individual's success is contingent upon the decisions of others. In essence, game theory dissects conflict and cooperation among rational decision-makers. Broadly, it bifurcates into cooperative games and non-cooperative games. Players potentially collaborate, with the central focus on equitable distribution of cooperative gains in cooperative games. In non-cooperative games, players act self-interestedly, with no emphasis on collaboration.

The division into these two branches rests on the understanding of player behavior and the nature of collaboration or competition. One of the renowned tools in cooperative games is the Shapley value, which equitably divides cooperative gains based on certain criteria. Given a cooperative game with N players, the Shapley value ascertains the average returns a player obtains from different coalitions, effectively capturing a player’s average marginal contribution.

A cooperative game of n players in the form of a characteristic function is an ordered pair G (N, v) in which N is a finite set with n members N = {1, 2,…, n} and in fact, N is a set of actors. The subset (S, S ⊆ N) is called a coalition. A coalition can be easily formed that includes an empty set and N itself. v is a real value that represents a total of 2 values of the suitability of the coalition actors. The main questions in the cooperative game model are from of coalitions and distribution of profit to players.

In general, ideas such as the value of Shapley have been proposed to distribute the benefits of the partnership. Each player has provided a fair distribution of the benefits of the partnership based on their own assumptions (Guillermo, 2015). For a collaborative N-player game, the value of Shapley is calculated as the average income each player receives from coalitions. This means that the value received by $\boldsymbol{u_i^*}$ of ith player is determined by this concept.

If the ith player joins Coalition C, his final outcome in this Coalition is defined as a 2-1 relationship:

{V (C) -V (C- (i))} (1)

It is assumed that coalitions are formed from one-to-two coalitions ... to N player, and any order of joining coalitions is possible, u_i^* then belongs to the i-th player, indicating his average final outcome in the game.

$$u^*_i = \sum_{\begin{cases} C \subset N \\ i \in C \end{cases}} \frac{(k-1)!(N-k)!}{N!} \{v(C) - V(C-(i))\} \tag{2}$$

So that:

Total players: N

Number of players in the C: k coalition

$\frac{(k-1)!(N-k)!}{N!}$ is probability of any coalition

Equation (2-2) is obtained from the sum of the calculations, for each possible coalition of the i-th participant.

To aggregate expert evaluations in a fair and systematic way, we employed the Shapley value from cooperative game theory. The Shapley value ensures that each expert's contribution to the collective performance assessment is fairly accounted for by computing their average marginal contribution across all possible coalitions of experts. This method is particularly useful when expert opinions are interdependent or when their combined judgments produce nonlinear outcomes. By using this approach, we avoid biases that can arise from arbitrary weightings or majority rules, instead ensuring an equitable influence distribution based on each expert's unique value to the evaluation process.

4. Conceptual framework of the proposed method

In this section, based on the literature review and identified gaps, a framework for optimal decision-making by managers has been designed. This pertains to the strategies and performance measurement of Melli Bank, integrating three key theoretical tools: The Balanced Scorecard, System Dynamics, and Game Theory. This integrated approach is then employed for modeling. The distinct research stages and the technique applied at each phase are presented in Table 1.

Table 1. Conceptual framework of the proposed method

Steps of Conducting Research	Technique used
Determine performance indicators for each scorecard perspective	Questionnaire
Identify cause and effect relationships between key performance indicators	Interviews and literature review
Provide a dynamic performance measurement system for Melli Bank	Using vensim software
Simulate and execute various decisions	Use of vensim software
Optimal decision making using game theory	Interview and using Lingo software

5. Analysis of findings

5.1. Determining the performance indicators of a balanced scorecard perspective

In this section, the conceptual framework and its steps were examined specifically for Melli Bank of Iran. A comprehensive four-section questionnaire was designed to pinpoint the vital performance criteria of Melli Bank, covering the four dimensions of a balanced scorecard. This questionnaire incorporated several shared criteria pertinent to financial and service organizations from each of these perspectives. The questionnaires were distributed among 30 organization managers and experts. Specifically, the sample size was guided by the principles of Delphi technique and expert judgment studies Okoli, and Pawlowski, S. D. (2004), where sample sizes typically range between 10–30 participants depending on the complexity of the topic and the availability of qualified experts. We ensured diversity in expertise across strategic planning, performance evaluation, and banking operations. Experts were selected based on relevant academic qualifications, professional experience in the banking sector, and prior involvement in strategic performance assessments.

Based on the feedback, specific criteria were identified for each perspective. The results are tabulated in Table 2.

Table 2. Key performance indicators of Melli Bank

Perspective	Key performance indicators	Cronbach's Alpha
Financial	1. Banking services revenue 2. Raised capital 3. Electronic turnover	0.91
Customer	1. Customer growth rate 2. Quality of service 3. Service time 4. Customer Satisfaction	0.83
Internal process	1. Customer Complaints Rate 2. Employee operational capacity 3. Number of electronic banking equipment	0.86
Growth and learning	1. Stability and longevity of employees 2. Employee satisfaction 3. Staff training	0.89

5.2. System dynamics

Given the inherent constraints of the Balanced Scorecard, System Dynamics emerges as a fitting tool to bridge these gaps. In essence, the Balanced Scorecard and System Dynamics are amalgamated for enhanced performance evaluation. Reddy et al. (2020) highlighted the potency of utilizing System Dynamics in the context of performance assessment. Contrary to Balanced Scorecards, System Dynamics boasts a rigorous validation mechanism. There are well-defined steps for the validation of System Dynamics models, widely recognized in academic literature. By adhering to these steps, one can ensure the robustness of the model. Subsequent steps involve analyzing the performance indicators specific to Melli Bank. The causal dynamics among organizational variables and indices within each perspective are separately scrutinized, culminating in a comprehensive causal model. The dynamic strategy map for Melli Bank is formulated based on the four-pronged perspectives of the Balanced Scorecard, integrating the causal loop diagram technique from System Dynamics.

Performance criteria identified earlier serve as primary variables for the causal loop diagram. Their inter-relationships, as well as feedback loops, are discerned and segmented by Balanced Scorecard dimensions. A survey aids in verifying the inter-variable effects. Drawing from the previously formed causal loop diagram, level and flow variables are detailed for every perspective. Leveraging statistical data from Melli Bank, as well as expert insights, equations and relationships among these variables are established. Supplementary questionnaires and interviews are employed to quantify these variable relationships. Subsequently, the models are amalgamated to provide a holistic model tailored for the organization. Based on Melli Bank's extant data, this model undergoes calibration and a decade-long simulation. In alignment with the bank's strategic objectives, missions, and visions, multiple decisions are floated for consideration by bank executives. These decisions are simulated, with results aiding in the selection of the optimal decision-making strategy. The causal diagram succinctly captures the positive and negative impacts of variables, represented by the symbols (+) and (-), respectively.

5.2.1. Causal diagram of growth and learning perspective

Causal diagram of growth and learning perspective depicted in Figure 3. In this perspective, employee stability and retention, employee training, employee satisfaction are performance indicators. This causal diagram elucidates that enhanced customer satisfaction bolsters employee stability. This stability, in turn, fosters further training opportunities. Consequently, as employees become more knowledgeable, service quality escalates, heightening customer satisfaction.

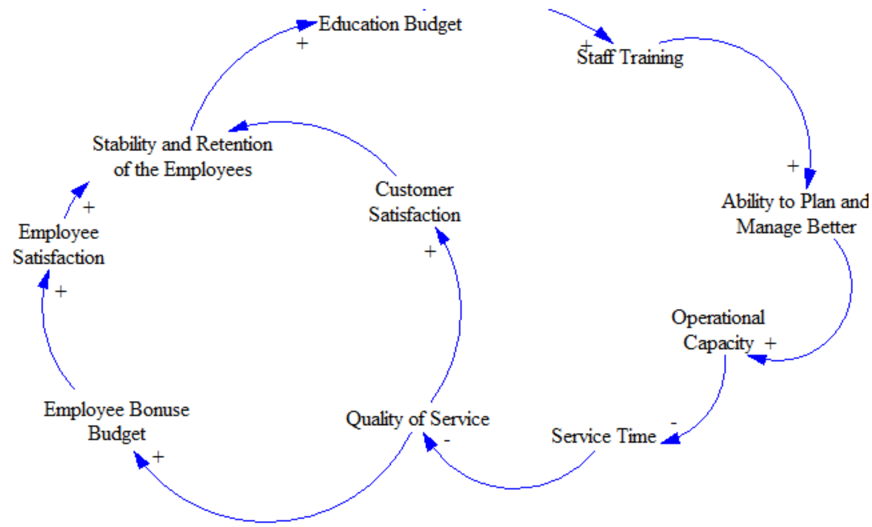

Figure 3. Causal diagram of growth and learning perspective

5.2.2. Causal diagram of internal processes perspective

Causal diagram of internal processes perspective presented in Figure 4. In this perspective, customer complaints rate, staff operational capacity, number of electronic banking equipment are performance indicators. An uptick in investment in electronic banking equipment enhances customer satisfaction, thus drawing in new clients. This surge aids operational capacity, accelerating service delivery.

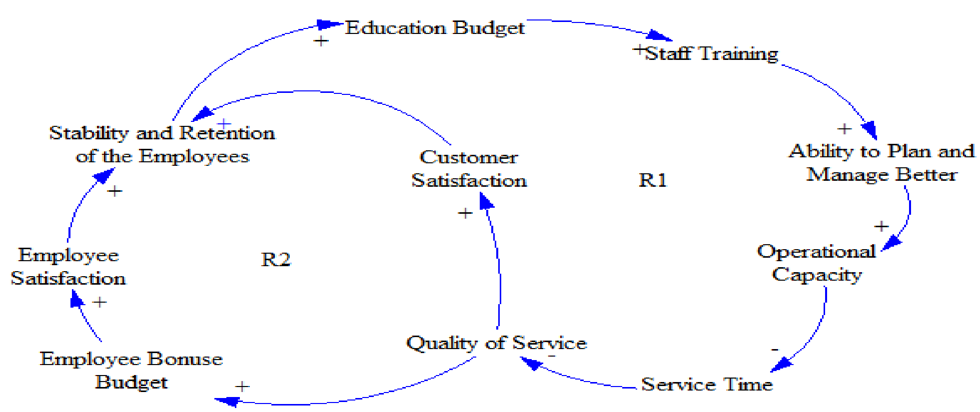

Figure 4. Causal diagram of internal processes perspective

5.2.2. Causal diagram of customer perspective

Causal diagram of customer perspective drew in Figure 5. In this perspective, customer growth rate, service quality, service time, customer satisfaction are performance indicators. The causal diagram amplifies the assertion that superior training enhances employee proficiency, which elevates customer satisfaction levels. This increment positively influences the bank's performance and customer satisfaction.

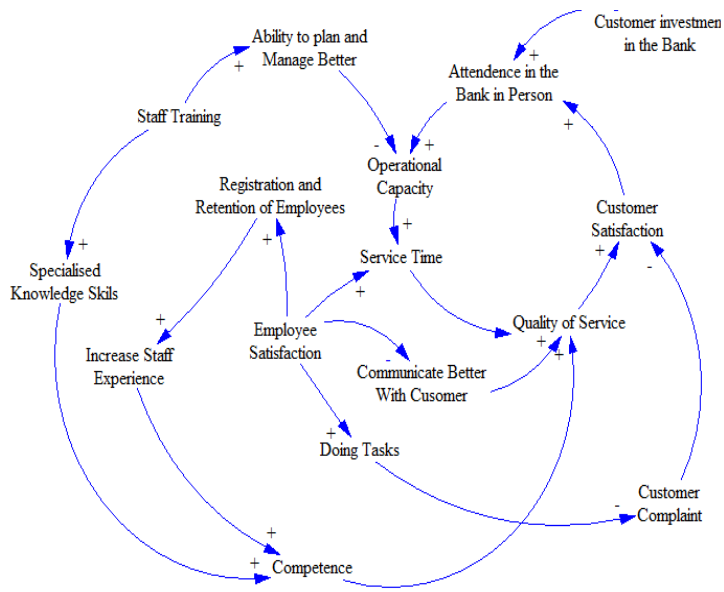

Figure 5. Causal diagram of customer perspective

5.2.3. Causal diagram of financial perspective

Causal diagram of financial perspective depicted in Figure 6. In this perspective, banking Services Income, Raised Capital, Electronic Turnover are performance indicators. The diagram illustrates those advancements in electronic banking trim down service fees, optimizing the bank's annual financial performance. This enhancement stems from the amplified customer base and increased capital.

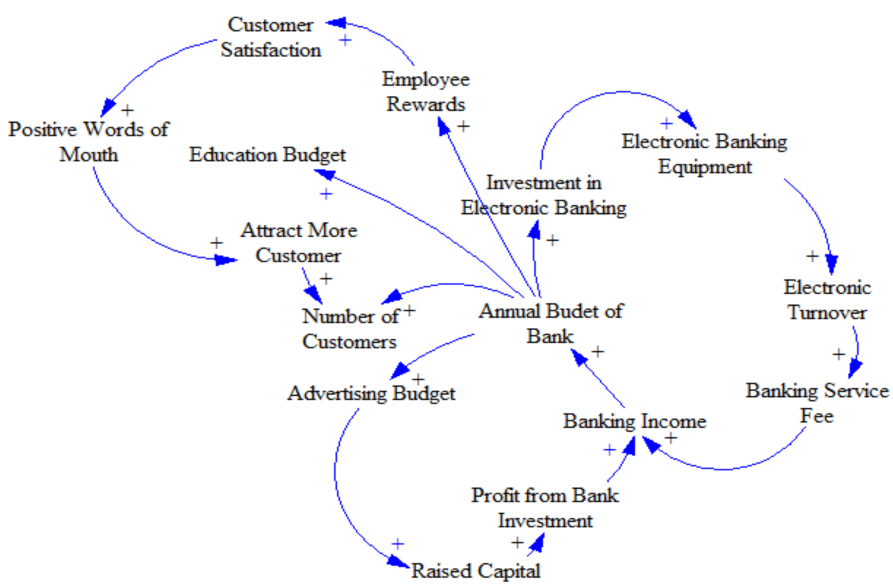

Figure 6. Causal diagram of Causal chart of financial perspective

5.3. Simulation and model implementation

Data, including metrics on electronic payment equipment, transactions, account and card statistics, from 2003 to 2019, were sourced from Melli Bank's performance reports, income statements, and balance sheets. Supplementary data were obtained via interviews and questionnaires.

Predictive simulations spanning the next decade were conducted for various indicators like customer satisfaction, capital inflow, operational efficiency, and electronic turnover.

Derived from the simulation results and aligning with the bank's vision, optimal scenarios and policies across the Balanced Scorecard quadrants are presented in Table 3. Table 4 delineates the influence of vital independent variables on dependent variables.

Table 3. Proposed scenarios for implementation in the bank

Financial perspective	Implementation of new investment methods	**F1**
	Increase the budget allocated for advertising	**F2**
	Implementation of new revenue-generating plans in accordance with the current economic situation	**F3**
Customer perspective	Focus on increasing the quality of service	**C1**
	Focus on better resolving customer complaints and requests	**C2**
	Focus on attracting new customers	**C3**
internal processes perspective	Increase the budget for the development of electronic banking equipment	**I1**
	Focus on increasing the operational capacity of employees	**I2**
	Focus on better task planning and process lubrication	**I3**
growth and learning perspective	Focus on ways to communicate well with customers	**L1**
	Focus on programs to increase bank employee satisfaction	**L2**
	Motivate by increasing employee rewards	**L3**

To validate the causal loop diagrams, we adopted a triangulated validation approach combining expert feedback and historical performance data. Expert reviews ensured alignment with domain knowledge, while historical trend comparisons confirmed the directionality and logical consistency of major feedback loops. This approach aligns with recommended practices in system dynamics model validation (Sterman, 2000).

This process is discussed as follows:

- Expert **validation**: After constructing the initial causal loop diagrams (CLDs) based on Balanced Scorecard perspectives and qualitative data, they were reviewed by the expert panel in two rounds. Feedback was incorporated to refine causal links, ensuring consistency with managerial experience and organizational realities.

- Historical **data comparison**: Where possible, we compared the **direction and behavior of identified feedback loops** with **historical performance trends** of Bank Melli over the past 5 years. For example, causal relationships involving customer satisfaction, service quality, and financial returns were cross-checked with past performance reports to verify the plausibility of loops.

- Scenario **plausibility checks**: The generated scenarios were reviewed to ensure that dynamic behaviors (e.g., reinforcing or balancing feedback) matched expected real-world outcomes in similar strategic situations.

Table 4. The average annual impact of independent variables on the dependent variable

Scenario	Dependent variable	Independent variable	Average annual impact
10% increase Annually	The budget allocated for advertising	Customer capital in the bank	1.25% increase
10% increase Annually	Quality of service	Customer Satisfaction	6.63% increase
10% increase Annually	Quality of service	Attract new customers	7.5% increase
10% increase Annually	Implement a policy to equipment development	Number of electronic banking equipment	13 % increase Annually
10% increase Annually	Implement a policy to equipment development	Electronic turnover	15% increase Annually
10% increase Annually	Implement a policy on increasing the operational capacity of employees	Customer Satisfaction	26% increase Annually

5.4 Selecting the optimal decision using game theory

This segment harnesses game theory, particularly the Shapley value, to pinpoint optimal decisions. The Balanced Scorecard perspectives are deemed players, and the best amalgamation of decisions is sought. The proposed scenarios for implementation and from different perspectives are visually represented in Figure 7. Following the steps outlined, the coalition characteristic function and the Shapley value for each perspective are detailed in Tables 5 and 6. The Shapley value highlights the strength and sensitivity of coalitions for each player.

1. Each perspective of the balanced scorecard is considered as a player (Figure 6). So, we want to choose the best decision by using corporative game theory. In other words, we want to choose the best combination of the desired decision. Strategic options are limited to three to avoid complexity.

2. All possible situations are specified from a 4-player game by creating different combinations of the considered decisions (1 decision from each perspective)

3. Simulate all the scenarios specified in the previous step separately, the results are presented to the managers and they are asked to assign a number between zero and 5 to each game. That zero means the least utility and 5 means the most utility created by the implementation of decisions.

4. All possible coalition is constructed.

5. Coalition tables are written in normal form.

6. The Shapley value is calculated based on desired relationships extracted in the previous sector for each perspective of the balanced scorecard to determine the best strategy.

Based on the mentioned steps, the Shapley value of each player (perspective) and the coalition characteristics function are presented in tables 5 and 6. The Shapley value of each player will be obtained from equation 2. Figure 7 illustrates the proposed scenarios for implementation and from different perspectives.

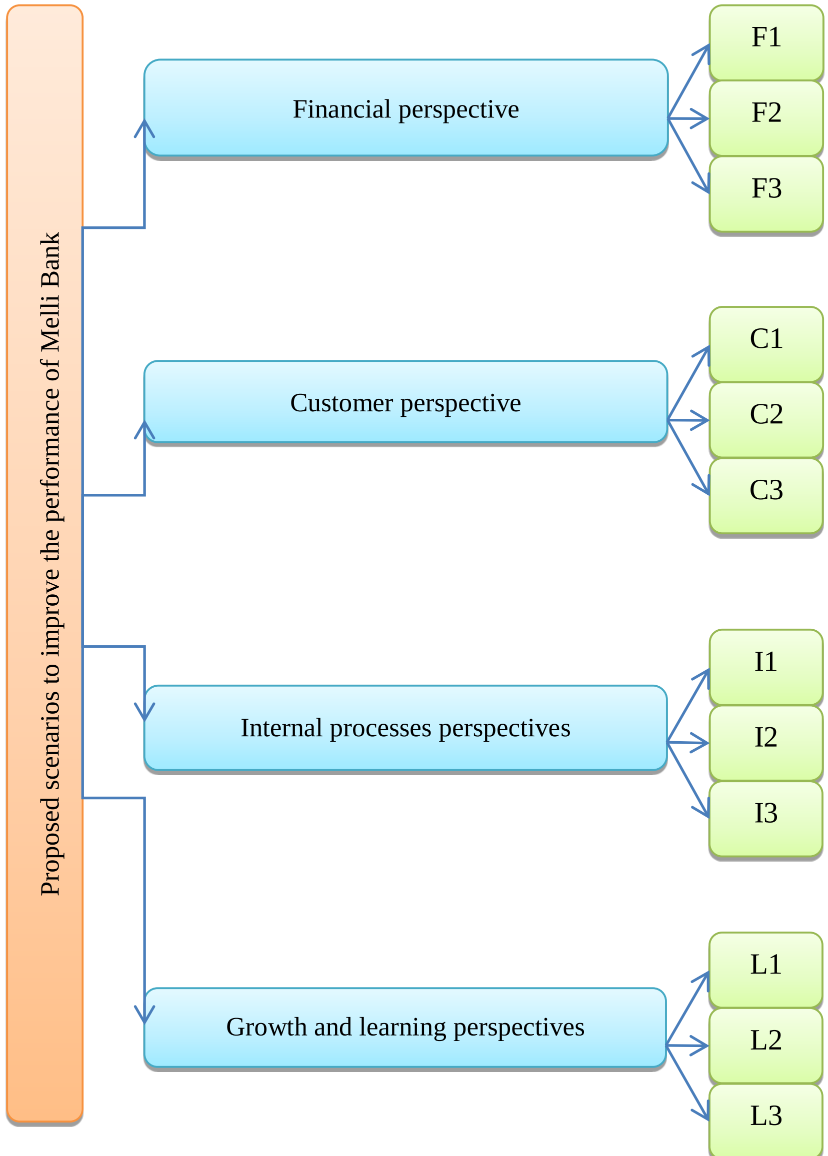

Figure 7. Proposed scenarios for implementation and from different perspectives

Table 5. Shapley value for each perspective

Perspective	Shapley value
C	5.377244
L	4.639965333
I	4.586124667
F	4.396666

Table 6. Coalition characteristics function

V(F)	1.25
V(C)	1.818182
V(I)	1
V(L)	0.9
V(F,C)	5.310345
V(F,I)	5.57143
V(F,L)	5.44118
V(I,L)	5.251917
V(C,L)	5.516854
V(C,I)	5.5
V(F,C,I)	10.8636
V(F,C,L)	11.18182
V(F,I,L)	9.62857
V(C,I,L)	12
V(F,C,I,L)	19

Table 7. The best decision combination for each perspective

C	**L**	**I**	**F**	**C-u**	**l-u**	**I-u**	**F-u**
3	**3**	**2**	**1**	5	3	5	5
3	**3**	**2**	**2**	**5**	**4**	**5**	**4**
3	**2**	**3**	**2**	5	0	1	3
3	**1**	**2**	**3**	5	2	2	4
3	**3**	**2**	**3**	5	4	3	3
3	**2**	**3**	**3**	5	1	3	4
3	**3**	**3**	**3**	5	1	3	1
2	**2**	**3**	**2**	5	3	2	5
2	**3**	**1**	**3**	5	1	2	3
2	**2**	**3**	**3**	**5**	**4**	**3**	**3**
1	**1**	**1**	**1**	**5**	**4**	**1**	**3**
1	**3**	**1**	**3**	5	0	2	3

Shapley value shows the strength and sensitivity in coalitions for players. The order and importance of each perspective are C > L > I > F. Therefore, for choosing the best decision combination to implement, the customer perspective plays an important role, then, by growth and learning, internal and finally financial processes, respectively. Considering 81 different combinations of decisions and the amounts received by each player from them, in 12 decision combinations, the amount received from the customer perspective is 5. Therefore, the customer perspective should choose its decision from these 12 decision combinations. Table 7 shows the combinations in which the customer perspective receives 5. After the customer perspective, the growth and learning perspective tries to maximize its revenue, so it chooses the combination of growth and learning that gets the most revenue. This process will continue until the last player selects a specific decision combination.

If the customer perspective chooses decision 1 from among the combinations that receive 5, the growth and learning perspective chooses decision 1 from the two choices of decision 1 with reception 4 and decision 3 with reception 0. By choosing the growth and learning perspective, there is no other choice for the next players, and internal and financial perspectives have chosen decisions 1 and 1 with receptions 1 and 3. Therefore, the $C_1L_1I_1F_1$ decision combination is finally chosen. If the customer perspective selects decision number 2, the growth and learning perspective selects a combination of $C_2L_2I_3F_3$ with reception 4, which is the highest input. By choosing the growth and learning perspective, there is no other choice for the next players and internal and financial perspectives have to choose decisions 3 and 3 with receptions 3 and 3. This selection process is also shown in Figure 8.

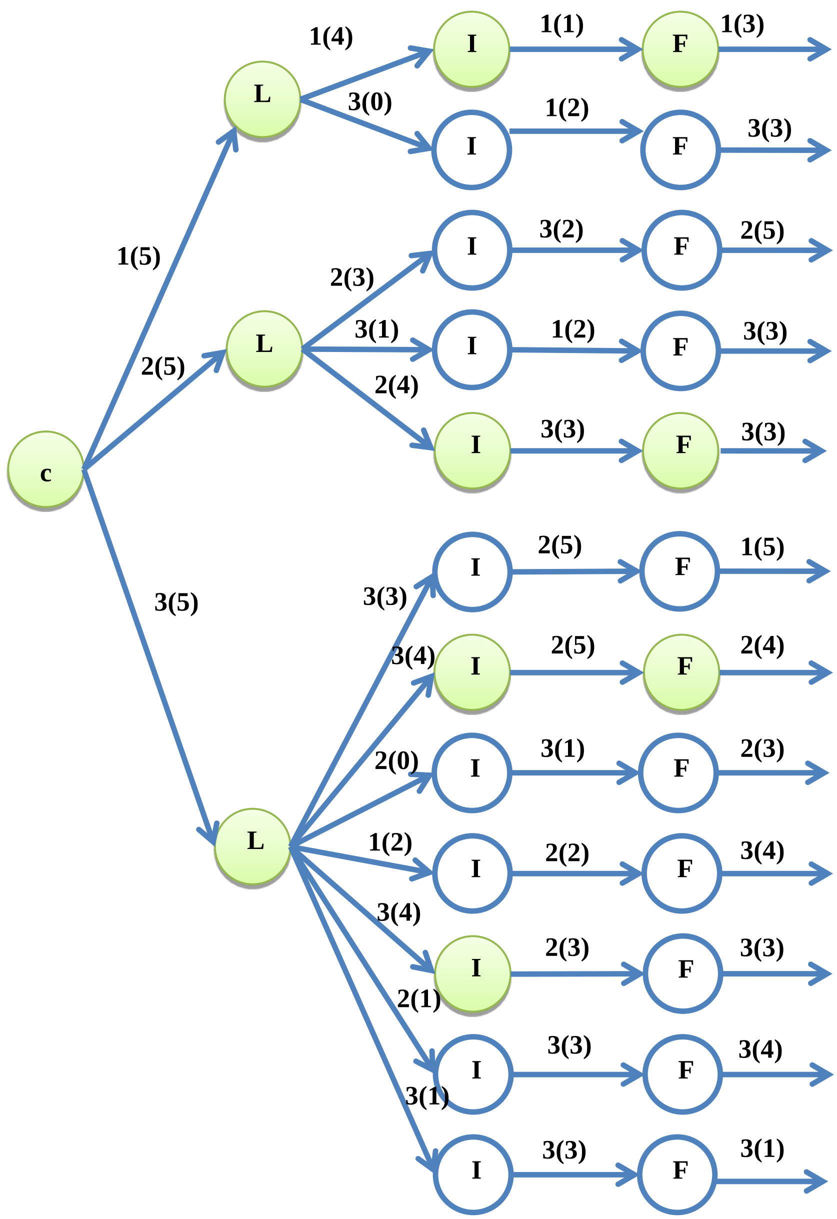

Figure 8. The process of selecting the best decision

For validation of the proposed method, three groups of 10 experts were asked to discuss their opinion about the obtained results of which 27 approved it and only 3 experts declared they had a neutral view of it. In addition to the obtained results, and the learning gained from the interactive proposed method, it can be well-established for other applications as well.

Based on the results of this study, several avenues for future research emerge:

1. Comparative Evaluation Across Sectors: Given the effectiveness of our integrated framework in the banking industry, future research could apply and compare the model across other sectors—such as healthcare, logistics, and education—to test its adaptability and sector-specific dynamics.

2. Enhanced Model Validation Using Real-Time Data: Future studies can incorporate real-time or longitudinal data to validate and update the causal loop diagrams dynamically, improving the accuracy of scenario-building and strategic decision-making tools.

3. Integration with Predictive Analytics: The combination of machine learning models (e.g., random forests, support vector machines) with our causal framework may enhance predictive capabilities. These models could automate parts of the expert analysis or provide early warning indicators based on performance data trends.

4. Coalition Dynamics Analysis: Building on our use of game theory for expert coalition formation, future work could explore how coalitions evolve over time, or how weighting expert credibility (e.g., via reputation systems) influences performance evaluations.

5. Model Customization for Strategic Planning Tools: Future studies could develop user-friendly software or dashboards based on this model to support strategy development in complex organizations.

6. Conclusion

In this study, we incorporated game theory modeling into system dynamics causal diagrams and the Balanced Scorecard (BSC) framework to assess the performance of Bank Melli, the largest bank in Iran.

While some literature has merged game theory with system dynamics, the challenges associated with conflicting coalitions in system dynamics scenario creation have not been previously addressed. Through extensive causal analyses, this research identified not only the influential BSC variables but also their causal relationships. In considering possible scenarios, contradictions were systematically categorized, and suitable game theory modeling was employed. A panel of experts evaluated the derived results, confirming the effectiveness of the novel approach presented. Future studies could explore the integration of more intricate game theory models into our proposed framework.

The proposed framework—integrating the Balanced Scorecard, system dynamics, and game theory—can be tailored to other complex sectors such as healthcare, logistics, and education, where strategic alignment and performance measurement involve multi-stakeholder decision-making and dynamic feedback systems. Moreover, Future studies could enhance the predictive capacity of the model by incorporating machine learning algorithms (e.g., regression models, decision trees, or neural networks) to analyze large-scale operational data, identify non-obvious patterns, and refine scenario-based forecasting. This integration could also support real-time decision-making and automation of expert input through data-driven inference.

References

Akkermans, H. A., Kim, E., & Van Oorschot, K. (2018). Relevance assumed: A case study of balanced scorecard development using system dynamics. In *System dynamics* (pp. 107–132). Palgrave Macmillan, London.

Anjomshoae, A., Ruth, B., Fareeduddin, M., & Nathan, K. (2022). A systematic review of humanitarian supply chains performance measurement literature from 2007 to 2021. *International Journal of Disaster Risk Reduction, 72*, 155–170.

Barnabè, F. (2011). A system dynamics-based Balanced Scorecard to support strategic decision making: Insights from a case study. *International Journal of Productivity and Performance Management, 60*(5), 446–473.

Bianchi, C., & Montemaggiore, G. B. (2008). Enhancing strategy design and planning in public utilities through “dynamic” balanced scorecards: Insights from a project in a city water company. *System Dynamics Review, 24*(2), 175–213.

Dudić, Z., Dudić, B., Greguš, M., Novacková, D., & Djaković, I. (2020). The innovativeness and usage of the balanced scorecard model in SMEs. *Sustainability, 12*, 3221.

Fatima, T., & Saïd, E. (2020). Balanced scorecard in the hospitality and tourism industry: Past, present and future. *International Journal of Hospitality Management, 91*, 102656.

García, J. M. (2023). *Theory and practical exercises of system dynamics: Modeling and simulation with Vensim PLE*.

Garces, E., Franco, C. J., Tomei, J., & Dyner, I. (2023). Sustainable electricity supply for small off-grid communities in Colombia: A system dynamics approach. *Energy Policy, 172*, 113314.

Ghannadpour, F., & Zandiyeh, F. (2020). A new game-theoretical multi-objective evolutionary approach for cash-in-transit vehicle routing problem with time windows (A real-life case). *Applied Soft Computing, 93*, 106378.

Glykas, M. (2013). Fuzzy cognitive strategic maps in business process performance measurement. *Expert Systems with Applications, 40*(1), 1–14.

Guillermo, O. (2015). Game theory. In J. D. Wright (Ed.), *International Encyclopedia of the Social & Behavioral Sciences* (2nd ed., pp. 573–581). Elsevier. https://doi.org/10.1016/B978-0-08-097086-8.42029-6

Linard, K. T., & Yoon, J. (2000). The dynamics of organizational performance: Development of a dynamic balanced scorecard. *Academia*.

Lyell, D., & McDonnell, G. (2011). A dynamic balanced scorecard for managing health systems performance. *Academia*.

Mehmanpazir, F., Khalili-Damghani, K., & Hafezalkotob, A. (2022). Dynamic strategic planning: A hybrid approach based on logarithmic regression, system dynamics, game theory and fuzzy inference system (Case study: Steel industry). *Resources Policy, 77*.

Okoli, C., & Pawlowski, S. D. (2004). The Delphi method as a research tool: An example, design considerations and applications. *Information & Management, 42*(1), 15–29. https://doi.org/10.1016/j.im.2003.11.002

Qinghua, H., Zidan, T., & Ting, W. (2022). Performance measurement methods in megaprojects: An analytical review. *International Journal of Project Management*.

Reddy, K., Rao, N., & Krishnanand, L. (2020). Manufacturer performance modeling using system dynamics approach. *Materials Today: Proceedings, 33*(1), 142–146.

Rigo, P., Siluk, M., Daniel, P., Rediske, G., & Rosa, C. (2022). The competitiveness factors of photovoltaic installer companies and a BSC model. *Solar Energy, 235*, 36–49.

Rydzak, F., Magnuszewski, P., Pietruszewski, P., Sendzimir, J., & Chlebus, E. (2004). Teaching the dynamic balanced scorecard. In *Proceedings of the 22nd International Conference of the System Dynamics Society*.

Schoeneborn, F. (2003). Linking balanced scorecard to system dynamics. *Brandenburgische Technische Universität*.

Seal, W., & Ye, L. (2014). The balanced scorecard and the construction of a management control discourse. *Journal of Accounting & Organizational Change, 10*(4), 466–485.

Shoving, S. H., & Tu, C. K. (2004). Exploring some dynamically aligned principles of developing a balanced scorecard. In *Proceedings of the International System Dynamics Conference*.

Sujitha, R. I., & Vishnu, R. U. (2020). Dynamical systems and complex systems theory to study unsteady combustion. *Proceedings of the Combustion Institute, 38*(3), 3445–3462.

Wolstenholme, E. (1998). Balanced strategies for balanced scorecards: The role of system dynamics in supporting balanced scorecard and value-based management. In *Proceedings of the International System Dynamics Conference*.

Zhang, Y., & Li, L. (2009). Study on balanced scorecard of commercial bank in performance management system. In *Proceedings of International Symposium on Web Information Systems and Applications (WISA'09)*, Nanchang, China (pp. 22–24).

Zhang, Y., Xiang, C., Li, L., & Jiang, H. (2021). Evolutionary game analysis and simulation with system dynamics for behavioral strategies of participants in crowd logistics. *Transportation Letters, 13*(7), 540–554.

Zhang, T., & Li, Z. (2008). A case study based on the dynamic balanced scorecard in manufacturing industry. In *Wireless Communications, Networking and Mobile Computing, 4th International Conference*.