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Research Article

A Dynamic Model for Assessing the Sustainability of Small and Medium Sized Enterprises

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Abstract

Development of any country, particularly from the economic aspect, largely depends on the performance of its small and medium-sized enterprises (SMEs). Accordingly, this study aims to dynamically model the sustainability of SMEs emphasizing on economic sustainability dimension. Research participants include the managers of in growth SMEs of Iran in 2023, out of them 18 managers were selected through purposive sampling. To develop the sustainability assessment model, a systematic review of the literature identified 71 sustainability assessment indicators across three dimensions of economic, social, and environmental. Subsequently, principal component analysis was employed to evaluate the indicators of each dimension and determine the key indicators. Based on the results, five social indicators (employees' health and safety, employees' satisfaction, organizational culture, equity, diversity and inclusion (EDI), and compliance with laws and regulations), five environmental indicators (energy consumption optimization, recycling capability, use of renewable resources, green product design, and environmental commitment), and seven economic indicators (productivity improvement, financial strength, resilience, profitability, investment management, quality, and economic value added) were identified as the main sustainability indicators. Finally, based on the key indicators, research causal loop diagram was depicted and used for simulating the SMEs sustainability. In policy design phase, six potential scenarios were defined based on the data availability and feasibility to evaluate how different strategic interventions such as increasing product prices, employee training hours, and the use of recycled materials, effect the economic performance of SMEs. The results show the superiority of Scenario 6 in enhancing SMEs' economic performance over a 10-year horizon.

Keywords: System Dynamic; Sustainability; Small and medium-sized enterprises; Financial indicators

1. Introduction

Small and medium-sized enterprises (SMEs) are among the most common forms of economic entities, and their role as the basis of national economies is widely recognized in many countries. They significantly contribute to increasing national income and creating employment in both developed and developing countries (Gherghina et al., 2020; Nahavandi et al., 2023). Numerous studies have shown that SMEs are the primary source of productive employment, the improvement of the entrepreneurial environment, the acceleration of creativity and innovation, and the creation of new business opportunities (Arasti et al., 2014). In other words, SMEs, due to their unique characteristics such as informal structure and flexibility in adopting and utilizing advanced technologies, can introduce new products faster than other companies, tailored to the conditions of local, regional, and global competition, thereby promoting economic growth and reducing unemployment (De et al., 2018).

An examination of the contribution of SMEs to employment, value-added creation, and gross domestic product (GDP) across various countries indicates that SMEs constitute a significant portion of all industries. For example, approximately 99.8% of businesses in the European Union, over 99% of companies in the United States and Japan, and nearly 95% of industrial units in India are SMEs (Prasanna et al., 2019). In Iran's economy, small and medium industrial enterprises, which make up more than 85% of the total number of industrial enterprises in Iran, account for an average of about 33% of employment and 14% of the value added of industrial enterprises with 10 or more employees (Kharaghani et al., 2023 a,b). These units play a crucial role in innovating new methods that lead to technological changes and increased production capabilities (Miklian & Hoelscher, 2022).

However, numerous studies indicate that a significant percentage of SMEs experience failure within their initial years, with approximately 32% failing in their first year and nearly 53% closing down by the end of their fifth year. The consequences of these failures extend beyond individual businesses, impacting broader economic indicators. For instance, SMEs constitute over 99% of businesses in the European Union and contribute around 65% of total employment. Moreover, SMEs account for about 33% of employment and 14% of value added in Iran's industrial sector (Arasti et al., 2014). Therefore, the high failure rate among SMEs not only threatens local job security but also diminishes contributions to GDP, highlighting the urgent need for robust sustainability assessments. By adopting effective sustainability practices, SMEs can improve their resilience, ultimately benefiting the economy through enhanced job creation and increased GDP contribution.

SMEs in emerging economies face a range of unique challenges compared to large corporations, particularly in the areas of sustainability (Prasanna et al., 2019). Unlike large enterprises, SMEs suffer several issues such as

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resource constraints (lack sufficient financial and human resources to invest in sustainable practices), regulatory and compliance pressures because of the shortage in internal infrastructure or financial capacity to efficiently navigate complex environmental and social regulations, SMEs are often excluded from these networks due to their smaller scale or lack of certifications, forcing them to rely on less sustainable local resources. They face greater risks as failed initiatives can have severe financial consequences (Ernst et al., 2022). Moreover, SMEs are particularly vulnerable to economic shocks like currency fluctuations or political instability, which can significantly disrupt their operations. Lastly, support systems and SMEs struggle with bureaucratic barriers and limited access to financial aid and government incentives (Miklian & Hoelscher, 2022).

Despite challenges such as economic sanctions and currency fluctuations, Iran's gross domestic product (GDP) witnessed significant growth between 2011 and 2023. According to the Iran Chamber of Commerce, Industries, Mines and Agriculture, the revenue of SMEs constituted an average of 7 to 9 percent of the GDP. Assuming an 8 percent share of SMEs in Iran's GDP, their revenue increased from 549,462 billion Rials in 2011 to 11,139,410 billion Rials in 2023. Table 1 presents some of the data used from 2011 to 2023, with 2016 considered as the base year. Trend of revenue for SMEs over a 10-year period is depicted in Figure 1.

Table 1
SMEs Income Trend (Billion Rials)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Income	549462.7	627360.2	843956.7	960399.9	943602.8	1114376	1294984	1674061	2117874	3183321	5221008	8145908	11139410

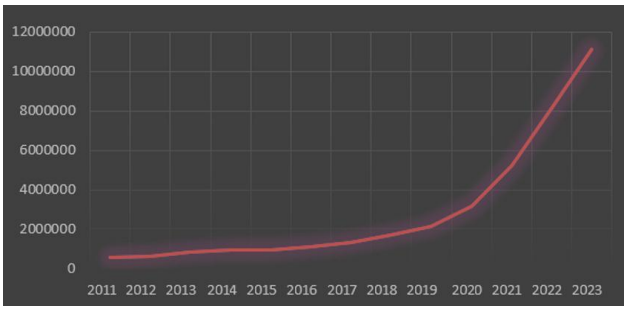

Fig. 1. Reference mode for SMEs income

social and environmental dimensions. Section 3 describes research methodology. Section 4 demonstrates the results and discusses the implications. Finally, section 5 summarizes the findings and proposes some research directions for future studies.

2. Literature Review

In recent years, sustainability has attracted significant attention, particularly with regard to integrating and balancing the environmental, economic, and social dimensions of a business (Ernst et al., 2022). Scholars and researchers emphasize that a truly sustainable business must address both environmental and social considerations alongside economic factors (Malesios et al., 2021).

Small and medium-sized enterprises (SMEs) often strive to incorporate corporate sustainability to align with regulatory policies and guidelines (Arasti et al., 2014). They aim to achieve sustainability through practices such as lean manufacturing, green manufacturing, and other eco-friendly initiatives. However, the relationship between social and environmental practices and both corporate sustainability and the economic performance of SMEs has yielded mixed results. Sustainability practices are broadly defined as those initiatives aimed at fostering sustainable

The survival rates of in growth SMEs in Iran are often low due to various challenges. In response to these challenges, some SMEs have integrated sustainability practices into their strategies (Sendawula et al., 2021). Alongside the previous studies, this research offers practical insights for SME managers and policymakers who need to navigate the increasing demand for sustainable business practices amidst fluctuating political and economic conditions such as currency instability or sanctions. Considering the financial, environmental, and social indicators, supported by exploratory factor analysis and principal component analysis (PCA) ensures that the proposed model is both theoretically and empirically substantiated, making it adaptable to different business contexts. On the other hand, scenario-based simulations, can help managers understand the long-term effect of specific financial, environmental, and social strategies and offer practical advices on how SMEs can improve their sustainable performance. Although, the primary objective of this study is to develop a dynamic model for assessing the sustainability of SMEs, emphasizing on financial indicators.

The remainder of this paper is organized as follows. Section 2 briefly reviews the recent literature on sustainability and summarizes its indicators in economic,

Toloie Eshlaghy et al. (2024) developed a sustainable network for distribution of agricultural items with suppliers, distribution centers, and retailers. Luthra and Mangla (2018) recognized key challenges to Industry 4.0 initiatives and prioritized them for supply chain sustainability in Indian manufacturing industry. Sendawula et al. (2021) examined the relationship between environmental commitment and environmental sustainability practices of SMEs in manufacturing sector of Uganda. Zare Mehrjerdi and Shafiee (2020) developed a resilient and sustainable closed-loop supply chain considering four dimensions of sustainability and 2 dimensions of resilience. Mura et al. (2018) provided a detailed review of sustainability measurement literature through a bibliometric method.

Despite the numerous reviews of sustainability practices and performance in large companies, studies on SMEs remain limited. Although both SMEs and large companies operate in the same market, they differ significantly in their operations and confront different challenges on both the supply and demand sides. SMEs, in particular, receive less attention in sustainability management compared to their larger counterparts due to characteristics.

Based on the literature review conducted in this phase, a list of initial proposed sustainability indicators was developed. These indicators are capable of measuring each of the three main dimensions of sustainability (environmental, economic, and social). The result of the aforementioned process is the identification of 16 environmental sustainability indicators, 15 social sustainability indicators, and 24 economic sustainability indicators which summarized in Table 2.

value creation (Baumgartner & Ebner, 2010). A company's sustainability performance, therefore, encompasses its performance across all dimensions of corporate sustainability (Kharaghani et al., 2023).

Various models and indicators have been developed to measure sustainability performance. Singh et al. (2009) provided a comprehensive overview of businesses sustainability indicators applicable to policy practices. Epstein and Roy (2011) developed a framework fo describing the drivers of corporate social performance, the actions that managers can take to affect that performance, and those social and financial consequences. Govindan et al. (2020) studied the impact of sustainability practices on firm performance using meta-analysis. Their findings confirmed a positive association between the various aspects of sustainability and firm performance. Ahi and Searcy (2015) investigated the metrics of green and sustainable supply chain management. According to the results, environmental issues were represented to the greatest extent. Geng et al. (2017) examined the link between sustainability practices and performance in large Asian companies, through a systematic literature review.

Eccles et al. (2011) reviewed the sustainability indicators for manufacturing sectors in terms of their consistent, repeated and standardized usage. Malesios et al. (2021) investigated the practice/ performance variables being considered for sustainability performance analysis and how are they related. De et al. (2018) examined the impact of lean practices and sustainability-oriented innovation, on supply chain sustainability performance of SMEs using a data envelopment analysis-based framework. Izadikhah and Farzipoor Saen (2016) proposed a two-stage data envelopment analysis model for sustainability evaluation in presence of negative input-intermediate-output data.

Table 2
Sustainability Assessment Indicators of SMEs

Environmental Indicators	**References**
Energy Optimization	Lotfi & Saghiri, 2018; De et al., 2018; Erol et al., 2011; Bourlakis et al., 2014; Ahi & Searcy, 2015; Tavakkol et al., 2023b; Kharaghani et al., 2023; Malesios et al., 2021
Waste Management	Zare Mehrjerdi & Shafiee, 2020; Malesios et al., 2021; Kharaghani et al., 2023
Recycling Capability	Zare Mehrjerdi & Shafiee (2020); Kharaghani et al., 2023; Govindan et al., 2020
Use of Renewable Resources	Erol et al., 2011; Govindan et al., 2020; Kharaghani et al., 2023; Tavakkol et al., 2023b
Pollutants Reduction	Izadikhah & Farzipoor Saen, 2016; Tavakkol et al., 2023b
Use of Clean Technologies	Carvalho et al., 2013; Fallahpour et al., 2017; Tavakkol et al., 2023b; Hakimi et al., 2024
Green product Design	Carvalho et al., 2013; Tavakkol et al., 2023b; Kharaghani et al., 2023; Soufi et al., 2023
Sustainability Reporting	Ahi & Searcy, 2015; Malesios et al., 2021; Hakimi et al., 2024
Greenhouse Gas Emissions	Korzenowski et al., 2018; Tavakkol et al., 2023b ؛Kharaghani et al., 2023
Green Packaging	Sendawula et al., 2021; Tavakkol et al., 2023b; Korzenowski et al., 2018
Use of Recycled Materials	Korzenowski et al., 2018; Govindan et al., 2020; Tavakkol et al., 2023b; Kharaghani et al., 2023; Soufi et al., 2023
Clean Production Processes	Malesios et al., 2021; Sendawula et al., 2021; Soufi et al., 2023; Hakimi et al., 2024
Environmental Commitment	Sendawula et al., 2021; Kharaghani et al., 2023; Malesios et al., 2021
Environmental Investment	Kharaghani et al., 2023; Malesios et al., 2021; ; Soufi et al., 2023
Environmental Performance Assessment	Ahi & Searcy, 2015; Epstein & Roy, 2001; Bourlakis et al., 2014; De et al., 2018; Kharaghani et al., 2023
Social Indicators	**References**
Justice and Human Rights	Kharaghani et al., 2023; Luthra & Mangla, 2018; Khan et al., 2019
Employees Training and Education	Zare Mehrjerdi & Shafiee, 2020; Tavakkol et al., 2023b; Kharaghani et al., 2023

Employees Health and Safety	Brammer et al., 2012; Kharaghani et al., 2023; De Neve et al., 2013
Employees Satisfiction	Tavakkol et al., 2023b; Kharaghani et al., 2023; Farooq et al., 2019
Society Communication	Kharaghani et al., 2023; Govindan et al., 2020; Malesios et al., 2021
Organizational Culture	Govindan et al., 2020; Tavakkol et al., 2023b; Kharaghani et al., 2023
Fair Working Conditions	Malesios et al., 2021; Govindan et al., 2020; Geng et al., 2017; Ebrahimi et al., 2024
Equality, Diversity and Inclusion (EDI)	Kharaghani et al., 2023 Govindan et al., 2020; Ebrahimi et al., 2024
Work- Life Balance	Malesios et al., 2021; Kharaghani et al., 2023; Govindan et al., 2020
Employees Participation in Decision Making	Farooq et al., 2019; Malesios et al., 2021; Govindan et al., 2020
Compliance with Regulations	De Neve et al., 2013; Kharaghani et al., 2023; Govindan et al., 2020
Customers Purchase Behavoir	Malesios et al., 2021; Tavakkol et al., 2023b; Kharaghani et al., 2023
Customer Satisfiction	Kharaghani et al., 2023; Tavakkol et al., 2023b; Ahi & Searcy, 2015
Responsiveness	Bourlakis et al., 2014; Tavakkol et al., 2023b; Govindan et al., 2020
Social Responsibility	Govindan et al., 2020Malesios et al., 2021; Tavakkol et al., 2023b; Hakimi et al., 2024
Economic Indicators	**References**
Productivity	Tavakkol et al., 2023a; Tavakkol et al., 2023b; Kharaghani et al., 2023
Cost Reduction	Zare Mehrjerdi & Shafiee, 2020; Fallahpour et al., 2017; Malesios et al., 2021
Income Diversity	Tavakkol et al., 2023b; Malesios et al., 2021; Ebrahimi et al., 2024
Financial Strength	Kharaghani et al., 2023; Zare Mehrjerdi & Shafiee, 2020; Tavakkol et al., 2023b
Distribution Cost	Zare Mehrjerdi & Shafiee, 2020; Kharaghani et al., 2023; Ebrahimi et al., 2024
Product Price	Kharaghani et al., 2023; Tavakkol et al., 2023b; Zare Mehrjerdi & Shafiee, 2022
Innovation and R&D	Zare Mehrjerdi & Shafiee, 2020; Tavakkol et al., 2023b
Risk Management	Kharaghani et al., 2023; Malesios et al., 2021
Resilience	Zare Mehrjerdi and Shafiee, 2020; Bourlakis et al., 2014; Tavakkol et al., 2023b
Profitability	Ahi & Searcy, 2015; Tavakkol et al., 2023b; Malesios et al., 2021
Operation Efficiency	Malesios et al., 2021; Tavakkol et al., 2023b
Investment Management	Eccles et al., 2011; Epstein & Roy, 2001; Malesios et al., 2021
Processes optimization	Tavakkol et al., 2023b; Kharaghani et al., 2023
Financial Management	Kharaghani et al., 2023; Hakimi et al., 2024; Ebrahimi et al., 2024
Sale Growth	Carvalho et al., 2013; Tavakkol et al., 2023b; Govindan et al., 2020
Technological Capabilities	Zare Mehrjerdi & Shafiee, 2020; Malesios et al., 2021
Government Incentives	Kharaghani et al., 2023; Tavakkol et al., 2023b
Financial Aids	Tavakkol et al., 2023b Kharaghani et al., 2023; Hakimi et al., 2024
Just in Time Production	Govindan et al., 2020; Lotfi & Saghiri, 2018
TQM	De et al., 2018; Lotfi & Saghiri, 2018; Malesios et al., 2021
Delivery Time	Carvalho et al., 2013; Ahi & Searcy, 2015; Fallahpour et al., 2017
Flexible Trasportation	Govindan et al., 2020; Tavakkol et al., 2023b; Geng et al., 2017
Quality	Bourlakis et al., 2014; Tavakkol et al., 2023b; Izadikhah & Farzipoor Saen, 2016
Economic Value Added	Tavakkol et al., 2023b; Kharaghani et al., 2023

Given the aforementioned points, there are three major distinctions between this study and previous research: (1) most of the studies on sustainability have primarily focused on the environmental and social dimensions (particularly job creation), (2) the majority of studies, have concentrated on agricultural sector, (3) there is a lack of applied financial research on SMEs in Iran, (4) Another research gap is the limited use of advanced data analysis and modeling methods. Many previous studies have been restricted to short-term, cross-sectional analyses, without proper attention to long-term evaluation of policies. This study applied a system dynamic approach for simulating and evaluating the SMEs sustainability and improve its dimensions over time. In this way we aim to enhance the sustainability knowledge.

3. Methodology

This study adopts a descriptive-explanatory research design to develop a dynamic model for assessing the sustainability of small and medium-sized enterprises (SMEs) in Iran, with an emphasis on financial indicators. Due to the diversity of SMEs in Iran, a purposive sampling method was used to select the SME managers as the research experts. To achieve theoretical saturation, 18 managers out of them were selected to participate in research. The methodology comprises multiple phases, each of them was carefully designed to ensure rigorous assessment and validation of sustainability indicators across economic, social, and environmental dimensions. Figure 1 illustrates the research framework.

The model's structural and behavioral validity has been confirmed through the implementation of various validation tests, including the structural boundary adequacy test, dimensional consistency test, integral error Test, Behavior Reproduction Test, Sensitivity Analysis (SyntheSim and Monte Carlo tests).

- *Boundary Adequacy Test*

The structural boundary adequacy test assesses whether the boundaries of the model are appropriate given its design objectives. In other words, the model boundaries should align with the design goals, encompassing all factors and components that influence the behavior of the variables

under study. Additionally, the definitions of endogenous and exogenous variables should be consistent with the model's objectives. This aspect of model validation is qualitative and is conducted by subject matter experts through the examination of diagrams and flow charts. For this purpose, the stock-flow diagrams were explained to business experts involved in the research. After making some adjustments, the final model was approved.

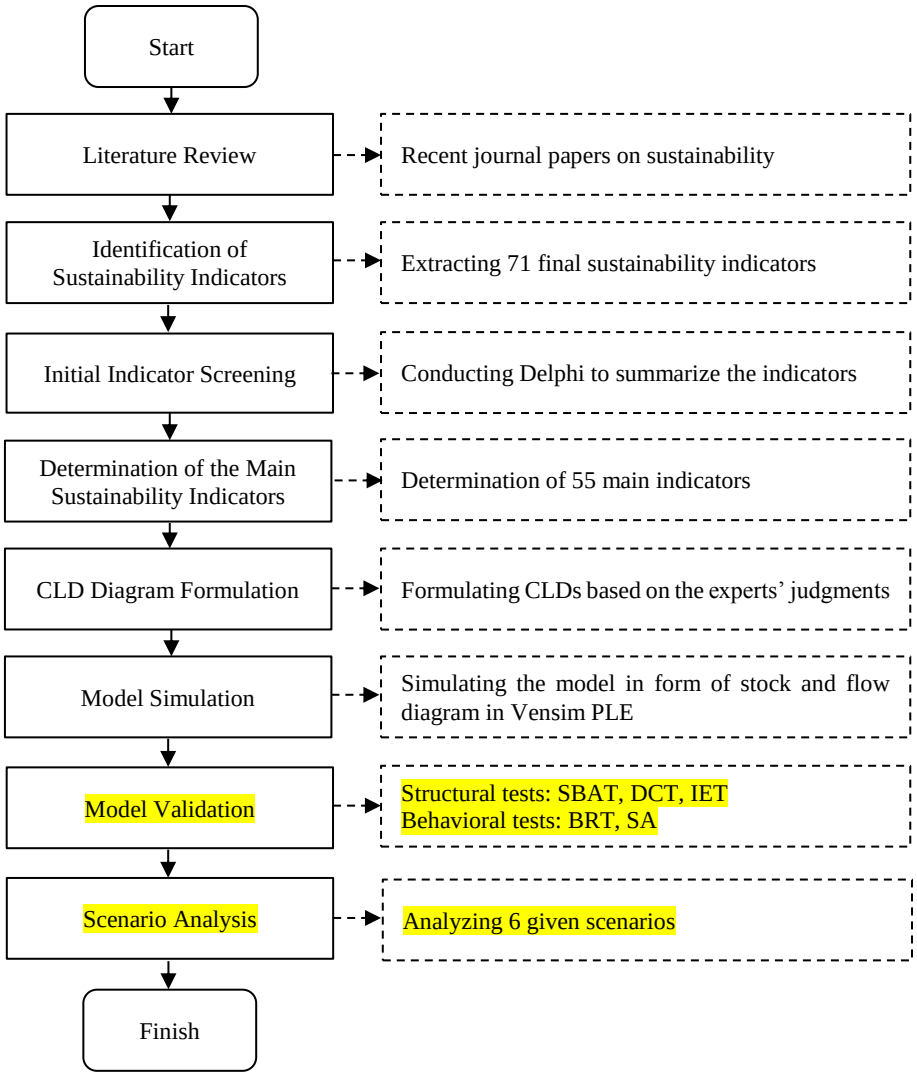

Fig. 2. Research framework

This study involves a mixed-method approach. The qualitative aspect includes a systematic review of existing literature and empirical studies, while the quantitative component is driven by the application of system dynamic simulation. As shown in Figure 2, first a literature review was conducted to identify sustainability assessment indicators for SMEs. The inclusion criteria required the articles to focus on SME sustainability across three dimensions (economic, social, and environmental) and to be published between 2010 and 2023. The result was a set of 71 initial indicators. Next, 18 managers were purposively selected for their experience and insight into sustainability practices for evaluating and screening the sustainability indicators. Using the main sustainability indicators, a causal loop diagram (CLD) was developed to visualize the interdependencies among the economic, social, and environmental factors in sustainability system. The CLD used as the basis for constructing and simulating a dynamic model, implemented in Vensim PLE 6.1 software. To ensure model validity, the study employed both structural and behavioral validation tests which will discuss in the next section. Finally, to evaluate the long-term sustainability performance of SMEs, scenarios will test using the dynamic model in a 10 years' time horizon.

4. Results

In this section, system dynamics is used as the analytical tool to investigate the behavior of the sustainability system. As mentioned before, 18 managers were selected based on their knowledge, practical experience and willingness to participate in the research. The data was collected by interview and questionnaire, and analyzed using Vensim PLE 6.1 software. The cause-and-effect diagrams for economic, social and environmental sustainability, are as the following.

4.1 CLD of SMEs Sustainability

- *Causal Loop Diagram of Economic Sustainability*

The causal loop associated with the economic sustainability of small and medium enterprises (SMEs) is examined below. In one part of this loop, the increased sales of growing SMEs in Iran will lead to higher revenues for these companies, which, in turn, will result in greater profitability. As profitability rises, the economic performance of the companies improves, creating opportunities to adopt more competitive strategies through advertising, franchising, and other means. This, in turn, influences customer purchasing behavior and boosts the company's product sales.

In another part of this loop, increased sales lead to higher revenues, which subsequently results in greater profitability for the companies. Enhanced profitability leads to better economic performance, facilitating the hiring of specialized and skilled human resources. Naturally, as the employment of such human resources increases, the company's payroll and, consequently, its expenses and costs will rise. Given that revenues and costs determine the company's profitability, this increase in expenses will reduce profitability and subsequently lower the company's economic performance.

In another segment of this loop, the increased profitability of growing SMEs in Iran leads to better economic performance, which enhances the company's ability to hire specialized and skilled human resources. As the employment of such human resources increases, the company's payroll and, consequently, its expenses and costs will rise. This increase in costs reduces the company's profitability and weakens its economic performance. As a result, investment in specialized human resources decreases, leading to lower payroll expenses, which, in turn, reduces costs and increases profitability.

Finally, in another loop, the improvement in financial capacity enhances the resilience of growing SMEs in Iran. It is expected that with increased resilience, the economic performance of the company will improve, enabling greater expenditure on hiring specialized labor and on training and empowering the current workforce, thereby increasing the company's operational efficiency and productivity. Improved productivity leads to an increase in value-added, profit margins, and profitability, which further strengthens the company's financial capacity. The mechanisms described can be examined in Figure 3.

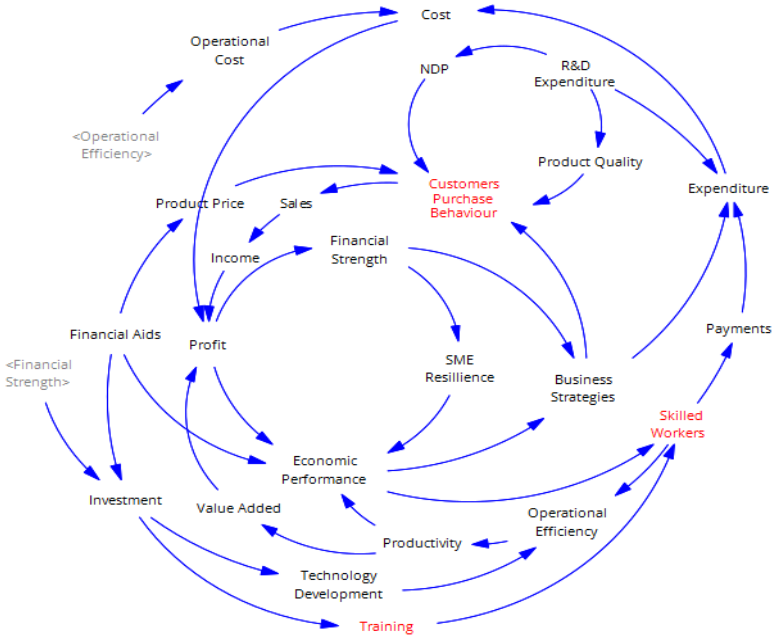

Fig. 3. CLD of economic sustainability

- *Causal Loop Diagram of Social Sustainability*

In the social dimension, improving working conditions directly enhances employee safety and promotes a better work-life balance, which leads to improved mental health among employees. This improvement leads to increased employee satisfaction, which further enhances their working conditions. Additionally, employee engagement strengthens a culture of collaboration and improves the organizational environment, enhancing diversity, equity, and inclusion (DEI). These improvements result in greater employee satisfaction and increased participation within the organization.

On the other hand, strengthening organizational culture leads to better implementation of corporate social responsibility (CSR). The outcomes of this include greater corporate accountability and improved relationships with the community. This, in turn, increases customer satisfaction and reinforces their purchasing behavior. Figure 4 illustrates the causal loops related to the social sustainability of SMEs.

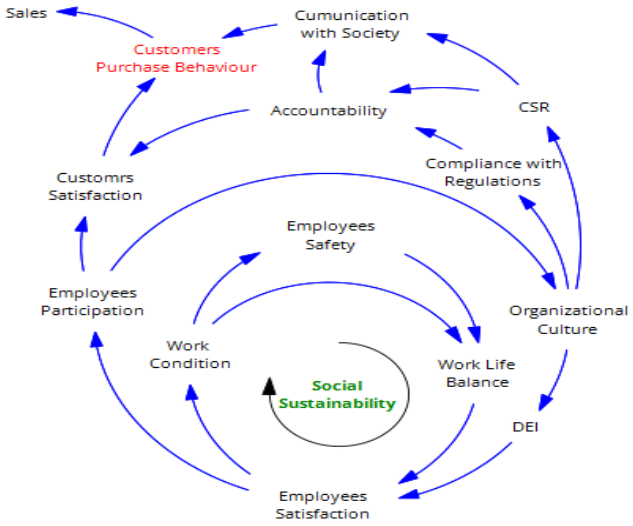

Fig. 4. CLD of social sustainability

- *CLD of Environmental Sustainability*

In the environmental dimension, causal relationships, like in other dimensions, involve multiple loops. On one hand, corporate social responsibility (CSR), as one of the variables of social performance, leads to increased environmental commitment and related investments. One consequence of this is the increased use of renewable resources, which results in reduced consumption of fossil fuels. Lower fossil fuel consumption leads to a decrease in greenhouse gas emissions and air pollution, which are key aspects of green production. As green production improves within the company, waste management is also enhanced, leading to reduced environmental pollution. Naturally, the reduction in pollution improves the quality of environmental reports and further realizes the company's CSR in practice.

On the other hand, greater investment in environmental issues promotes the use of green technologies and cleaner production, both of which are essential to green production and contribute to making it even more sustainable. Strengthening green production within the company also improves waste management, leading to less environmental pollution. This reduction in pollution results in better environmental reports and a more effective implementation of CSR. This, in turn, increases the company's commitment to environmental investment. Finally, greater investment in environmental issues enhances the ability to recover consumable materials and increases the use of recyclable materials, further greening the production process. This, along with improved waste management systems, reduces environmental pollution. Naturally, the reduction in pollution leads to better environmental reporting and elevates the company's social standing, which further strengthens its commitment to environmental investment. These relationships are depicted in Figure 5.

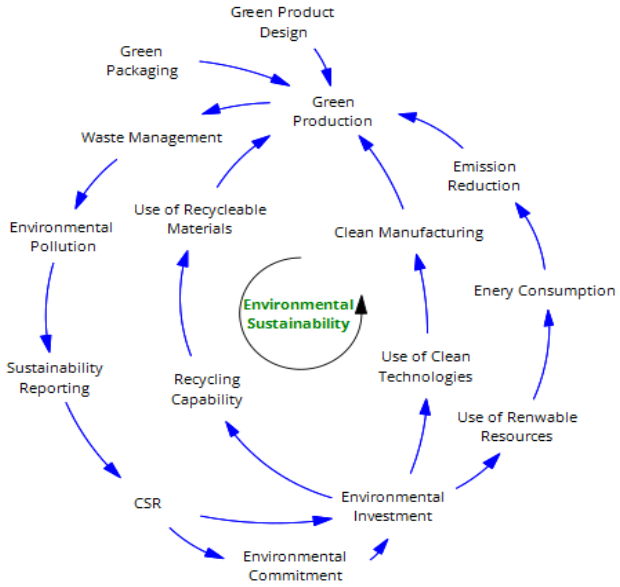

Fig. 5. CLD of environmental sustainability

Based on the causal loop diagrams in Figures 3 to 5, the CLD of SMEs sustainability were designed, which will be used as a basis for simulating stock & flow diagram.

4.2 Stock and Flow diagram of SMEs sustainability

In accordance with the causal loops described in the previous section, the stock & flow diagram of the research model is drawn (See Figure 6). Consequently, the variables identified in the causal loop diagram of SME sustainability were provided to three academic experts, who were asked to define the nature of these variables. Based on the consensus of the experts, the model consists of 2 stock variables, 4 flow variables, 47 auxiliary variables (including intermediary variables and table functions), and 2 constants.

In evaluating sustainability, some of the auxiliary variables are defined as lookup functions, where one variable is expressed causally in terms of other variable(s).

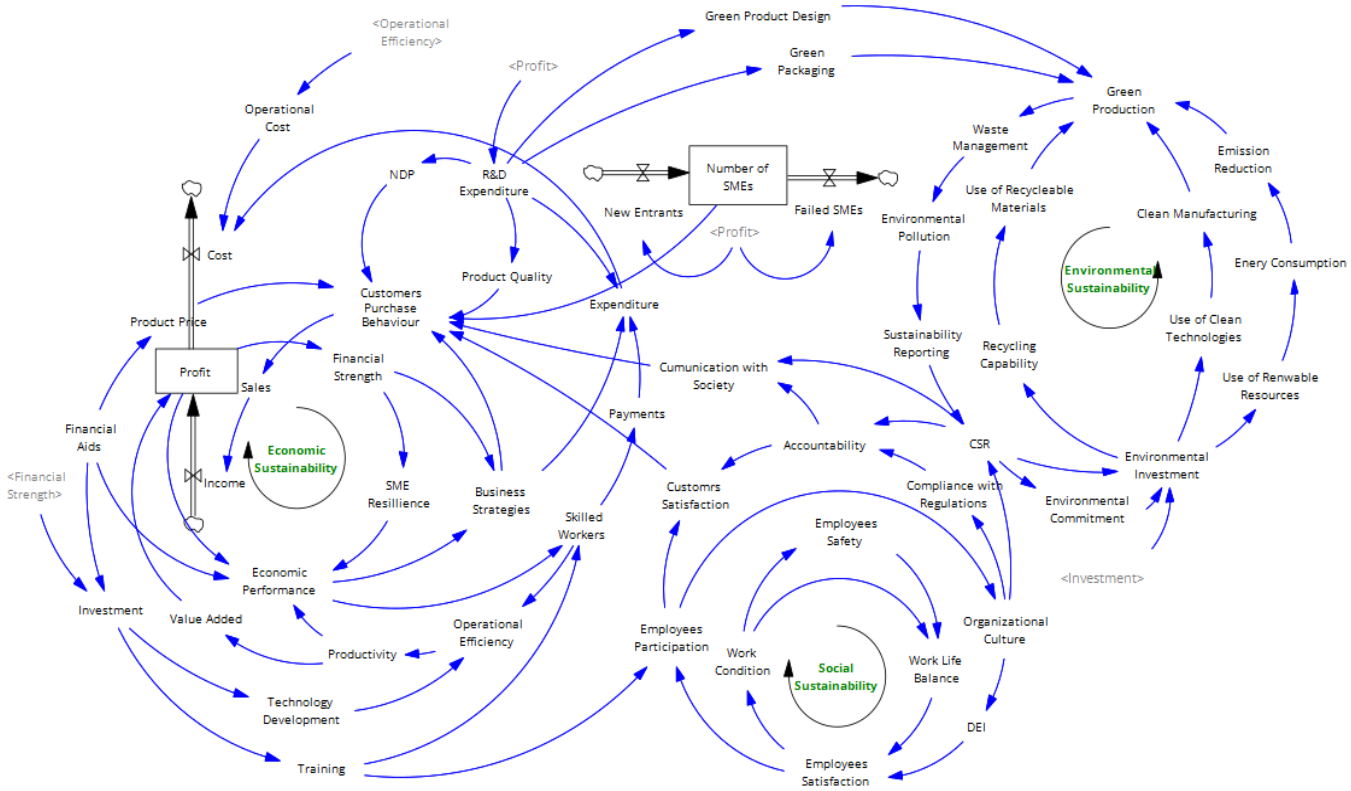

Fig. 6. Stock & Flow diagram for SMEs sustainability

4.3 Model validation

The model's structural and behavioral validity has been confirmed through the implementation of various validation tests, including the structural boundary adequacy test (SBAT), dimensional consistency test (DCT), integral error test (IET), behavior reproduction test (BRT), sensitivity analysis (SA) including SyntheSim and Monte Carlo tests.

- *Boundary Adequacy Test*

The structural boundary adequacy test assesses whether the boundaries of the model are appropriate given its design objectives. In other words, the model boundaries should align with the design goals, encompassing all factors and components that influence the behavior of the variables under study. Additionally, the definitions of endogenous and exogenous variables should be consistent with the model's objectives. This aspect of model validation is qualitative and is conducted by subject matter experts through the examination of diagrams and flow charts. For this purpose, the stock-flow diagrams were explained to business experts involved in the research. After making some adjustments, the final model was approved.

- *Dimensional Consistency Test*

To perform this structural test, the accuracy of the behavior of various variables within the stock & flow diagram—connected through differential equations—was evaluated using Vensim PLE software. By implementing the "Units Check" command in the "Model" menu of the Vensim PLE, the message "Units are OK" is displayed, that indicates all units are correctly assigned and consistent within the mathematical model. Additionally, "Check Model" command in the "Model" menu generates a window that appears in the center of the flow diagrams. If the message "Model is OK" is displayed, the model works properly (See Figure 7).

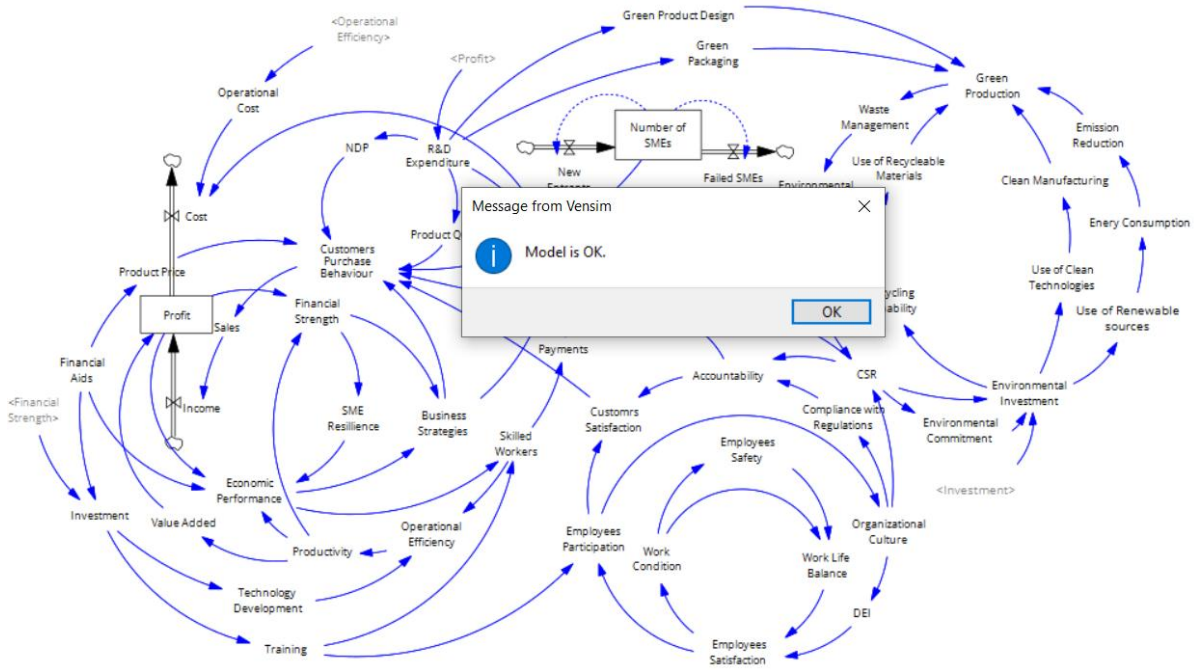

Fig. 7. Dimensional consistency test

- *Integral Error Test*

This test is conducted to confirm the appropriateness of the model's time step. In addition to the initial simulation performed with 10 annual time steps, another simulation was carried out using six-month intervals. The results for several key variables were compared between these two simulations. According to the model's output, the behavior of the main variables remained consistent in both cases, indicating that the integral error is negligible. For the first validation, feedback was obtained from two industry experts with over ten years of experience managing small and medium-sized enterprises (SMEs). They confirmed the causal structure, the table functions used in the model, and the simulated behavior.

- *Behavior Reproduction Test*

In this test, the behavior generated by the simulation of key variables is compared with their reference behavior. If the percentage error is minimal, the model can be considered to have behavioral validity. For this purpose, we compared the simulation results of certain variables with the forecasted values derived from time series data. The root mean square percentage error (RMSPE) is a statistical measure used to validate the model's behavior, reflecting the difference between actual and simulated data. For system behavior validation, the RMSPE should be less than 0.1. Based on the calculations, the RMSPE value in this simulation was 0.07, which is less than 0.1, thereby confirming the model's behavioral validity.

- *Sensitivity Analysis*

Generally, in Vensim software, sensitivity analysis can be performed in two ways: SyntheSim Sensitivity Analysis and Monte Carlo Sensitivity Analysis. The sensitivity analysis in the designed model has been conducted using both methods. Figures 8 and 9 provide an illustration of the SyntheSim sensitivity analysis. For the second validation, several simulations were carried out with sudden and significant changes in certain model parameters to assess the model's responsiveness to these alterations. For example, if the revenue significantly increases in the base scenario, the model should show a higher increase in the number of SMEs (Figure 8) and their profitability (Figure 9).

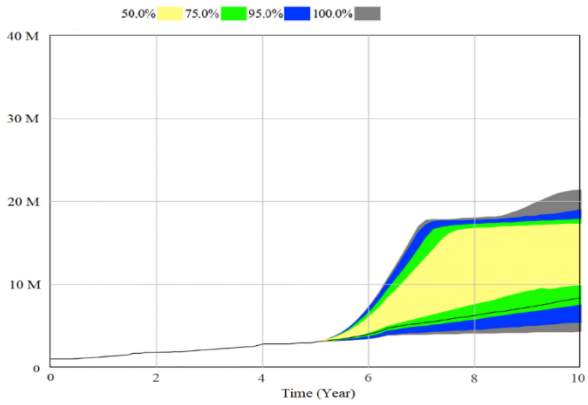

Fig. 9. Sensitivity analysis of the smes profitability

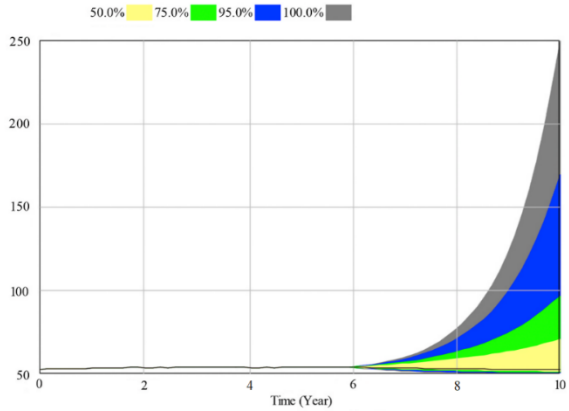

Fig. 8. Sensitivity analysis of the number of SMEs

4.4. Sustainability assessment scenarios

After conducting validation tests, the simulated model can be utilized to evaluate various scenarios. In this step, the scenarios should be considered based on the availability of necessary data, the feasibility of input-increasing and input-decreasing policies based on the companies' capabilities, and their prioritization from the managers' perspective. In this study, six scenarios have been devised according to the policies and resources of small and medium-sized enterprises (SMEs). It is important to note that the scenarios related to the economic performance variable have been defined based on the availability of data and the feasibility of planning. These scenarios are influenced by changes in variables such as product quality, training, and the use of recycled materials.

As shown in Table 3, in the baseline scenario (Scenario 4), the values of the variables for product price, training, and the use of recycled materials remain unchanged from those defined in the simulated model. In the first scenario, a 6% increase in product price is considered without any changes in training hours or the percentage of recycled materials (according to an agreed-upon approach, a 1% increase in product price equates to a 10% increase in training hours and a 3% increase in the recycling of raw materials. This ensures a balanced adjustment of the scenario variables, as the variables differ in importance).

In the second scenario, a 2% increase in product price, a 20% increase in training hours, and a 6% increase in recycled materials are considered. In the third scenario, a 4% increase in product price, a 20% increase in training hours, and no change in the percentage of recycled materials are considered. In the fifth scenario, the product price remains unchanged, while training hours increase by 20% and recycled materials by 12%. Finally, in the sixth scenario, the product price remains unchanged, but training hours increase by 40% and recycled materials by 6%.

Table 3
Research Scenarios

Scenario	Price	Training	Recycled Material
Scenario 1	6% increase	-	-
Scenario 2	2% increase	20% increase	6% increase
Scenario 3	4% increase	20% increase	-
Baseline	-	-	-
Scenario 5	-	20% increase	12% increase
Scenario 6	-	20% increase	6% increase

It is noteworthy that due to the importance of training, this variable has been increased in all scenarios except the first one. Figure 10 presents the simulation results for the economic performance variable under the implementation of different scenarios.

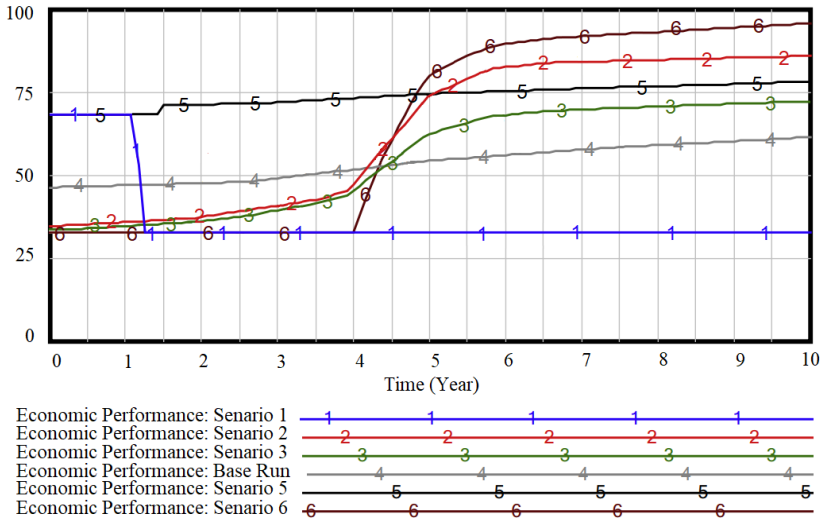

Fig. 10. Effect of scenarios on the economic performance

Given that this study aims to provide a dynamic model for evaluating the sustainability of small and medium-sized enterprises (SMEs) in Iran, with an emphasis on financial indicators, it examines the impact of changes in product quality (economic), employee training (social), and the use of recycled materials (environmental) on the economic performance of SMEs. According to the results, among the six scenarios presented, Scenario 6, which involves a 40% increase in training hours and a 6% increase in material recycling without changing the product price, leads to the highest improvement in economic performance over a 10-year period. It is evident that the development of scenarios should consider existing potentials and the decisions of business owners, and any scenario can be implemented and evaluated within the research model.

5. Conclusion

The sustainability of SMEs extends far beyond their immediate economic performance—it requires a balance between economic, social and environmental dimensions. This study illustrates that economic growth alone is not sufficient to ensure long-term viability for SMEs, particularly in changing economic environments like Iran's. The scenario analysis, underscore a profound insight: investment in human and environmental capital can drive economic growth in ways that are sustainable and self-reinforcing. The success of Scenario 6, which demonstrated superior economic performance through increases in employee training and recycling efforts, suggests that sustainability strategies rooted in workforce development and resource optimization can yield significant returns. This challenges the conventional notion that economic success must come at the expense of social or environmental concerns. At a deeper level, these findings highlight the interconnected nature of sustainability. Improvements in one dimension—whether it be training employees or adopting greener practices—create ripples that influence the other dimensions. By fostering a culture of continuous learning and environmental responsibility, SMEs can build resilience not only to financial challenges but also to broader systemic disruptions, such as political instability or environmental regulations.

The findings could influence policy at both national and international levels, in several ways: From the national view, where SMEs face unique challenges such as economic sanctions, political instability, and fluctuating currency rates, this study provides actionable insights that can help to SME financial resilience through the identification of financial indicators that boost long-term sustainability, such as employee training and investment in green technologies. In addition, demonstrating that sustainability challenges in SMEs are different from those in large corporations could encourage policymakers to create SME-specific sustainability frameworks that address their unique resource constraints. Finally, concentrating on SMEs aligns with the broader goal of fostering economic diversification in Iran could integrate our findings into strategies that prioritize the development of sustainable SMEs as a way to boost employment, enhance productivity, and increase GDP. From the international view, SMEs can improve their financial, environmental, and social performance through strategic interventions which can guide international development programs focused on growth and sustainability. Agencies like the World Bank, UNDP, or OECD could use the proposed model to design interventions that help SMEs in emerging markets achieve the sustainable development goals. Organizations that provide financial aid and technical support to SMEs, such as the World Bank or International Finance Corporation (IFC), could also leverage the findings to design targeted interventions for improving SME sustainability. Policymakers in emerging economies could use the dynamic model to learn from Iran's SME sustainability challenges, adapting successful strategies to their own countries.

While this study provides valuable insights into SME sustainability in Iran, limitations include the relatively small sample size of SME managers, which may limit the generalizability of the findings. Additionally, the study focuses on the Iranian context, and its applicability to SMEs in other regions may vary. Future research could expand the sample size and explore cross-country comparisons. For future studies, expanding the research to include cross-country comparisons could provide a more comprehensive understanding of how sustainability practices vary across different economic and regulatory environments. Moreover, while this study emphasizes financial indicators, future research could explore other dimensions in greater depth, such as innovation and digital transformation, which are increasingly relevant to the sustainability of SMEs.

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