System Dynamics Approach in Supporting The Achievement of The Sustainable Development on MSMEs: A Collection of Case Studies

Julia Kurniasih[1], Zuraida Abal Abas[2], Siti Azirah Asmai[3], Agung Budhi Wibowo[4]
Dept. of Informatics, Universitas Sarjanawiyata Tamansiswa, Yogyakarta, Indonesia[1]
Faculty of Information and Communication Technology, Universiti Teknikal Malaysia Melaka, Melaka, Malaysia[1, 2, 3]
School of Vocational, Universitas Gadjah Mada, Yogyakarta, Indonesia[4]

***Abstract*—Sustainable development in MSMEs is very important to encourage economic growth, improve the welfare of people, and ensure environmental sustainability. However, achieving sustainability in the MSME sector faces many challenges due to the complex interdependencies and dynamic interactions among various factors. The system dynamics approach makes it possible to model and simulate dynamic feedback loops, time delays, and nonlinear relationships between these factors. This paper provides an overview of the system dynamics approach and its suitability to address the complexities inherent in the MSME sector in its application to sustainable development. It explores the issues faced by MSMEs in achieving sustainable development and how the system dynamics approach models and analyzes the behavior of these MSMEs. These issues cover the dimensions of product development, technology and ICT inclusion, supply chain, business development, financial resources, and organizational support. This study was conducted on several case studies from various industries, namely the steel industry, agro-industry, craft industry, tourism industry, plastic molding, manufacturing, cosmetics, and digital companies; who come from various countries. From this study it was concluded that the system dynamics approach has significant potential to support the achievement of sustainable development in MSMEs, because it allows MSMEs to be able to effectively model and simulate the behavior of various factors that affect their operations, such as resource allocation, environmental impacts, and social considerations; proactively addressing sustainability challenges, adapting to changing market conditions, and contributing to broader socio-economic and environmental objectives.**

***Keywords*—System dynamics; sustainable development; Micro Small and Medium Enterprises (MSMEs)**

I. INTRODUCTION

The agreement of the agenda on Sustainable Development Goals (SDGs) 2030 which aims to end poverty, social inequality, and protect the environment represented by three pillars namely economic growth, social inclusion, and environmental protection is still being pursued and implemented. One of the SDGs adopted by the United Nations which is goal 8 relating to decent work and economic growth, aims to promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all. This goal aims to promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity, and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services.

Micro-, small- and medium-sized enterprises (MSMEs) are drivers of economic growth in many countries [1]. MSMEs have a very important role in economic development as a significant contributor to gross domestic production (GDP) and job creation [2]. Because the existence of MSMEs has a positive influence on development, the sustainability of MSMEs needs to be maintained, especially by the government. The factors that influence the sustainability of MSMEs are different, depending on the point of view of each institution.

The concept of sustainability is interpreted as a socio-ecological process that takes place dynamically and continuously, resulting in a system that works and can be applied for the long term; where the underlying thing is the concern of all parties about efforts to improve the quality of human life, to efforts to change behavior to meet sustainable living needs not only for the present but also for the future, especially related to the problem of worsening natural damage.

Sustainable development is an abstract idea with complex and involving goals in various aspects. Because MSMEs and their sustainable development are complex systems and involve many stakeholders and perspectives in seeing how MSMEs are affected and what variables influence them, it is necessary to map the complexity of the system comprehensively from a macro perspective. Knowing this complexity requires a tool and understanding of sustainable development. One tool that can be used to formulate and model sustainable development is a system dynamics approach. This approach is widely used because it can provide an overview of real-world phenomena and the interrelationships of various elements of the dynamic variable. By understanding the complex dynamics of MSMEs that are influenced by various interrelated factors such as market conditions, economic policies, and social dynamics; the system dynamics approach provides a structured framework for understanding and modeling these complex dynamics, helping stakeholders gain insight into MSME behavior and sustainability challenges. Sustainable development in MSMEs often involves handling feedback loops which can lead to a strengthening or balancing effect. System Dynamics can help identify and mitigate reinforcement loops that perpetuate unsustainable practices or amplify negative impacts. On the

other hand, System dynamics can also identify counterbalance loops that promote sustainable behavior and ensure long-term viability. The System Dynamics model can highlight points of influence where interventions can be strategically implemented to achieve sustainable development in MSMEs. By simulating various scenarios and analyzing the impact of interventions on system behavior, decision-makers can prioritize and design effective policies, practices, and interventions that lead to positive results. In addition to providing an analysis of long-term effects, System Dynamics can also provide an analysis of delays in achieving sustainable results. This capability helps MSMEs and policymakers evaluate the potential consequences of decisions and policies taken so that new scenario analyses and simulations can be carried out to identify strategies that can balance short-term and long-term goals.

Based on the complexity that exists in MSMEs and the capabilities that can be provided by system dynamics, the authors conducted a review of the existing literature related to the application of system dynamics in the MSME sector. This study is expected to provide insights to support sustainable development in MSMEs by focusing on understanding complex interactions, identifying points of influence for positive change, analyzing long-term effects, assessing policy interventions, promoting learning and capacity building, and increasing collaboration between stakeholders. In this paper, two terms are used in mentioning the object of study, namely Micro, Small, and Medium Enterprises (MSMEs) and Small and Medium Enterprises (SMEs) with the same purpose. The use of each term will be based on the literature studied.

II. Sustainable Development and SDGs Overview

A. Sustainable Development

Sustainable development is a concept that refers to meeting the needs of the present generation without compromising the ability of future generations to meet their own needs. It is based on the idea of balancing economic growth, social well-being, and environmental protection, to create a better future for all. Sustainable development involves a long-term approach to decision-making that takes into account the social, economic, and environmental impacts of policies and practices. It recognizes that economic growth is necessary for human development, but that it must be pursued in a way that is socially inclusive and environmentally sustainable.

Achieving sustainable development requires collaboration between governments, civil society, and the private sector. It involves making choices that promote economic, social, and environmental sustainability, and that are based on an understanding of the interconnectedness of these three areas.

B. Sustainable Development Goals (SDGs)

The United Nations has played a key role in promoting sustainable development through the adoption of the Sustainable Development Goals (SDGs) in 2015. The SDGs are a set of 17 goals and 169 targets that aim to end poverty, protect the planet, and ensure prosperity for all. The 17 SDGs cover a range of economic, social, and environmental issues, including poverty; hunger; health; education; gender equality; clean water and sanitation; affordable and clean energy; decent work and economic growth; industry, innovation, and infrastructure; reduced inequalities; sustainable cities and communities; responsible consumption and production; climate action; life below water; life on land; peace, justice, and strong institutions; and partnerships for the goals.

The SDGs are designed to be universal and apply to all countries, regardless of their level of development or income. They are also intended to be integrated and interconnected, recognizing that progress in one area can have positive or negative impacts on other areas.

Achieving the SDGs requires action at all levels, from local to global, and involves a range of stakeholders, including governments, civil society, the private sector, and individuals. The SDGs provide a shared vision, roadmap, and comprehensive framework for achieving sustainable development, and represent an important opportunity to address the most pressing of world challenges, including poverty, inequality, and climate change.

III. System Dynamics Overview

System dynamics models typically use stocks and flow to represent the accumulation and flow of resources or information within a system. They also incorporate feedback loops, which are the interactions between different components of the system that influence each other's behavior over time.

System dynamics refers to the study of the behavior of complex systems over time. System dynamics was first built by Forrester in 1969 with the aim of building models that can understand complex systems and states [3]. With system dynamics, we can analyze complex systems in a simpler way to get a complete system understanding, based on boundaries and scope discussion. Systems dynamics has been applied to various fields, including business management, engineering, environmental science, and public policy.

System dynamics involves building a computer model of a system that incorporates key components (i.e. stock and flow), relationships, and feedback loops. This model can be used to simulate system behavior over time and test various scenarios and policies. Data in system dynamics is not only in quantitative form but can also be in qualitative form, because some of the variables considered in the model may not be in quantitative form. System dynamics can facilitate qualitative forms by using dummies (quantifying qualitative data).

One of the key strengths of system dynamics is its ability to capture the nonlinear and dynamic nature of many real-world systems and to identify the underlying causes of persistent problems or unexpected outcomes. System dynamics models can help decision-makers to better understand the complexities of the systems they are dealing with and to make more informed and effective decisions based on data-driven insights.

IV. Micro, Small, and Medium Enterprises Overview

Micro, Small, and Medium Enterprises (MSMEs) are important drivers of innovation and economic growth, and they can be a source of employment and income for low-skilled workers and marginalized groups. In recent years, there has been increasing recognition of the importance of supporting the development of MSMEs, particularly in developing countries

where they can play a critical role in poverty reduction and sustainable development. Governments, development agencies, and other stakeholders are working to provide MSMEs with access to finance, technical assistance, and other resources to support their growth and development.

Small and Medium Enterprises (SMEs) are entities that can support the economic development of a country [4], [5]. Meanwhile, specifically for developing countries, the context of Micro, Small, and Medium Enterprises (MSMEs) is more widely used because micro-enterprises continue to increase from time to time [1]. Based on EU recommendation, the European Commission defines micro, small, and medium enterprises based on several main factors namely the number of employees (staff headcount), sales (turnover), and profit (balance sheet total). A micro business is a company that has less than 10 employees, sales, and profit of at most EUR 2 million. While small business is a company that has employees less than 50 people, sales and profit of at most EUR 10 million per year. Finally, medium-sized businesses have fewer than 250 employees, and sales of at most EUR 50 million or EUR 43 million of profit per year. If the company has a larger amount than this provision, it can be categorized as a large company.

MSMEs have a critical role to play in achieving the SDGs, as they are a major source of employment and economic growth in many countries. However, they also face significant challenges in adopting sustainable business practices and contributing to the achievement of the SDGs. Efforts to support MSMEs in achieving sustainable development can help to accelerate progress towards the SDGs and promote a more inclusive and sustainable global economy.

V. Discussion on System Dynamics and MSMEs

In the context of MSMEs (Micro, Small, and Medium Enterprises), system dynamics can help business owners and managers to understand the interdependencies between various components of their organization and how they interact over time. System dynamics can be used in MSMEs to model the behavior of the business and identify potential problems or opportunities. By analyzing the behavior of the business over time, system dynamics can also help MSMEs to identify areas where they can improve efficiency and performance.

Table I provides an overview of system dynamics applications in MSMEs/SMEs. The industries included are the steel industry, agro-industry, manufacturing, cosmetics, craft, plastic molding, and other non-categorized industries. The year represents the date of publication, so it may differ from the year the study was conducted. It shows that using system dynamics for sustainable development started many years ago and is still relevant today. The column 'Main Goals' shows the main purpose of using system dynamics for each study. The sections that follow are summaries of each of the studies and their implementation of the system dynamics approach.

A. Product Development

Improve product development planning is recommended as one of the strategies to support company performance. Based on that, research [6] identifies and analyzes the factors that influence the advantages and product development success in the steel industry in Iran. The steel industry has a dynamic development structure because there are dynamics in the interrelationships between the elements that influence the quality and success of SMEs in this sector. Therefore, companies need to adopt an all-encompassing strategy related to creating and maintaining collaboration rather than concentrating on a single issue. Using system dynamics techniques in this study, it was found that the factors which influence the success and excellence of SMEs in the steel industry are organizational, managerial, human, marketing, and environmental factors. The interrelationships between variables commitment, mutual trust, and satisfaction in collaboration play an important role in the success and excellence of small and medium enterprises in the steel industry. The consequence is companies must be able to choose the right and compatible partners in terms of sales markets and work activities within the company structure to minimize non-functional conflicts.

TABLE I. Applications of System Dynamics on MSMEs/SMEs

Sector	Case	Paper	Year	Main Goals
Product development	Steel industry	[6]	In press	Product development
Technology - ICT	South African SMEs	[7]	2021	Digitalization
	Indonesian MSMEs	[1]	2019	Digitalization
	SMEs	[8]	2022	Digitalization
	SMEs	[9]	2019	Building Information Modeling (BIM) adoption
	SMEs	[11]	2019	Mobile analytics adoption
Supply chain	Malaysian agroindustry	[12]	2018	Performance measurement
	Indonesian agroindustry	[13]	2019	Performance measurement
	Agri-food SMEs in Kunming, China	[14]	2020	Home delivery agri-food supply chain
Business development	Manufacturing companies	[15]	2019	Crisis management
	Cosmetic company	[16]	2021	Sustainable strategy
	WoC-owned SMEs in the US	[17]	2022	Business sustainability
	Indonesian craft industry	[18]	2019	Business sustainability
	Plastic molding industry	[19]	2020	Risk management
	Digital companies	[20]	2021	Business model innovation
	Iranian SMEs	[21]	2019	Increased ROI
	Iranian SMEs	[22]	2021	Business management
Finance	Indonesian SMEs	[23]	2022	Bankability
	Malaysian SMEs	[24]	2018	Financial risk
Organizational	Mexican tourism industry	[25]	2023	Organizational resilience
	Developing country SMEs	[26]	2018	Industrial clustering

B. Technology – ICT

In this era, digitalization is becoming increasingly important for micro, small, and medium enterprises (MSMEs) to remain competitive and relevant in a fast-paced business environment. Process transformation involves many interrelated variables, and digitalization is no different. To make it easier for SMEs to navigate, a model was developed using the case of SMEs in South Africa to understand the complexity and management of digitization [7]. This model uses a system dynamics approach by considering the dynamic interactions between the determining variables which are productivity, finance, and skill of the workforce. Productivity is shown by the Labor Productivity Factor which refers to the percentage of the number of skilled workers, skill of the workforce is divided into skilled workers and unskilled workers, and finance is represented by the flow variable, namely the expenditure variable which is the result of calculations from sales, marketing costs, digitization costs, and wastage contingency. The developed model provides knowledge that digitalization has an impact on increasing sustainability performance; this condition demands the need for digital empowerment. Besides that, efficient process control with the right technology, especially for a large enough scale of operation, requires automation to avoid unexpected things.

The process of digitizing MSMEs is complex and requires a holistic approach that considers various factors, one of which is the adoption of technology such as ICT inclusion. Reference [1] conducted research using a system dynamics approach in building MSMEs models with the involvement of ICT to increase MSMEs income, based on case studies in Indonesia. Because this is a macroscopic model, aspects other than ICT are also included, namely aspects of the market, MSMEs business stocks, government, and financing, which are considered to affect the increase in MSMEs income. From the causal loop diagram they developed, it is known that the ICT aspect is seen from the type of MSMEs whether it is micro, small, or medium level. For all levels, ICT capabilities are influenced by three components, namely digital operations, internet users, and e-banking services. Because ICT is an investment and is a long-term commitment, ICT inclusion requires adequate financial support from various parties, it can be personal, the government, or other parties funding. This means that the ICT capability at each level of MSME is influenced by these funding sources; as previously stated that ICT inclusion is aimed at increasing MSMEs income. Income is represented by the number of orders which is one of the variables in the market aspect. This linkage means that the more orders, the income of MSMEs business will be higher. Where each type of MSMEs business has its level of ICT capability, the number of orders will also be influenced by the MSMEs ICT capability itself. Meanwhile, the MSMEs business stocks and government aspects do not have a direct relationship with ICT aspects but are connected with market and funding aspects. From this model, the recommendation given is the need to increase the level of ICT capability in each type of MSME to increase their income.

ICT forms the foundation for digital transformation by providing the infrastructure and capabilities an organization needs to digitize its operations while facilitating social interaction, content sharing, and networking among users can be done using social media platforms. For businesses, social media in general can provide an avenue for companies to engage with customers, build communities, conduct market research, and promote their products and services, in other words increasing market share. To identify the interrelationships of variables to increase SME market share due to the involvement of social media platforms, [8] utilizes one of the social media that is Instagram to study it using a system dynamics approach. From the developed model it is known that to increase market share, it is also necessary to increase engagement. The scenario model shows that engagement increases after including Instagram (social media) features in the simulation model. The increasing trend is found in the number of new customers, total business sales, and profit value. In other words, the use of social media in this case Instagram, helps SMEs in increasing their market share. The Instagram features considered in the simulation model are the number of comments, saves, views, likes, followers, and posts. This means that engagement can be increased by increasing the number of posts and interactive activities and maximizing the usage of Instagram (social media) features.

In the construction industry, system dynamics is used to explore BIM adoption in SMEs in developing countries [9]. Building Information Modeling (BIM) is a digital technology that has revolutionized the construction industry by enabling the efficient planning, design, construction, and management of building and infrastructure projects. The main benefit of BIM for SMEs is in facilitating information management, communication, and collaboration between supply chain actors [10]. System dynamics in this study is used to understand the dynamics and challenges faced in BIM adoption. The two conceptual causal models developed show a causal relationship between BIM adoption behavior at the organizational/project level and the industry level. Awareness, management support, benefits, and costs of investing in BIM are variables influencing at the organizational level while awareness, organizations, benefits, and government are influencing variables at the industrial level. From system dynamics modeling, policy insights are obtained for better BIM adoption to be executed in practice in SMEs.

The development of new digital technology that continues to move increasingly has an impact on SMEs. Research methods carried out by SMEs have also begun to utilize information technology, one of which is mobile analytics. Mobile analytics uses data from mobile apps, mobile websites, and other mobile platforms to gain insight into user behavior, preferences, and trends. Research [11] conducted a study on the impact of mobile analytics for SMEs using system dynamics simulations. From the model simulation carried out, insight was obtained that mobile analytics is the main key to competitive advantage in SMEs. With mobile analytics, companies can survive data vulnerabilities and can access real data for better organizational decision-making, which will ultimately build an agile organization, because organizations already understand how users interact with their business, identify areas for improvement, and make data-driven decisions to optimize and drive their business.

C. Supply Chain

Being in a dynamic and competitive business environment, small and medium enterprises (SMEs) need to measure their supply chain performance to evaluate their business activities. While it is known that most SMEs do not have an effective performance measurement system because they do not identify their internal strengths and weaknesses but instead focus on external opportunities and threats. Related to this interest, [12] proposes a system dynamics approach to identify the main drivers of supply chain performance, develop strategies for performance improvement, and measure the impact of strategies on overall supply chain performance; by using case studies on companies engaged in agro-based industries in Malaysia. By using a system dynamics approach to model how information, actions, and consequences interact to produce a dynamic behavior strategy, it is known that lead time, product quality, and availability are the three main sequences of a company's strategy in winning customers. Purchasing domestic raw materials and production quality will help reduce lead time by providing products at any time to meet customer demand. It is the main focus of a responsive supply chain because it will improve company performance. Therefore companies need to have good collaboration with their supply partners so that they can integrate well to improve on-time delivery. The use of IT in planning delivery activities from suppliers and deliveries to customers is also important in a responsive supply chain. IT will act as a driving force for collaboration, process integration, and delivery speed. To achieve this goal, it is necessary to build a good information technology structure to support corporate responsiveness so that it can identify changes in the needs and desires of customers and other parties.

The development of other supply chain performance measurement models was also carried out using the case of the passion fruit agroindustry in North Sumatra Province, Indonesia. Study [13] identifies the factors that influence the performance of the passion fruit agroindustry supply chain for the sustainability of MSMEs and designed a supply chain performance measurement model using a system dynamics approach. Behavior on supply chain performance in building the sustainability of passion fruit agroindustry MSMEs is expressed as an increase in farmer production and income; and manufacture of essences and syrups. The key variables of the model are proven to affect the performance of the passion fruit agro-industry supply chain used to design sustainable MSME supply chain development scenarios, namely farmer skill and availability of land. Passion fruit production rate is influenced by the skills of farmers. The higher the level of passion fruit production, the more is passion fruit collector. Increasing collector passion fruit will increase extract industry production. This condition will increase waste products that can be composted and sold to farmers. The higher the compost production, the higher the efficiency of using the compost turn will produce environmentally friendly products. The consequence is an increase in the carrying capacity of the environment will have an impact on the availability of passion fruit land. With increasing availability of passion fruit land then it will increase fruit production rates. In the end, this condition will increase the income of SMEs and build the sustainability of the industry.

The agri-food supply chain is a multifaceted system that involves the production, processing, distribution, and consumption of agricultural products. To navigate these complexities effectively, stakeholders within the industry recognize the need for collaboration and cooperation. This prompted the formation of an agri-food supply chain alliance. Related to this problem, [14] developed a system dynamics model to investigate the stability of the cooperation of a "home-delivery-oriented agri-food supply chain" (HASC) alliance using a case study of an alliance built by an agri-food company in Kunming. HASC is a concept defined as an agri-food supply chain based on an alliance structure and collaborative strategy, which organizes agri-food SMEs with various competencies in the agri-food e-commerce (AE) market to provide services in meeting the daily needs of customers through home delivery. The results of this study indicate that the performance of the HASC alliance concerning time showed significant variation initially, but gained stability with the implementation of an appropriate control strategy. There was a decrease in the stability of the alliance in the early stages due to the running-in process between members and the process of adaptation of the alliance system to its internal environment. The model simulation shows that the stability of the HASC alliance cooperation is very sensitive to performance regarding strategies that control customer and environmental variations. Trust and market fluctuations have a great effect on the stability of membership and relationships. It is necessary to pay attention and focus on increasing mutual trust among members and controlling market fluctuations to minimize the risk of local markets. The model simulation results also show that for the HASC alliance, higher control strategy costs do not guarantee better stability. Therefore, it is necessary to control costs within a certain range that can help the HASC alliance to maintain stability and performance.

D. Business Development

Within the scope of MSMEs business development, a system dynamics perspective can be included in the enterprise life cycle, crisis management, resilience, and business continuity management. Research [15] presents an analysis of the factors that lead to crises in small and medium enterprises (SMEs) and proposes a system dynamics model to explain the phenomenon. The model provides knowledge by explaining the mechanism of how during the crisis in SMEs, system dynamics help to predict the impact of various possible managerial decisions. This study was conducted in the Czech Republic and the model developed for the case of manufacturing companies. In this study, the crisis is categorized into 19 aspects, namely employees; customers/demand; inputs and supplies; regulations–bureaucracy–taxes; collecting bills; competition; owners; financial capital; capacity; natural disasters; technical breakdown; selling prices; quality of production; entrepreneur–personal crisis; thefts; placement of business; processes; outdated product; and legal entity. These aspects were analyzed through three stages using descriptive statistics, cross-tabulation, and association rules mining. The results of the analysis show several patterns underlying the crisis. Crisis classification is divided into two, namely crises in the internal environment and the external environment. Crises in the internal environment are related to employees, capacity, and

quality of production, while those in the external environment are related to input and supply, customers, and competition. By using a system dynamics approach, they develop a model explaining the relationship between the variables of the number of production employees and labor market; production capacity; production; outsourced product; stock of finished products; product quality and claims; inputs and supplies (including limitations, purchasing prices); demand (related to the price offered, competition and quality of previous investments, delivery delays, R&D and marketing); orders and their fulfillment; and revenues, costs, and profits. By testing and analyzing crisis scenarios, managers will gain knowledge and insight into the variables that affect aspects of a crisis, can predict the impact, and be able to determine actions to anticipate or resolve the crisis. This indirectly encourages sustainable development for the company and its business activities.

The system dynamics approach is also used in the Cosmetics Small and Medium Industries to develop a sustainable industrial strategy model that uses a case study of a personal care cosmetic company in Indonesia [16]. This strategy model is built from the integration of the system dynamics method and the open innovation approach. In this case, system dynamics is used to explore the complexity of SME problems that involve factors, actors, and dynamic relationships that affect output performance. While the open innovation approach is used to provide effective strategic choices in increasing output performance, both in terms of manufacturing operations; and economic, environmental, and social indicators. There are three strategic scenarios considered, namely self-lean improvement, limited collaboration, and comprehensive collaboration. From the simulation, it is known that in the self-lean improvement strategy, the productivity and profitability ratio shows a downward trend, including a decrease in demand, as well as an insignificant increase in improvement to environmental damage and human health. While limited and comprehensive collaborations demonstrated improvements in general depreciation and costs; cost savings; increased productivity and profitability; and reduced environmental and human health impacts. Limited collaboration shows a flatter slope of improvement compared to comprehensive collaboration which gives the best results. Comprehensive stakeholder involvement in an open innovation community effectively supports the achievement of the sustainability goals of SMEs. This support includes technical assistance from research and academic institutions, engagement of suppliers and distributors in lean and green improvement, assistance from cosmetics associations, and financial support from the government. Without such support, it is difficult for SMEs to grow and achieve sustainability, because there is a portion that is difficult to fulfill by the company itself. This collaboration is one strategy suitable for dealing with complex and dynamic sustainability challenges, with the takeover of resource support by external parties.

Studies on women concerning SMEs have also been carried out using a system dynamics approach. Study [17] conducted research to uncover the challenges faced by women of color (WoC)-owned SMEs in the United States. This research is based on the finding that the majority of SMEs belonging to WoC failed in the first years of its establishment. This research focuses on the success of entrepreneurs (number of people) not on business success (number of entities) because people's (entrepreneurs) success is defined as business sustainability or profitable monetization events. This study's findings from the developed model suggest that access to capital (financing), social networks, and education and training are crucial factors that impact the success of women of color-owned SMEs. The variables that play a role in this model are opportunity rate, necessity factor, and desired financing rate. The opportunity rate is the number of WoC candidates, and the necessity factor is the number of WoC that startups out of need rather than an opportunity; which of these two variables will have an impact on the stock of aspiring WoC entrepreneurs. Meanwhile, the desired financing rate is the target as a goal gap modeling archetype which will affect the flow rate, namely the financing rate variable. The emphasis on these interventions as early as possible is intended so that WoC SMEs can survive in the early years of their establishment which is ultimately the sustainability of their business can be maintained.

The importance of the craft industry and its contribution to economic development and job creation prompted [18] to research the dynamics of budget allocation competition in this sector. This study uses the case of the craft industry in Indonesia and the system dynamics (SD) approach supported by the Balanced Scoreboard (BSC) framework and the ARCH-type model Success to Successful (StoS) approach. At the SD model development stage, the BSC framework is used as the basic development framework and the StoS approach of the ARCH-type model is used as a problem-solving concept. The system dynamics approach is used to model the interaction of the variables from the craft industry system, with budget allocations. From the model simulation, it is known that the budget allocation is not too significant in increasing SME revenue growth, so it is necessary to innovate budget allocation policies so that they have a significant impact on the development of SMEs. In those models, the exogenous variables are demand, price, and carrying capacity. Demand is related to changes in price as a form of response and carrying capacity affects the supply of raw materials. Ultimately the three variables have an impact on the production rates.

In another scope, [19] has studied the process of risk analysis and assessment using the integration of system dynamics techniques and Layers of Protection Analysis (LOPA) to improve risk management results. This research was conducted in the plastic molding industry in the case of fire risk assessment. The methodological approach integrated with this study is a structured risk assessment technique to obtain failure scenarios that may occur and assess the probability of an accident occurring, and system dynamics models are used to measure the interaction effects of various scenarios. From the developed SD model, it is known that the probability of events is associated with the risk of explosion in the supply system and the risk of spreading fire due to some engine malfunctions (engine aging effect). Scenario analysis in more detail considers the possibility of failure by using the time function. It turns out that if the period is longer, the possibility of damaged components becomes higher. As a

result, the system may fail to fulfill its security function. The probability value of the possibility of an explosion and its relationship to the possibility of spreading fire is a function of the values of several control variables, namely the frequency of maintenance and safety procedures. Through this study, it can be understood that the dynamics and uncertainties inherent in risk assessment and management in complex systems can be identified using a systems dynamics approach.

In the context of digital companies, which operate in technology-driven and rapidly evolving environments, business model innovation is essential for staying competitive and achieving sustainable growth. For that purpose, [20] developed a system dynamics model to increase evolutionary and innovative business models using an open innovation (OI) approach. In this study, the major influential factors of OI are identified as IP-sharing and key partners. These factors are concrete variables that exhibit positive feedback loops in the context of business model innovation (BMI). Positive feedback loops indicate that the company experiences growth and expansion when implementing OI. When more parties are involved, the amount of capital investment needed decreases. The company engages in collaboration with customers and suppliers. Extensive cooperation with partners will help companies identify more technologies and opportunities. This will encourage the achievement of sustainable growth. The simulation outcomes indicate that the implementation of OI has a substantial impact on company performance. This is based on the revenue-boosting effect resulting from accelerated product development and expanded market access facilitated by partnerships and IP sharing.

Iranian SMEs face many problems related to management. These problems often take root in strategic decision-making by managers. One such decision is related to the production department. Many of these companies provide production infrastructure at a high cost; however, they were unable to gain their share of the market, and eventually, they suffered losses. Related to these problems, [21] developed a model using the Schmid model as a basic model and a system dynamics approach aimed at evaluating existing policies to prevent capital loss. The developed model investigates whether customer networks in businesses without prior production have a role in increasing the return on investment (ROI). The model consists of 10 main elements, namely balance sheet, profit loss, machinery, production, customer, network, reputation, employee, innovation, and qualification. From the developed model, it proves that if the production unit is involved in selling the product to be produced, determines a network of loyal customers, and increases its production capacity, then the rate of return on investment under the same conditions will be five times higher than the original production plan. With this condition, the problem of return on investment (ROI) and capital losses can be overcome.

In addition to facing problems on the management side, SMEs in Iran also experience problems of uncertainty in their operating environment. Understanding their behavior patterns can help identify factors that contribute to success or failure. Reference [22] conducted a study focused on the development and application of a qualitative system dynamics model to analyze the behavior patterns of SMEs in Iran. The identified behavior patterns are changes in the concept of technology due to a lack of market interest, an imbalance in the allocation of resources on the development of the technical and management side, and market development concerning the utilization of technology. From the simulation, it is known that the government needs to establish regulations that protect the flexibility and freedom of SME managers; provide marketing services and market research; and facilitate connections to the industry. It is also necessary to use a mentoring mechanism for coaching and leadership at all levels of SMEs, such as managing financial allocations, market planning, and improving the management structure and style. Facilitating administrative consulting provides a role to increase business area and workforce participation; reasonable control and can build a balance between the development of technological ideas and the capabilities of SMEs, especially in terms of human resources.

E. Finance

In the field of finance, a study was conducted to identify the driving factors and constraints faced in efforts of MSMEs upgrading. Using system dynamics modeling [23] reveals and shows how the dynamics of the transition of Indonesia MSMEs towards bankability during the COVID-19 pandemic. The focus of this analysis is MSMEs that initially have limited or no access to bank loans. From the developed model, it is known that several critical variables accelerate the status of MSME bankability from un-bankable to bankable, namely time to bankability (for entrepreneurial/micro enterprises), channel business, and the non-performing loan (NPL) of MSMEs. Extending the projected timeframe for entrepreneurial MSMEs to achieve bankability can expedite the process of transitioning un-bankable MSMEs into bankable ones more rapidly than the current circumstances. Building strong business channels or networks plays an important role in enabling MSMEs to recognize the benefits of financial services and foster closer relationships with stakeholders. This, in turn, accelerates the process of transitioning un-bankable MSMEs into bankable entities. Reducing the non-performing loans (NPL) of MSMEs can expedite the transition of un-bankable MSMEs into bankable entities compared to the present situation.

Investment decision-making is a critical process that involves assessing various financial risks associated with investment opportunities. In the current dynamic and complex financial environment, investors must have a comprehensive understanding of the potential risks and their impact on investment outcomes. Using the investment case on solar thermal heating installation in Malaysian SMEs, [24] undertook system dynamics modeling of financial risk as a valuable approach. The simulation results of the model show that government support (guarantee) and financial funding (soft loan) mechanisms have a major influence on investment decisions that lead to increased solar thermal installation capacity by Malaysian SMEs. Increasing the percentage of government support reduces the risk of Net Present Value (NPV). This means that government support plays a role in financial risk trends, and this should help increase installed capacity; because indirectly, it helps increase industry awareness to invest in solar thermal technology. With this model, policymakers can tailor appropriate policies for SMEs.

The right policies can contribute to risk analysis for other categories such as construction and operations.

F. Organizational

In the context of SMEs, which often have limited resources and capabilities compared to larger organizations, building resilience is critical to their long-term sustainability and success. Resilience refers to the capacity of an organization to effectively respond to and recover from disruptive events or shocks, such as economic downturns, natural disasters, or market fluctuations, and to adapt and thrive in the face of adversity. Research [25] studies the resilience and sustainability of SMEs by taking the case of the tourism industry in Mexico, through identifying the factors that need to be addressed to secure and promote their business. This study begins with conducting social network analysis (SNA) to obtain the latest understanding of organizational resilience in the SME literature. The results of SNA were then used to develop a conceptual model and simulate scenarios using system dynamics. The model simulation shows that organizational resilience is related to feedforward, buffering, and feedback control as critical factors that demand continuous coordination on the mechanisms between core operations and management. The need to stabilize organizational cycles by providing a buffer against fluctuations and weakening variations in existing capacity. These results can help managers rethink corporate resilience related to restructuring relations in operational and strategic units, improving autonomy, and strengthening strategic planning as well as feedback means.

Creating sustainable economic growth requires a synergistic and supportive ecosystem where companies, institutions, and stakeholders can collaborate, innovate and thrive. By clustering related industries and resources, it can stimulate economic development, increase competitiveness, and encourage innovation and entrepreneurship. In addition, within an industrial cluster, companies can collaborate and share resources, including energy-related infrastructure and technology. This can lead to optimizing energy systems and adopting energy-efficient practices. To gain insight into new economic dynamics related to industrial cluster growth and demand for energy intensity, [26] developed a model and simulated it using a system dynamics approach. The simulation results show the factors that affect growth cluster activities and productivity transaction cost barriers are energy intensity, energy efficiency, and energy conservation. Energy consumption patterns based on energy needs are stimulated by government policies through the development of cluster dynamics that utilize the innovations of energy intensity and efficiency. SMEs share a leading role in the development of innovative energy intensity. Which, the greater the energy efficiency, the smaller the calculated energy savings based on energy requirements. Therefore, cluster growth indirectly promotes technology spillover and higher GDP, and ultimately promotes economic growth. This will also provide macro benefits in the form of reduced energy demand and energy conservation.

System Dynamics, as previously discussed regarding its application to MSME sectors, offers valuable applications in various sectors. In product development, it enables modeling and optimization of product life cycles, demand patterns, and decision-making for design and market entry strategies. In the technology and ICT domain, it helps in analyzing technology adoption, market dynamics, and risk management. In supply chain management, it facilitates an understanding of the complex dynamics and optimization of inventory, production, and distribution processes; optimizes performance and responsiveness. For business development, System Dynamics provides insight into market demand, competition, and growth strategies. In finance, it helps with financial forecasting, risk analysis, and policy evaluation. Lastly, in the organizational sector, it supports the modeling of decision-making, workforce dynamics, and organizational culture, assisting in organizational improvement and performance enhancement. Overall, System Dynamics offers versatile tools for understanding and optimizing the complex systems in the sector, enabling informed decision-making and sustainable growth.

VI. Conclusion

From the review and description in the discussion section, it can be stated that the System Dynamics approach has the potential to make a significant contribution to achieving sustainable development in Micro, Small, and Medium Enterprises (MSMEs). Through the System Dynamics approach, MSMEs can effectively model and simulate the behavior of various factors that affect their operations, such as resource allocation, environmental impact, and social considerations; proactively address sustainability challenges, adapt to changing market conditions, and contribute to broader socio-economic and environmental objectives. This allows for a comprehensive understanding of the long-term consequences and feedback loops associated with different decisions and strategies.

The System Dynamics approach also enables MSMEs to identify points of influence and potential unintended consequences, facilitating informed decision-making toward sustainable development goals. By analyzing the causal relationships between different variables, MSMEs can develop effective strategies and promote a holistic perspective, keeping in mind the interrelationships of MSMEs in larger systems such as supply chains, technology adoption, local economy, and society. This perspective encourages collaboration, stakeholder engagement, and the identification of common goals and strategies for innovation, sustainable development, and resilience in the face of an evolving business landscape.

Despite the progress made in implementing system dynamics in various sectors, there are still important issues that need further study. In product development, research can explore integrating customer feedback and preferences into models to enhance product design and innovation. Regarding technology and ICT, further investigation is needed to understand the dynamics of emerging technologies, such as artificial intelligence and blockchain, and their implications for organizations. In supply chain management, research can focus on the integration of new technologies in supply chain networks. In business development, further studies are needed to incorporate competitive behavior. In the field of finance, research can study modeling the impact of changing regulations and global economic factors on the financial

system. Finally, in the organizational sector, research can explore the dynamics of organizational culture, leadership, and change management, and their impact on organizational performance and adaptability. Addressing these issues will contribute to a deeper understanding of System Dynamics applications and increase their effectiveness in addressing the complex challenges of achieving sustainable development in MSMEs.

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REFERENCES

[1] T. Inayati, I. E. Riantono, and T. F. Tjoe, "Inclusion of Information and Communication Technology to MSMEs Strategic Planning in Indonesia," International Journal of Recent Technology and Engineering (IJRTE), vol. 8, issue 2, July 2019.

[2] A. Subroto, "Using System Dynamics Approach To Support Sustainable Growth Number of Small and Medium Enterprises in Indonesia: Some Policies Consideration," Universitas Indonesia, Graduate School of Management Research Paper No. 13-01, January 2012. http://dx.doi.org/10.2139/ssrn.1992760.

[3] J. Forrester, "Urban Dynamics". Industrial Management Review, vol. 58, 1969.

[4] OECD, "SME and Entrepreneurship Policy in Indonesia 2018. In OECD Studies on SMEs and Entrepreneurship," [Online], 2018. https://doi.org/10.1787/9789264306264-en.

[5] R. K. Singh, S. K. Garg, and S. Deshmukh, "The Competitiveness of SMEs in A Globalized Economy: Observations from China and India," Management Research Review, vol. 33(1), pp. 54–65, 2018.

[6] R. Barkhordari, H. D. Dehnavi, and A. M. Sharifabadi, "Identifying and Analyzing Factors Affecting The Excellence and Success of Small and Medium Industries Using The System Dynamics Approach," Int. J. Nonlinear Anal. Appl., in press.

[7] R. Viswanathan and A. Telukdarie, "A Systems Dynamics Approach to SME Digitalization," Procedia Computer Science 180, 816–824, 2021.

[8] E. Suryani, R. A. Hendrawan, B. Limanto, F. Wafda, and I. Auliyah, "The Impact of Social Media Engagement on Market Share: A System Dynamics Model," Journal of Information Systems Engineering and Business Intelligence, 8 (1), 71-79, 2022.

[9] A. B. Saka, D. W. M. Chan, and F. M. F. Siu, "Adoption of Building Information Modelling in Small and Medium-Sized Enterprises in Developing Countries: A System Dynamics Approach," CIB World Building Congress 2019 Hong Kong SAR, China, 17 – 21 June 2019.

[10] C. Vidalakis, F. H. Abanda, and A. H. Oti, "BIM Adoption and Implementation: Focusing on SMEs," Construction Innovation, Vol. 20 No. 1, pp. 128-147, 2020.

[11] N. Akhlaghinia and A. R. Ghatari, "Developing System Dynamic Model for Mobile Analytics in SMEs," Specialty J. Eng. Appl. Sci., Vol. 4 (4), pp. 58-64, 2019.

[12] K. V. Konneh, S. A. Helmi, A. Ma'aram, and M. Hisjam, "System Dynamics Approach to Supply Chain Performance Measurement in Small and Medium Enterprise," Proceedings of the International Conference on Industrial Engineering and Operations Management, pp. 2101-2110. Bandung, Indonesia, March 6-8, 2018.

[13] K. F. Kodrat, S. Sinulingga, H. Napitupulu, and R. A. Hadiguna, "Supply Chain Performance Measurement Model of Passion Fruit Agro-Industry for Sustainable Micro, Small, and Medium Enterprises with System Dynamics in North Sumatra Province," International Journal on Advanced Science, Engineering and Information Technology, Vol.9, No. 6, 2019.

[14] C. Han, A. Pervez, J. Wu, X. Shen, and D. Zhang, "Home-Delivery-Oriented Agri-Food Supply Chain Alliance: Framework, Management Strategies, and Cooperation Stability Control," Sustainability, 12, 6547, 2020.

[15] V. Vojtko, L. Rolínek, and M. Plevný, "System Dynamics Model of Crises in Small and Medium Enterprises," Economic Research-Ekonomska Istraživanja, vol. 32, no. 1, pp. 168–186, 2019.

[16] U. Amrina, A. Hidayatno, and T. Y. M. Zagloel, "A Model-Based Strategy for Developing Sustainable Cosmetics Small and Medium Industries with System Dynamics," J. Open Innov. Technol. Mark. Complex, 7, 225, 2021.

[17] S. Koul, I. W. Taylor, O. A. Falebita, T. Ono, R. Chen, and M. T. Vogel, "Examining The Success of Women of Color-Owned Small and Medium-sized Enterprises in the United States: A System Dynamics Perspective," International Entrepreneurship and Management Journal, 18, pp. 1373–1401, 2022.

[18] A. H. Nasution, A. E. Tontowi, B. M. Sopha, B.Hartono, and S. F. Persada, "A Dynamic Model of Budget Competition Allocation on Craft Industry: Evidence from Indonesia," Problems and Perspectives in Management, Volume 17, Issue 4, 2019.

[19] M. D. Nardo, M. Madonna, M. Gallo, and T. Murino, "A Risk Assessment Proposal Through System Dynamics," Journal of Southwest Jiaotong University, Vol. 55, No. 3, 2020.

[20] R. Yuana, E. Agus Prasetio, R. Syarief, Y. Arkeman, and A. I. Suroso, "System Dynamic and Simulation of Business Model Innovation in Digital Companies: An Open Innovation Approach," J. Open Innov. Technol. Mark. Complex..7, 219, 2021.

[21] F. H. Rad, R. Ghadimi, and F. Goldoust, "Evaluation of Trade and Production Policy in Iranian SME (A System Dynamics Model)," Journal of Industrial Engineering International, 15 (Suppl 1), pp. S69–S86, 2019.

[22] A. H. G. Saryazdi and D. Poursarrajian, "Qualitative System Dynamics Model for Analyzing of Behavior Patterns of SMEs," HighTech and Innovation Journal, Vol. 2, No. 1, 2021.

[23] R. Prijadi, P. Wulandari, F. A. Pinagara, and P. M. Desiana, "The Dynamics of Micro and Small Enterprises (MSE) toward Bankability with Coronavirus Pandemic Adjustment," J. Open Innov. Technol. Mark. Complex., 8, 193, 2022.

[24] A. S. Baharom and N. Y. Dahlan, " Financial Risk System Dynamics Modeling for Investment Decision in Solar Thermal Technologies for Malaysia's Industries," International Journal of Electrical and Electronic Systems Research, Vol. 13, 2018.

[25] J. Y. Sa´nchez-Garcı´a, J. E. Nu´n˜ez-Rı´os, C. Lo´pez-Herna´ndez, and A. Rodrı´guez-Magan˜a, "Modeling Organizational Resilience in SMEs: A System Dynamics Approach," Global Journal of Flexible Systems Management, 24(1), pp. 29–50, 2023.

[26] S. Soponkij, P. Teekasap, and S. Teekasap, "Cluster's Growth and Energy Demand Simulation Model: A System Dynamic Approach," Journal of Renewable Energy and Smart Grid Technology, Vol. 13, No. 1, 2018.