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# A System Dynamics Model for Dynamic Capability Driven Sustainability Management

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**Abstract:** This study aims to develop a system dynamics (SD) model for sustainability management driven by dynamic capabilities (DC) perspective. DC has been suggested as a vital organization theory for gaining sustainable competitive advantage. In contrast, SD has been used to model the complex system and support the decision-making process. Modeling sustainability management with SD driven from DC has not been previously investigated, particularly in global south industrial firms. This study explored the complex and dynamic relationships of the variables involved. For a simulation experiment, the study utilized a case from a large apparel industrial park in Africa, located in Ethiopia. The simulation revealed that the capability growth trend for sustainability management follows a natural sigmoid function or S curve shape supporting the dynamic hypothesis. In particular, sustainability training efforts, waste management practice, ethical management, supervision, and minimum worker's wage have been found to be influential variables and innovation points for capability growth towards sustainability management. The SD model contributes to the empirical gaps on dynamic models to overcome the challenges of firms in simultaneously managing sustainability dimensions. The study is the first to explore DC-driven sustainability management using SD, particularly from the case of a global south country.

**Keywords:** sustainability management; dynamic capability; system dynamics model

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## 1. Introduction

Sustainability management is the simultaneous integration of environmental, social, and economic sustainability aspects and practices into an enterprise's core operations [1]. Due to the high pressure from internal and external stakeholders, firms, especially in the industrial sector, are starting to incorporate social and environmental strategies in line with their business performance [2,3]. Sustainability is becoming the core organizational strategy for a firm's long-term development. Sustainability management includes the strategies, techniques, and practices to support the triple bottom (TBL) sustainable dimensions, including economic, social, and environment [4]. Sustainability management aims to improve organizations' economic, environmental, and social sustainability performance [5]. The management focuses on maintaining profits as shareholders expect, minimizing harmful ecological damages, and improving social quality of life [6].

Research in sustainability management has been focusing at the macro-level towards improving sustainable development goals; the attention at the micro-level, particularly on how industrial firms build their dynamic sustainability capability, has been the less-researched agenda [7]. Although the research is growing in the umbrella of supply chain sustainability management [8–10], understanding the focal firm-level strategy in integrating and managing sustainability has been a question of academia and practitioners. One of the primary challenges is the simultaneous management of the TBL dimensions and identifying the capabilities required [11]. This challenge requires new capabilities with skills [5], which leverages companies to structure their business process to achieve lasting performance [5]. Researchers in the field are urging to introduce sustainability into corporate capabilities and make organizations more dynamic to overcome sustainability challenges. However, there is a lack of research systematizing the available knowledge on DC [12] and sustainability and simultaneously managing the dimensions, as their relationships are complex and dynamic. According to [13], only 15 studies have focused on dynamic capabilities and sustainability in an integrated manner. Dynamic capability is first defined by [14] towards achieving business performance, but not extended toward social and environmental sustainability. Ref. [15] extended the concept of dynamic capabilities for sustainability and defined it as a firm's ability to sense, seize, and transform opportunities related to sustainability issues and attain a balanced economic, social, and environmental performance [15]. Ref. [16] also defined dynamic capability for sustainability as the firm's ability to address stakeholders' rapidly evolving sustainable expectations by purposefully modifying functional capabilities for simultaneous pursuit of economic, social, and environmental performance. DC-driven sustainability management can help firms adjust strategies and improve organizational capabilities without avoiding sustainability issues [17–19]. However, so far, there is less research on modeling the integration of DCs and sustainability, focusing on the micro-foundations of DCs and triple bottom lines of sustainability for dynamic sustainability capabilities [12]. The overall concepts of DCs and sustainability are not even deeply rooted regarding global south industrial firms, where a unique innovation eco-system exists.

This study's primary aim is to model the triple bottom lines, including economic, social, and environment, basing the dynamic capability theory. Several modeling approaches were applied in studying sustainability in particular. However, the modeling approaches are frequently statical [20] or conceptual [21], and less limited in showing the dynamic and complex relationships of the factors. In this regard, dynamic modeling approaches are more preferred for real-time data input and simulation of the existing performance. Scholars have used system dynamics in modeling complex relationships and applied them in different research fields [22,23]. The system dynamic modeling bases the system theory on the complementarities among elements, their integration, and the outcomes resulting from their interactions. Complex systems are generally networked with sub-units being, and [24] articulated that DC exhibits this behavior and in TBL of sustainability [25,26].

Therefore, this paper presents SD model integrating sustainability pillars and dynamic capability. The model simulation and experimentation were conducted with additional external factors considering a global south apparel industrial park firm's eco-system. The apparel industrial park firms are located in Ethiopia, an emerging country with the ambitious goal of building Africa's largest sustainable industrial hub. Ethiopia is the second-most populous nation in Africa and the fastest growing economy in the sub-Sahara, with 6.1 percent growth in 2019/20. The sustainability context of application in the industrial park firms of Ethiopia is relevant to the literature. Because the firm's key buyers are large multinational companies (MNC) with high compliance to sustainability standards, they can urge the manufacturing firms to have dynamic sustainability capabilities [27]. In this regard, we have found the case study situation suitable for exploring the literature challenges and understanding the complexity and dynamism of DC-driven sustainability management. Moreover, expert's data accessibility for the model simulation was found to be convenient.

The study will contribute to the literature by extending the conceptualization of DC theory for sustainability management. In particular, the SD model will provide a gateway to understanding the dynamic relationship and influence between sustainability measures and dynamic capabilities. The model will support firms' managers as a decision-making approach in the case study.

## 2. Theoretical Background

### 2.1. Sustainability Management

Sustainability management is mainly based on the TBL, including economic, environmental, and social. Economic sustainability focuses on organizational activities towards maximizing the financial benefits for internal and external stakeholders. The economic sustainability dimensions target the financial aspect and stick with quantitative indicators. Cost is a significant indicator utilized by several authors [28]; this includes equipment, material, and other costs, return on investment, cost management, and operation efficiency [29–32]. Environmental sustainability focuses on analyzing and implementing organizational activities towards minimizing the consequences of energy and natural resource consumption and waste releases. Critical dimensions include materials [33], energy, biodiversity, emissions, waste [34], and resource consumption and efficiency [35]. Other dimensions include company image, product quality, innovative ideas, raw materials, solid waste, recycling [36] and environmental management, environmental aspect, and responsibility consumptions [37–39].

The last dimension, social sustainability, emphasizes analyzing and implementing organizational activities towards maximizing the human well-being of internal and external stakeholders. Social sustainability, at a macro-level, focuses on how communities or societies live; it is about equity and basic needs. At the micro or firm level, issues related to employees' working conditions, fair wages, health, and safety are the major dimensions. Specifically, the first category takes key sub-indicators: job opportunities, employment compensation, health and safety practices, research, and development [40]. The dimensions identified include compensation, physical and mental safety, demand, variety of tasks and roles, social interaction, growth of skills and knowledge, opportunities for accomplishments and status, the value of work, autonomy, and growth, and personal development [41], occupational health and safety [42]. For work practices, adequate working conditions, diversity, equal opportunities, and social policy compliance were identified [43]. For social related practices, work conditions, safety, equity, etc. were identified [44]. For salary and benefits, satisfaction level, human resource, and health and safety were identified [31,45–48].

Sustainability has become the core research agenda, and different themes have been studied. Ref. [49] studied sustainability at the firm level from the supplier selection view. The study used a fuzzy multi-criteria approach for measuring the sustainability performance of a supplier based on a triple bottom line approach. Ref. [50] considered electro-electronic companies in Brazil and studied the relationship between environmental management maturity and green supply chain management adoption through qualitative and quantitative methods. Ref. [51] developed a framework that integrated operation management principles with green supply chain management for environmental issues. The study is a crucial stepping stone for firms to conceptualize environmental sustainability by implementing operation management practices. However, the research lacks integrating a holistic framework of other two dimensions of sustainability (economic and social). Another recent work by [52] focuses on studying Industry 4.0 as an enabler of sustainability diffusion in the supply chain.

Ref. [53] presented an overview of the most widely used theories of the firms, such as stakeholder theory resource-based view theory, and analyzed their contribution to corporate sustainability. Ref. [54] reviewed the sustainability of manufacturing and services to develop a sustainable business model framework in manufacturing and service industries. The study is well articulated and appreciated in covering sustainability in different aspects of manufacturing operation; however, the focus is only on the environmental dimension perspective. Ref. [55] also used the term sustainability in his study on green product recovery systems to analyze the interrelationships between green variables (environmental) such as supplier commitment, cost, regulations, etc.

Ref. [56] examined how traceability for sustainability could improve the triple-bottom-line sustainability of firms. Ref. [57] articulated that integrating sustainability into firms requires action that exceeds organizational boundaries. Expressly, the study implied the importance of stakeholder integration, supplier partnerships, development of appropriate performance measures, and low-income countries among the future research needed in this regard. Another paper was also reviewed by [58] 191 articles from 1994 to 2007 and developed a conceptual framework for the sustainable supply chain management. Another contribution was made by focusing on sustainable supply chains [20,59,60]. Ref. [61] contributed to understanding what should be done and why business sustainability performances should be improved in supply chains through a balanced theoretical sustainability model encompassing framework and propositions.

Ref. [62] applied a hierarchical framework for assessing corporate sustainability performance using a hybrid fuzzy synthetic method-DEMATEL. The study used the Taiwanese textile industry; the decision approach is feasible, but incorporating the operational indicators of sustainability on all the triple bottom lines is very limited and generic. However, [63], in his recent work of a comprehensive and in-depth literature review on triple bottom lines, found that the TBL is insufficient to cover all concepts of sustainability: engineering, technology, and operation aspects should be taken into account. The findings agree that firm-level sustainability should consider the firms' operational and management factors. In this regard, Ref. [64] also explored integrating corporate sustainability into company strategic management and understanding firms lack a strategic approach concerning sustainability integration. The study found that future research should focus on whether or not companies need to integrate sustainability into strategic management and how this could be done in practice. In a similar pattern research gap, Ref. [65] addressed the sustainability performance measurement system from business process management by presenting a pentagon of SPMS focusing on considering business processes.

Sustainability at the firm level requires a framework that links environmental and social management with the business and competitive strategy. In this regard, Ref. [66] proposed an integrative framework for sustainability performance measurement and management adaptable as a base model for studying firm-level sustainability. The framework presented three stages: the first (Integration stage) is firms should identify the social and environmental aspects they are exposed to, which are strategically relevant for their business cases, and how these aspects should be linked and integrated. The second (Measuring) is to identify the key performance indicators and collect information systems for the key indicators. The last stage (Reporting) is communicating and following up their sustainability performance. Understanding the gap in integrating sustainability assessment, management control, and reporting, Schaltegger reviewed in the thematic area, and findings suggest that research is done in various ways and isolated [67]. An additional factor added to sustainability assessment and management is stakeholders' expectations [68]. The study articulates that stakeholders are dissatisfied with the current sustainability assessment and management approaches. From this study author's knowledge, there has not been an empirically validated model at the firm level compromising Schaltegger's conceptual framework. Of course, much has been done on evaluating sustainability performance based on the triple bottom line using different approaches, leaving the integration and reporting stage alone. Schaltegger also extended the concept of sustainability performance measurement and management towards the supply chain [69].

### *2.2. Dynamic Capability*

The resource-based view (RBV) has been a foundational theoretical framework for strategic management [70]. However, the limitation of RBV in explaining how firms maintain these advantages over time in dynamic environments lays the ground for the DC. Ref. [14] defined DC as the firm's ability to integrate, build, and reconfigure internal and external competencies to address a rapidly changing environment. DC emerged because it was believed that firm operational capabilities alone are insufficient to sustain a long-term competitive advantage [71]. DC stress resource renewal (reconfiguring resources into new combinations of operational capabilities) differs from RBV, which emphasizes resource picking (selecting resource combinations). Until now, no standard definition of dynamic capability has been adopted; however, [72] highlighted similar concepts tying the DC notion to the innovation process have been created in the literature, such as architectural innovation [73], configuration competence [74,75], and combinative capabilities [76,77]. Ref. [14], in their seminal paper, considered the most influential source together with a current framework of DC [78]. The DC theory suggests competitive advantage comes through leveraging a firm's managerial and organizational processes. It explains the process of the change of resource and capabilities usefulness over time [79]. DC theory is the latest development of strategic management theory [80] and the most influential theoretical lens to study the firm's strategic management process [72]. Ref. [81] defined DC as the firm's process that uses resources to match and create market change and leads firms to achieve competitive advantage [82]. Another progress of DC focus on organizational learning, where it has been found as the overlaps of knowledge management and DC [83]. In this regard, Ref. [84] further considered learning as a mechanism through which organizations develop their DC.

### *2.3. Dynamic Capability Driven Sustainability Management*

Sustainability in industrial firms is dynamic and shows rapid change, demanding firms follow a unique management strategy, create new resources, and renew or alter their resource mix [85]. Dynamic capability for sustainable growth is all about getting started, getting better, and getting different [86]. Dynamic capabilities contain three process cycles [87]. The first, sensing capability, is the ability to spot, interpret, and pursue opportunities in the environment. The second seizing capability is to embed knowledge into the operational capabilities by creating a shared understanding and collective sense-making. The last transforming capability is orchestrating and deploying tasks, resources, and activities in the new functional capabilities. The dynamic capability view focuses on an organization's capacity facing a rapidly changing environment that has to create new resources and renew or alter its resource mix [85]. Refs. [9,88] are a stepping stone to understanding the recent competitive theories for sustainability. However, scholars introduced the approach, but its application towards sustainability management is still in its infancy [89].

DC plays a vital role in increasing an organization's sustainability performance [90]. Sustainability issues around social, economic, and environmental are always dynamic and show an unpredictable change [91]. Dynamic changes and balance research convey that firms need to be flexible and adaptive by continually sensing, learning, and transforming to respond to sustainability challenges. Dynamic capabilities are considered crucial in achieving and balancing sustainability performance [92]. Dynamic capabilities positively impact sustainability performance [93]. There is an indirect positive impact of dynamic capability on financial performance [94]. Ref. [95] used a conceptual model to explain dynamic capabilities for sustainability. Studies on dynamic capabilities and sustainability performance are increasing; Ref. [96] also applied a systematic literature review to conceptualize and articulate dynamic capabilities for sustainability, Ref. [12] on their relation taking resource management capabilities as mediating factor. Ref. [96] used a multi-case study in the fashion industry and applied dynamic capabilities of sensing, seizing, and transforming the opportunity for environmental sustainability. A recent survey on SME suppliers' (small and micro enterprises) dynamic capabilities was applied to make corporate social responsibility efforts under customer pressure [97]. Considering firm strategy and market dynamism, [98] studied the influence of dynamic capabilities on firm performance and concluded that dynamic capabilities are related to an internal factor rather than external market dynamism. Ref. [99] also addressed the impact of dynamic capabilities on a firm's performance with the moderating role of organization competency. Sustainability-oriented dynamic capabilities and their impact on green product innovation were studied by [100] in manufacturing firms, considering key variables of resource integration, building, and reconfiguration. Ref. [101] also found a positive effect on sustainability innovations from sensing, seizing, and reconfiguring dynamic capabilities. Ref. [102] studied the dynamic capability approach to develop suppliers' integration capabilities for competitive advantage.

Studies on DC relating to sustainability management in the global south countries in Africa are in their infancy. Based on competitive advantage theory, Ref. [103] studied the economic sustainability variables and [104] investigated DC variables from South Africa SME. Ref. [105] studied DC's impact on Kenya's firm performance by considering critical economic, social, and environmental sustainability dimensions. However, the DC measuring variables are not sustainability-oriented. Another study from food manufacturing firms in Kenya investigated the effect of DC on firm performance found that firm performance depends on reacting rapidly and flexibly to the changing market environment [106]. Ref. [107] studied the linkage between DC and environmental sustainability in emerging economies' multinational companies (MNC). The study considered environmental strategies, operation, and coordination efforts as micro-level DC.

Although the recent studies are stepping stones in linking dynamic capabilities and sustainability, their research perspective and measuring variables are different, leading to contrasting findings [108]. Ref. [108] highlighted the low clarity of literature in showing the effect of DC in all the TBL sustainability dimensions, where most studies focus on the economic aspect. Besides, the study also finds that research focuses on the relation of DC and sustainability within the umbrella of supply chain management [109,110]. Ref. [111] articulated DC-driven sustainability management; however, his study frame focuses on the role of knowledge transfer between supply chain partners. Thus, there is still an unfilled gap in framing DC-driven sustainability management encompassing all the TBL dimensions at the firm level, particularly in model development and empirical validations. We believe that further empirical investigations are essential to clear these contrasting findings, especially from emerging countries where scarce resources and studies exist. Thus, developing an SD model of the DC-driven sustainability management dimensions and simulating it with an empirical case study would contribute to existing knowledge of the fields. The perspectives and variables are summarized in Table 1.

**Table 1.** Summary of literature perspectives and variables.

| Dimensions | Variables | Sub-Variables | Sources |
|---|---|---|---|
| Economical Sustainability | Financial | Profit, export performance | [30,112,113] |
| | | Competitiveness advantage | |
| | Operational | Order delivery performance | |
| | | Product quality | |
| | | Productivity | |
| Social Sustainability | Health and safety | Working accidents, illness | [114–116] |
| | | Safety training | |
| | Labor development and work satisfaction | Commitment and motivation, Fair wage schemes, turnover | |
| | Decision-making skills | Sustainability awareness, training, and education | |
| | Decent work and ethics | Absence, culture | |

**Table 1.** *Cont.*

| Dimensions | Variables | Sub-Variables | Sources |
|---|---|---|---|
| Environmental Sustainability | Management | Sustainable and waste reduction practices | [117–120] |
| | | Environmental management system, standard | |
| | | Green production strategies and management | |
| | Resource utilization | Energy and water utilization practice | |
| | | Environmental friendly machines and equipment's | |
| Dynamic Capability | Sensing sustainability capabilities | Crowdsourcing sustainability information's | [11,82,111] |
| | | Strive to early sense sustainability issues | |
| | Seizing sustainability capabilities | Sustainability training efforts | |
| | | Sustainability practice and tools implementation | |
| | Transforming sustainability capabilities | Regular review of sustainability performance | |
| | | Continuous improvement of sustainability practices | |
| | External Capabilities | Collaboration with stakeholders for sustainability initiatives | [121,122] |
| | | Long term engagement with stakeholders | |
| | | Sustainability international standards and certifications | |

### *2.4. System Dynamics*

Due to the increasing dynamic complexity that characterizes today's competitive arenas, traditional management systems need to be combined with simulation-based methodologies [123]. This allows firms to improve their learning processes dynamically and easily detect possible risks and weak signals of change emerging from the business environment. SD is applied for modeling and simulating complex physical and social systems and experimenting with the models to design policies for management and change [124]. The application of SD in sustainability management starts with understanding the relationship between the process and behaviors. Bianchi [125] applied the SD modeling approach for implementing dynamic performance management to support a firm's strategic planning and control. Beyond strategic issues, system dynamics can be used to understand one system's behavior by observing key factors' interrelationship effects and simulating their growth behavior in a given time horizon [126]. Process structure determines the system behavior, and system behavior shows the firm performance.

## 3. Research Setting and Method

The study follows a case study approach to simulate and validate the model. Based on the Hawassa Industrial Park (HIP), Ethiopia, Africa's largest textile and apparel industrial park, initial data values were collected. Conducting research through the case study method is appropriate when a developmental phenomenon and its variables have not been adequately identified [127]. Case studies allow for a thorough analysis of a phenomenon in a real-life situation and provide in-depth insight [128,129]. In order to collect primary data for validating the simulation of the SD model, we have conducted a semi-structured interview with eight experts: three corporate sustainability management experts, one expert from external sustainability auditors, two from the government (industry park operation management), one from non-government offices (NGO), and one from MNC buyer company. Following an expert approach to data collection would increase the model's validity and create a participatory platform to gain more information on the holistic understanding of model variables [126,130].

Based on the SD modeling procedures in Figure 1, this research starts with developing a dynamic conceptual model (Figure 2), showing a hypothetical relationship of the identified literature variables for developing dynamic capability-driven sustainability management. The hypothetical relationship of the variables was modeled with Sigmoidal function to fit with an S-curve capability development shown in Figure 3. In discussion with the experts, contextualizing and adding sub-influencing variables according to the situation in Hawassa industrial park were conducted, which finally delivers the SD holistic model (Figure 4). The management experts rate models constant initial values. Through an in-depth interview, the continuous variables were rated from 0 to 1, based on the existing performance of HIP. Following consecutive model unit and equation validation, the initial simulation showed the current capability growth for sustainability.

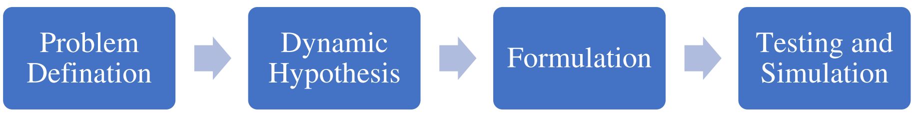


**Figure 1.** SD Modeling Process.

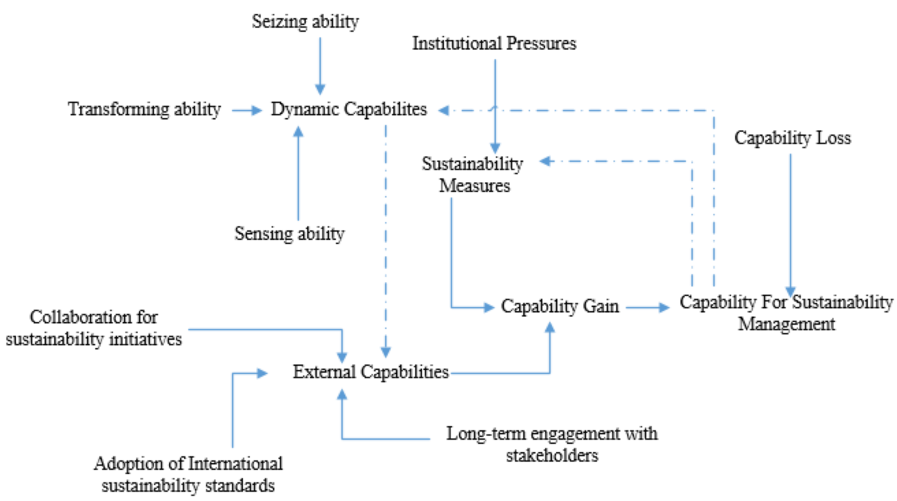


**Figure 2.** SD Conceptual Model.

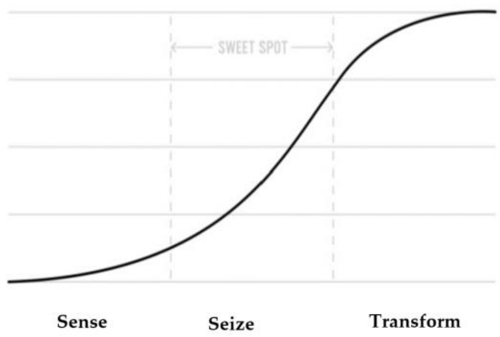


**Figure 3.** S-curve Capability Growth.

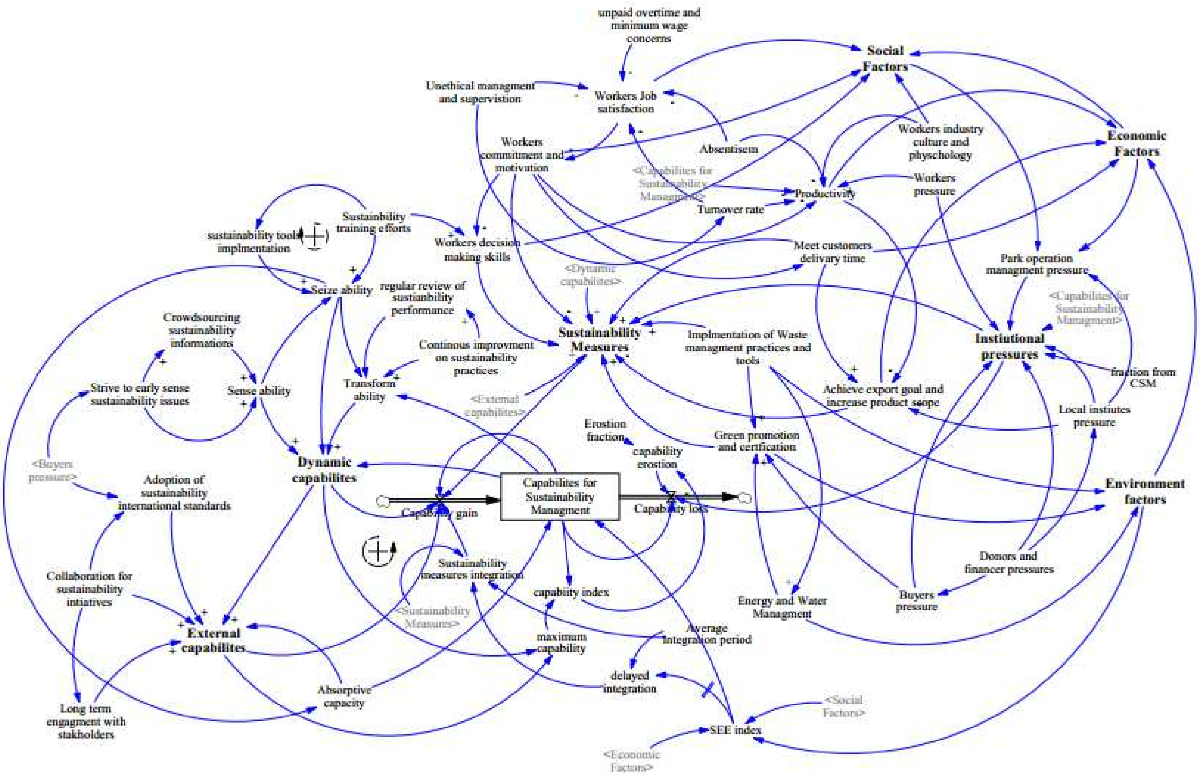


**Figure 4.** Holistic SD Model.

A simulation experiment was conducted with different scenarios on critical factors, with the base of the experts identifying the significant factors. The model development was performed using Vensim Professtional×64. The study followed the SD modeling procedure suggested by Ref. [126]. Finally, the study summarized and discussed the SD simulation findings by prioritizing the significant variables based on a Pareto chart.

### 3.1. Step 1: Problem Definition

Articulating and defining the problem is the foundational step in dynamic system modeling. In this study, the theoretical rationales behind SD model basing the relationship of dynamic capability and sustainability perspectives are presented. For defining the problems in a system, the system dynamic method focuses on endogenous factors in a complex system [130]. As cited [131], it is preferable to simplify the system as much as possible to include the main system-related variables.

### 3.2. Step 2: Dynamic Hypothesis

Based on the identified critical literature variables, a conceptual dynamic hypothesis model showing variables relationship is the foundational step for building the complex SD model. The dynamic hypothesis bases the inside-out and outside-in capability path theory [79,132]. We framed the internal functional capabilities of firms with DC encompassing constructs of sense, seize, and transforming sustainability capabilities. The external capabilities focus on the interaction with stakeholders in developing sustainability capabilities. The dynamic SD model hypothesizes that firms' ability to sense, seize, and transform sustainability opportunities and use their external capabilities creates a better capability accumulation for managing sustainability along the time path.

### 3.3. Step 3: Formulation: Causal Loop Diagram and Stock and Flow Diagram

A causal loop diagram is used in dynamic system modeling to establish the relationship between different variables in the sustainability management system. It is very applicable for explaining the system behavior. The casual loop model is then used to develop stock and flow diagrams based on the nature of variables. The stock variable is any accumulation of resources; for example, the capability accumulation for sustainability management in this study.

### 3.4. Step 4: Testing and Running the Model

Before running the simulation, structural, behavior, and unit tests for the SD models are conducted. The structural tests compare the structure of the SD model with the real system structure, so the mathematical equations are compared with the relationship between the elements in the real system [133]. Additionally, behavior tests determine whether the model behavior corresponds to the actual system behavior, and finally, unit consistency is checked [134].

## 4. Overview of the Case Study: Ethiopian Industrial Park Firms

The World Bank Group defined industrial parks as dedicated areas for industrial use at suitable sites that ensure sustainability by integrating social, economic, and environmental aspects into management and operations. Industrial parks are one policy instrument that started being implemented by Asia and a few African countries in the late 1990s and 2000s. They are geographically demarcated areas with different administrative, regulatory, and government policies. The development of industrial parks alleviates the traditional company's problem, and the primary goal is to provide foreign exchange earnings job employment and attract FDI to the host country. Industrial parks are developed to provide better infrastructure, research, and development, and offer different incentives that firms do not access outside of the zone [135]. As one of the African countries with a fast industrialization track, Ethiopia envisioned having the highest manufacturing capability through sustainable development, considering industry parks as solutions for industry growth. To facilitate the development, the government of Ethiopia approved the parliament industrial park proclamation [136]. Industry park development plays a critical role in changing the traditional industrialization system and opening the door to attract FDI and boost export performance. As a strategic objective, the proclamation puts IP development in sustaining export growth, human capital development, technological learning, upgrading and innovation, and employment generation. The country aims to target 30 industrial parks by 2025 to become an African manufacturing hub with this strategic goal. Eight industrial parks have been launched since 2014. When all planned parks become operational, two million job opportunities will be created, and annual revenue will be increased to 145 millon dollars from textile and apparel export alone [137].

Ethiopia started with the first large-scale private industrial park (Eastern Industrial Zone in Dukem) nine years ago, followed by Bole Lemi I and Hawassa IP. Bole Lemi I is the first IP operating under the industrial park development strategy, established with the help of the World Bank loan in 2012, and started operations in 2014. The zone covers 156 hectares of land located about 10 km southeast of Addis Ababa with direct access to the airport and Djibouti port highway. The Ethiopian government has invested 113 million USD in the zone and secured a loan from the World Bank of 250 million.

On the other hand, Hawassa industrial park, following in their footsteps, developed what was to be the most significant and model park in Africa, focusing entirely on the garment and textile sector. Current statistics show 22 industrial parks under various establishment phases: nine are operational (five government and four private). Textiles and garments are the top products currently manufactured in the parks, with 81 out of the 141 investors focused on this sector. The industry park's total targets on the export market engage leading global apparel and textile companies from America, Europe, China, India, Sri Lanka, and a few local companies. The construction of the industrial parks was constructed with state-of-the-art technologies, and the exemplary Hawassa industrial park was built at the cost of 250 million dollars, intended mainly for textile and apparel manufacturing. The park primarily utilizes renewable electricity sources and fully implements energy and water conservation strategies, including maximizing natural lighting and ventilation, fitting energy-efficient light bulbs, recycling water, and solar-powered LED street lights.

## 5. Modeling the Perspectives and Variables: SD Model

### *5.1. Problem Articulation*

In the theoretical direction, the dynamic complex relationship between perspectives and variables of sustainability management has not yet been deep routed. Moreover, their influence on company capability accumulation growth for managing sustainability is another empirical gap that requires more investigation. With this rationale, the SD modeling and experimentation aims to answer the research question:

How do the interrelationships of the sustainability measures, capability variables, and institutional pressures influence the capability accumulation of once due company managing sustainability?

### *5.2. Key Variables and Mathematical Equations*

#### 5.2.1. Dynamic Capabilities

Dynamic capabilities are one of the strategic management approaches firms follow to build their capabilities. The literature explains that DC has an internal aspect containing three sub-categories: sensing, seizing, transforming, and external capabilities. These factors were discussed as follows:

- *Sensing ability:* This is an auxiliary variable influenced by other control variables under the firm's management. The variables that affect these auxiliary variables are striving for an early sense of sustainability issues and crowdsourcing sustainability information. Striving for an early sense of sustainability issues influences the crowdsourcing sustainability information. The early sense for sustainability issues is influenced by another control variable—the buyer's pressure designed as the average percentile value.

  *Sensing ability = f (striving for an early sense of sustainability issues, crowdsourcing sustainability information)*

- *Seizing ability:* This is the second auxiliary variable within the DC framework. A variable that influences the seizing ability here is the sustainability tools implementation and sustainability training. The sustainability training is designed with a range of 0 to 1, where zero implies that sustainability training has not been delivered, and 1 implies that sustainability training has been delivered well. Sustainability training influences the sustainability tool implementation. In addition to that, the sensing capability has an additional impact on seizing ability, and the function is presented as:

  *Seizing ability = f (sustainability tools implementation, sustainability training, seizing ability)*

- *Transforming ability:* Two sub-influencing variables are incorporated in this third auxiliary variable. The first is the regular review of sustainability performance, and the second is the continuous improvement of sustainability practices. Further, transforming ability is influenced by the previous factor seizing ability and a feedback influence from the capability accumulation for sustainability management. In this regard, the function is presented as:

*Transforming ability = f (regular review of sustainability performance, continuous improvement on sustainability practices, seizing capability, capability for sustainability management)*

- *External capabilities Collaboration for sustainability initiatives*: This is the first control variable within the framework of external capabilities influencing the adoption of international sustainability standards and the long-term engagement of firms with their crucial stakeholder. The value is designed within 0 to 1, from 0 implying no collaboration, and continues to 1 with strong partnerships for sustainability initiatives. *Adoption of international sustainability standards*: This is the second auxiliary variable, influenced by the firm's effort towards collaboration for sustainability initiatives and further from buyer's pressure as a control variable. *Long-term engagement with stakeholders*: The third auxiliary variable is influenced by the control variable and function of the firm's collaboration for sustainability initiatives. The more the collaboration of firms with stakeholders for sustainability initiatives, the more their long-term engagement with stakeholders continues.

*External capabilities = f (collaboration for sustainability initiatives, adoption of international sustainability standards, long term engagement with stakeholders)*

#### 5.2.2. Sustainability Measures

- *Economic sustainability Factors*: The economic factors are influenced in two ways. The first is from economic sub-factors and environmental sustainability factors. The first sub-factors are productivity, meeting customer delivery time, and achieving export goals/increasing product scope. From the external view, the environmental sustainability factors are energy and water management, green promotion and certification, and implementation of waste management practices and tools.

*Economic sustainability Factors = f (Productivity, customer delivery time, export target)*

- *Social sustainability factors*: Social sustainability factors are influenced by social sustainability and economic sustainability factors. Within the social aspects, key influential variables are worker job satisfaction, commitment and motivation, decision-making skills, worker's industry culture, and physiology.

*Social factors = f (Workers commitment and motivation, Workers decision-making skills, Workers Job satisfaction, Workers industry culture and psychology)*

- *Environmental sustainability factors*: Environmental sustainability factors comprehend energy and water management, green promotion, certification, and implementation of waste management practices.

*Environmental sustainability factors = f (Energy and Water Management, Green promotion and certification, Implementation of Waste management practices and tools)*

5.2.3. Institutional Pressures from the Case Study

Institutional pressures perceived here in this study are pressures that come from stakeholders for firms to develop their capability for sustainability. Critical pressures include buyers, donors/financers, local institutes, workers, and management pressures.

*Institutional pressures = (Buyers pressure, Donors and financer pressures, Local institutes pressure Workers pressure, management pressure)*

*5.3. Dynamic Hypothesis*

The dynamic hypothesis is formulated containing the critical perspectives and variables discussed in Section 5.2. Capability gain is the inflow, while the capability loss is the outflow, and capability for sustainability management is stored as stock. Gaining capability comes from internal or external; the internal contains the dynamic capabilities of sensing, seizing, and transforming the firms' sustainable management strategies. The external is from the firm's efforts, with the external environment putting sustainability as a central point. These include collaborating for sustainability initiatives, adopting international sustainability standards, and building a long-term engagement with its stakeholders. Moreover, the capability gain is also influenced by the firm's sustainability performances measured at the economic, social, and environmental levels, which is also influenced by the institutional pressures pushing the firm to improve its sustainability performance. The dynamic hypothesis is summarized in Figure 2 as a conceptual model.

*5.4. Mapping: Causal Diagrams and Stock and Flow Maps*

The sum of the capability bundles from dynamic capabilities, external capabilities, and the sustainability measures influence the capability gain rate. As there is an increase in institutional pressures and firms engage in a broader global supply chain market, every variable builds up and facilitates further capability gain. This is bound by integrating firms' economic, social, and environmental measures along the time horizon. The integration of sustainability measures with a sigmoid function multiplied with capability variable yields the S- growth curve. A typical S-curve is illustrated in Figure 3.

Capability gain adds on the stock of capability for sustainability management, whereas capability loss is a weakening variable. The typical value of sustainability measures indicates the curve's steepness or how rapidly capability will be accumulated. The shorter the period, the smaller the time required to reach the maximum limit for sustainability management.

Capability gain = ((Dynamic capabilities + External capabilities + Sustainability Measures) + (Capabilities for Sustainability Management)) ∗ Sustainability measures integration

$$\text{Sustainability measures integration} = \frac{\text{Delayed Integration} * \text{Average integration period}}{1+e^{-(\text{sustainability measures})}}$$

$$\text{Capability for sustainability managment} = \int(\text{Capability gain} - \text{Capability loss}) * (\text{Absorptive capacity} + \text{SEE index})$$

SEE index is the average measure value of social, economic, and environmental sustainability Figure 3: S-growth curve with sigmoid function measures.

*5.5. Formulation of a Simulation Model*

Initial Parameters Setting

Firm management experts have measured the performance of the critical variables identified for the model simulation and summarized them as a base value in Table 2.

**Table 2.** Data collection from management experts for system dynamics initial input.

| Variables | Description | Average Experts Rate (0 to 1) |
|---|---|---|
| Sustainability training | Existing training delivered by most firms focuses on the worker's technical and soft skills. Training on social and sustainability management issues is in its infancy. | 0.35 |
| Ethical management and supervision | Expat and few local experts do management and supervision. There are concerns about manager's unethical behavior, including shouting and insulting workers. | 0.60 |
| Productivity influencing factors | Productivity of the firms is being affected highly by worker's frequent absence from work, limited industry culture, wage concerns. In addition, workers put pressure by raising their concerns on wages housing transportation, and several strikes have been made. The minimum wage has not been set at the country level, and firms are paid the lowest wage compared to the leading apparel manufacturers, e.g., Bangladesh | Absent (0.08)<br>Industry culture (0.4)<br>Workers pressure (0.3)<br>Wage concern (0.45) |
| Implementation of waste management practices and tools | Industrial parks have relatively better infrastructure to handle waste. However, pro-active management practices and standards are still lacking. | 0.55 |
| Donors and financers pressure | Donors and financers have influenced firms to adopt sustainability measures, practices, and standards. | 0.65 |
| Continuous improvement on sustainability practices | Implementation of sustainability practices and developing continuous improvement strategies focusing on sustainability practices are minimal. | 0.45 |
| Collaboration for sustainability initiatives | Collaboration with buyers suppliers on sustainability management initiatives is growing in adopting international standards. However, more efforts are required from stakeholders. | 0.52 |

Following the existing capability simulation, a possible experimental investigation was conducted to understand the change in influential critical variables on the key capability variables. Altered parameters and values are summarized in Table 3.

**Table 3.** Experiment altered parameters.

| | Altered Variables | Base Value | Seizing Capability S1 | Social Factors SF1 | SF2 | SF3 | SF4 | SF5 | Environment Factor WM | External Capability CS |
|---|---|---|---|---|---|---|---|---|---|---|
| Seizing Capability | Sustainability training effort (S1) | 0.35 | **0.60** | 0.40 | 0.45 | 0.08 | 0.40 | 0.3 | 0.55 | 0.52 |
| Social factors | Unethical management and supervision (SF1) | 0.40 | 0.35 | **0.25** | 0.45 | 0.08 | 0.40 | 0.3 | 0.55 | 0.52 |
| | Overtime and minimum wage concerns (SF2) | 0.45 | 0.35 | 0.40 | **0.25** | 0.08 | 0.40 | 0.3 | 0.55 | 0.52 |

**Table 3.** *Cont.*

| | Altered Variables | Base Value | Seizing Capability S1 | Social Factors SF1 | SF2 | SF3 | SF4 | SF5 | Environment Factor WM | External Capability CS |
|---|---|---|---|---|---|---|---|---|---|---|
| | Workers industry culture and psychology (SF3) | 0.40 | 0.35 | 0.40 | 0.45 | 0.08 | **0.7** | 0.3 | 0.55 | 0.52 |
| Environmental Factors | Implementation of waste management practices (WM) | 0.55 | 0.35 | 0.40 | 0.45 | 0.08 | 0.7 | 0.3 | **0.65** | 0.52 |
| External capability | Collaboration for sustainability (CS) | 0.55 | 0.35 | 0.40 | 0.45 | 0.08 | 0.7 | 0.3 | 0.55 | **0.7** |

## 6. Results

### *6.1. Existing Capability Growth with Initial Base Values*

As discussed, we start the model simulation with the base case, where the system is in a steady state. Regarding capability accumulation, the growth pattern for sustainability management follows a natural sigmoid function or S curve shape. In addition to the capability accumulation growth, capability gain, and external capability and dynamic capability for sustainability management result are shown in Figure 5. Although the capability growth shows an S curve, the capability growth period takes longer.

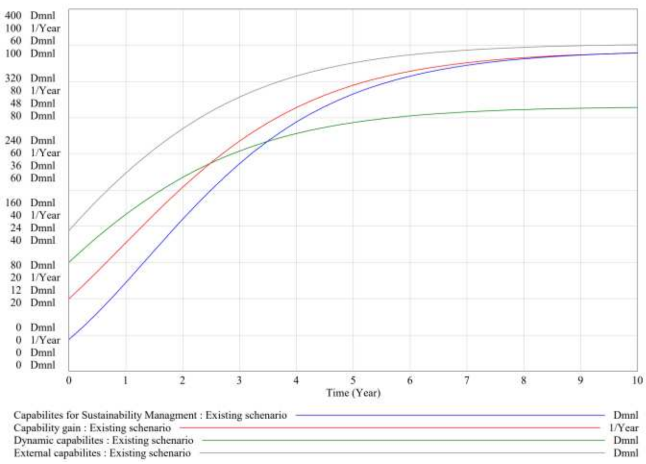


**Figure 5.** Current capability growth.

### *6.2. Experimental Scenario Simulation*

#### 6.2.1. Scenario One: Sustainability Training Efforts

Based on the first scenario, a change from the base value of 35% to a maximum value of seizing capability of 70% by the firm's strategic management has resulted in a promising capability growth simulated for the next ten years. With this change value, full capability for sustainability management has been reached on the 6th year, which is shorter than the original simulation. Other capability growths have been shown in Figure 6.

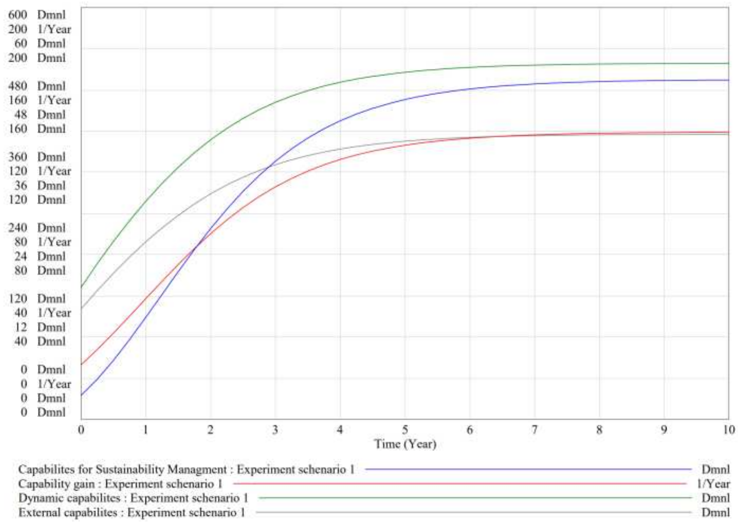


**Figure 6.** Sustainability training effort experiment result for selected capability variables.

### 6.2.2. Scenario Two: Collaboration for Sustainability Initiatives

As shown in Figure 7, scenario two, changing the current collaboration sustainability initiatives' performance parameters, has not made a much more significant difference than the original simulation.

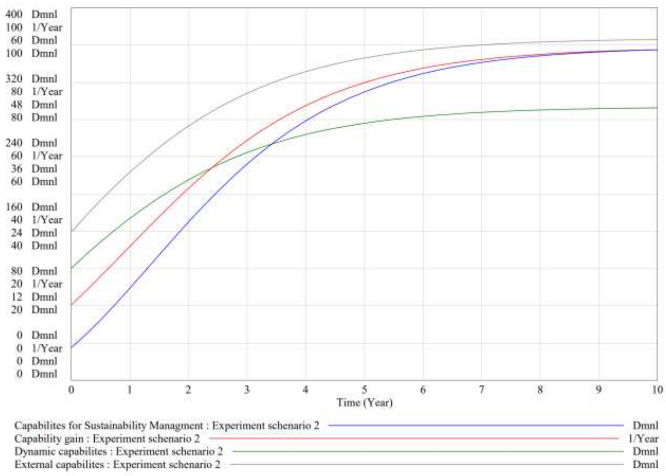


**Figure 7.** Collaboration for sustainability initiatives experimental result for selected capability variables.

### 6.2.3. Scenario Three: Industry Working Culture

Employee awareness about industry culture affects the sustainable competitiveness of the firms in the market arena. For this, focusing on making a change in building the industry culture will significantly impact the firm's sustainability capability. Experimenting with the initial value from 0.4 to 0.7 has made relatively better performance but more minor improvements than the previous scenarios 1 and 2 (Figure 8).

### 6.2.4. Scenario Four: Implementation of Waste Management Practice

Non-value-adding activities or wastes are another constant factors where the existing values have been altered to 0.65. As shown in Figure 9, there has been a potential increment in the capability growth and shortening of the period.

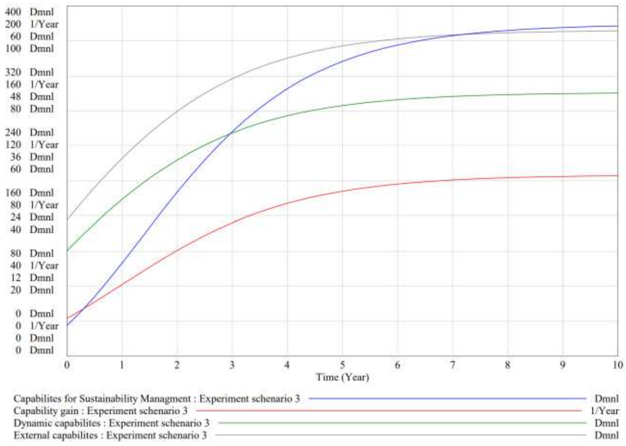


**Figure 8.** Workers industry culture experiment result.

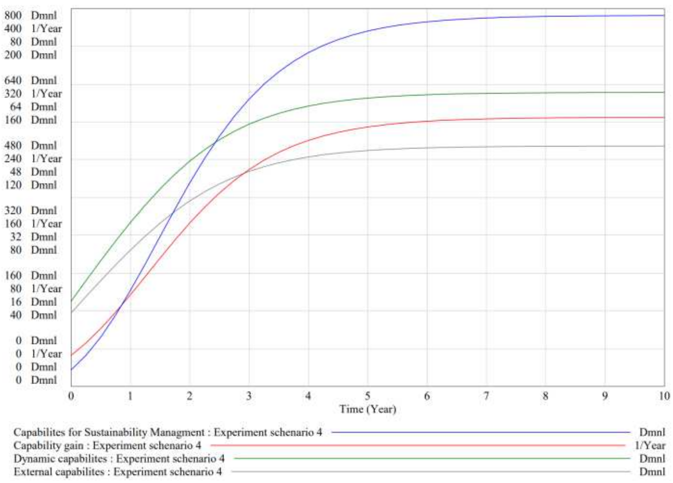


**Figure 9.** Implementation of waste management practice experimental result.

### 6.2.5. Scenario Five: Unethical Management and Supervision

Management and supervision play a critical role in developing the firm's capability to manage sustainability. As depicted in Figure 10, improving unethical management and supervision from 0.4 to 0.25 has significantly changed the capability growth value and the period.

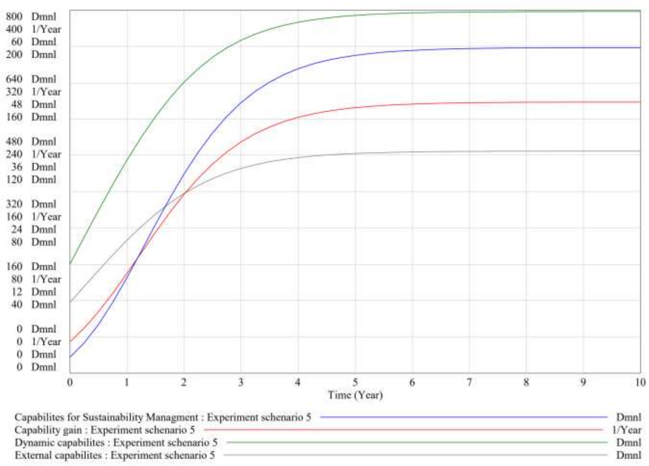


**Figure 10.** Management and supervision experiment result for selected capability variables.

6.2.6. Scenario Six: Minimum Wage Concerns

Minimum workers' wage concerns have been repeatedly variable, and have been given attention by the experts' feedback. Improving the original data value and minimizing the problems has shown a better capability growth than the existing simulation (Figure 11).

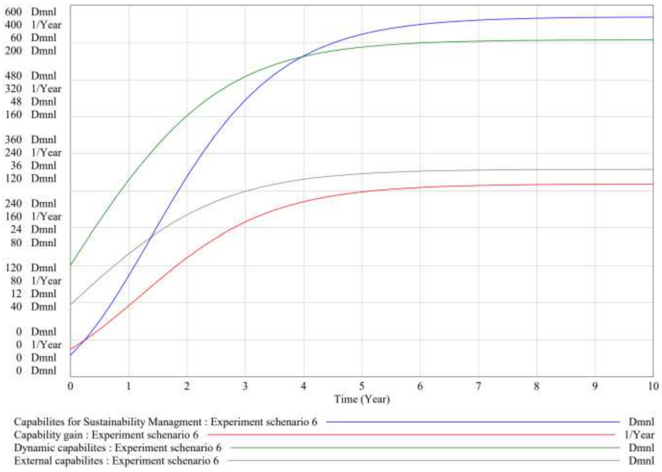


**Figure 11.** Minimum wage concerns experiment results for selected capability variables.

## 7. Summary and Discussion

### *7.1. Existing Capability Simulation*

Observing the existing simulation based on the original data value, Figure 12 shows that the total capability accumulation reached 350 by the end of the tenth year. This is ten times the initial capability accumulation. In general, the capability growth doubles each year, assuming all the variables are incorporated in the firm's management.

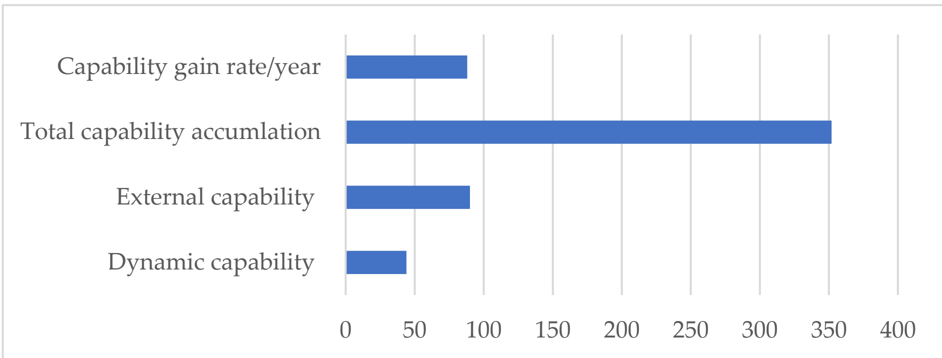


**Figure 12.** Capability values based on original simulation data.

### *7.2. Experimental Scenario Simulation*

A Pareto analysis chart was used to summarize the significant variables from the experiment scenarios.

7.2.1. Dynamic Capability

The experimental simulation results of the SD model have made a change in the capability growth. Altering the variable unethical management and supervision (Scenario V) would significantly impact the dynamic capability of the firms towards sustainability management. Minimizing or eliminating negative contributing variables would be the priority to improve the existing dynamic capability. From the case study, unethical management and supervision were negative influencing variables. The experiment shows that altering the variable from the base value would increase 36.6% significant change in the dynamic capability. As a second significant variable, altering the implementation of waste management practice (Scenario IV) would significantly impact the dynamic capability. Improving the waste management practices from the base value would increase 27.2% on the dynamic capability from the existing. The third significant variable was found on the minimum wage concerns (Scenario VI). The alteration of this value would increase the current dynamic capability by 22.7%. The percentage difference of all the scenarios summarized in Figure 13.

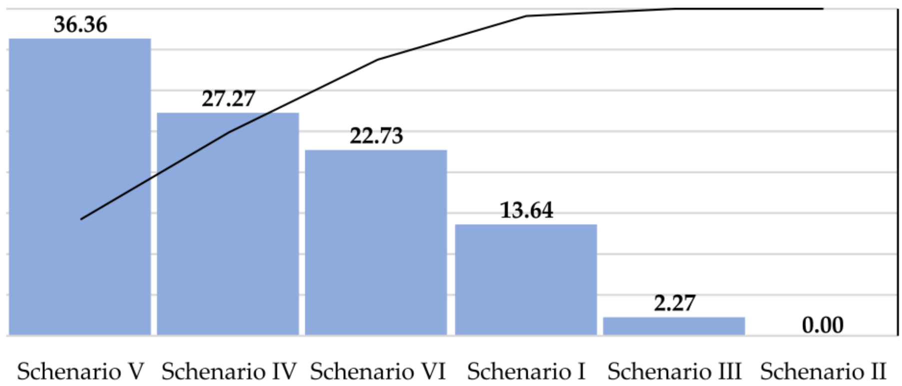


**Figure 13.** Experiment scenarios' percentage difference with a cumulative line for dynamic capability(Pareto-Chart).

### 7.2.2. External Capability

Compared to the current simulation, the experiment scenarios have significantly increased external capability (44.44% on the scenario I, 35.56% on scenario V, 26.67% on scenario IV, and 23.33% from scenario VI). Scenario III and II were found to have a minor increase in the capability gain. The percentage difference of all the scenarios summarized in Figure 14.

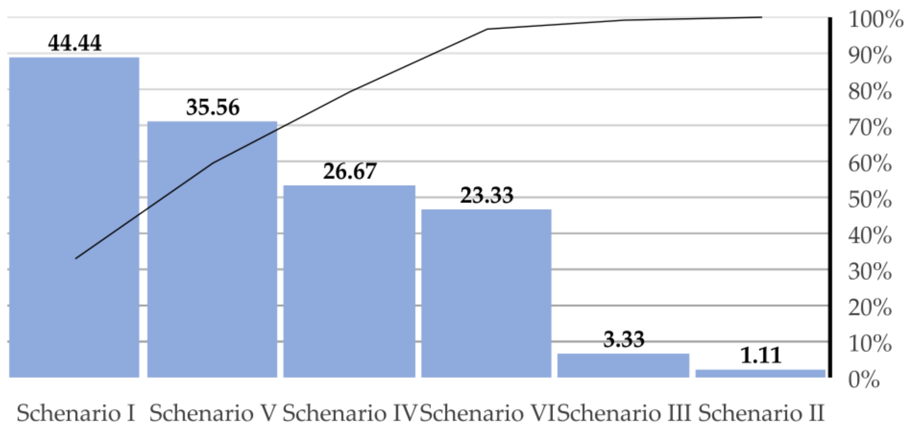


**Figure 14.** Experiment scenarios' percentage difference with a cumulative line for external capability (Pareto-Chart).

### 7.2.3. Capability Accumulation for Sustainability Management

Observing the capability accumulation growth from the SD growth, there has been a significant change in scenarios V, IV, VI, and I. However, Scenario III and II influence was found insignificant and did not differ much from the current simulation. Compared to the current simulation, the experiment scenarios have shown a significant increase in capability accumulation (103.7% on scenario V, 75.85% on scenario IV, 64.77% on scenario VI, and 33.24% from scenario IV I). The percentage difference of all the scenarios is summarized in Figure 15.

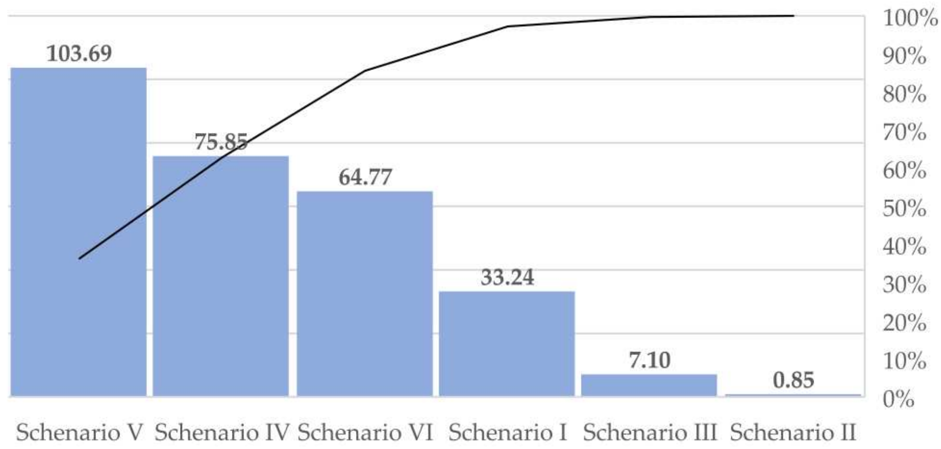


**Figure 15.** Experiment scenarios' percentage difference with a cumulative line for total capability accumulation (Pareto-Chart).

### 7.2.4. Capability Gain Rate

Compared to the current simulation, the experiment scenarios have significantly increased the capability gain rate (238.64% on scenario V, 135.23% on scenario VI, 127.27% on scenario IV, 47.73% from scenario IV scenario I, and 17.05% from scenario III). Scenario II found the slightest increase in the capability gain. The percentage difference of all the scenarios summarized in Figure 16.

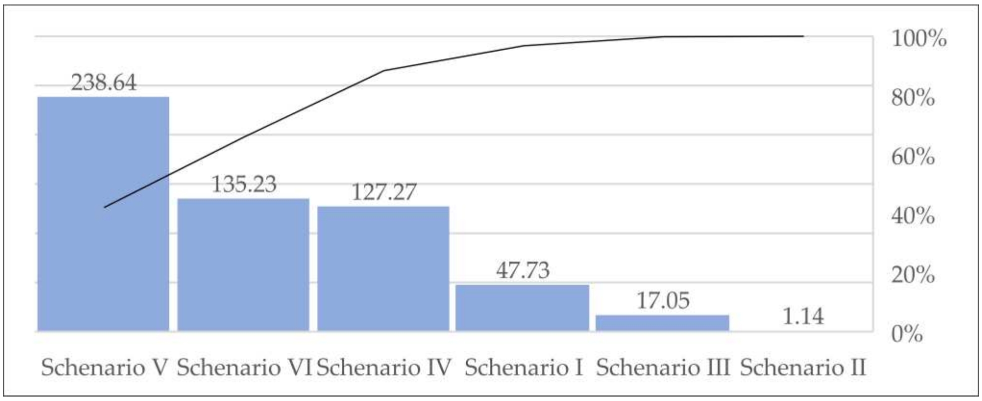


**Figure 16.** Experiment scenarios' percentage difference with a cumulative line for total capability accumulation (Pareto-Chart).

## *7.3. Dynamic Capability Driven SD Model and Implication for Open Innovation*

Due to internal and external pressure from stakeholders, firms are starting to integrate sustainability pillars and shifting towards sustainable development. Moreover, the complexity of sustainability has also made firms explore system-oriented management models and simplify their decision-making process. Building dynamic capability-driven sustainability management and supporting the complex decision-making process with system dynamics opens a platform for firms to develop their innovation and paves the way for open innovation.

Developing dynamic capability-driven sustainability management allows firms to sense, seize, and transform all of the opportunities and information related to sustainability issues. Concerning data management, the SD model supports firms monitoring and reporting a wide range of sustainability performance indicators, including the triple bottom lines and capability information and influence of all internal and external stakeholders involved. The sensing dynamic capability where firms crowdsource sustainability information is necessary to perform open innovation processes and find new opportunities to develop their capability for managing sustainability.

Our developed SD model helps innovative processes in the generic industrial firms in three manners:

First, the model shows strategies for enhancing sustainability capability through dynamic capability micro-foundations, including sensing, seizing, and transforming abilities. An inability to develop dynamic capability-driven sustainability management leads to the temporary competitive goal and does not lead to the long-term competitive advantage of firms.

Second, we have shown the importance of information sharing through the sustainability management processes. Continual capability development through the DC approach is critical for knowledge building and transfer in open innovation processes. It should be considered a crucial strategy to achieve a sustainable competitive advantage [138].

Third, the SD model shows how firms could easily monitor their capability development in managing sustainability issues over time. A holistic, dynamic frame has been a challenging issue for firms in decision-making. This leads managers to understand the critical indicators and helps them to develop continual innovation improvement strategies.

Overall, developing effective dynamic capability-driven sustainability strategies designed in detail in this study helps open the innovation system. The innovation system involves firm-level sustainability dimensions and stakeholders in its implementation and benefits the management by integrating, monitoring, reporting, and sharing more information to achieve their sustainability goals.

### *7.4. Managerial and Theoretical Implication of the Study*

The developed DC-driven SD model can help managers in the decision-making process and improve sustainability management. The identified influencing variables from the simulation scenario support managers to emphasize and establish system-based strategic directions to improve sustainability management. Being aware of the critical influencing variables and DC constructs helps managers to reconfigure their functional capabilities and monitor the challenges they are likely to face in improving the overall sustainability of the firm. Furthermore, the SD model analysis has included the primary sustainability criteria at the economic, social, and environmental levels. This would support managers to overcome the institutional challenges in simultaneously managing the TBL for sustainable development. Moreover, it allows managers to make quick decisions while monitoring sustainability dimensions. The case study simulation results suggest that managers should develop and maintain sustainability training efforts, waste management practice, ethical management, supervision, and improve wages for better sustainability management.

From the theoretical aspect, we have found DC to be a useful theoretical lens to frame firm-level sustainability management and SD for understanding the relationships of the decision variables involved. The study comprehensively explored the relationship constructs of DC and sustainability dimensions. Unfortunately, a scarce resource has been linking DC and sustainability management and investigating their relationship with empirical case studies, especially from the global south countries. In this regard, the study would give most academicians a basis to empirically test the relationships involving additional construct variables. On top of this, the study has several theoretical implications to the current literature field of corporate sustainability management. One of the implications is that it enlightens the significance of DC constructs for sustainability management in emerging industrial firms. In addition, the use of a dynamic model like SD for sustainability management would assist in real-time data collection and performance analysis in the sustainability field.

## 8. Conclusions

This study used case study expert's data from the apparel industrial park in Ethiopia to simulate a system dynamic model. Based on the Pareto percentage summary, we found that, regarding the overall capability development and dynamic capability, "the waste management practice," 'minimum wage concerns', and 'ethical management' and supervision have been found to be the crucial elements. However, in particular to external capability development, "sustainability training efforts, 'waste management practice', and 'ethical manage supervision' have been found to be the crucial elements for sustainability management.

Although the perspectives and factors of sustainability management are all crucial, our case study for the simulation run observed that overall, the minimum wage concerns from the employee side, waste management practices, ethical management, and supervision are given more priority than the other elements. The findings also indicate that a firm's sustainability management requires an innovative approach in addressing these crucial elements in setting fair wages and incentives, developing innovative waste management approaches, and equipping managers with soft skills in leadership according to the local culture and norm. Regarding external capability, the firms are expected to make an effort to sense new sustainability information and innovation strategies and build their capability towards it.

The study provided information about sustainability management elements and their relationships and showed the significance of different decisions on this complex system through a scenario simulation. The study results clearly show the generic firm-level dynamic capability development for sustainability management and other industrial companies that other countries, especially those from the global south, can benefit from. Due to the limitation of company data records in the study case, we have mainly used the average rated values of the expert's opinion to estimate data and run models. We agree that the rated values may differ from the actual data if available. However, we tried to minimize these limitations as much as possible by using triangulation through secondary research documents. Future research aims to expand the SD actual data and incorporate new dimensions of sustainability, linking with the emerging concepts of industry 4.0 technologies.

Last but not least, based on the significance of DC-driven sustainability management, we recommend that further empirical studies are required, particularly in linking and contextualizing additional constructs of DC and sustainability dimensions from emerging countries. Furthermore, we recommend that practitioners and managers use the developed SD model to understand their capability to achieve their sustainability goals along the time path. They can have clarity on the critical influencing drivers of sustainability management, which allows them to narrow down their efforts to focus on the relevant and practical functional capabilities to develop DC-driven sustainability strategies and achieve sustainable development successfully.

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