

# **IMPACT OF AFFORDABILITY, ADAPTABILITY, AND AVAILABILITY IN ACHIEVING SUSTAINABILITY: A SYSTEM-DYNAMIC APPROACH**



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## **DEDICATION**

Dedicated to my exceptional parents, adored siblings and caring friends whose  
tremendous support and cooperation led me to this wonderful achievement

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Due praises are given to Allah Almighty, the Creator, and the Sustainer, without whose instruction not a single minute pass. He who has given us forte and blessed us with plenteousness without any measure. There are no words which can do justice to Him. I am empowered to Read and Write only by Him, who has bestowed upon me the knowledge I carry forward. I would first like to acknowledge EME College NUST that enabled me to conduct the research. I would like to extend much appreciation and gratitude to my advisor Dr. Shahbaz Abbas whose countless inspiration and guidance made it possible to complete my research work. In addition, Dr. Yasir and Dr Afshan in the capacity of committee members; gave me guidance and feedback throughout the thesis process. I sincerely express my solemn gratitude with earnest sense of reverence to my parents for their encouragement, heartfelt prayers and kind wishes for successful completion of my studies along with this research work. Specially, I want to thank my siblings and caring friends from all my heart for always supporting and motivating me at every point of my research journey.

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## ABSTRACT

The Sustainable Development Goals (SDGs) are a set of 17 goals adopted by the United Nations in 2015 to achieve sustainable development by 2030. However, progress towards achieving these goals has been slow due to a number of challenges, including the interconnectedness of the goals, the lack of resources, marginalization and inequality, and global cooperation. System Dynamic Models (SDMs) are used to simulate complex and interconnected systems. They can be used to test different policies and strategies to see how they would impact the system. The purpose of this research is to develop AAA framework (Availability, Affordability, and Adaptability) that can be used to guide the development of SDMs for the SDGs that can play as a game-changer role in achieving the devised targets set by the UN SDGs to be achieved by 2030. Policymakers and decision-makers can thoroughly seek systematic and in-depth insights from the application of SDMs through the lens of the AAA approach towards sustainability to develop policies and interventions that are feasible, resilient, robust, befitting, and equitable, enabling a global and unanimous approach towards long-term sustainable development.

**Keywords:** Sustainable Development Goals (SDGs), System Dynamics Models (SDMs), AAA Framework, Availability, Affordability, Adaptability, Interconnected Systems, Policy Testing, Strategies Impact, Marginalization, Inequality, Global Cooperation, Policymakers, Decision-makers, Feasible, Resilient, Robust, Befitting, Equitable, Long-term Sustainable Development.

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## LIST OF ABBREVIATIONS

AI:	Artificial Intelligence
BRI:	Belt and Road Initiative
BRICS:	Brazil, Russia, India, China, South Africa
CBA:	Cost-Benefit Analysis
CO <sub>2</sub> :	Carbon Dioxide
COP:	Conference of the Parties
CSOs:	Civil Society Organizations
CSR:	Corporate Social Responsibility
EIA:	Environmental Impact Assessment
EMR:	Environmental Management and Restoration
ESG:	Environmental, Social, and Governance
EU:	European Union
FAO:	Food and Agriculture Organization
FSC:	Forest Stewardship Council
GDP:	Gross Domestic Product
GHG:	Greenhouse Gas
GIS:	Geographic Information System
GRI:	Global Reporting Initiative
HDI:	Human Development Index
HRA:	Human Rights Assessment
ICT:	Information and Communication Technology
IP:	Intellectual Property
IPCC:	Intergovernmental Panel on Climate Change
IUCN:	International Union for Conservation of Nature
IT:	Information Technology
KPIs:	Key Performance Indicators
LCA:	Life Cycle Assessment
MDGs:	Millennium Development Goals
MDPI:	Multidisciplinary Digital Publishing Institute
NGOs:	Non-Governmental Organizations
NGT:	Nominal Group Technique
NRM:	Natural Resource Management
OECD:	Organization for Economic Co-operation and Development
CRP:	Country Risk Policy
DAC:	Development Assistance Committee
PPP:	Public-Private Partnership
R&D:	Research and Development
RIO:	Resource Input-Output
SES:	Social-Ecological System
SDA:	Sustainable Development Agenda
SDGs:	Sustainable Development Goals
SDM:	System Dynamic Model
SGD:	Sustainable Development Goal
STEM:	Science, Technology, Engineering, and Mathematics
SWOT:	Strengths, Weaknesses, Opportunities, Threats
UN:	United Nations
UNDP:	United Nations Development Program

UNESCO: United Nations Educational, Scientific and Cultural  
Organization  
WHO: World Health Organization

## CHAPTER 1: INTRODUCTION

The concept of sustainable development has been associated with the Brundtland Commission Report (1987) and has since been at the forefront of the UN's policies towards sustainable development (World Commission on Environment and Development, 1987). The 17 UN SDGs were developed in 2015 by global leaders as the 2030 Agenda for Sustainable Development (United Nations, 2018). The focus of these goals was to encompass environmental, economic, and social factors focused on their integrated approach towards sustainable development across the globe. The report also highlighted the importance of affordability, adaptability, and availability in achieving sustainable development. Achieving sustainability requires addressing the crucial factors of affordability, adaptability, and availability. The overall success of sustainable development efforts heavily depends on these three aspects. They ensure that sustainable practices are accessible and feasible for all individuals and communities, regardless of their socioeconomic status. By considering affordability, adaptability, and availability in sustainable development initiatives, it becomes possible to create solutions that are inclusive and equitable. These factors help in overcoming barriers and challenges that may hinder the adoption and implementation of sustainable practices.

### 1.1 Challenges faced in achieving SDGs

However, it is notable to understand that the progress towards achieving these goals has been under scrutiny and criticism for not being able to meet the designated targets (Spangenberg, 2016; Kroll et al., 2019). The concept of sustainable development has been associated with the Brundtland commission Report (1987) and has since been at the forefront of the UN's policies towards sustainable development (World Commission on Environment and Development, The criticism for not being able to achieving the SDGs as designated has been credited to a diverse variety of factors and challenges. Sustainable Development Goals seek to address a myriad of challenges facing cities, including climate change, urban livability, and energy demand. These goals serve as a comprehensive framework for evaluating planning strategies and monitoring progress through diverse indicators. Yet, the integration of heterogeneous data and flexible frameworks is crucial for effectively evaluating SDG-related planning metrics. These challenges are addressed as follows:

#### *1.1.1. Interconnectedness and Complex Nature*

It is pertinent to acknowledge that SDGs are interconnected or interrelated to each other, i.e., managing one goal might directly or indirectly hinder the progress towards achieving the other (Wu et al., 2022). These complex feedback loops and systematic trade-offs thoroughly create a complicated and complex system for developing solutions that are unanimously enhancing the progress towards sustainable development without altering any of the 17 SDGs. It is essential to adopt a comprehensive and cohesive approach when dealing with the SDGs. It is important to consider the interrelated and intricate nature of these goals while addressing the Sustainable Development Goals. The goals are

interconnected, meaning that progress in one goal can have a direct or indirect impact on progress in another goal. For example, addressing poverty may contribute to the reduction of inequality and promote inclusive economic growth. Similarly, efforts to combat climate change can contribute to the achievement of multiple goals, such as sustainable cities and communities, clean energy, and responsible consumption and production. To effectively address the challenges and achieve the SDGs, it is crucial to adopt a holistic and integrated approach that recognizes the interconnectedness and interdependencies between the goals (Dei & Asante, 2022).

### *1.1.2. Lack of Resources*

SDGs are a global target, and the provision of adequate funding, expertise, resources, and technology is necessary for achieving these goals across the globe (Patole, 2018). It is important to mention that there is a disparity amongst countries across the globe in allocating adequate resources to meet the SDGs, indicating poor progress in comparison to the designated targets (McMichael, 2017). Hereby, indicating an unequal capacity of countries across the globe to achieve the SDGs. The accomplishment of the SDGs presents a significant challenge due to various factors. the lack of resources, such as funding, expertise, and technology, which are necessary for implementing and monitoring progress(Xue et al., 2018). One possible approach to overcoming the challenge of limited resources is through international collaborations and partnerships. By pooling resources and expertise, countries can share the burden and work together to implement sustainable practices and achieve the SDGs.

### *1.1.3 Marginalization and Inequality*

Furthermore, the role of marginalization, discrimination, and prevalent structural inequality across the globe has been at the forefront of hindering the progress towards achieving the SDGs (Carant, 2016; Freistein & Mahlert, 2016). These factors require immediate action and the provision of equal access to opportunities and Resources are pivotal for achieving sustainability. Addressing the SDGs requires addressing the challenges of marginalization, discrimination, and structural inequality that hinder progress. Efforts must be made to ensure equal access to opportunities and resources in order to achieve sustainability and overcome the challenges posed by marginalization and inequality. It is crucial to address the challenges of limited resources and marginalization in order to effectively achieve the Sustainable Development Goals.

### *1.1.4 Global Cooperation*

As stated earlier, SDGs are a globally oriented approach and subsequently require effective cooperation, teamwork, and collaboration at the global level to achieve them (Florini & Pauli, 2018). However, poor coordination, differences in opinions, geopolitical differences, and tensions have been drastically impacting the progress towards achieving these goals.

Therefore, there is an ardent need to establish new paradigms for achieving sustainable development goals and strengthen the interrelationship between the three pillars of sustainability to foster progress towards the achievement of the SDGs in an effective manner. It will empower a robust, resilient, and befitting approach towards accomplishing the targets of the UN SDGs by systematically enhancing the interrelationship between the Paraphrased: The three dimensions of sustainability, namely social, economic and environmental. Doing so will establish a strategic approach that will foster sustainable development while considering the complicated and complex nature of sustainability paradigms. Addressing the challenges of marginalization, discrimination, and inequality is crucial to attain the Sustainable Development Goals. In order to achieve the Sustainable Development Goals, it is essential to address the challenges of marginalization, discrimination, and prevalent structural inequality that hinder progress.

## **1.2 System dynamic models and strengthening sustainability**

Nevertheless, it is important to understand that the complex and dynamic nature of the factors involved in implicating sustainability needs a better understanding for effectively accomplishing the targets set by the UN SGDs. The role of the System Dynamic Model (SDM) is integral to visually simulating the complex system of sustainability and provides a better understanding of developing new mechanisms that unanimously contribute towards achieving overall sustainability without hindering the progress of any of the goals (Honti et al., 2019). For the said reasons, the following approach can be utilized through the development of a robust SDM: "To address the challenges of limited resources and marginalization, it is crucial to establish new paradigms for achieving sustainable development goals and strengthen the interrelationship between the three pillars of sustainability: social, economic, and environmental. This can be achieved through a systemic and dynamic approach, utilizing models like the System Dynamic Model. The System Dynamic Model will allow for a comprehensive understanding of the complex interactions and feedback loops within the sustainability system, enabling the development of effective strategies and policies for sustainable development.

### *1.2.1 Adaptability*

The scenario-testing mechanism and simulating abilities of SDMs are instrumental in analyzing and testing different policies and strategies to enhance sustainability (Bastan et al., 2018). The incorporation of the "adaptability" factor in SDMs will provide a systematic understanding of the changing interventions of various factors in the system and their mutual implications on the behavior of the system. It will be strategically integral in thoroughly identifying potential policies and strategies that can systematically bear unforeseen changes and effectively withstand uncertainties, leading to long-term sustainability. To ensure the long-term sustainability and adaptability of policies and strategies, it is crucial to incorporate the "adaptability" factor in system dynamic models to better understand the dynamic interactions and feedback loops between different components of the system. This will help in identifying potential policies and strategies that can withstand uncertainties and ensure long-term sustainability. By incorporating the "adaptability" factor in system dynamic models, we can better understand the dynamic

interactions and feedback loops between different components of the sustainability system and assess their ability to adapt and respond to changing circumstances. This approach will enable us to identify and implement policies and strategies that are resilient and can effectively navigate unforeseen changes, leading to long-term sustainability. By utilizing a robust System Dynamic Model that incorporates the "adaptability" factor, we can gain a systematic understanding of the changing interventions

### *1.2.2 Affordability*

Affordability is regarded as one of the most prominent aspects of implementing sustainability strategies (Hoover et al., 2020). SDMs can effectively use simulations to identify the economic feasibility of strategies and policy interventions to provide insight to decision-makers for analyzing and identifying the financial feasibility of interventions in the system (Mareeh et al., 2022). It will ensure that the strategies or policies are not only focused on sustainability but are also affordable for widespread implementation to seek long-term sustainability.

To achieve long-term sustainability, it is essential to consider the affordability of policies and strategies. SDMs can be used to simulate and analyze the economic feasibility of different interventions, providing decision-makers with insight into the affordability of sustainability strategies. System dynamic models play a crucial role in ensuring the long-term sustainability and adaptability of policies and strategies. By incorporating the "adaptability" factor, SDMs offer a systematic understanding of the dynamic interactions and feedback loops between different components of the system. This enables a comprehensive analysis of potential policies and strategies that can withstand uncertainties and dynamically adapt to changing interventions from various factors in the system. As a result, decision-makers are better equipped to identify and implement effective long-term sustainability measures that can endure unforeseen changes and uncertainties. Moreover, the affordability of sustainability strategies is another critical aspect that SDMs can address. By using simulations, SDMs can assess the economic feasibility of different interventions, allowing decision-makers to evaluate the affordability of sustainability strategies. The integration of affordability considerations into system dynamic models can provide decision-makers with valuable insights into the financial feasibility of sustainability strategies and policies.

### *1.2.3. Availability*

As discussed earlier, the availability of adequate services, resources, finances, and opportunities can be pivotal in the overall accomplishment of SDG targets (Shen et al., 2009; Schwerhoff & Sy, 2017). SDMs can simulate the availability of aspect of resources across the system and devise relevant strategies or intervention policies to ensure that resources are adequate for long-term sustainability accomplishment (Pallant & Lee, 2017). In this manner, availability can be traced and analyzed through the complex nature of SDGs and Consequently, relevant policy frameworks can be developed.



The study by Wang (2023) provides unique perspectives into the complexities of post-disaster environmental consciousness, highlighting the impact of social interactions and regional environmental variables. It reveals that tragedies raise pollution awareness, but that strong social relationships can attenuate this effect. Notably, the study calls preconceptions into question by demonstrating no substantial changes in awareness across income brackets or socioeconomic backgrounds. It emphasizes the possibility for promoting sustainability in the face of catastrophes. Furthermore, Zeng et al. (2022) broadens the conversation about sustainability and resilience in urban areas by proposing important indicators that are critical for assessing and managing risk in rapidly urbanized ecosystems.

The inclusion of these indicators in SDMs can enhance the understanding of the complex interdependencies between urbanization, sustainability, and resilience, and inform policy decisions that promote sustainable development in urban areas. In conclusion, the use of System Dynamics Models allows for effective scenario simulation and analysis of complex systems, such as those related to sustainability and resilience in urban areas. By integrating feedback concepts and simulating different scenarios, SDMs can help assess the availability of resources and devise intervention policies to ensure long-term sustainability. However, Vogt and Weber (2019) challenge prevalent misunderstandings about sustainability, notably in seven aspects, i.e., political, economic, socio-economic, cultural, environmental, theological, and democratic domains. The findings further lead to a deeper comprehension and emphases of the significance of planetary sustainability ethics. Furthermore, the study by Nishant et al. (2020) contends that AI's environmental sustainability promise rests not only in reducing resource consumption, but also by promoting thorough environmental governance. It outlines concerns and calls for a cross-disciplinary strategy, urging future research to take into account multidimensional viewpoints, system dynamics, design thinking, psychological as well as social variables, and financial considerations to develop successful AI-powered sustainability solutions.

The above sources highlight the importance of using system dynamics models to assess and manage risk in urban areas and promote sustainability. These models provide a comprehensive understanding of the complex interdependencies between urbanization, sustainability, and resilience, allowing policymakers to make informed decisions for long term sustainability.

Therefore, introducing the "AAA framework," i.e., availability, affordability, and adaptability, through SDMs can be a game-changer in achieving the targets set by the UN SDGs to be achieved by 2030. Policymakers and decision-makers can thoroughly seek systematic and in-depth insights from the application of SDMs through the lens of the AAA approach towards sustainability to develop policies and interventions that are feasible, resilient, robust, befitting, and equitable, enabling a global and unanimous approach towards long-term sustainable development.

## CHAPTER 2: LITERATURE REVIEW

### 2.1 THREE PILLARS OF SUSTAINABILITY

Sustainability is becoming a popular concept nowadays, and scholars and practitioners are both attracted by it. Sustainability comprises three main pillars: social, economic, and environmental. Sustainability is the integration of these pillars in human life for preserving natural sources for the current and future generations (Ranjbari et al., 2021). All of these pillars of sustainability are interconnected and each of them is very crucial in attaining sustainable development (Purvis et al., 2019). There have been many studies on the environmental pillar of sustainable development due to the awareness of ecological issues in society. However, there is limited data and frameworks available on the social and economic pillar of sustainable development (Gaviglio et al., 2016).

The focus of social sustainability is the personal assets of an individual, like education, abilities, experience, intake, salary, and occupation (Dempsey et al., 2011). Social sustainability revolves around the quality of life, the likelihood of providing for oneself and all the dependents, having access to means of income for everyone willing to work, and social security (Omann & Spangenberg, 2002). Social sustainability is defined as the extent of continuity of social values, identities, relationships, and institutions in the future, by Black (2004). The social pillar of sustainability is the most critical one for the survival of the human race.

The future economic activity of the human race should be based on the foundation of the environment and natural resources, as economic progress will be highly dependent on these factors. Economic sustainability is increasingly getting recognition from world leaders and economists as the global economic crisis has highlighted the importance of economic sustainability (Moldan et al., 2012). Economic sustainability is defined as utilizing the available sources effectively and efficiently (Mustapha et al., 2017).

In order to accomplish sustainable development, it is essential to maintain a balance among the three pillars of sustainability, namely social, economic, and environmental (**Handayani, 2022**). A system dynamic approach can be employed to analyze the interrelationships and feedback loops among these pillars of sustainability and assess their impacts on overall sustainability. A system-dynamic approach to sustainability can provide valuable insights into the interdependencies between the social, economic, and environmental pillars of sustainable development and help identify policies and strategies that promote a balanced and resilient system.

The focus of environmental sustainability is to protect the sources of raw materials that are used by humans to enhance welfare and to prevent them from harm by ensuring that the waste is limited (Goodland, 1995). Another definition of environmental sustainability is preserving the integrity of the systems that support life on Earth (Moldan et al. al., 2012). Environmental sustainability is a commonly established term. It focuses on the climate systems, habitats and human settlements, energy systems, terrestrial systems, aquatic systems, and carbon and nitrogen cycles (Robertson, 2021). The criteria for environmental sustainability are: regeneration, substitutability, assimilation, and avoiding irreversibility.

### *2.1.1. Improving Affordability*

There is a way to enhance the relationship between the two pillars of sustainability, i.e., social and economic. That way by improving affordability. The term "affordability" is used regularly. People with a background in economics translate the word "affordable" into "sustainable" (Milne, 2006). The following aspects will provide a brief insight into enhancing the relation between the economic and social aspects of sustainability through the lens of affordability.

The subsequent factors will offer a concise understanding of improving the connection between the economic and social facets of sustainability from the perspective of affordability. In order to enhance the relationship between the economic and social aspects of sustainability, improving affordability plays a crucial role. Improving affordability can contribute to achieving economic sustainability by ensuring that resources and opportunities are accessible to a wider population. Improving affordability also promotes social sustainability by reducing inequality and ensuring that essential goods and services are accessible to all members of society.

#### *2.1.1.1. Reducing Poverty and Inequality*

The access of people to resources determines their affordability (Hancock, 1993). Making goods and services accessible to the public by improving their affordability can prove to help reduce poverty in a society (Rosca et al., 2017). It also helps with bridging the wealth gap, and making society more equitable. The society becomes more stable with enhanced social cohesion in it if a broader segment of society has access to basic life necessities and opportunities.

Improving affordability can contribute to reducing poverty and inequality, as it ensures that goods and services are accessible to a wider population. In addition, improving affordability can also lead to a reduction in poverty and inequality, as it ensures that essential goods and services are accessible to a wider population, including those who are marginalized or disadvantaged. By improving affordability, we can create a more equitable society where basic necessities and opportunities are accessible to all. Improving affordability is crucial for enhancing the relationship between economic and social aspects of sustainability. Improving affordability plays a crucial role in enhancing the relationship between the economic and social aspects of sustainability.

#### *2.1.1.2. Enhancing Quality of Life*

The quality of life is dependent on economic activities (El Din et al., 2013). When economic activities are affordable for communities and individuals, their quality of life improves (Grum & Kobal). Grum, 2020). The well-being of people sees improvement when housing, Healthcare, education, and other life necessities are affordable (Clark, 2003). Therefore, it is pertinent to understand that the enhancement of quality of life effectively indicates a strong bond between economic and social dimensions of sustainability through the concept of affordability.

Improving affordability is a crucial step in enhancing the relationship between the economic and social aspects of sustainability. By making goods and services more affordable, economic sustainability can be achieved by ensuring that resources and opportunities are accessible to a wider population, thereby reducing poverty and inequality. Improving affordability is essential for achieving economic and social sustainability as it ensures that necessary resources and opportunities are accessible to a wider population, reducing poverty and inequality and ultimately improving the overall quality of life for individuals and communities. Moreover, improving affordability in housing can directly contribute to the enhancement of quality of life.

#### *2.1.1.3. Promoting Inclusive Economic Growth*

A business can have a longer reach and more customers if the products and services are in the range of a broader segment of society (Ghosh & Rajan, 2019). The demand for products and services will increase and it will encourage development and economic growth (Ain et al., 2020). Inclusive economic growth involves a situation where economic activities are benefiting everyone and the participation of everyone is possible (Ranieri). & Almeida Ramos, 2013). Therefore, inclusive growth will enhance the economic empowerment of society, further indicating the role of affordability in promoting the nexus between the social and economic pillars of sustainability.

In summary, enhancing affordability in housing and other economic activities has multiple benefits. Improving affordability not only enhances the quality of life for individuals and communities but also contributes to inclusive economic growth by increasing access to goods and services

#### *2.1.1.4. Encouraging Social Innovation*

Social innovation is defined as fulfilling social needs by the implementation and development of new ideas, products, or services (Santoro et al., 2018). Social innovation has two potential drivers, and they are “internal market orientation” based human resource policy development and communication and information technology proficiency (Sanzo Perez et al., 2015). Improving efficiency and reducing costs usually requires looking for innovative solutions (Peters et al., 2011). This means that improving affordability encourages social innovation as it can lead to the development of economic viable products. This will impact society and address the challenges of society while providing people with options that are affordable as well.

Improving affordability in housing can encourage social innovation by creating opportunities for the development of new ideas, products, and services that meet social needs while remaining economically viable. Inclusive economic growth involves a situation where economic activities benefit everyone, allowing for the participation of all members of society.

#### *2.1.1.5. Addressing Social Needs Through Economic Means*

Social issues can be addressed by the economic pillar, as it provides the funds and resources for addressing these issues (Lee & Woo, 2020). Economic prosperity and affordability can be made possible by investing in sectors like infrastructure, social programs, and community development.

Investing in these sectors not only addresses social needs but also promotes affordability, making essential services and resources accessible to a broader segment of society. By addressing housing affordability and promoting inclusive economic growth, society can experience benefits that go beyond improved living standards for low-income groups. These benefits can include a reduction in income inequality, increased social cohesion, and improved overall societal well-being. Furthermore, by addressing social needs through economic means, society can create a more inclusive and sustainable development.

#### *2.1.1.6. Boosting Customer Spending and Satisfaction*

The satisfaction of the customers and their spending on products increases when the products and services are affordable (Mundel et al., 2017). This leads to the economic growth of a country and stimulates job creation in the region and further innovation in the products (Singh et al., 2010). It further indicates the role of affordability in enhancing the relationship between the social and economic pillars of sustainability.

In summary, enhancing affordability in housing and other economic activities has multiple benefits, including encouraging social innovation, addressing social needs through economic means, and boosting customer spending and satisfaction. In summary, enhancing affordability in housing and other economic activities has multiple benefits. It can improve access to essential services and resources, reduce income inequality, promote social cohesion, and contribute to overall societal well-being. Inclusive growth is a desired outcome that focuses on improving the social and economic wellbeing of marginalized communities by providing them with resources, capabilities, and opportunities (**George et al., 2012**).

#### *2.1.1.7. Enhancing Social Stability and Resilience*

When opportunities and affordable resources are easily accessible to a broader segment of society, resilience and social contribution increases as affordable resources and opportunities contribute towards it (Morrow, 2008). Social tensions can be reduced by providing people with economic opportunities and addressing the disparities in society (van Niekerk, 2020). It contributes to the general well-being of society. Furthermore, for long-term success, it is essential to maintain a balance between the three pillars of sustainability (Schilirò, 2019). Environmental sustainability should not be compromised in improving affordability (Blair et al. al., 2004). Social considerations should be taken into account while improving affordability in a society (Mulliner et al., 2013). Henceforth, a prosperous

and more sustainable future is guaranteed if these three pillars are integrated by focusing on the synergies between these pillars.

### *2.1.2. Improving Adaptability*

A way to enhance the connection between the environmental and economic aspects of sustainability is by improving availability. In the literature on climate change, adaptability is defined as the adjustment of human systems and natural processes as a reaction towards the predictable or actual climate effects or stimuli which cause destruction or feats the beneficial prospects (Adger et al., 2009). Generally, adaptability is the ability of an individual or a society to adjust to conditions like changing environments, threats, and challenges (Smit & Wandel, 2006). There are three dimensions that constitute the path around the limits of adaptation. These three dimensions are economic limits, technological limits, and ecological limits (Nelson et al., 2007).

Different analytical capabilities are offered by these dimensions for investigating adaptation to changes in the environment and adaptation as a part of policy assessment (Béné et al., 2012). Physical modelling offers prospects for the investigation of physical or ecological limits like biodiversity or agriculture in climate change (Adger et al., 2009). However, economic limits for adaptation can be investigated by using cost-effective analysis (Dottori et al., 2023). By advancing adaptability, the connection between the economic and environmental aspects of Sustainable development can be strengthened. A system dynamic approach to sustainability can help enhance adaptability by identifying and understanding the complex relationships and feedback loops between environmental and economic factors (Serra et al., 2022).

#### *2.1.2.1. Resilience to Environmental Changes*

The concept of resilience was introduced by a scholar named C.S. Holling. He introduced this concept to understand the capability of ecosystems (Folke et al., 2010). Some fields define resilience as the ability to return to the original state of equilibrium after a perturbation (Reid & Botterill, 2013). The environment of the earth is constantly changing and communities and societies are significantly affected by environmental challenges like climate change, floods, and natural disasters (Van Aalst, 2006). Societies can cope and deal with these challenges by being adaptable and they can recover from these disasters (Tompkins & Adger, 2004; Brown & Westaway, 2011; Eriksen et al., 2021). Adaptability also helps with preserving social well-being and reducing the negative consequences (Prime et al., 2020). Therefore, the role of adaptability in fortifying the environmental and social dimensions of sustainability are evidently integral.

#### *2.1.2.2. Addressing Environmental Vulnerabilities*

Disasters and environmental degradation impact the poor, native populations, and marginalized communities (Harlan et al., 2015). They are the most disproportional segment of society that suffers from the worst impacts of these disasters (Aker & Mallick, 2013). Adaptability strategies can deal with addressing the vulnerabilities associated with

disasters and help these groups build the capacity to respond to environmental changes effectively (Maru et al., 2014; Thomas et al., 2019). It indicates that adaptability plays a decisive role in strengthening the relationship between the social and environmental dimensions of sustainability. In the context of climate change, resilience and adaptability are crucial for both biodiversity and agriculture.

#### *2.1.2.3. Collaborative Decision-Making*

One of the requirements of adaptability is engagement and collaboration between all the involved stakeholders. This includes governments, native communities, and non-governmental organizations (Akompab et al., 2012; Henstra, 2017). This collaborative strategy builds social cohesion in society and empowers people to take an interest and participate in processes like environmental decision-making that affect their lives (Agyeman & Angus, 2003; Agyeman & Evans, 2004; Mustalahti, 2018). It further elaborates the role of adaptability in strengthening the social and environmental pillars of sustainability by paving a way forward for effective social integration in decision-making that directly implicates the environment. In conclusion, the concept of adaptability is crucial in addressing environmental vulnerabilities and fortifying the social and environmental dimensions of sustainability.

#### *2.1.2.4. Sustainable Resource Management*

Practices like sustainable resource management are encouraged by adaptability (Armitage et al., 2008; Armitage et al., 2009; Pollard & du Toit, 2011). Societies can conserve and protect their resources by implementing measures once they understand the environmental conditions that are changing (Tompkins & Adger, 2004; Hallegatte, 2009; Martin et al., 2016; Brown et al., 2022). They can ensure the availability of the sources for their future generations and can also promote social equity and justice for intergeneration by adaptability (Summers & Smith, 2014; Puaschunder, 2016; Cox et al., 2018; Newell et al., 2021). Therefore, sustainable resource management can effectively be achieved through adaptability and further fortify the relationship between the social and environmental aspects of sustainability. The system-dynamic approach to sustainability recognizes that adaptability plays a crucial role in strengthening the relationship between the social and environmental dimensions of sustainability.

#### *2.1.2.5. Promotion of Sustainable Lifestyles*

The adoption of sustainable lifestyles is a consequence of adaptability (Ozarisoy & Altan, 2017). Societies can improve their overall social well-being by embracing practices that are eco-friendly like reducing waste, saving energy, and using renewable energy sources (Moon, 2018). Henceforth, sustainable lifestyle adaptation also indicates the role of adaptability in further enhancing the relationship between the social and environmental aspects of sustainability. The system-dynamic approach to sustainability recognizes that fostering adaptability supports the sustainable management of resources and the

advancement of sustainable lifestyles, thereby enhancing the connection between the social and environmental aspects of sustainability.

#### *2.1.2.6. Empowerment and Capacity Building*

A lot of factors are involved in building adaptability. For example, providing information and training on environmental concerns, preparedness for disaster, and sustainable practices (Allen, 2006; van Aalst et al., 2008; Djalante et al., 2013). The ability of an individual to adapt to environmental issues increases when they are empowered with knowledge and skills and also enhances their social standing (Allen, 2006; Ansari et al., 2012; Gil-Rivas & Kilmer, 2016). Therefore, capacity-building and empowerment on the social aspect, adaptability plays a decisive role in enhancing the environmental aspect of sustainability. The system-dynamic approach to sustainability recognizes that empowerment and capacity building through adaptability are vital for enhancing the environmental aspect of sustainability, as they enable individuals to actively engage in sustainable practices and contribute to the preservation of the environment. The system dynamic approach to sustainability emphasizes the importance of adaptability in strengthening the relationship between the social and environmental aspects of sustainability.

#### *2.1.2.7. Health And Well-Being*

Access to natural places, quality of water, air, and public health are affected by environmental changes (Younger et al., 2008). It becomes possible for societies to improve the general well-being of their residents and protect the health of their people by adapting to the changes in the environment (Corvalan et al., 2005; Wali et al., 2017). Therefore, climate change and adaptability play a vital role in the wellbeing of society, further indicating the role of adaptability in enhancing the relationship between the environmental and social pillars of sustainability. The system-dynamic approach to sustainability recognizes that adaptability is essential in promoting sustainable resource management and the adoption of sustainable lifestyles, which strengthens the connection between the social and environmental dimensions of sustainability.

#### *2.1.2.8. Cultural Preservation*

Preservation of traditional knowledge and cultural heritage is also part of environmental adaptability (Berkes et al., 2000). Traditional knowledge and cultural heritage are known for holding valued comprehension of sustainable practices (Son et al., 2021). They also have information on the ways to develop harmonious links with the environment (Gross et al., 2018). In other words, environmental adaptability increases the social cohesion of communities and contributes to cultural identity. Henceforth, adaptability through cultural heritage and indigenous knowledge can effectively enhance the relationship between the social and environmental aspects of sustainability. The system-dynamic approach to sustainability recognizes that empowerment and capacity building through adaptability are vital for enhancing the environmental aspect of



sustainability, as they enable individuals to develop the necessary skills and knowledge to effectively respond to environmental changes. In summary, the system-dynamic approach to sustainability emphasizes the importance of adaptability in strengthening the relationship between the social and environmental aspects of sustainability.

#### *2.1.2.9. Social Innovation and Technology*

Technological developments and social innovations are driven by adaptability (Baker & Mehmood, 2013; Cho & Yi, 2022). Quality of life is improved, and social progress is supported by new technologies and innovative solutions that address the challenges of the environment (Mohammadian & Rezaie, 2019; Ravazzoli & Valero, 2020; Kassim et al., 2022). It indicates that the adaptability factor plays a prominent role in driving social and technological innovations towards a more robust socio-ecological implementation of sustainability, indicating its fortifying role.

Therefore, the system-dynamic approach to sustainability recognizes that adaptability is essential in promoting sustainable resource management and the adoption of sustainable lifestyles. The system-dynamic approach to sustainability recognizes that adaptability, including cultural preservation and social innovation and technology, is crucial for enhancing the relationship between the social and environmental aspects of sustainability. Social innovations and technological advancements have greatly impacted the adaptability of societies to environmental changes. The intersection of technology and social innovation has led to the development of solutions that facilitate the adaptability of communities to varying environmental conditions. One of the key impacts of social innovation and technology is the enhancement of communities' capacity to adapt to environmental changes. Innovations such as advanced weather forecasting systems, early warning mechanisms for natural disasters, and sustainable energy solutions have significantly contributed to societies' ability to respond to environmental challenges. These innovations provide communities with the tools and knowledge necessary to anticipate and mitigate the impacts of environmental changes, thus enhancing their adaptability.

Furthermore, the adoption of modern technologies and social innovations has played a crucial role in promoting sustainable resource management and the preservation of environmental integrity. The integration of smart technologies, such as IoT devices for efficient resource utilization and environmental monitoring, has empowered communities to manage their resources more sustainably. Additionally, social innovations, such as community-based conservation initiatives and collaborative resource management strategies, have fostered a stronger connection between the social and environmental dimensions of sustainability, contributing to greater adaptability.

Moreover, the use of technology and social innovation has also facilitated the development of platforms for knowledge sharing and capacity building. Online education, virtual training programs, and interactive knowledge-sharing platforms have empowered individuals and communities with the necessary skills and information to adapt to evolving environmental conditions. This has led to a more informed and prepared society, capable of responding effectively to environmental changes, thereby strengthening the environmental aspect of sustainability. Overall, the intersection of social innovation and technology has not only enhanced the adaptability of societies to environmental changes but has also contributed to the sustainable development of communities by promoting a

more resilient and responsive approach to environmental sustainability. This demonstrates the crucial role of social innovation and technology in fortifying the relationship between the social and environmental dimensions of sustainability, especially in the context of adaptability.

#### *2.1.2.10. Global Cooperation*

Environmental issues impact ecosystems worldwide, which is why they are global, requiring robust and effective international cooperation for swift mitigation (Falkner et al., 2010; London et al., 2013; Keohane & Victor, 2016). Global collaborations and partnerships are fostered by improving adaptability as it promotes the culture of shared responsibility for dealing with challenges of the environment and preserving a sustainable future for the coming generations (Waas et al., 2011; Andriollo et al., 2021). Embracing adaptability leads to the building of a sustainable and resilient relationship by a society among the social and environmental pillars of sustainability (Dale et al., 2010; Romero-Lankao et al., 2016). It helps with building the basis of the long-term well-being of a society and contributed to its prosperity. Therefore, global cooperation is empowered through adaptability to further strengthen the bond between the social and environmental aspects of sustainability.

The recent acceleration of global environmental changes underlines the urgency of global cooperation in fostering adaptability and resilience across diverse ecosystems and societies. Global collaborations and partnerships play a pivotal role in promoting adaptability as they facilitate the exchange of knowledge, resources, and best practices among nations. By sharing experiences and expertise, countries can collectively enhance their capacity to address environmental challenges such as climate change, natural resource depletion, and biodiversity loss. Moreover, global cooperation fosters a culture of shared responsibility, emphasizing the interconnectedness of environmental, social, and economic systems. Embracing adaptability on a global scale helps build the foundation for sustainable and resilient relationships between societies and their environments. This shared commitment to adaptability contributes to the long-term well-being and prosperity of societies across the globe.

Furthermore, global cooperation empowers nations to address environmental challenges in a comprehensive and coordinated manner, reflecting the recognition that environmental issues transcend geopolitical boundaries. By working together, countries can mobilize resources, leverage expertise, and implement collective strategies to mitigate the impacts of environmental changes and promote sustainable practices. In essence, global cooperation, driven by adaptability, serves as a cornerstone for strengthening the bond between the social and environmental aspects of sustainability on a global scale. It reinforces the interconnectedness of societies and ecosystems, highlighting the collective responsibility to safeguard the environmental integrity and wellbeing of present and future generations. This underscores the critical role of global collaboration in advancing adaptability and sustainability on a planetary level.

#### *2.1.3. Improving availability*

Enhancing the connection between the environmental and economic aspects of sustainability can be achieved through improved availability. The key element in studies involving resource selection is the decision of biologists about how much is decided as available (Johnson, 1980; Endara & Coley, 2010). An assumption is made with each definition of availability about the amount and accessibility of some resources that are available to a population (Buskirk & Millspaugh, 2006). Availability is defined as the abundance and accessibility of ecosystems and natural resources that can support economic activities (Li et al., 2022; Song et al., 2023). There are a lot of positive impacts on the environment and economy of properly managed and sustainable availability of natural resources, as explained in the forthcoming subsections. Enhancing the availability of ecosystems and natural resources is essential for improving the interconnection between environmental and economic sustainability.

#### *2.1.3.1. Resource Efficiency and Cost Reduction*

One method of pollution prevention is using the resource efficiency strategy. It can reduce the negative impact of a business on the environment (Delmas & Pekovic, 2015; Cainelli et al., 2020). It can also contribute towards reduced procurement costs and reduced waste management costs, and cost savings generally (Delmas & Pekovic, 2015). Economic activities become more efficient when there is wide availability and management of natural resources (George et al., 2015). Resources sufficiency helps businesses to decrease their waste, decrease their costs and optimize the process of production (Bocken & Short, 2016). This helps with increasing the profitability of the business and improving the economic competitiveness of the business. It indicates how availability plays a vital role in integrating the environmental and economic aspects of sustainability.

#### *2.1.3.2. Stability and Resilience of Economies*

The stability and resilience of economies can be improved by increasing the sustainable availability of the required resources (Sharifi & Yamagata, 2016; Baars et al., 2020). When a business or a society depends on resources that are finite or scarce, it leads to uncertainties and economic vulnerabilities (Desing et al., 2020). Changes in the availability of resources and shocks to economies can be handled well if there is a sustainable and steady supply of resources (Rose, 2007; Khan et al., 2022). Therefore, through the aspect of availability, the approach towards effective resource management can be vital for achieving both economic and environmental aspects of sustainability.

#### *2.1.3.3. Conservation of Ecosystem Services*

The goods and services that are offered by ecosystems towards the contribution of the well-being of people are ecosystem services (Meraj et al., 2021). The services of ecosystems include clean water, clean air, carbon sequestration, and pollination (Tallis & Polasky, 2009). For the sustainable future of humanity, the assessment and conservation of ecosystem services have become a priority of all nations (Naidoo et al., 2008; Meraj et al., 2022). The availability of these services in an ecosystem is crucial for the well-being of

humans and economic activities. These ecosystem services support manufacturing, tourism, and agriculture sectors (Raudsepp-Hearne et al., 2010; Quintas-Soriano et al., 2016). This makes the conservation of ecosystem services valuable and the requirement to ensure that this support continues to become more significant. It further indicates how the availability approach integrates the economic and environmental aspects of sustainability and fortifies their relationship.

#### *2.1.3.4. Long-Term Investment Opportunities*

Businesses have long-term investment opportunities if there is sustainable availability of resources (Le Breton-Miller & Miller, 2006; Robaina & Madaleno, 2020). Companies can increase the chances of secure access to resources when they invest in regenerative and renewable practices (Neto et al., 2018; Andronie et al., 2019). Businesses also contribute towards environmental preservation by this (Wood et al., 2013). The presence of renewable or sustainable resources can enable businesses to pursue profitable, long-term investments, leading to the successful achievement of both environmental and economic aspects of sustainability. In order to achieve both environmental and economic aspects of sustainability, businesses should focus on long-term investment opportunities that prioritize sustainable and renewable resources.

#### *2.1.3.5. Avoiding Environmental Degradation*

Environmental degradation starts when the natural ecosystems and resources are overexploited by humans, further leading to economic losses as well (Zhang et al., 2021). This harm to the environment is irreversible. However, humans can avoid this damage by being mindful towards the use of natural resources and by sustainably managing these resources as these resources are extremely important for the long-term possibility of economic activities (Cazalis et al., 2018). It can be effectively performed through circular economy approaches based on effective resource management and the preference towards renewable resources (Kalmykova et al., 2018). Henceforth, availability of these resources enables an effective economic growth along with environmental protection, further indicating how availability enhances the relationship between the economic and environmental pillars of sustainability.

#### *2.1.3.6. Supporting Green Technologies and Industries*

Local and global goals of sustainable development can be achieved by implementing green technology, which plays a crucial role in mitigating the negative impacts of economic development model (Guo et al., 2020). Implementation and expansion of green practices in technology and industry are usually encouraged by the large availability of sustainable resources (Govindan & Hasanagic, 2018). Adoption of these green technologies result in the reduction of the environmental impact by different sectors, job creation, and economic growth (Ghisetti & Quatraro, 2017; Guo et al., 2020). It further emphasizes the availability of renewable and sustainable resources for effectively refining the relationship between the environmental and social pillars of sustainability.

### *2.1.3.7. Fostering Corporate Social Responsibility (CSR)*

No one can deny the prominence of CSR in sustainable development. From the perspective of the public, revenue, and planet, businesses can thrive by becoming more sustainable (Wilson & Post, 2011). CSR is capable of giving a competitive advantage to a business however it can be difficult to implement it as it requires sources like finances, humans, and time (Susnienė & Žostautienė, 2016). Companies that are socially responsible, pay heed towards environmental conservation and prioritize the use of sustainable resources (Tai & Chuang, 2014). The reputation of a company improves when it focuses on CSR. The company can improve its market share and attract customers that are environmentally conscious by focusing on CSR (Crifo & Forget, 2014). Therefore, effective CSR adherence through the availability of the required resources can simultaneously benefit the economy, and environmental aspects of business operations, leading towards strategically achieving sustainability.

### *2.1.3.8. Mitigating Climate Change Impacts*

The impacts of climate change can be reduced by using renewable sources of energy like hydro, solar, and wind readily available (Owusu & Asumadu-Sarkodie, 2016). Switching to low-carbon emissions and renewable sources of energy results in the creation of economic opportunities in the green energy sector and it also benefits the environment greatly (Ntanos et al., 2018; Yuan et al., 2022). Balancing economic growth with resource conservation and environmental preservation are very important for attaining sustainable development (Gough, 2018). A synergetic connection between the environmental and economic aspects of sustainability can be established by ensuring the availability of ecosystem services and natural resources. This helps in creating a future that is full of prosperity and resilience.

## **2.2. UNDERSTANDING SYSTEM DYNAMIC MODELING**

The primary role of the System Dynamic Model (SDM) is to effectively analyze and understand complicated and complex mechanisms and systems over the passage of time (Zhang et al., 2014). It has been dominantly effective and efficient in analyzing systems that incorporate non-linear interactions and relationships, feedback loops, and systematic time delays (Rad et al., 2015). SDMs are primarily used to provide a simulated insight into the interaction between adverse set of variables within a complex system and their influence on each other, further incurring a change in the behavior of the system under analysis over the course of time. Furthermore, SDMs are visually represented in accordance with the use of stock-and-flow diagrams, i.e., representing movements (flows) and accumulation (stock) of different quantities within the complex system (Black, 2013). Henceforth, it enables us to identify the dynamic behavior of variables and their influence on each other, further providing an understanding of the changing system behavior under study.

### *2.2.1. SDM and Sustainability*

The role of SDM in the contemporary context of sustainability can be regarded as highly effective and efficient (Honti et al., 2019). The following sub-sections shed light on the role of SDMs in understanding and achieving Sustainable Development Goals (SDGs). System dynamics modeling offers a unique and advantageous approach to understanding and achieving Sustainable Development Goals. It allows for the analysis of complex systems, incorporating non-linear interactions, feedback loops, and time delays.

#### *2.2.1.1. Feedback Loops and Complex Systems*

Sustainability offers a complex interaction between a variety of interconnected variables and factors that directly or indirectly affect each other (Liu et al., 2015). SDMs can be effectively utilized for thoroughly indicating and simulating these complex interactions and feedback loops between interconnected variables, and lead to a better insight into understanding their impact on the system's behavior (Stave, 2010). Therefore, SDMs provide an effective understanding of the unintended implications, effects, and consequences of policies, decisions, factors in understanding sustainability.

#### *2.2.1.2. Long-Term Perspective*

SDGs are focused on long-term orientation and entail the concepts of sustainability that focus on the long-term well-being of society and the environment (Bobylev & Solovyeva, 2017). SDMs can effectively simulate complex interactions and interrelationships amongst various factors and indicate the evolution of the system's behavior over time, enabling insight into long-term implications of strategies and policies pertaining to sustainability (Ullah, 2008; Varga et al., 2020; Moran et al., 2022). Henceforth, SDMs can be fruitful in simulating the long-term implications of intertwined factors across sustainability paradigms and provide a better pragmatic understanding of effective, sustainable development.

#### *2.2.1.3. Scenario Testing and Policy Analysis*

The ability to simulate complex systems with intensive interrelationships between different factors enables SDMs to virtually test policy and strategy interventions to achieve sustainability prior to practical implementation (Wu et al., 2021). The simulation ability of SDMs is integral in providing a promising field for developing and testing diverse scenarios with regard to sustainability policies (Bastan et al., 2018). It enables significant improvement in decision-making and policy development by thoroughly analyzing and examining the outcomes of different variations in the interconnected factors pertaining to sustainability in the spectrum of the system under consideration. It provides strategic oversight to decision-makers in understanding the strategic dynamics and implications of the policy intervention and the possibility of enhancing their efficiency in better

implementation of sustainability. Henceforth, the role of SDMs in effective Scenario testing and policy analysis are integral to effective sustainability.

#### *2.2.1.4. Leverage Point Identifications*

It is pertinent to mention that the simulating ability of SDMs can be effective in identifying focal points where small changes can create long-term and significant implications for behavioral change in the system (Egerer et al., 2021). Furthermore, it is these “leverage points” that are instrumental in making strategic decisions that empower stronger and more promising prospects for achieving sustainability and effectively achieving the SDGs. Therefore, SDMs are effective in identifying these leverage points to make effective, efficient and robust policy interventions to ardently achieve sustainability.

#### *2.2.1.5 Holistic Understanding*

The reality of sustainability is entailed across trans, inter, and cross-disciplinary disciplines that encapsulate a diverse and wide array of factors from environmental, social, and economic paradigms (Becker et al., 2015). SDMs are known to simulate the interactions between these factors in a holistic manner, enabling an in-depth analysis of the interactions between these factors and their influence on each other, further impacting the overall system’s behavior (Kotir et al., 2016). Henceforth, SDMs enable a holistic overview of the concept of sustainability and provide an effective, pragmatic, and in-depth insight into the concept of sustainability.

#### *2.2.1.6. Public Engagement*

SDMs can be regarded as one of the most effective approaches to communicating complicated and complex sustainability problems and complications to stakeholders, policymakers, and the general public (Sahin et al., 2016). The visual representation through the use of stock-and-flow diagrams enables a promising ability to understand the causal implications of different policy interventions and their respective impacts on the system’s overall behavior (Videira & Antunes, 2016). Therefore, visualization of the complex system of sustainable development enables a systematic understanding of the factors involved and plays a prominent role in developing robust policy interventions to achieve sustainability in its true essence.

The intricate and interconnected nature of sustainability presents a multifaceted challenge for organizations aiming to incorporate sustainable practices into their strategic decision-making processes. The insightful discussions on system dynamics modeling in the context of sustainability provide a comprehensive understanding of the complexity and depth of sustainable development goals. Expanding on the relationship between feedback loops and complex systems, the utilization of SDMs allows for a thorough examination of interconnected variables and their impact on system behavior. This analysis provides a nuanced understanding of the unintended consequences of policies and decisions, highlighting the intricate web of cause and effect within sustainability frameworks. Moreover, the long-term perspective embedded in the SDGs necessitates a robust

evaluation of the evolving system behavior over time. SDMs emerge as valuable tools for simulating the long-term implications of sustainability strategies.

The interconnected nature of different factors and their impact on sustainable development paradigms. Furthermore, the ability of SDMs to virtually test policy interventions offers a strategic advantage, enabling decision-makers to analyze and examine the outcomes of diverse sustainability scenarios. This facilitates informed decision-making and policy development, enhancing the efficiency of sustainability initiatives. In addition, the identification of leverage points through SDMs is crucial for making strategic decisions that foster significant and enduring behavioral changes within the system. By utilizing SDMs, policymakers can identify key leverage points where targeted interventions can exert the most substantial impact on system behavior, leading to positive and sustainable outcomes.

#### *2.2.1.7. Adaptive Management*

The process of sustainability is continuous and systematically requires an adaptive management approach (Schultz et al., 2015). SDMs can be effectively refined in the advent of newly available data, providing a systematic opportunity to refine policy interventions and strategic decision-making to foster sustainable development in a robust and ardent manner. This adaptive management approach allows for agility and flexibility in addressing emerging challenges and adjusting sustainability strategies accordingly. Moreover, the iterative nature of SDMs and their ability to incorporate new data enable decision-makers to continuously refine and update policy interventions.

### **2.3. Hypotheses**

On the basis of the aforementioned literature review, it can be effectively stated that the three pillars of Sustainability can be effectively achieved and viewed through a more robust lens and approach, i.e., affordability, adaptability, and availability. These three A's can be instrumental in fortifying the interrelationships between the social, economic, and environmental domains of sustainability. Therefore, the following hypotheses were developed:

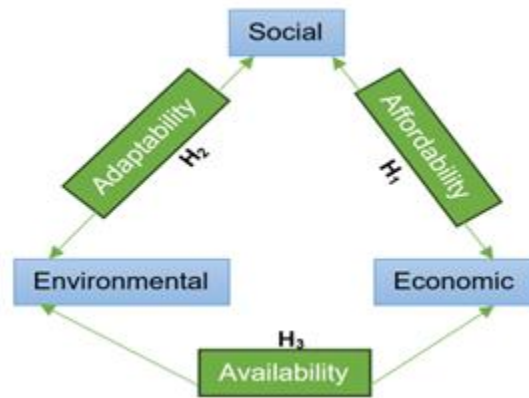
**H1:** The relationship between the social and economic pillars of sustainability can be strengthened by affordability.

**H2:** The relationship between the social and environmental pillars of sustainability can be strengthened by adaptability.

**H3:** The relationship between the economic and Environmental pillars of sustainability can be strengthened by availability.



## 2.4. Conceptual Framework



*Figure 1 1 Conceptual Framework of the "AAA Model of Sustainability" (Author's Own Work, 2023)*

### **CHAPTER 3: RESEARCH METHODOLOGY**

The research methodology for this study adopts a mixed-methods paradigm, incorporating qualitative research method including both primary data and secondary data. It gives a broad yet in-depth exploration of the subject matter. The methodology used comprises two phases: data extraction from literature review and conducting semi structured interviews. The study was effectively focused on the implementation of the Systems Dynamic Model (SDM) for effectively assessing the relationships between the three pillars of sustainability through affordability, adaptability, and availability. Nevertheless, Systems Dynamics Model has already been discussed in detail with regard to its role in assessing the relationships of affordability, adaptability, and availability in reinforcing sustainability. The study was focused on developing the inflows and outflows of different factors that were related to affordability, adaptability, and availability whilst assessing their implications in influencing sustainability. It is pertinent to knowledge that Systems Dynamic Models (SDMs) have been highly efficient and effective in understanding sustainability in contextual and contemporary aspects (Honti et al., 2019). Zhang et al. (2014) have indicated the importance of SDMs in assessing and analyzing complicated, complex, and intricate systems and mechanism in a dynamic time domain. Furthermore, Rad et al. (2015) indicated that SDMs have been an efficient approach to analyzing systems that are thoroughly involving feedback loops, non-linear engagements, interactions, and relationships, and intricate systematic time delays. Their ability to visually simulate interactions and interfaces between a variety of variables inside an intricate system and their implications on each other, further inducing a change in the behavioral properties of the systems enable a comprehensive analysis of the system understudy in a dynamic time domain. Furthermore, SDMs have been widely used to assess the role of affordability, adaptability, and availability, in their individual domains across a variety of studies. Bastan et al. (2018) applied System Dynamics Model to effectively assess agricultural sustainability through simulated approaches for efficient decision-making with regard to adaptability. Likewise, Mareeh et al. (2022) applied System Dynamics Model to evaluate the profitability and sustainability of Malaysian crude oil supply chains by simulating a variety of variables across the complex system. In this manner SDM was used to assess the affordability aspect with regard to sustainability. Similarly, Pallant & Lee (2017) assessed the efficiency and sustainability of agricultural land management systems through the use of SDM and provided key insights with regard to the availability variable. In this manner, it can be seen that SDMs are highly effective in analyzing sustainability through affordability, adaptability, and availability in a complex, dynamic, complicated, and intricate system. For these reasons, SDM was applied to analyse the three pillars of sustainability with regard to affordability, adaptability, and availability. Nevertheless, the application of System Dynamics Model for this study was subsequently based on an effective and extensive literature review of peer-reviewed sources to ensure reliability, authenticity, and credibility of the results.

### **3.1 Literature Review and Hypothesis Formulation**

The first phase of the study uses extensive literature review from diverse sources including academic journals, books, and reports, focusing on topics revolving around sustainability, system dynamics, and policy interventions. Based on the literature review, the study formulates hypotheses regarding the effectiveness of system dynamics modeling in analyzing sustainability, specifically in terms of affordability, adaptability, and availability. It is evident from the extensive literature review that the application of System Dynamics Models in analyzing sustainability through the lenses of affordability, adaptability, and availability has been a prevalent and effective approach in various domains. The use of SDMs to virtually test policy interventions and scenarios has undoubtedly provided decision-makers with a strategic advantage, offering them the opportunity to assess and examine the outcomes of diverse sustainability strategies. This systematic approach to decision-making and policy development, based on the insights derived from SDMs, can significantly enhance the efficiency and long-term impacts of sustainability initiatives. Moreover, the identification of leverage points through SDMs is crucial in strategically fostering enduring behavioral changes within complex systems. By pinpointing these leverage points, policymakers can implement targeted interventions that yield substantial impacts on system behaviors, leading to positive and sustainable outcomes. The continuous and adaptive nature of sustainability necessitates an adaptive management approach, as highlighted in the literature by Schultz et al. In this context, SDMs can be refined and updated based on new data, providing a systematic opportunity to adjust policy interventions and strategic decision-making in a responsive and robust manner. The developed hypotheses regarding the strengthening of interrelationships between the social, economic, and environmental pillars of sustainability through affordability, adaptability, and availability resonate deeply with the findings of the literature review. The efficacy of System Dynamics Models in assessing and analyzing complex systems underscores the significance of the proposed conceptual framework of the "AAA Model of Sustainability." Moving forward, the research methodology, encompassing a mixed-methods paradigm, aligns with the comprehensive exploration required for the study. The integration of qualitative and quantitative research methods offers a nuanced understanding of the subject matter, providing a robust foundation for implementing the System Dynamics Model in assessing the relationships between the pillars of sustainability. The literature review and the subsequent formulation of hypotheses serve as a solid grounding for the study's research design, and it is evident that the extensive scholarly sources have contributed to shaping a thorough understanding of the significance of SDMs in sustainability analysis and decision-making. Now, the study can delve into the practical application of SDMs in the context of affordability, adaptability, and availability to strengthen sustainability, drawing upon the rich insights and empirical evidence presented in the literature review.

### **3.2 Interviews**

The second phase of this study involved conducting semi-structured interviews with individuals representing diverse fields associated with sustainability. The objective of these interviews was to assess the effectiveness of affordability, adaptability, and availability in

the context of sustainability, utilizing system dynamic modeling. The individuals selected for the interviews possessed expertise in social, economic, and environmental aspects of sustainability, thereby ensuring a comprehensive assessment of the three pillars of sustainability. The semi-structured nature of the interviews allowed for a flexible yet focused approach, ensuring that relevant themes and insights pertaining to the effectiveness of affordability, adaptability, and availability in sustainability were adequately explored. The interviews aimed to elicit in-depth perspectives and experiences, providing a rich understanding of the interrelationships between these pillars and the broader implications for sustainable development. Following the interviews, a rigorous process of data analysis was undertaken to comprehensively assess the insights gathered and derive meaningful conclusions. The interview results were systematically analyzed, both thematically and statistically, to discern patterns, trends, and correlations. Thematic analysis allowed for the identification of recurring themes and key points emerging from the interviews, providing qualitative insights into the perceptions and experiences of the participants. On the other hand, statistical analysis facilitated quantitative assessment, enabling the examination of relationships and associations between variables related to affordability, adaptability, availability, and their impact on sustainability. The utilization of system dynamic modeling in conjunction with the insights obtained from the interviews facilitated a holistic evaluation of the complex interplay between these critical factors and their implications for sustainability. By integrating qualitative perspectives from the interviews with the quantitative insights derived from system dynamic modeling, this study aimed to provide a comprehensive understanding of the effectiveness of affordability, adaptability, and availability within the sustainability paradigm. Moreover, the integration of system dynamic modeling allowed for the virtual testing of policy interventions, enabling a strategic analysis of diverse sustainability scenarios. This approach empowered decision makers to simulate and evaluate the outcomes of potential policy interventions, fostering informed decision-making and enhancing the efficacy of sustainability initiatives. In conclusion, the semi-structured interviews with experts in various domains of sustainability, along with the subsequent thematic and statistical analysis, provided valuable insights into the intricate relationships between affordability, adaptability, availability, and sustainability. The systematic integration of qualitative and quantitative analysis, supported by system dynamic modeling, has the potential to yield impactful conclusions and recommendations for advancing sustainability practices and policies. The combination of qualitative and quantitative data analysis, supported by system dynamic modeling, enabled a comprehensive evaluation of affordability, adaptability, availability, and their impact on sustainability.

### **3.3 Interviews Analysis**

Upon reviewing the existing data, a set of factors was created to analyze the themes and patterns in the interview-based primary data. The alignment of these factors with the primary data will support our research efforts to integrate the AAA framework through an SDM approach, aiming to bridge sustainability across three pillars. These pillars include economic, environmental, and social aspects, all of which are crucial for achieving sustainability in a holistic manner. The use of system dynamic modeling in this research

facilitated a comprehensive evaluation of the interplay between affordability, adaptability, and availability within the sustainability paradigm.

S No	Factors
1.	Ability to absorb disturbance
2.	Adaptability
3.	Adaptive capacity
4.	Affordability
5.	Availability
6.	Community engagement
7.	Community networks
8.	Consumption of goods and services
9.	Costs of goods & services
10.	Development & enhancement
11.	Ecological diversity & resilience
12.	Economic condition
13.	Economic development
14.	Education & community engagement
15.	Environmental degradation
16.	Environmental management
17.	Equity & social justice
18.	Essential goods & services
19.	Governance & policies
20.	Human well being
21.	Income
22.	Income & employment
23.	Income support program
24.	Learning & innovation
25.	Natural resources
26.	Preserving ecosystems
27.	price control
28.	Rate of development & enhancement
29.	Resource regeneration
30.	Social development
31.	Social innovation and empowerment
32.	Social well being
33.	sustainable development
34.	Sustainable govt policies
35.	Sustainable lifestyle
36.	Sustainable resource management
37.	Technological advancements

*Table 3 1 Factors (Author's Own Work, 2023)*

### **3.4 Data Analysis**

Both the quantitative data from the literature review and the qualitative data from the interviews are integrated and analyzed parallelly. The insights drawn from the analysis form a comprehensive comprehension of the dynamics of systems approach to sustainability. This mixed-methods approach benefits from the strengths of both qualitative and quantitative research, providing a well-rounded perspective of the research problem. It allows for an in-depth understanding of the topic while also offering empirical evidence to support the hypotheses. The combined use of qualitative and quantitative data analysis techniques in this study contributes to a more robust understanding of the factors and implications for sustainability. The integration of qualitative and quantitative data in this research enhances the understanding of sustainability by providing a comprehensive evaluation of affordability, adaptability, availability, and their effect on sustainability. This holistic approach to data analysis enables a deeper exploration of complex research problems, allowing for the identification of patterns, relationships, and trends that may not be apparent through a single methodological approach.

### **3.5 Data Validity And Reliability**

To increase the reliability of the research, a rigorous review of the data collection and analysis methods was carried out frequently. The constant comparative method is applied to ensure that interpretations remain consistent throughout the study. In terms of validity, the research employs triangulation by using multiple data sources, i.e., the literature review and interviews. Triangulation enhances the validity by cross verifying the findings from different data sources. Integration of qualitative and quantitative data analysis in this study allows for a more comprehensive understanding of the dynamics of sustainability. By integrating qualitative and quantitative data analysis methods, this research significantly enhances the validity and reliability of the findings. The integration of qualitative and quantitative data analysis methods in this study provides a robust and comprehensive analysis of the dynamics of sustainability, increasing the validity and reliability of the research findings. This integration also helps in addressing any potential biases or limitations of a single method, as the strengths of one method can compensate for the weaknesses of another. By incorporating both qualitative and quantitative data, the research aims to minimize bias and strengthen the validity and reliability of the findings. Overall, the use of qualitative and quantitative methods in this study contributes to a more robust understanding of sustainability by providing comprehensive evaluations, identifying patterns and relationships, and enhancing the validity and reliability of the findings.

### **3.6 Research Limitations And Ethical Considerations**

All research methodologies have certain limitations; acknowledging these limitations can increase the credibility of the findings. Possible limitations of this methodology might include sample size of the interviewees and potential bias in the literature review. Furthermore, ethical considerations are fundamental to this research. All participants in the interviews will provide informed consent, and the confidentiality and anonymity of their responses will be ensured. The researcher has adhered to ethical guidelines regarding data

collection, analysis, and reporting to protect the rights and privacy of participants. As a postgraduate student conducting this research for your thesis, it is essential to address the ethical considerations that have been taken into account throughout the entire research process. It is pertinent to mention, ethical considerations are fundamental in ensuring the integrity and credibility of the research. It is imperative that all participants in the interviews have provided informed consent, and measures have been taken to guarantee the confidentiality and anonymity of their responses. This is crucial in upholding the rights and privacy of the participants, demonstrating respect for their autonomy and ensuring that their contributions are valued and protected. Furthermore, ethical guidelines have been strictly adhered to regarding data collection, analysis, and reporting. This includes ensuring that the data is handled and stored appropriately, following ethical standards to prevent data breaches, and maintaining the highest level of integrity throughout the research process. Additionally, it is important to acknowledge the limitations of the research methodology. By openly addressing these limitations, such as sample size and potential bias in the literature review, the research aims to increase the transparency and credibility of the findings. An honest and transparent discussion of the limitations serves to demonstrate the researcher's commitment to ethical and rigorous research practices. By carefully considering and integrating ethical principles into your research, you demonstrate a commitment to upholding the highest standards of integrity, confidentiality, and respect for the participants. This ensures that the research not only yields valuable insights but also contributes to the advancement of knowledge in a responsible and ethical manner.

### **3.7 Research Implications**

The findings of this research have significant implications for both academia and practice. In academia, this research highlights the importance of incorporating ethical considerations into research methodologies and processes. This underscores the need for researchers to not only focus on obtaining valid and reliable data, but also to prioritize the protection and well-being of research participants. Additionally, the findings underscore the importance of transparency and rigor in research practices, as well as the need to address and acknowledge limitations. Through this mixed-methods approach, this study aims to contribute meaningfully to the current body of knowledge on the System Dynamics modeling approach to sustainability. The findings of this research could have implications for policy makers, decision makers, and sustainability practitioners, providing them with new perspectives and insights to incorporate into their practices. The results are also hoped to stimulate further research in this area. By employing a mixed-methods triangulation design, this research ensures a comprehensive and thorough analysis of the system dynamics approach to sustainability.

## CHAPTER 4: DATA ANALYSIS AND RESULTS

The data analysis was based on the comprehensive review of existing literature by the researcher, and it was further supported by the interview results and by using the System Dynamics Model. The in-depth analysis of the literature provided compelling insights into understanding the role of adaptability, affordability, and availability in strengthening the relationship between the three pillars of sustainability. Nevertheless, the findings of the data gathered data are provided in tabulated forms, i.e., Table 1, Table 2, and Table 3 for adaptability, affordability, and availability with relevant inflows and outflows as per the SDM illustrations.

The research methodology included a triangulation approach, combining qualitative and quantitative methods, to ensure the accuracy and validity of the findings (Akkad et al., 2023). The results of the data analysis revealed a strong correlation between adaptability, affordability, and availability in enhancing the overall sustainability of the system. Therefore, the System Dynamics modeling approach can be an effective tool for achieving sustainability goals by considering these three factors in a holistic manner. The findings suggest that incorporating adaptability, affordability, and availability into sustainability strategies can lead to a more resilient and effective system. Furthermore, the analysis showed that the System Dynamics modeling approach provides valuable insights into the interdependencies and feedback loops within the system, allowing for a better understanding of how changes in one aspect of the system can impact other aspects, and ultimately, the overall sustainability (Liu et al., 2023). By employing a system dynamics approach, this study not only provides valuable insights into the interdependencies and feedback loops within a complex system but also highlights the importance of considering adaptability, affordability, and availability as crucial factors in achieving sustainability. Additionally, the findings demonstrate the effectiveness of the System Dynamics modeling approach in analyzing and addressing sustainability challenges. The dynamic nature of sustainability necessitates ongoing adaptations to improve the model, as highlighted by the Dynamic Sustainability Framework (Dombrowski et al., 2023). The dynamic modeling approach, such as System Dynamics, provides a valuable tool for understanding and addressing sustainability challenges (Aasa et al., 2020). It allows for the characterization and representation of complex feedback interactions, nonlinearity, delays, and causality within the system. By adopting a system dynamics approach, researchers and practitioners can capture the dynamic nature of sustainability challenges, including feedback loops and causality, enabling a deeper understanding of the underlying dynamics and complex interconnections at play. In conclusion, the System Dynamics modeling approach is a valuable tool for analyzing and addressing sustainability challenges (Tirado et al., 2015).

### 4.1. Adaptability

The role of adaptability in strengthening the relationship between the social and environmental pillars of sustainability can be seen in Table 1 and Figure 2. Figure 2 categorically indicates that resilience act as a prominent inflow with regard to the Systems Dynamic Modelling approach to analyze the relationship between the social and environmental aspects of sustainability. It is pertinent to acknowledge that Table 1 indicates the tabulated form of Figure 2. Table 1 shows that both social resilience and



ecological resilience are prominent variables as inflows for the SDM of adaptability. Nevertheless, social resilience is further fueled by adaptive capacity, community networks, development & enhancement, knowledge acquisition, and social innovation and empowerment. It can be effectively stated that these factors are instrumental in developing a robust social resilience that acts as a positive inflow for adaptability for strengthening the relationship between the social and environmental pillars of sustainability, as shown in Figure 2.

Similarly, ecological resilience is further driven by the ability to absorb disturbance in the natural ecosystem, rate of development and enhancement across the society, governance & policies, sustainable lifestyles, effective environmental management, and taking necessary steps to preserve the ecosystems. It is further notable to quote that development & enhancement rate of the society will act as a negative inflow, whereas the rest of the factors will act as positive inflows for adaptability for strengthening the relationship between the social and environmental pillars of sustainability, as shown in Figure 2.

Figure 2 also indicates outflows for the SDM of adaptability with regard to sustainability, as shown in Table 1 in tabulated form. It can be seen that green actions are the prominent outflows and are influenced by notable factors like sustainable resource management, human well-being, ecosystem preservation, learning & innovation, sustainable lifestyles, environmental management, community management, social innovation & empowerment, and governance & policies. These factors are pivotal in driving green actions as a prominent outflow variable when considering the SDM of adaptability for strengthening the relationship between the social and environmental pillars of sustainability.

Therefore, the dynamic relationship between social and environmental aspects of sustainability relies on factors such as social resilience, ecological resilience, adaptive capacity, community networks, knowledge acquisition, social innovation, empowerment, sustainable resource management, governance and policies, ecosystem preservation, and green actions. These factors mutually reinforce each other and contribute to the overall adaptability and resilience of socio-ecological systems, which are essential for achieving sustainability goals. The dynamic relationship between social and environmental aspects of sustainability relies on factors such as social resilience, ecological resilience, adaptive capacity, community networks, knowledge acquisition, social innovation, empowerment, sustainable resource management, governance and policies, ecosystem preservation, and green actions. This dynamic relationship between social and environmental aspects of sustainability is crucial for enhancing adaptability and resilience in socio-ecological systems. These factors interact and influence each other, creating a feedback loop that strengthens the adaptability and resilience of socio-ecological systems. It can be concluded that the development and enhancement rate of society, as well as factors such as sustainable resource management, human well-being, ecosystem preservation, learning & innovation, sustainable lifestyles, environmental management, community management, social innovation & empowerment, and governance & policies have a direct impact on the green actions and overall sustainability of a system.

<b>Adaptability</b>
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Inflows			
Variables		Factors	Impact
Resilience	Social resilience	Adaptive capacity	+
		Community networks	+
		Development & enhancement	+
		Knowledge acquisition	+
		Community engagement	+
		Social innovation and empowerment	+
	Ecological resilience	Ability to absorb disturbance	+
		Rate of development & enhancement	-
		Governance & policies	+
		Sustainable lifestyles	+
		Environmental management	+
		Preserving ecosystems	+
Outflows			
Green actions	Sustainable resource management	+	
	Human well being	+	
	Preserving ecosystems	+	
	Learning & innovation	+	
	Sustainable lifestyles	+	
	Environmental management	+	
	Community engagement	+	
	Social innovation and empowerment	+	
	Governance & policies	+	

*Table 4 I* SDM of Adaptability w.r.t. Social & Environmental Pillars of Sustainability (Author's Own Work, 2023)

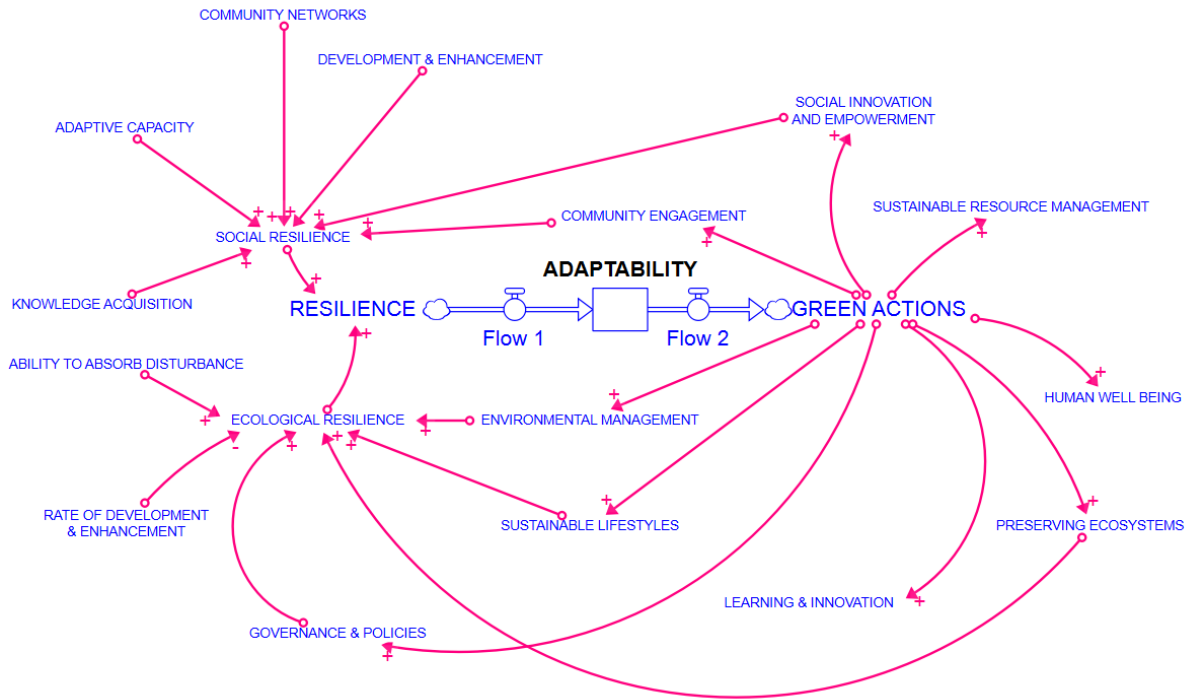


Figure 4 1 SDM of Adaptability w.r.t. Social & Environmental Pillars of Sustainability (Author's Own Work, 2023)

### Equation for Adaptability

$$\frac{d(\text{Adaptability})}{dt} = \text{Adaptability} + \frac{d(\text{Resilience})}{dt} - \frac{d(\text{Green Actions})}{dt}$$

### 4.2. Affordability

In order to assess the interaction between the social and economic dimensions of sustainability, Figure 3 succinctly shows that resource availability acts as a significant inflow. It is important to note that Table 2 exhibits Figure 3 in tabular form. Table 2 demonstrates the importance resource conversion, sustainable government policies, economic resources, and social development as inflows for the SDM of affordability. Whereas, demand, expenditure, economic resources, price inflations, and social development act as effective secondary variables with primary variable as income as an outflow for the SDM of affordability.

It can be seen from Figure 3 and Table 2 that resource conservation is effectively influenced by a key factor of having robust government policies that are focused on sustainability and are sustainable too. Furthermore, sustainable government policies are further affected by equity & social justice, robust price control, and income support programs to foster socio-economic growth. Similarly, economic growth is further influenced by a key factor, i.e., income & employment. It is paramount to understand that all these factors positively influence the inflow of the SDM of affordability with regard to the social and economic aspects of sustainability. Likewise, it can be seen from Figure 3

and Table 2 that social development is also influenced by key factors, i.e., income, essential goods & services, and cost of goods & services. However, it is noticeable to mention that the former two factors are positively, whereas the latter is negatively influencing the inflow of SDM of affordability with regard to the social and economic aspects of sustainability.

Figure 3 also illustrates the outflows of affordability with regard to the social and economic aspects of sustainability, as tabulated in Table 2. It can be clearly seen that income acts as the primary variable of the outflow of affordability with regard to the social and economic aspects of sustainability. Furthermore, the secondary variables, i.e., demand of resources positively influences the outflow. Similarly, expenditure is further impacted by key factors, i.e., essential goods & services. Likewise, economic resources are influenced by a factor, i.e., income & employment. Additionally, price inflation is influenced by key factors, i.e., cost of goods & services, price control regulations, and economic conditions. Lastly, social development is influenced by essential goods and services. All these factors act as a positive outflow in establishing the overall outflow of SDM of affordability with regard to the social and economic aspects of sustainability. The analysis highlights the interconnectedness of various factors in influencing the affordability of sustainable development.

Affordability			
Inflows			
Variables		Factors	Impact
Available resource	Resource conservation	Sustainable govt policies	+
	Sustainable govt policies	Equity & social justice	+
		Price control	+
		Income support program	+
	Economic resources	Income & employment	+
	Social development	Income	+
		Costs of goods & services	-
		Essential goods & services	+

Outflows				
Income	Demand		+	
	Expenditure	Essential goods & services	+	
	Economic resources	Income & employment	+	
	Price inflation	Cost of goods & services		+
		Economic condition		
		Price control		
Social development	Essential goods & services	+		

Table 4 2 SDM of Affordability w.r.t. Social & Economic Pillars of Sustainability (Author's Own Work, 2023)

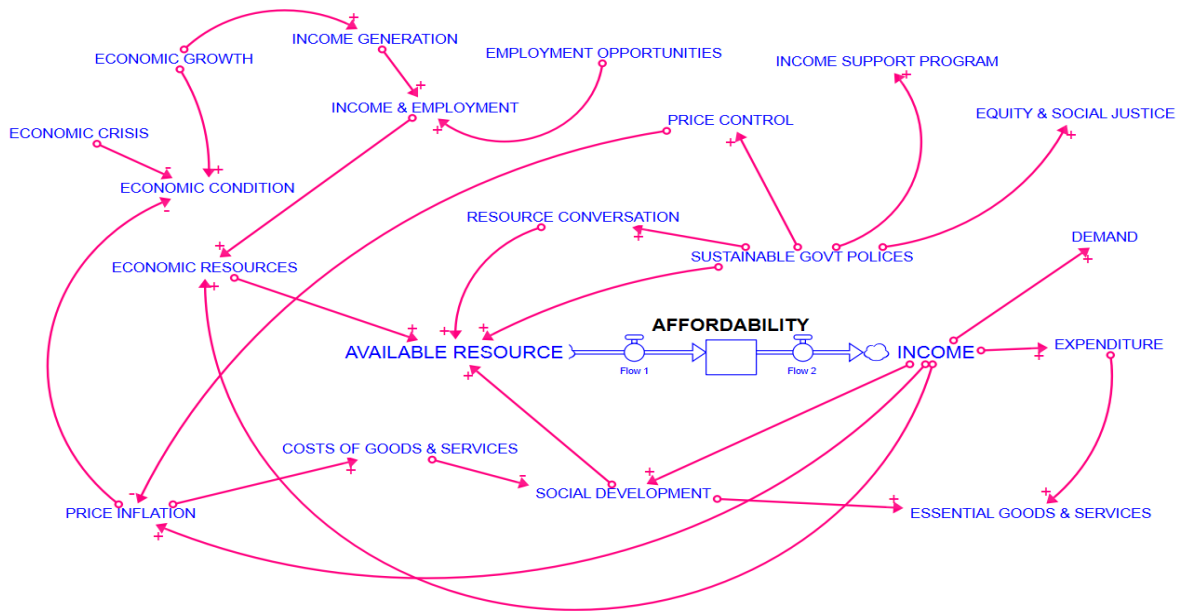


Figure 4 2 SDM of Affordability w.r.t. Social & Economic Pillars of Sustainability (Author's Own Work, 2023)

### 4.3. Availability

Table 3 and Figure 4 show the significance of availability in fostering the bond between the economic and environmental pillars of sustainability. In order to assess the relationship between the economic and environmental dimensions of sustainability, Figure 4 categorically shows that resource availability acts as a significant inflow. It is important to note that Figure 4 is depicted in tabular form in Table 3. Table 3 demonstrates that

resource consumption and availability are important factors acting as an inflow and an outflow for the SDM of availability.

It is imperative to note that Table 3 and Figure depicts a comprehensive insight into the outflows and inflows of availability with regard to the economic and environmental aspects of sustainability. It can be clearly noted that resource availability is the primary variable considering the inflow of availability. It is further influenced by secondary variables, including, natural resources, resource extraction, production of goods & services, social well-being, and imports. Subsequently, all these variables are influenced by notable factors as shown in Table 3. For instance, natural resources are influenced by ecological diversity & resilience and environmental degradation. The former positively, whereas the latter negatively impacts the inflow of affordability with regard to natural resources as a variable. Similarly, resource extraction is further affected by key factors like natural resources and sustainable government policies acting as a positive inflow. Social wellbeing is affected by social development and act as a negative inflow. Whereas, both imports and production of goods & services are also acting as positive inflows for affordability.

Whereas, consumption acts as a primary variable for the outflow of affordability followed by secondary variables including, economic development, waste generation, consumption of goods & services, and social development. Additionally, economic development is affected by a key factor, i.e., social development. Waste generation is influenced by key factors, including, technological advancements and education & community engagement. Consumption of goods & services is affected by social development. Lastly, social development is influenced by economic development, consumption of goods & services, social wellbeing, and resource regeneration, as seen in Table 3 and Figure 4.

Table 3 and Figure 4 provide a comprehensive overview of the inflows and outflows of availability in relation to the economic and environmental aspects of sustainability, highlighting the complex interconnections and influences between various variables. This analysis demonstrates the intricate relationships between availability of resources and various factors, including natural resources, production, consumption, social development, and government policies. The analysis of the inflows and outflows of availability in relation to the economic and environmental aspects of sustainability highlights the complex interconnections and influences between various variables and factors. This understanding can inform policy decisions aimed at promoting sustainable consumption and production, as it emphasizes the need to consider the interplay of economic, environmental, and social factors in order to achieve a balanced and sustainable use of natural resources. The analysis of the inflows and outflows of availability in relation to the economic and environmental aspects of sustainability highlights the complex interconnections and influences between various variables and factors. This understanding can inform policy decisions aimed at promoting sustainable consumption and production, as it emphasizes the need to consider the interplay of economic, environmental, and social factors in order to achieve a balanced and sustainable use of natural resources.

A system dynamic approach is crucial in understanding and addressing sustainability challenges. It allows for the examination of the complex relationships and feedback loops

between economic, environmental, and social factors, and how they interact over time. By using a system dynamic approach, policymakers can better comprehend the long-term consequences of their decisions and the potential impacts on sustainability. This approach takes into account the interdependencies and interrelationships between the three dimensions of sustainability, considering the dynamic nature of these relationships. Furthermore, a system dynamic approach enables the analysis of different scenarios and their potential effects on sustainability. Ultimately, a system dynamic approach to sustainability provides a holistic framework for understanding and addressing the complex challenges we face in achieving sustainable development (Kumar et al., 2017). This approach recognizes that sustainability is not just about individual actions or initiatives, but rather about understanding the complex interactions and dynamics of the entire system.

By considering feedback loops, nonlinearity, and delays within the system, a system dynamics approach to sustainability offers a deeper understanding of the long-term perspective and potential impacts of decisions on sustainability (Aasa et al., 2020). Therefore, it is an appropriate modeling approach for sustainability questions as it allows for the identification of causal relations and feedback dynamics inherent in the system. In conclusion, a system dynamic approach to sustainability recognizes the complex interconnections and interactions between human and environmental systems (Unsal, 2017). Researchers and policymakers can develop a more thorough comprehension of the intricate dynamics that result from interactions between human and environmental systems using tools such as System Dynamics. This understanding is crucial for developing effective strategies and policies that promote sustainability and address the challenges we face in achieving a balanced and sustainable use of natural resources. By incorporating system dynamics into sustainability research and decision-making, policy makers can make more informed choices that lead to positive outcomes for social-ecological systems. Additionally, the system dynamics approach enables the identification of generative structures and causal links within complex systems, providing insights into problem behavior and potential solutions for sustainability.

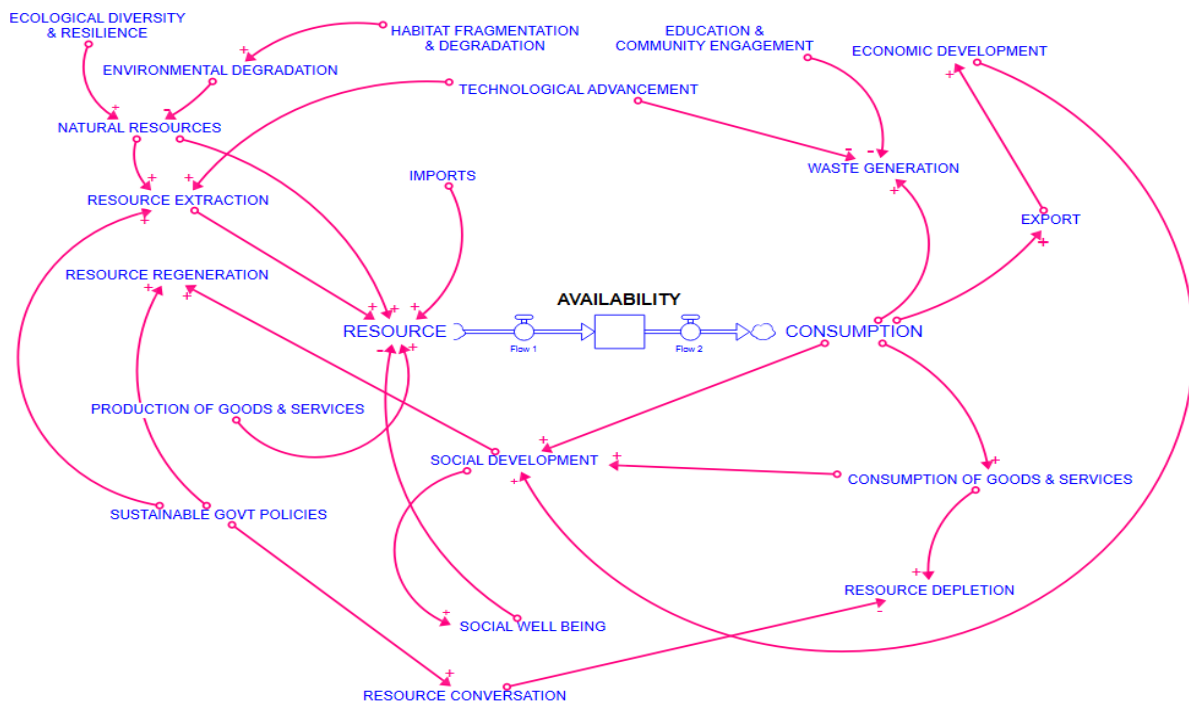


Figure 4 3 SDM of Affordability w.r.t. Environmental & Economic Pillars of Sustainability (Author's Own Work, 2023)

### Equation for Availability:

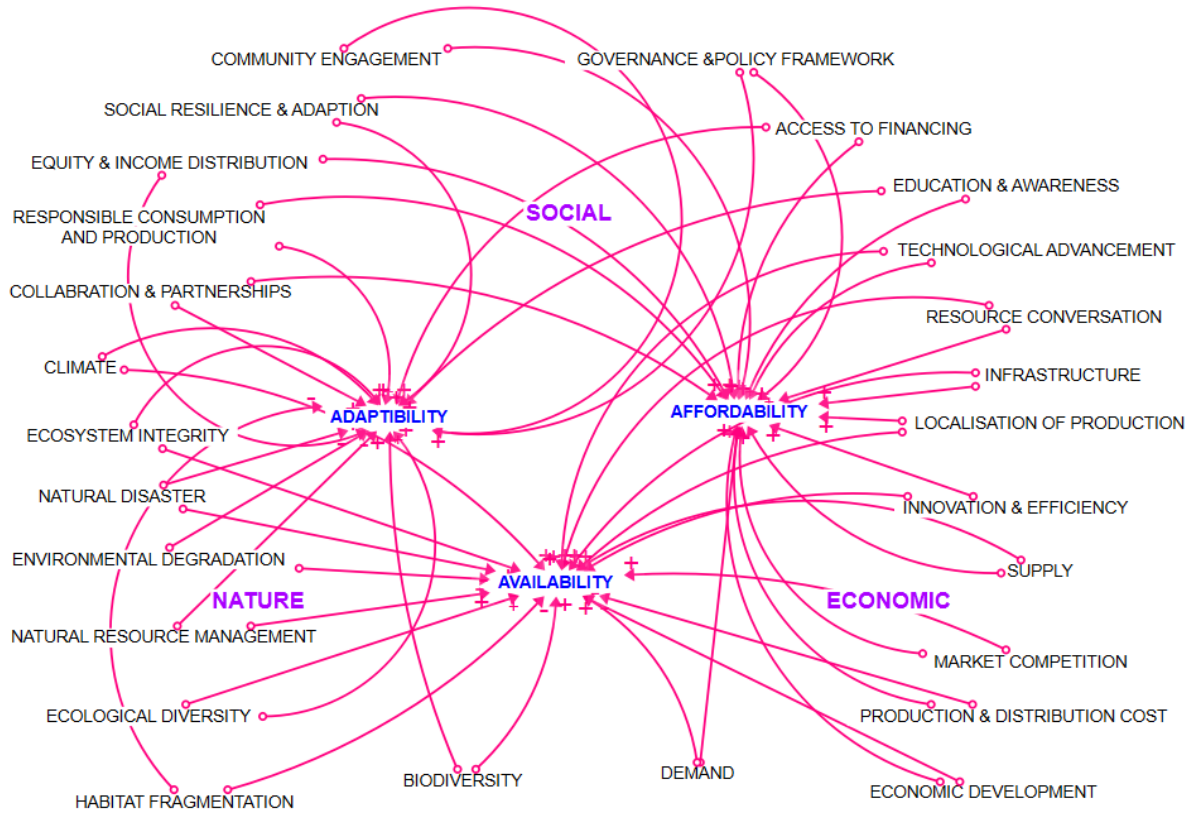
$$\frac{d(\text{Availability})}{dt} = \text{Availability} + \frac{d(\text{Resource Existence})}{dt} - \frac{d(\text{Consumption})}{dt}$$

Availability			
Inflows			
Variables		Factors	Impact
Resource	Natural resources	Ecological diversity & resilience	+
		Environmental degradation	
	Resource extraction	Natural resources	+
		Sustainable govt policies	
	Production of goods and services		+
Social well being	Social development	-	
	Imports		+



Outflows			
Consumption	Economic development	Social development	+
	Waste generation	Education & community engagement	+
		Technological advancement	
	Consumption of goods and services	Social development	+
	Social development	Economic development	+
		Consumption of goods and services	
		Social well being	
		Resource regeneration	

*Table 4 3 SDM of Affordability w.r.t. Environmental & Economic Pillars of Sustainability (Author's Own Work, 2023)*



*Figure 4 4 SDM of Adaptability, Affordability, and Availability w.r.t. Social, Environmental, and Economic Pillars of Sustainability (Author's Own Work 2023)*

It can be seen from Figure 5 that adaptability, affordability, and availability integrate across the entire system in a dynamic manner to strengthen the relationship between the social, economic and environmental aspects of sustainability. Needless to say, it can be effectively seen that the dynamic nature of sustainability paves way for a variety of factors and variables to act as inflows and outflows in illustrating the interaction of the three pillars of sustainability. A detailed insight in lieu with academic justification and reasoning into the findings will be provided in the forthcoming section, i.e., Discussion and Conclusion.

### 4.3 Interview Results And Discussion

The results generated from the analysis of the interview data have provided significant insights into our research topic. Utilizing NVivo software, thematic analysis was executed to identify prominent trends, patterns, and themes across the collected data considering the established factors as discussed earlier. Several key themes were discovered during the coding process. While each theme was unique and offered distinct perspectives, it was clear that many of them overlapped or were interconnected. Understanding these relationships gave us a more holistic picture of the participants' views and experiences. We sought to unpack these complexities, and in doing so, the results presented numerous pathways for our examination. Subsequently, a comprehensive

comparison was conducted between these interview findings and the existing literature in the field. A striking similarity was observed between these two data sources which bolstered the validity of our results and their implications. The existence of commonalities between the interview observations and established scholarship provides a strong, reinforcing narrative about our field of interest.

#### 4.3.1 Adaptability

The findings from the interviews indicated that adaptability is essential for attaining sustainability. Participants consistently highlighted the need for individuals, organizations, and communities to be adaptable in order to address sustainability challenges. The table below shows the outcomes of interview information that aligns with adaptability factors.

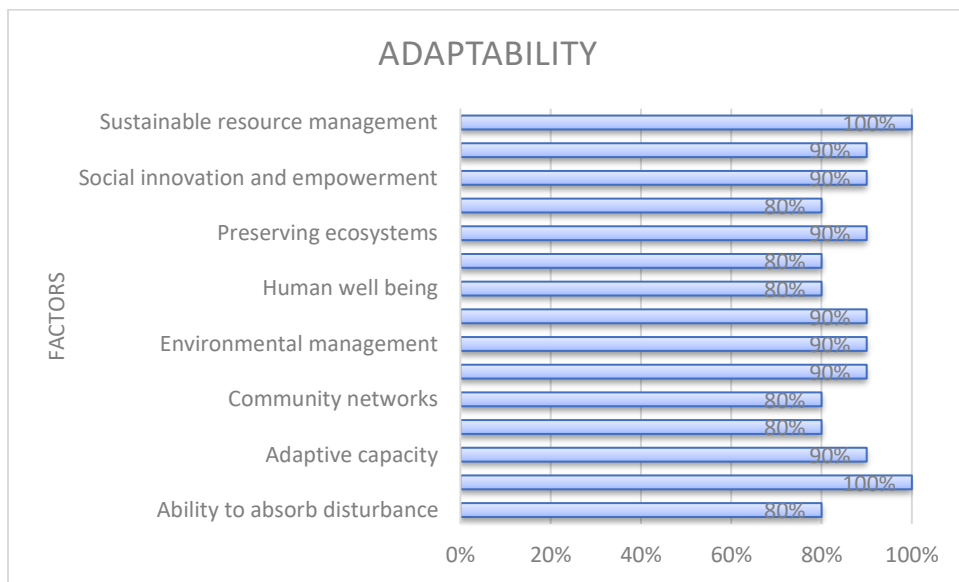


Table 4 4 Adaptability Factors for thematic analysis of interviews (Author's Own Work, 2023)

#### 4.3.2 Affordability

The findings from the interviews revealed that affordability plays a crucial role as the bridge between the social and economic pillars of sustainability. It serves as a pivotal factor in ensuring equilibrium between these two aspects. The table below presents detailed outcomes of interview information, highlighting specific factors relevant to affordability and their impact on sustainability.

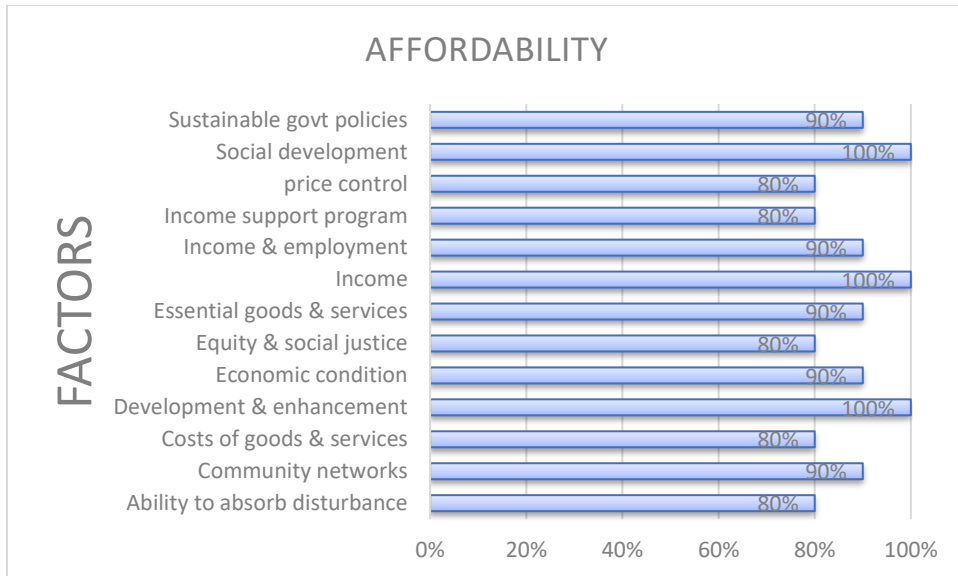


Table 4 5 Affordability Factors for thematic analysis of interviews (Author’s Own Work, 2023)

### 4.3.3 Availability

The results of the interviews underscored the critical importance of ensuring availability in both environmental and economic aspects to achieve sustainability goals. The following table provides a comprehensive overview of the interview findings, shedding light on specific factors related to availability and their influence on sustainability.

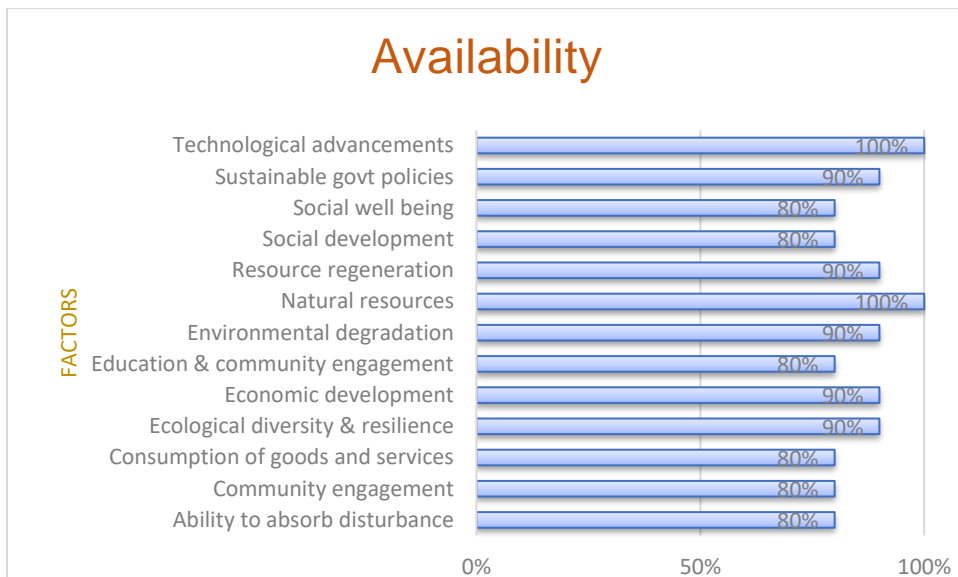


Table 4 6 Availability Factors for thematic analysis of interviews (Author’s Own Work, 2023)

The complementing insights derived from the interviews and literature greatly enriched our understanding of the topic, providing a broad yet nuanced view. Moreover, the convergence of the interview data with the literature review strengthens the reliability of our findings and underscores the relevance of our research. In conclusion, the analysis

of the interview responses has yielded vital perspectives that are in line with the academic literature reviewed. The integration of adaptability, affordability, and availability is crucial for achieving sustainability goals, as highlighted by the findings from the interviews. These findings present a substantial contribution to our understanding of AAA framework, while also offering potential approaches and recommendations for future research in this area. Thus, the alignment of these two data sources has authenticated the research outcomes and provided a compelling narrative around our research objectives.

#### **4.4 Hypotheses Testing And Justifications**

In light of the extensive research and interviews conducted for this thesis work, the following three hypotheses have been formulated:

**Hypothesis 1:** The relationship between the social and economic pillars of sustainability can be strengthened by affordability.

**Hypothesis 2:** The relationship between the social and environmental pillars of sustainability can be strengthened by adaptability.

**Hypothesis 3:** The relationship between the economic and environmental pillars of sustainability can be strengthened by availability.

The hypotheses formulated are rooted in comprehensive research and extensive interviews, which provide a robust foundation for further exploration and analysis. The subsequent sections of this study will present the thorough testing and justifications for these hypotheses, elucidating the definitive outcomes derived from the amalgamation of empirical findings and theoretical frameworks. The completion provided is a coherent and logical continuation of the given sources.

## CHAPTER 5. DISCUSSION, LIMITATION AND CONCLUSION

### *5.1.1. Adaptability*

The importance of adaptability in enhancing the relationship between sustainability's social and environmental pillars has been discussed in the results section through system dynamic modelling. According to the Systems Dynamic Modelling technique implied to understand the interplay between the social and environmental aspects of sustainability, resilience is a significant inflow. Both social and ecological resilience are important elements as inflows into the SDM of adaptability. Adaptive capacity, community networks, development and enhancement, knowledge acquisition, and social innovation and empowerment all contribute to social resilience. It can be effectively argued that these variables contribute to the development of strong social resilience, which works as a positive inflow for adaptability, hence increasing the interaction between the social and environmental pillars of sustainability. The analysis of the interview results has also revealed similar findings. Whereas, ecological resilience is also influenced by the ability of natural ecosystems to absorb disturbance, the rate of development and improvement across society, governance and regulations, sustainable lifestyles, effective environmental management, and taking required efforts to maintain ecosystems.

Environmental adaptability includes the preservation of traditional knowledge and cultural assets (Berkes et al., 2000). Traditional knowledge and cultural legacy are known to possess valuable understanding of sustainable practices (Son et al., 2021). They also contain information on how to establish harmonious relationships with the environment (Ullah et al., 2023). Moreover, providing environmental information and training, disaster preparedness, and sustainable practices (Allen, 2006; van Aalst et al., 2008; Djalante et al., 2013). Individuals' ability to adapt to environmental challenges improves when they are equipped with information and skills, which also improves their social resilience (Allen, 2006; Ansari et al., 2012; Gil-Rivas & Kilmer, 2016). It indicates that social resilience through knowledge acquisition and development & enhancement can befittingly improve adaptability, further fortifying the bond between the social and environmental pillars of sustainability. This conclusion has also been reached through the analysis of interview results.

Global collaborations and partnerships are encouraged by increasing adaptability, which encourages a culture of shared responsibility for dealing with environmental concerns and ensuring a sustainable future for future generations (Waas et al., 2011; Andriollo et al., 2021). Embracing adaptation contributes to a society developing a sustainable and resilient relationship with the social and environmental pillars of sustainability (Dale et al., 2010; Romero-Lankao et al., 2016). It contributes to the long-term well-being of a society and contributes to its prosperity. Nevertheless, adaptability drives technological advancements and social advances (Baker & Mehmood, 2013; Cho & Yi, 2022). New technology and innovative solutions that address environmental concerns increase quality of life and assist social growth (Mohammadian & Rezaie, 2019; Ravazzoli & Valero, 2020; Kassim et al., 2022). Engagement & collaboration among all stakeholders is one of the conditions for adaptation through governmental, indigenous groups, and non-governmental organizations (Akompab et al., 2012; Henstra, 2017). This collaborative technique fosters social cohesiveness and encourages individuals to take an interest in and

engage in processes that influence their lives, such as environmental decision-making (Agyeman & Angus, 2003; Agyeman & Evans, 2004; Mustalahti, 2018). It indicates that social & ecological resilience through adaptive capacity building, community networks, development and enhancement, knowledge acquisition, and social innovation and empowerment can befittingly improve adaptability, further fortifying the bond between the social and environmental pillars of sustainability. In summary, the integration of social resilience and adaptability is crucial for strengthening the bond between the social and environmental pillars of sustainability. This integration allows for a society to effectively cope with external stresses, adapt to changes, and address environmental concerns.

Furthermore, it promotes collaboration and shared responsibility among various stakeholders, leading to collective actions towards a sustainable future. Using a systems dynamics approach, this study aims to assess the interconnectedness of social resilience, adaptive capacity, and environmental sustainability in order to propose strategies for achieving long-term resilience and sustainability. In conclusion, a systems dynamics approach is essential in understanding and addressing the complexity of sustainability. It allows for a comprehensive analysis of the feedback loops, interdependencies, and dynamic relationships between social, ecological, and institutional factors that influence resilience and adaptability in the face of environmental shocks and challenges. In conclusion, a systems dynamics approach is necessary to fully understand the interconnectedness of social resilience, adaptive capacity, and environmental sustainability.

Adaptability allows societies to cope with and recover from environmental disasters (Tompkins & Adger, 2004; Brown & Westaway, 2011; Eriksen et al., 2021). Adaptability also contributes to the preservation of social well-being and the reduction of negative repercussions (Prime et al., 2020). Disasters and environmental degradation have a negative impact on the poor, indigenous peoples, and marginalized communities (Harlan et al., 2015). They are the most disproportionately affected section of society by these disasters (Akter & Mallick, 2013). Adaptability techniques can reduce disaster-related risks and assist these groups in developing the capacity to adjust to environmental changes effectively (Maru et al., 2014; Thomas et al., 2019). Once societies comprehend the changing environmental conditions, they can implement actions to conserve and protect their resources (Tompkins & Adger, 2004; Hallegatte, 2009; Martin et al., 2016; Brown et al., 2022). By adaptation, they can secure the availability of supplies for future generations while also promoting social equality and justice for future generations (Summers & Smith, 2014; Puaschunder, 2016; Cox et al., 2018; Newell et al., 2021). Adaptability leads to the adoption of sustainable lifestyles (Ozarisoy & Altan, 2017). Societies can improve their overall social well-being by embracing eco-friendly practices such as trash reduction, energy conservation, and the use of renewable energy sources (Moon, 2018). It clearly indicates that ecological resilience also adds a stimulating value to social resilience, and both integrate towards improving adaptability to strengthen the bond between the social and environmental pillars of sustainability.

In conclusion, the integration of social, ecological, and institutional factors is crucial for understanding resilience and adaptability in the face of environmental shocks and challenges. The concept of socio-ecological resilience emphasizes the interconnectedness of social resilience, adaptive capacity, and environmental sustainability (Zhang et al., 2022). The interconnectedness of social resilience, adaptive capacity, and

environmental sustainability highlights the importance of integrating social, ecological, and institutional factors in order to understand and As a result, green actions are the most visible outflows and are influenced by significant factors such as sustainable resource management, human well-being, ecosystem preservation, learning and innovation, sustainable lifestyles, environmental management, community management, social innovation and empowerment, and governance and policies. Similar conclusions have also been drawn from the analysis of interview results When evaluating the SDM of adaptability for increasing the relationship between the social and environmental pillars of sustainability, these elements are critical in pushing green actions as a key outflow variable.

### *5.1.2. Affordability*

To examine the relationship between the social and economic components of sustainability, it is demonstrated that resource availability functions as a significant inflow. As inflows for affordability, SDM insights emphasize the importance of resource conversion, sustainable government policies, economic resources, and social development. Whereas, for the SDM of affordability, demand, expenditure, economic resources, price inflations, and social development operate as effective secondary variables, with income as the key variable as seen in the results. To explore the dimension of affordability within the context of sustainability, it is essential to consider the interplay between resource availability, economic factors, and social development in order to create a comprehensive understanding of the affordability aspect of sustainability. In order to fully understand and assess the dimension of affordability within the context of sustainability, it is crucial to take into account the interdependencies and interactions between resource availability, economic factors, and social development. Given the interconnected nature of affordability with resource availability, economic factors, and social development, it is essential to consider and analyze these factors holistically in order to develop effective strategies for achieving affordability and sustainability. The integration of social, ecological, and institutional factors is crucial for understanding and promoting long-term resilience and sustainability.

The findings suggest that having comprehensive government policies that are focused on sustainability and are also sustainable has a significant impact on resource conservation. Furthermore, equity and social justice, strict pricing regulation, and income support program to promote socioeconomic progress all have an impact on sustainable government policies. Similarly, a significant factor influencing economic growth is income and employment. Same has also been deduced from the interview results analysis. It is critical to recognize that all of these elements have a beneficial impact on the inflow of the SDM of affordability in terms of the social and economic aspects of sustainability. Key elements such as income, needed products & services, and the cost of goods & services all have an impact on social development. However, it is worth noting that the former two factors have a good impact on the influx of SDM of affordability in terms of the social and economic elements of sustainability, whilst the latter has a negative impact. Understanding the complexity of sustainability and the interconnectedness of its social, ecological, and economic dimensions is paramount in developing effective strategies for promoting long-term resilience and sustainability. The relationship between social well-being,



environmental sustainability, and economic factors is multifaceted and requires a comprehensive approach. The role of governance and institutions in shaping resilience outcomes cannot be understated. Effective government policies focused on sustainability and resource conservation have a significant impact on creating a balance among the three sustainability dimensions. Similarly, ensuring equity and social justice, implementing strict pricing regulations, and providing income support programs are crucial for promoting socioeconomic progress within the framework of sustainability. Furthermore, the economic dimension of sustainability is closely intertwined with social development and requires attention to factors such as income, employment, and the affordability of goods and services.

Making goods and services more affordable to the general public can help eliminate poverty in a society (Rosca et al., 2017). It also aids in closing the wealth gap and making society more equal. When a larger segment of the population gets access to fundamental living necessities and possibilities, the society becomes more stable. Economic activities that are affordable to communities and individuals increase their quality of life (Grum & Kobal Grum, 2020). People's well-being improves when housing, healthcare, education, and other basics of life are inexpensive (Clark, 2003). The demand for goods and services will rise, promoting development and economic expansion (Ain et al., 2020). Inclusive economic growth entails a condition in which economic activities benefit everyone and participation is open to all (Ranieri & Almeida Ramos, 2013). It indicates that an economic system based on affordable pricing, price regulation, poverty reduction policies, overall improvement in quality of life, and focusing on inclusive economic growth for everyone plays a vital role in enhancing affordability to further strengthen the bond between social and economic components of sustainability. Recognizing the importance of affordability in the broader context of sustainability highlights the intricate relationship between social and economic dimensions. The ability to make goods and services more affordable not only contributes to addressing poverty and promoting social equality but also plays a key role in fostering economic growth and development. The affordability of fundamental needs like housing, healthcare, and education significantly affects the welfare of individuals and communities, ultimately shaping the overall stability of society. Achieving affordability is not solely a matter of economic considerations but also requires a focus on social inclusivity and equitable access to resources and opportunities. By creating an economic system that emphasizes affordable pricing, price regulation, and poverty reduction policies, societies can work towards not only enhancing affordability but also strengthening the interconnectedness between the social and economic components of sustainability. Inclusive economic growth, characterized by economic activities that benefit everyone and allow for widespread participation, is fundamental in promoting affordability. This approach signifies a shift towards a more equitable economic system, emphasizing overall improvement in the quality of life and ensuring that economic opportunities are accessible to all. By focusing on inclusive economic growth, societies can further solidify the bond between the social and economic dimensions of sustainability, fostering a more resilient and sustainable future for all.

When opportunities and cheap resources are freely accessible to a greater portion search for novel solutions (Peters et al., 2011). This means that increasing affordability

fosters social innovation by allowing for the development of economically feasible items. The economic pillar may address social concerns because it gives the funds and resources to do so (Lee & Woo, 2020). Economic prosperity and affordability can be achieved by investments in infrastructure, social programs, and community development. When items and services are affordable, buyers are more satisfied and spend more money (Mundel et al., 2017). This leads to a country's economic progress, employment creation in the region, and further product innovation (Singh et al., 2010). Henceforth, social innovation & development adds systematic value to affordability to play its role in improving the relationship between social and economic pillars of sustainability. However, this innovation and development should not come at the cost of environmental degradation or hindering sustainable development in any domain, whatsoever. Therefore, a system dynamic approach to sustainability is necessary when addressing housing affordability and sustainable development. This approach acknowledges the interconnectedness between affordability, social equity, economic growth, and environmental sustainability. It recognizes that these dimensions are not isolated from each other, but rather, they interact and influence one another within a complex system. By employing a system dynamic approach, policymakers and stakeholders can understand the feedback loops, delays, and interdependencies within the system. They can identify leverage points and unintended consequences, allowing for a more holistic and effective decision-making process. Moreover, a system dynamic approach can help in identifying long-term trends and potential future scenarios, considering the dynamic nature of sustainability challenges. By considering the interlinkages and dynamics of the social, economic, and environmental pillars of sustainability, a system dynamic approach can lead to more balanced and integrated solutions for housing affordability and sustainable development. These solutions can address social inequities, stimulate economic growth, and promote environmental stewardship, creating a more sustainable and resilient society for future generations. In conclusion, a system dynamic approach to sustainability is crucial in addressing housing affordability and sustainable development. When opportunities and cheap resources are freely accessible to a greater portion of society, resilience and social participation improve (Morrow, 2008). Social tensions can be eased by giving economic opportunity and resolving societal imbalances (van Niekerk, 2020). It contributes to society's overall well-being. Furthermore, maintaining a balance between the three pillars of sustainability is critical for long-term performance (Schilir, 2019). In order to improve affordability, environmental sustainability should not be compromised (Blair et al., 2004). While improving a society's affordability, social factors should be taken into account (Mulliner et al., 2013). It indicates that an economic system based on quality and growth for everyone fosters social resilience and participation, further playing a vital role in enhancing affordability to further strengthen the bond between social and economic components of sustainability. Therefore, a system dynamic approach to sustainability is essential in addressing housing affordability and promoting sustainable development by considering the interconnectedness of social, economic, and environmental factors and identifying leverage points for effective decision-making. A system dynamic approach to sustainability offers a comprehensive and integrated framework for addressing the complexities of housing affordability and sustainable development. By utilizing this approach, policymakers and stakeholders can gain a deep understanding of the dynamic interactions between social, economic, and environmental factors, thereby creating

strategies that lead to balanced and enduring solutions. Moreover, the systemic nature of sustainability issues necessitates a long-term perspective, and a system dynamic approach is well-suited to analyze and model such complex, interconnected systems over extended periods. This enables decision-makers to anticipate future scenarios and plan for sustainable development while considering the dynamic nature of societal needs and environmental challenges. Furthermore, a system dynamic approach provides a platform to identify and \ evaluate the causal links between affordability, social equity, economic prosperity, and environmental conservation. Through this approach, policymakers can identify feedback loops, delays, and leverage points within the system, which is essential for making informed decisions that lead to holistic and transformative changes. In addition to addressing affordability, a system dynamic approach can shed light on the social implications of economic policies and initiatives. It can highlight the potential impacts on social resilience, participation, and overall well-being, providing invaluable insights for inclusive and sustainable development. By recognizing the importance of a system dynamic approach, society can ensure that affordability is improved without compromising environmental sustainability. It becomes possible to embed social considerations into economic systems, fostering resilience, equality, and participation while maintaining a delicate balance among the pillars of sustainability. This holistic approach allows for the exploration of innovative ways to achieve affordability and sustainable development while safeguarding the environment and promoting social well-being. Moreover, in the pursuit of sustainable housing and urban development, it is paramount to adopt an integrative approach that considers diverse system-thinking research methods, as well as the dynamics within and beyond the city. By incorporating a systems approach, policymakers and urban planners can gain a comprehensive understanding of the interconnectedness between economic, ecological, and social systems, ultimately leading to more resilient and inclusive urban development strategies. The integration of system dynamics into the sustainable development framework is essential for addressing the complex challenges posed by affordability, social equity, and environmental sustainability. By employing feedback structures and outcome behaviors through causal loop diagrams, the system dynamics approach can facilitate a more in-depth analysis of the interconnected systems, guiding strategic decisions for sustainable urban development. Furthermore, when considering the economic sustainability of urban systems, the systems approach offers a flexible and adaptable framework that accounts for new challenges and opportunities. This adaptability is crucial in fostering sustainable urban development that responds to changing economic, social, and environmental dynamics, ensuring the long-term resilience and inclusivity of urban communities. In conclusion, the integration of system dynamics and a systems approach is imperative for addressing the multifaceted challenges of housing affordability and sustainable urban development. By recognizing the interconnected nature of economic, social, and environmental systems, policymakers and urban planners can develop innovative and inclusive strategies that promote affordability, social equity, and environmental stewardship, laying the foundation for sustainable and resilient urban communities.

Resultantly, income clearly operates as the key determinant of the outflow of affordability in terms of the social and economic dimensions of sustainability. Furthermore, secondary variables, such as resource demand, have a favorable impact on the outflow.

Similarly, expenditure is influenced by critical elements such as vital goods and services. Similarly, economic resources are influenced by a factor, such as income and employment. Furthermore, major factors such as the cost of goods and services, price control rules, and economic conditions all influence price inflation. Finally, fundamental commodities and services have an impact on societal development. All of these issues contribute to the total outflow of SDM of affordability in terms of the social and economic dimensions of sustainability.

### *5.1.3. Availability*

The findings highlight the importance of availability in strengthening the link between the economic and environmental pillars of sustainability. The findings show that resource availability functions as a crucial factor in order to examine the interaction between the economic and environmental components of sustainability. When considering the inflow of availability, it is evident that resource availability is the primary variable. Secondary elements that influence it include available natural resources, resource extraction, production of goods & services, social well-being, and imports. As a result, all of these variables are influenced by significant factor. In order to address the affordability challenge and promote sustainable development, it is crucial to understand the interconnectedness of economic, social, and environmental systems. By understanding the complex interactions and feedback loops between income, resource demand, expenditure, economic resources, price inflation, societal development, and availability of resources, policymakers can develop more effective policies and strategies to promote sustainability.

Natural resources, for example, are influenced by biological diversity and resilience, as well as environmental degradation. The former has a beneficial impact on the influx of affordability with regard to natural resources as a variable, whilst the latter has a negative impact. Similarly, fundamental elements such as natural resources and sustainable government policies have a favorable impact on resource exploitation. Social development has an impact on social wellbeing and acts as a negative inflow. Imports and creation of goods and services, on the other hand, are both positive inflows for affordability.

A Resource efficiency strategy can lessen a company's negative environmental impact (Delmas & Pekovic, 2015; Cainelli et al., 2020). It can also help to minimize procurement expenses, waste management costs, and overall cost savings (Delmas & Pekovic, 2015). Economic activities become more efficient when natural resources are widely available and managed (George et al., 2015). Sufficient resources enable organisations to reduce waste, cut expenses, and optimize manufacturing processes (Bocken & Short, 2016). Increased sustained availability of essential resources can increase economic stability and resilience (Sharifi & Yamagata, 2016; Baars et al., 2020). When a business or community relies on finite or scarce resources, it creates uncertainty and economic vulnerabilities (Desing et al., 2020). Changes in resource availability and economic shocks can be handled well, provided there is a sustainable and consistent supply of resources (Rose, 2007; Khan et al., 2022). Therefore, resource availability through resource efficiency and resilient economic policies & actions can be instrumental in

improving availability, further improving the bond between the economic and environmental aspects of sustainability.

The assessment and conservation of ecosystem services has become a priority of all nations for the sustainable future of humanity (Naidoo et al., 2008; Meraj et al., 2022). The provision of these services in an ecosystem is critical for human health and economic activity. These ecosystem services benefit the manufacturing, tourist, and agricultural industries (Raudsepp-Hearne et al., 2010; Quintas-Soriano et al., 2016). This makes the conservation of ecosystem services valuable, and the need to ensure that this support continues to grow. Furthermore, humanity may avert environmental degradation by being conscious of the use of natural resources and managing them sustainably, as these resources are critical for the long-term viability of economic operations (Cazalis et al., 2018). It can be done efficiently using circular economy approaches that are based on effective resource management and a preference for renewable resources (Kalmykova et al., 2018). Therefore, resource availability through preservation of the ecosystem and avoiding degradation of the environment can be instrumental in improving availability, further improving the bond between the economic and environmental aspects of sustainability.

Green technology can help reach local and global goals for sustainable development by minimizing the negative effects of the economic development model (Guo et al., 2020). The of green practices in technology and industry (Govindan & Hasanagic, 2018). Adoption of these green technology reduces the environmental impact of various industries, leads to job creation, and economic growth (Ghisetti & Quatraro, 2017; Guo et al., 2020). Moving to low-carbon emissions and renewable energy sources creates economic prospects in the green energy sector while also considerably benefiting the environment (Ntanos et al., 2018; Yuan et al., 2022). It is critical to achieve sustainable development by balancing economic expansion with resource conservation and environmental protection (Gough, 2018). Therefore, resource availability through green innovation & technologies and promptly devising policies and strategies to mitigate climate change can be instrumental in improving availability, further improving the bond between the economic and environmental aspects of sustainability.

As a result, consumption serves as the major variable for the outflow of affordability, followed by secondary variables such as economic development, waste generation, consumption of goods and services, and social development. Furthermore, economic development is influenced by a critical aspect, namely social development. Key elements influencing waste generation include technology breakthroughs, education, and community engagement. Social development influences consumption of commodities and services. Similar conclusions have also been drawn from the analysis of interview results. Finally, economic development, consumption of goods and services, social well-being, and resource regeneration all have an impact on social development. All of these factors contribute to the total outflow of SDM of availability in terms of the environmental and economic dimensions of sustainability.

## **5.2. Limitation**

SDM model is developed on stocks and their flows are established accordingly. The given inflows and outflows are selected from the previous studies as mentioned in the literature review. SDM in this study is generic and it has been ensured that each necessary inflow and outflow is highlighted. However, considering the systems' boundaries and subjectivity, inflows and outflows can be modified as per the requirements of the system. There is a need of upgradation of model with the passage of time. SDM will come up with new inflows and outflows in the future, which can be the future work based on this study.

## **5.3 Conclusion**

In conclusion, the impact of availability, adaptability, and affordability on achieving sustainability through system dynamic modeling reveals the interconnected relationship between economic growth, environmental protection, and social well-being.. This framework guides policy measures and investments towards a sustainable and inclusive economy that prioritizes environmental protection and social well-being alongside economic growth. This comprehensive approach is crucial for achieving sustainability through system dynamic modeling and is essential for addressing the complex challenges posed by economic growth, environmental preservation, and social development.

Sustainability triangle is a niche since the realization of keeping the natural resources for future generations. Systems claiming as sustainable systems must be aligned with the three components of sustainability including social, economic and environmental aspects. Systems are dynamic and complex; it is required to manage this complexity by a comprehensive model which is not subjective. This study contributes to the existing literature of sustainability science with a new triplet in addition to the fundamental sustainability triangle. SDM suggests that the interconnectivity and interactions between the components of sustainability triangle is strengthened by "AAA" i.e. adaptability, affordability and availability. Stock and flows in SDM model recommend that there are significant micro flows with each macro flow. The identified flows with associated stocks are a source of information for the sustainable development stakeholders such as society and industries in general, corporate sector, service sector, developers, designers and policy makers in particular. These stakeholders may structure their systems following these results of this study.

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