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Article

Impacts and drivers of SME X.0: Delineating sustainable growth via the X.0 wave framework and transformative 7PS and 9PSG governance for future outlook by fuzzy Delphi analysis

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Abstract: The transition of small and medium-sized enterprises (SMEs) to the SME X.0 paradigm marks a shift toward sustainable practices across economic, social, and environmental dimensions. This study integrates Prof. Hamid Mattiello's X.0 wave theory with the Seven Pillars of Sustainability (7PS) and Nine Pillars of Sustainable Governance (9PSG) frameworks, introducing the 5N.BG.7PS model, which highlights five critical networks—political, technical, organizational, economic, and interdisciplinary community networks—necessary for sustainable innovation and governance. The research addresses challenges like climate change, resource depletion, and technological disruptions by leveraging Internet of Things (IoT) technologies and Smart Cyber Governance principles. A mixed-method approach, combining qualitative thematic analysis and fuzzy Delphi techniques with a panel of 69 experts, identifies key drivers such as Edu-Culture 7PS, strategic foresight, and organizational adaptability. Outcomes include improved transparency, social and environmental accountability, and customer satisfaction. The findings emphasize Smart Cyber Governance as vital for fostering innovation, resilience, and societal well-being, providing actionable insights for policymakers and business leaders to support the sustainable growth of hybrid SMEs aligned with global development goals.

Keywords: The X.0 wave theory; smart cyber governance; seven pillars of sustainability (7PS); 5N.BG.7PS model; nine pillars of sustainable governance (9PSG); SME X.0/Hybrid SME concept; digital transformation; sustainable development; IoT-driven governance; business model innovation

1. Introduction

SMEs are at a pivotal juncture, transitioning into the SME X.0 paradigm—a hybrid model that integrates advanced technologies, transformative governance frameworks, and sustainability principles. This shift signifies more than an evolution; it represents a comprehensive redefinition of operational norms, emphasizing resilience, adaptability, and accountability as cornerstones of future business ecosystems [1]. SMEs, which are critical to the global economy, face unprecedented challenges and opportunities. The transition to the SME X.0 model is vital for fostering sustainable growth and addressing the complexities of 21st-century challenges, such as climate change, resource depletion, and socio-economic disparities [2–8].

The SME X.0 paradigm, explored through the lens of Prof. Hamid Mattiello's X.0 wave theory, combines governance innovation with technological agility. The framework draws on the 7PS and 9PSG, which provide a structured approach to aligning SME operations with global sustainability objectives [9,10]. Prof. Mattiello

developed the SME X.0 concept through his scholarly work since 2017, emphasizing how SMEs can leverage best practices in governance and technological integration to navigate global crises [9–12]. Complementing these frameworks, the 5N.BG.7PS model highlights the interconnected roles of political, technical, organizational, economic, and interdisciplinary community networks, which are essential for overcoming contemporary challenges in business management [12,13].

This study is driven by the need to understand how SMEs can strategically adapt to and thrive in the face of global crises, including climate risks, socio-economic inequalities, and resource uncertainties [13–15]. The urgency of this research is heightened by the accelerating pace of digital transformation and the increasing societal expectation for businesses to align with the United Nations' Sustainable Development Goals (SDGs) [15–18]. As engines of innovation and employment, SMEs must now embody resilience and sustainability not just as operational goals but as intrinsic qualities essential for long-term viability.

The primary objectives of this research are threefold:

1) To identify the critical impacts of SME X.0 on economic, social, and environmental dimensions.
2) To introduce the X.0 wave framework as a strategic roadmap for fostering innovation, resilience, and sustainable growth.
3) To examine the transformative potential of the 7PS governance model, particularly through the integration of Smart Cyber Governance principles, in shaping future-ready SME ecosystems.

By integrating the X.0 wave theory with the 7PS and 9PSG frameworks, this study offers a comprehensive approach to navigating the transition of SMEs into hybrid, sustainability-driven enterprises. The findings provide actionable insights for policymakers, business leaders, and academics, offering a robust roadmap to cultivate SMEs that excel in resilience, innovation, and public service delivery. This research bridges theoretical advancements with practical applications, ultimately fostering ecosystems that prioritize societal welfare while advancing long-term sustainability.

2. Background (literature review)

2.1. Small and medium-sized enterprises (SMEs)

SMEs are businesses that maintain revenues, assets, or a number of employees below a specific threshold. These enterprises play a crucial role in driving economic growth, innovation, and employment, contributing significantly to global business activity. While the precise definition of SMEs varies by country and sector, they are generally characterized by their limited scale in comparison to large corporations. Despite their size, SMEs often possess entrepreneurial agility, allowing them to innovate and adapt quickly to market changes.

SMEs are particularly prevalent in industries that require fewer employees or lower initial capital investments, such as retail, hospitality, technology, and manufacturing. In many economies, SMEs are seen as the backbone of the labor market, providing substantial employment opportunities and fostering innovation through their close-knit organizational structures. Furthermore, SMEs often have the ability to serve niche markets and offer personalized products and services, giving

them a competitive advantage in certain sectors. However, SMEs also face a number of challenges that can hinder their growth and sustainability. These challenges include limited access to capital, a lack of advanced technological infrastructure, and difficulties in scaling operations to compete with larger multinational corporations. The rise of globalization and increased market competition have made it even more difficult for SMEs to thrive, particularly when they lack the resources to invest in research, development, and digital transformation. Despite these challenges, SMEs remain a critical source of entrepreneurial skills, job creation, and innovation. They are also key contributors to a country's Gross Domestic Product (GDP), particularly in emerging economies where the formal corporate sector is still developing. As such, fostering the growth and sustainability of SMEs is crucial for achieving long-term economic development and social well-being [17–21].

2.2. Tomorrow's SMEs (SMEs X.0/Hybrid SMEs)

Tomorrow's SMEs, often referred to as SMEs X.0 or Hybrid SMEs, represent the evolution of traditional small and medium-sized enterprises. These businesses are environmentally responsible, socially conscious, and economically efficient, embodying the vision of a sustainable future. By integrating environmental and social responsibility with business success, SMEs X.0 are poised to shape a more inclusive and sustainable economy. At the core of this transformation lies the concept of Smart Cyber Governance, where SMEs prioritize environmental responsibility and social cohesion, while business performance and economic efficiency are important but secondary goals. Government strategies play a pivotal role in incentivizing companies to adopt practices that promote environmental and social responsibility.

Several key principles drive these innovative and socially responsible organizations:

- Resource efficiency: SMEs X.0 aims for reduced resource use while improving performance.
- 360-degree transparency and accountability: Ensuring openness in operations and decision-making processes.
- Improved employee experience: Enhancing job satisfaction and organizational culture.
- Platform and service-oriented entrepreneurship: Shifting towards business models that focus on services and platforms rather than traditional product-centric approaches.
- Evolution from CSR (Corporate Social Responsibility) to CSE (Corporate Startup Engagement): Moving beyond CSR to engage in more innovative, startup-like approaches that create value for both society and business.

These businesses, as influential players in the economy, are expected to promote their brand by demonstrating a strong commitment to environmental and social causes, aligning their operations with both societal needs and ecological balance to ensure long-term sustainability [22–26].

The two wings of SMEs X.0—environmental responsibility and social responsibility—are visualized as the foundation of this innovative business model, as illustrated in **Figure 1**. SMEs X.0 breaks away from traditional product-centric models

by adopting new technologies that foster product innovation. Companies in competitive environments, driven by market demands, often demonstrate higher levels of innovation. Policies that encourage flexibility and reduce restrictions on innovation are crucial for enabling SMEs to unlock value through performance and innovation. Aside from market-driven strategies, the unique characteristics of each company also influence its ability to innovate.

The transition from CSR 1.0 to CSR 2.0 and further to CSE (Corporate Startup Engagement) and CGS (Corporate Governance Strategies) is seen as a pathway for businesses to overcome modern challenges and prepare for future crises. Product innovation is best achieved through a market-oriented approach that integrates educational strategies alongside the adoption of new technologies. As theorized by Prof. Hamid Mattiello, hybrid SMEs embody these principles of sustainability, innovation, and governance to achieve long-term success [26–30].

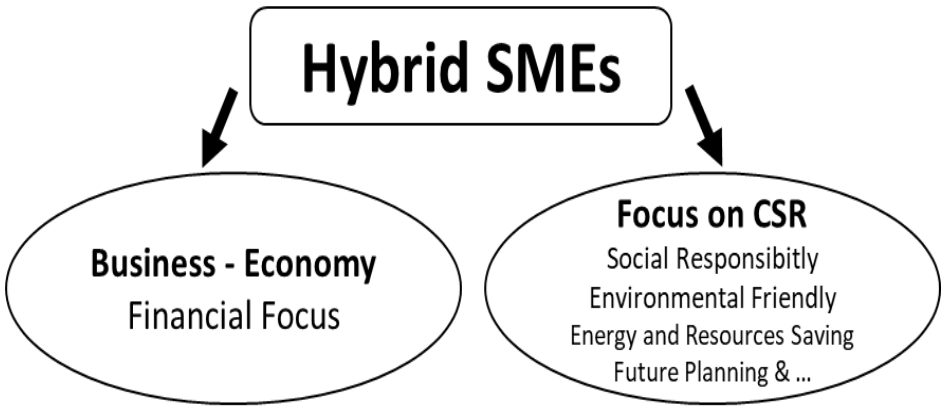


Figure 1. Hybrid SMEs/SME 5.0/tomorrow's SMEs' two wings (Prof. H. Mattiello, 2010-17).

As the theorist behind the X.0 wave theory and the concept of Tomorrow's SMEs, Prof. Hamid Mattiello highlights the following attributes and characteristics of Hybrid SMEs as shown in **Figure 2**:

(1) The 3D Socio-Eco-Environment SMEs model, prioritizing:
   P1. Environmentally responsibility;
   P2. Social cohesion;
   P3. Economic efficiency.
(2) Digital and smart integration;
(3) Larger SMEs (250-499 MoS) with more opportunities for innovation and growth;
(4) Innovation-driven organizations;
(5) Industry and industry-related services;
(6) SMEs' digital culture and a focus on fostering digital competencies;
(7) Sustainability at the core of business operations;
(8) Blue-Green/Clean Economy practices;
(9) Future-oriented planning;
(10) CSR 1.0, CSR 2.0, and CSE approaches;
(11) Talent management: HR competencies, qualifications, and training;
(12) Succession planning for long-term sustainability;
(13) Focus on the Internet of Business (IoB);

(14) The D3 revolutions:
(15) Focus on D3 revolutions.

- Digitalization;
- De carbonization;
- De centralization.

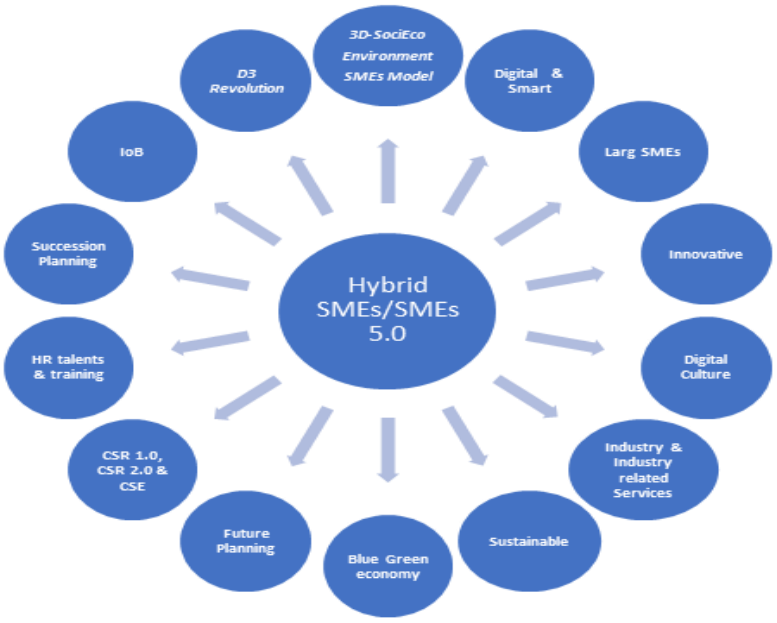


Figure 2. Hybrid SMEs/SMEs X.0, or tomorrow's SMEs, are/have 14 points (Prof. H. Mattiello, 2010-17).

The SMEs X.0, or tomorrow's SMEs, represent a forward-looking vision of small and medium-sized enterprises, combining sustainability, innovation, digitalization, and strategic planning to build businesses that are economically successful, environmentally responsible, and socially cohesive. These businesses are central to the development of a more sustainable, inclusive economy that thrives in the digital era, as shown in **Figure 3**.

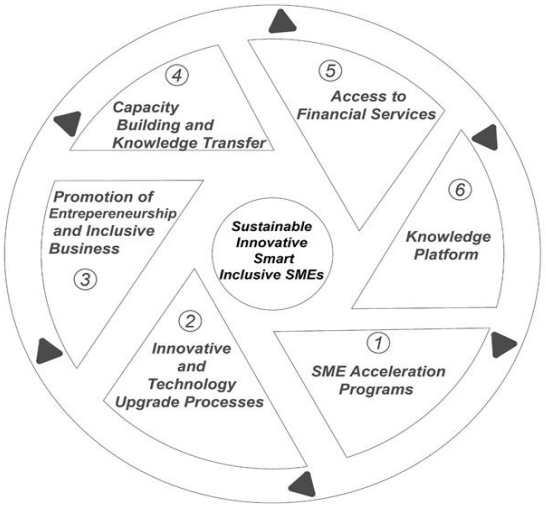


Figure 3. Towards sustainable, innovative, smart, and inclusive SMEs (Prof. H. Mattiello, 2017–2019).

2.3. Smart cyber governance

Smart Cyber Governance is a critical element of overall enterprise governance, focusing on how organizations leverage cyberspace while managing risks associated with digital threats such as hackers, phishers, and other malicious actors. As businesses embrace interconnected digital systems and smart technologies, they must develop governance practices to address the growing complexity of cybersecurity threats. A well-designed cybersecurity governance policy includes clearly defined risk management strategies, technical controls, and administrative policies that guide organizations in identifying vulnerabilities and managing cybersecurity risks efficiently.

The concept of Smart Cyber Governance involves the establishment of robust frameworks that help organizations defend against various types of cyberattacks. These frameworks must address attack vectors, privacy concerns, and the overall impact of potential data breaches. A strong cybersecurity governance policy is crucial to ensuring that organizations maintain the integrity, privacy, and protection of sensitive information, especially as they integrate digital transformation processes. The outcome of an effective cybersecurity governance program is a comprehensive understanding of an organization's security posture—specifically where the vulnerabilities lie, the potential risks it faces, and the steps necessary to protect valuable data. Furthermore, tools, skills, and resources are essential to detect security issues and irregularities in real-time, which can prevent data breaches and cyberattacks [31,32].

Incorporating the Internet of Things (IoT) and smart governance models within SMEs is an essential step towards enhancing operational efficiency, security, and sustainability. Recent studies suggest that adopting IoT and intelligent governance models significantly contributes to SMEs' readiness for Industry 4.0, creating smarter and more secure ecosystems for growth. Notably, research by Doost Mohammadian [32] provides detailed frameworks on how SMEs can adapt to the rapid pace of digital transformation. Further studies [33–37] explore IoT integration, Cyber Governance, and educational components designed to improve digital competencies [38–41].

2.4. KTB (knowledge, technology, business) model

The KTB (knowledge, technology, business) model is part of the 5th wave theory, examining how today's challenges and tomorrow's crises impact knowledge, technology, and business. These issues shape how knowledge is acquired, how technology evolves, and how businesses adapt to new realities.

1) Knowledge: The evolving nature of challenges like climate change reshapes knowledge, creating new fields or making existing ones obsolete. The rise of remote work and digital literacy emphasizes the importance of continuous learning and critical thinking.
2) Technology: Technology adapts to address pressing challenges. The COVID-19 pandemic spurred innovations like telemedicine and contact tracing apps, while the rise of AI, blockchain, and IoT revolutionizes industries, raising both opportunities and ethical questions.

3) Business: Businesses face disruption through changes in markets and societal expectations. The growth of e-commerce challenges traditional retail, while a focus on environmental responsibility and stakeholder capitalism is reshaping business models.

The KTB model helps anticipate the "key data that comes next", enabling organizations to navigate future challenges. It underscores the interconnectedness of knowledge, technology, and business in a rapidly changing world. By analyzing these areas, businesses can develop strategies for a more resilient, equitable, and sustainable future as shown in **Figure 4**.

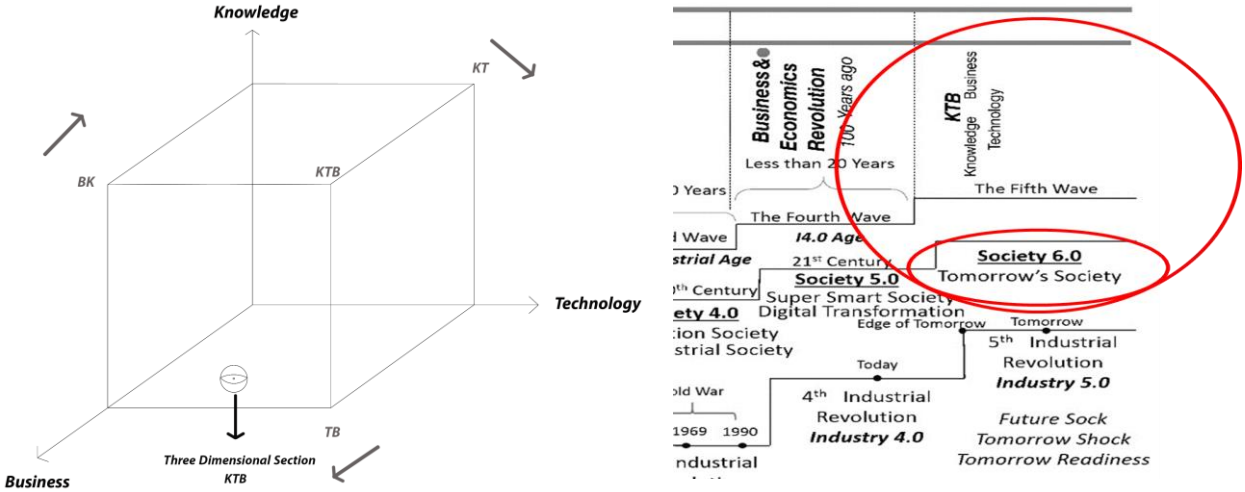


Figure 4. Knowledge, technology, business (KTB) model comes next as key data (Prof. H. Mattiello, 2010–2017).

2.5. Seven pillars of sustainability (7PS) model

The 7PS model, developed by Prof. Dr. Hamid Mattiello, is a comprehensive framework designed to achieve sustainability by recognizing the interconnectedness of various dimensions of human life. The model emphasizes the importance of a holistic and systemic approach to sustainable development. It consists of seven key pillars: culture, environment, society, economy, technology, education, and politics, with peace and love serving as the foundational values underpinning all aspects of sustainability.

In the context of Hybrid SMEs/SMEs 5.0, the 7PS model plays a pivotal role in ensuring that sustainability is prioritized when developing new business models and technologies. Hybrid SMEs, with their focus on environmental and social responsibility, can adopt the 7PS framework to identify critical areas of action that support sustainable practices and contribute to shaping a sustainable future. These businesses, through Smart Cyber Governance, can utilize the model to address challenges and implement sustainable solutions in the digital transformation process.

The 7PS model also aligns with X.0 wave theories, which emphasize the systemic and holistic nature of sustainability. By integrating these theories, businesses can better predict potential challenges related to sustainability and proactively develop strategies to address them. This alignment makes the 7PS model a valuable tool for businesses, policymakers, and individuals striving to contribute to a sustainable future.

However, SMEs face significant challenges in adopting sustainable development paths, particularly due to their limited resources and the various barriers they encounter. These challenges often impede their transition to a model of sustainability consistent with their specific industries and operational dimensions. Integrating sustainability principles into daily operations becomes crucial for SMEs, especially when transitioning to more sustainable models. One practical approach is adopting hybrid working models, which promote sustainability by utilizing repurposed buildings, incorporating recycled materials, and optimizing shared resources such as Wi-Fi and printers. These models reduce the environmental impact by having smaller carbon footprints and higher occupancy rates compared to traditional office buildings [37–41].

The Seven Pillars of Sustainability in detail:

The seven pillars of the 7PS model are:

1) Culture—Cultivating a culture of sustainability through values that promote social responsibility, environmental awareness, and ethical practices.
2) Environment—Prioritizing ecological conservation, resource efficiency, and the reduction of environmental impact in all business operations.
3) Society—Enhancing social cohesion, equity, and community well-being, while ensuring businesses contribute positively to society.
4) Economy—Fostering economic efficiency, profitability, and sustainable business models that benefit both the organization and the wider economy.
5) Technology—Leveraging innovative technologies to drive sustainability and digital transformation while reducing negative impacts on the environment.
6) Education—Promoting education and awareness of sustainable practices and equipping stakeholders with the skills necessary to embrace sustainability.
7) Politics—Engaging with governmental policies and regulations that support sustainability and advocating for political frameworks that enable sustainable business practices.

In addition, Peace and Love are essential values that guide the entire framework, emphasizing cooperation, ethical behavior, and the long-term well-being of all stakeholders involved in the sustainability journey as shown in **Figure 5**.

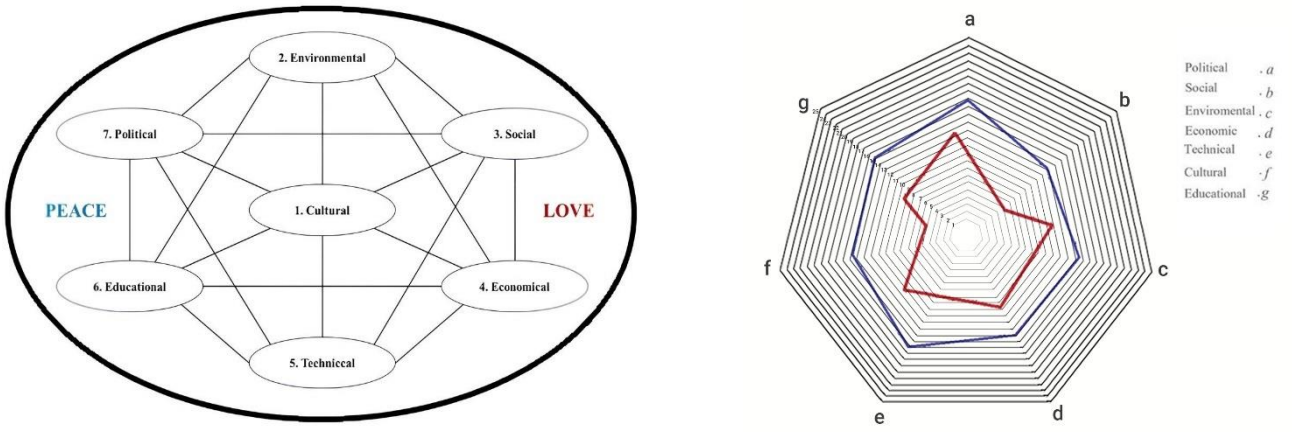


Figure 5. Seven Pillars of Sustainability (7PS) model with the priority and connections (Prof. H. Mattiello, 2010–2017).

Prioritization of the 7PS model:

Based on Fuzzy AHP (Analytic Hierarchy Process), the ranking of the 7PS indicators reflects their relative importance in achieving sustainability. As shown in **Table 1**, the rankings are as follows:

Table 1. Ranking of 7PS model indexes based on Fuzzy AHP [41].

7PS Model Indicators	Source	Rank
Cultural	0.481	1
Environmental	0.382	2
Social	0.353	3
Economic	0.324	4
Technical	0.251	5
Educational	0.221	6
Political	0.175	7

These rankings indicate the priority order in which SMEs should focus their efforts to achieve sustainability, with cultural aspects being the most crucial, followed by environmental and social factors. This prioritization helps SMEs determine where to allocate resources and which sustainability dimensions to emphasize in their strategies.

2.6. The X.0 wave/age theory

The X.0 wave/age theory, proposed by Prof. Dr. Hamid Mattiello, is grounded in the broader concept of technological evolution and societal change, building on existing theories of industrial and information revolutions [41,42]. The theory asserts that each wave of civilization is propelled by transformative technological advances that shape human societies in profound ways.

Technological advancements and societal change:

As various authors have explored, each wave of technological change presents opportunities and challenges that require society to adapt both structurally and culturally. For instance, Industry 4.0 has redefined the nature of manufacturing and production processes through IoT, AI, and automation [43], enabling unprecedented connectivity between machines, systems, and human operators. These advancements align with the evolution of SME X.0, which integrates these technologies to maintain competitiveness [44]. As these shifts occur, it becomes clear that technological systems not only optimize operational efficiencies but also redefine societal roles and expectations, especially in governance and business models [45].

This theory is defined by the following equation:

$$\text{The X.0 wave/age theory, } f(x), \text{ when } X = 1,2,3,4,5,6, \ldots.$$

Waves of civilization:

(1) The Agrarian Age ($1.0 \leq X.0$)—This stage, which began around 500,000 BCE to 70,000 BCE, saw the transition from hunting and gathering to settled agricultural societies. This fundamental shift allowed humans to form stable communities and complex social structures. It is also known as the pre-industry period. It was

characterized using fire, light, and wheels and had a significant impact on mechanical production and enhancing the agriculture industry, which led to the development of mechanical production and an enhanced agriculture industry. The development of agriculture allowed people to settle in one place and led to the emergence of cities and complex societies.

(2) The Industrial Age (X.0 = 2.0)—This era, starting in the 17th century, was driven by steam power, mechanization, and fossil fuels, leading to mass production, urbanization, and modern capitalism.
    1) 1st Industrial Revolution—X.1 = 2.1 (Industry 1.0/SME 1.0): Emerging in the 17th century, it introduced steam power, mechanization, the chemical industry, and water machines, enabling large-scale manufacturing and the expansion of factories and railways.
    2) 2nd Industrial Revolution—X.2 = 2.2 (Industry 2.0/SME 2.0): Beginning around 1870, it saw the rise of mass production, assembly lines, electrical energy, and expanded railway networks, transforming industries and urban development.

(3) The Information Age (X.0 = 3.0)—Beginning in the late 20th century, the rise of computers and the internet revolutionized the way information was processed, communicated, and shared. This age also ushered in the era of knowledge-based industries and globalization. This wave started with the advent of the Digital Revolution in the 20th century and is known as the Post-Industrial Age. It was characterized by the development of computers, automation, electronics, information, and communication technology. This wave emerged in the 20th century as the 3rd Industrial Age/Revolution began during the Cold War until 1969, with the advent of the digital revolution. It is also known as Industry 3.0 and SME 3.0 and was characterized by the development of computers, automation, electronics, information, and communication technology. This wave has transformed the way we live and work, leading to the development of new industries such as information technology, telecommunications, and the internet. Alvin Toffler's Three Waves of Civilization is a theory that describes the evolution of human societies over time. According to Toffler, there have been three major waves, or stages, of civilization, each

(4) The Intelligence Age or Digital Age (X.0 = 4.0)—This stage, which is ongoing, is defined by artificial intelligence (AI), machine learning, biotechnology, and digitalization. Automation and data-driven technologies are reshaping industries, work, and society. This wave emerged around the 70s of the 20th century and is also known as I4.0. It is characterized by the digitalization and automation of every part and manufacturing process of the company. This wave has not only brought huge changes in production but also in every aspect of life. This wave emerged at the end of the 20th century and the first 10 years of the 21st century (2000–2010) through the digitalization and automation of every part and manufacturing process of a company. It is also known as Industry 4.0, biotechnology, virtual reality, superintelligence society, digital transformation, Society 5.0, and SME 4.0. This wave has brought about huge changes not only in production but in every aspect of life. It has led to the development of new technologies, such as artificial intelligence, robotics, and biotechnology, and has

transformed the way we live and work. This wave is characterized by the emergence of artificial intelligence and machine learning. It is expected to bring about significant changes in the workplace, including increased automation and the development of new industries such as biotechnology and virtual reality.

(5) The Human Age or Tomorrow Age (X.0 = 5.0)—This wave represents the future of Industry 5.0 and Society 5.0, where human-centric technologies and sustainable development practices will address the pressing challenges of the present and future crises. Prof. Mattiello has introduced several related theories, models, and concepts for this era, including Society 6.0, Urban 6.0 (Utopia), Entrepreneurship 5.0, Edu 5.0, Welfare 5.0, and SME X.0/hybrid SMEs, or tomorrow's SMEs. These theories emphasize the importance of preparing for tomorrow's shocks and addressing the potential risks and challenges associated with this fifth wave. The 5th wave is still emerging, and its full potential is not yet clear. However, it is expected to bring about significant changes in the way we live and work and to lead to the development of new industries and technologies. This wave is marked by the integration of technology and humans, where humans and machines work together in a seamless way to achieve goals. This wave is characterized by the development of the Internet of Things (IoT), which connects physical objects to the internet, and the rise of smart homes, smart cities, and autonomous vehicles.

(6) The Transhuman Age (X.0 ≥ 6.0)—The final frontier of human civilization, where technological advancements transcend current understanding. This wave envisions a future of radical transformation, where human limitations are overcome by advancements in biotechnology, AI, and other emerging technologies. The X.0—The Transhuman Age is a concept put forth by Mattiello's X.0 wave/age theory. According to this theory, human evolution is divided into different "waves" or "ages", each representing a distinct period of advancement in technology and society. The Transhuman Age is the latest wave, marked by the merging of technology and biology and the transcendence of human limitations. This new age is expected to bring about significant changes in human society, including the possibility of immortality and the exploration of new frontiers in space. The theory suggests that we are currently in a transitional period between the fourth and fifth waves, as we grapple with the challenges and opportunities presented by rapidly advancing technologies and changing social and economic conditions. The X.0 wave/age theory proposes that there may be many more waves to come as we continue to evolve and adapt as a species. The theory highlights the importance of understanding and anticipating the potential impacts of technological advancements on society and the need for responsible innovation to ensure that these changes benefit humanity as a whole. Prof. Mattiello has introduced several related theories, models, and concepts for this era, including Society X.0, Urban X.0 (Future Utopia), Entrepreneurship X.0, Edu X.0, Welfare X.0, and SME X.0 and Transhuman. These theories emphasize the importance of preparing for tomorrow's shocks and addressing the potential risks and challenges associated with this X.0 wave/age [41–45].

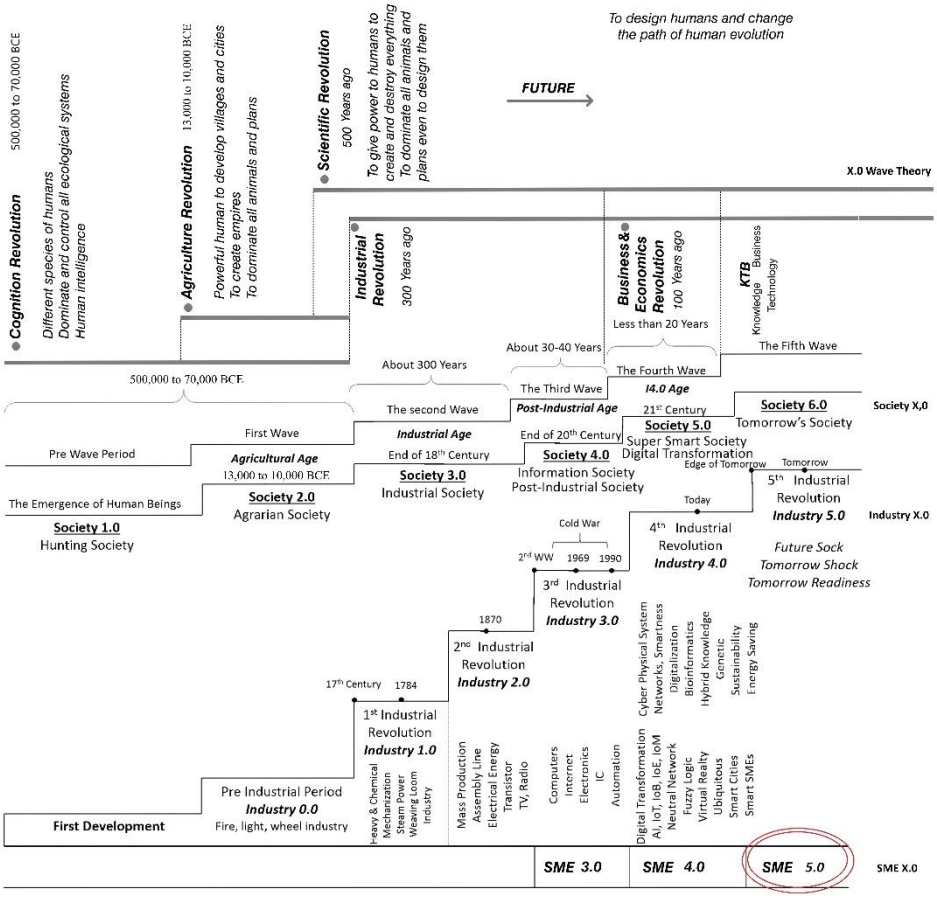


Figure 6. The X.0 wave/age ($1.0 \leq X.0 \leq 5.0$) theory, revolutions, ages, society, industries, technologies, and SMEs (Prof. H. Mattiello, 2010–2017).

Figure 6 illustrates the evolution of civilization through the X.0 Wave/Age Theory, capturing the transition from the Agrarian Age ($1.0 \leq X.0$) to the anticipated Transhuman Age ($X.0 \geq 6.0$).

While each wave is built upon the innovations of the previous one, it also brings with it new challenges, including job displacement, environmental degradation, and social inequality. The theory underscores the need to address these risks to ensure sustainable progress.

SME 4.0 and Industry 4.0:

SMEs have increasingly integrated digital tools into their operations to survive and thrive in an industry dominated by large-scale corporations [46]. SME 4.0, underpinned by the digital transformation associated with Industry 4.0, presents a unique paradigm where SMEs leverage IoT, AI, and cloud computing to foster innovation and agility [46]. These developments point to a key gap addressed by the X.0 wave theory in understanding the intersection of digital capabilities and entrepreneurial resilience, particularly in non-Western economies.

Human-centric futures and society 5.0:

While Industry 4.0 focuses on the automation and optimization of industrial processes, Society 5.0 extends this by placing human-centric innovation at the core of technological development [47]. This future-oriented society integrates artificial intelligence, robotics, and IoT to address global challenges such as climate change,

inequality, and social justice, which are critical concerns of the X.0 wave theory. Prof. Mattiello's contributions to Society 5.0 and related models like Edu 5.0 and SME X.0 position his theory as a comprehensive framework for understanding the societal shifts needed for a sustainable and technologically advanced future [48–50].

The implications of the X.0 wave theory for business and society:

- SMEs X.0: Small and medium-sized enterprises leveraging digital technologies to remain competitive in an increasingly tech-driven world.
- Industry X.0: The fourth Industrial Revolution, characterized by smart manufacturing, IoT, AI, and big data integration.
- Society X.0: A data-driven society where real-time access to information transforms how people interact and work.
- Work X.0: The evolving workforce, where AI and automation create new types of jobs and disrupt traditional employment structures.
- Entrepreneurship X.0: The democratization of entrepreneurship, facilitated by technological tools that allow anyone with an idea to launch a business.
- Job X.0: The shift to a more flexible, agile workforce that thrives on remote work and cross-border collaboration.
- Edu X.0: The transformation of education, where technology enables personalized and accessible learning experiences.
- Welfare X.0: Harnessing technology to tackle the world's most urgent issues, such as climate change, inequality, and poverty.

The X.0 wave/age theory encourages individuals and organizations to embrace these technological advancements and adapt to a rapidly changing landscape. It emphasizes innovation, digitalization, and human-centric approaches to ensure continued progress in the face of emerging challenges.

However, the X.0 in the theory refers to an unknown future wave or age that will be characterized by a technological advancement that is currently beyond our imagination [5,13–16].

Smart governance and digital transformation:

The governance frameworks required to support these transformative shifts have also evolved. Smart governance, characterized by data-driven decision-making and the integration of technologies such as blockchain, AI, and predictive analytics, has been identified as critical for managing the complexities of modern society [49]. These technologies enable more transparent, efficient, and responsive governance models, aligning with the X.0 wave theory's notion of a data-driven society [50].

The technological driving forces:

The theory highlights the technological advancements that define each wave and how these innovations shape future scenarios:

- Automation & AI: These technologies disrupt traditional industries and open up new opportunities in various sectors, including manufacturing, healthcare, and services.
- Entrepreneurship & innovation: Technology levels the playing field, empowering individuals to start businesses and create new solutions to global challenges.

- Education & workforce: Education systems are evolving to equip students with the skills necessary to thrive in a digital world. Workforces are adapting to new forms of collaboration and remote engagement.
- Sustainability: Technology is also positioned as a solution to the planet's most pressing environmental and social issues, offering tools for climate change mitigation, poverty reduction, and equitable development.

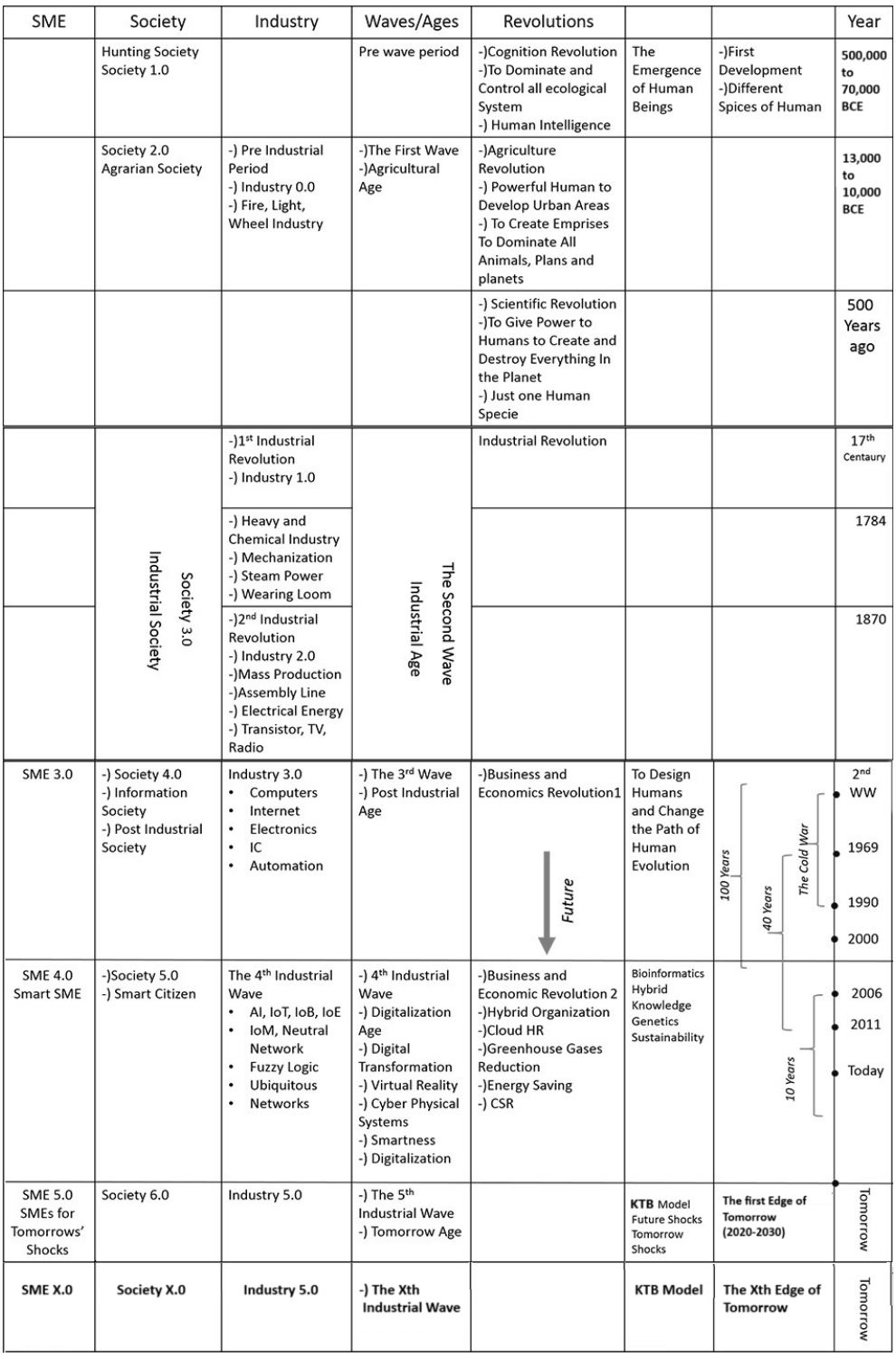


Figure 7. Histomap of the X.0 wave/tomorrow age framework ($1.0 \leq X.0 \leq 6.0$) (Prof. H. Mattiello, 2010-17).

The X.0 wave/age theory provides a lens through which to view the technological and societal transformations that are reshaping our world. By understanding these waves, businesses and societies can navigate the complexities of the future and capitalize on the opportunities created by emerging technologies. The theory builds upon the earlier wave theories, such as the Industrial Revolution and the Information Age, and proposes that we are currently in the X.0 age, where X can be any number greater than 5 [50].

Figure 7 presents a Histomap of the X.0 Wave/Tomorrow Age Framework ($1.0 \leq X.0 \leq 6.0$), offering a longitudinal perspective on societal evolution driven by technological, economic, and cultural transformations.

Technologies and future scenarios in the X.0 wave theory: The X.0 wave theory is driven by advancements in technology, which are set to shape the future of human civilization. This framework, first introduced by Dr. Hamid Mattiello, explores the interplay between technology, society, and human potential as we transition through several key waves of development. Each stage is defined by technological innovation that transforms work, entrepreneurship, education, welfare, and other sectors, collectively shaping future societal structures.

Work X.0: Automation and artificial intelligence (AI) are poised to disrupt traditional job structures. This wave will usher in a new era where the nature of work becomes more flexible, with remote collaboration across borders and the rise of AI-driven work environments.

Entrepreneurship X.0: Technology has democratized entrepreneurship by lowering barriers to entry, enabling anyone with an idea to launch a business. This transformation is allowing individuals to become innovators and change-makers on a global scale, irrespective of location or resources.

Job X.0: The workforce is shifting towards greater agility, with remote working and job customization becoming the norm. The traditional 9-to-5 structure is evolving, and flexible, freelance, and gig-based work models are increasingly popular.

Edu X.0: Education is being revolutionized by technology, making learning more personalized and accessible. The future of education will see a shift towards self-directed learning, supported by AI and digital platforms, allowing for tailored educational paths.

Welfare X.0: Advances in technology have the potential to address the world's most pressing challenges, such as climate change, poverty, and inequality. With the introduction of AI, biotechnology, and digital platforms, new solutions for health, social equity, and sustainability are emerging.

Key waves of human civilization: The X.0 wave theory divides human history into several distinct waves, each marked by a transformative technological advancement:

X.1: The Agricultural Age (1.0): Starting around 70,000 BCE, this wave is characterized by the domestication of plants and animals, leading to settled agriculture and the formation of permanent societies. It was marked by early innovations such as the use of fire and the wheel, which laid the foundation for later technological advancements.

X.2: The Industrial Age (2.0): Beginning in the 17th century, the Industrial Revolution saw the rise of machines powered by steam and fossil fuels. Mass

production, urbanization, and the growth of capitalist economies defined this wave, leading to the development of modern factories, transportation systems, and a new socio-economic order.

X.3: The Information Age (3.0): With the advent of computers and the internet, the 20th century brought about the Information Age, a period marked by the spread of knowledge and globalization. The digital revolution introduced automation, electronics, and communication technologies, transforming industries and fostering interconnected global networks.

X.4: The Intelligence Age (4.0): Emerging from the late 20th century, this wave is characterized by artificial intelligence, machine learning, and biotechnology. With the advent of smart technologies and the digitalization of all sectors, this wave is marked by increasing automation, intelligent systems, and virtual reality, which redefine industries, work processes, and daily life.

X.5: The Human Age (5.0): Also known as the Age of Integration, this wave signifies the merging of technology with human biology. Advances in biotechnology, genetic engineering, and brain-machine interfaces are expected to bring about improvements in health and human performance, leading to a future where humanity and technology are integrated seamlessly.

X.6: The Transhuman Age (X.0): The latest phase, the Transhuman Age, is marked by the fusion of biological and technological entities. Human evolution, fueled by cutting-edge technologies, is expected to transcend current physical and cognitive limitations. This wave envisions the possibility of immortality, space exploration, and radical societal transformation, as human beings evolve beyond their current form, embracing the next frontier of technological evolution.

Future scenarios: The X.0 wave theory provides a lens through which to examine the potential future scenarios that may unfold as technology and society continue to evolve:

1) Society X.0: A society driven by data and innovation, where digital technologies redefine how individuals live, work, and interact. While this shift brings unprecedented possibilities, it also raises privacy concerns as personal data becomes increasingly commodified.
2) Innovation and markets: As technological advancements continue to accelerate, new industries and market dynamics will emerge. Future waves will lead to new business models, opportunities for growth, and innovative solutions to global challenges.
3) Privacy and ethical considerations: With the increased reliance on technology, issues surrounding data privacy, surveillance, and ethical AI governance will become central. The X.0 wave highlights the importance of navigating these challenges responsibly to ensure that innovation serves the greater good of humanity.

The theory suggests that the current state of the digital economy can be understood as a shift towards Society X.0, where data is a key driver of innovation and growth. However, this shift also raises significant privacy concerns, as personal data is increasingly commodified and exploited by corporations.

The X.0 wave/age theory provides a useful framework for understanding the implications of this trend for innovation, markets, and privacy. The theory suggests

that the current state of the digital economy is just one stage in a larger process of technological and social evolution, and that future waves or ages may bring about new challenges and opportunities. By adopting a long-term perspective and considering the potential future scenarios suggested by the X.0 wave/age theory, policymakers and industry leaders can develop more effective strategies for promoting innovation, ensuring competition, and protecting privacy in a rapidly changing digital landscape. [45, 50–53].

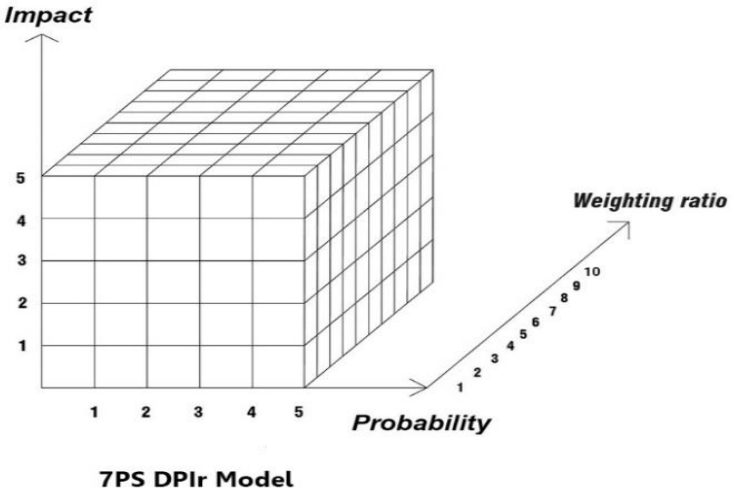


Figure 8. 7PS and DPIr model (Prof. H. Mattiello, 2017–2019).

Prof. Mattiello, in **Table 2**, presents a framework for measuring sustainability, which is based on a trinity of Impact (I), Probability (P), and Normalized Ratio (r), as illustrated in **Figure 8**.

Figure 8 presents the 7PS and DPIr Model, a comprehensive framework for evaluating sustainability through multidimensional assessment criteria.

Prof. H. Mattiello introduces a structured methodology for measuring sustainability, grounded in the trinity of Impact (I), Probability (P), and Normalized Ratio (r), as outlined in **Table 2**. The DPIr model provides a systematic approach to quantifying sustainability efforts, integrating risk assessment and outcome measurement to enhance strategic decision-making. Complementing this, the 7PS model (Seven Pillars of Sustainability) offers a holistic lens to analyze economic, social, and environmental dimensions, ensuring balanced and long-term progress in organizational and societal contexts.

Table 2. Sustainability measurement [45,50–53].

Index	Description	Row
Si	Sustainability	1
Pi	Probability of each Pillar	2
Ii	Impact of each Pillar	3
ri Normal	Normalized ratio of each Pillar	4
Si = ∑ (Pi × Ii × ri Normal)		

By leveraging these models, businesses and policymakers can adopt data-driven strategies to address sustainability challenges, optimize resource utilization, and mitigate risks associated with global transitions in technology and governance.

Conclusions:

The global economy has undergone a profound transformation, shifting from a traditional business economy to a data-driven business economy. This transition reflects the increasing reliance on digital infrastructure, automation, and artificial intelligence to drive value creation, decision-making, and economic growth.

The X.0 Wave Theory underscores this paradigm shift, illustrating how successive technological waves have progressively reshaped economic structures, societal functions, and governance models. When X.0 = 5.0, this wave is characterized by the seamless integration of big data, AI, IoT, and blockchain, marking the emergence of a future world economy where digital assets, decentralized finance, and smart automation redefine traditional economic principles.

As depicted in **Figure 9**, the X.0 Wave Economy (when X.0 = 5.0) is built on interconnected digital ecosystems, where real-time data access, algorithmic decision-making, and predictive analytics become central to competitiveness and innovation. While this data-centric model enhances efficiency and drives technological advancement, it also introduces new challenges related to data sovereignty, cybersecurity, digital ethics, and socioeconomic disparities, all of which require strategic governance and sustainable solutions.

Figure 9. Future world economy in the X.0 wave theory (Prof. H. Mattiello, 2017–2019).

2.7. The 5N.BG.7PS model

The 5N.BG.7PS model is a critical framework integrated within the X.0 wave theory to guide SMEs in their transition to sustainability and innovation. It is especially relevant when addressing the complex challenges posed by emerging global crises, such as climate change, resource depletion, and technological disruptions, as well as the integration of advanced technologies like the Internet of Things (IoT).

Key components of the 5N.BG.7PS model include five essential networks as shown in **Figure 10**:

1) Political networks: These networks consist of policymakers, government agencies, and regulatory bodies that create and enforce policies for sustainability. They shape the legal and regulatory environment in which SMEs operate, fostering the development of a favorable ecosystem for innovation and growth.
2) Technical networks: Comprising engineers, researchers, and technological experts, these networks focus on the development and application of cutting-edge technologies. They are crucial for driving innovation in sustainability practices

and technological solutions, such as clean energy and sustainable management systems.

3) Organizational networks: This network includes businesses, non-governmental organizations (NGOs), and community groups. It represents the organizations that collaborate to put sustainable practices into action, translating political and technical strategies into operational practices. These networks are vital for the implementation of sustainability initiatives on the ground.
4) Economic networks: Involving financial institutions, investors, and funding bodies, economic networks provide the financial resources necessary for SMEs to implement sustainability innovations. They ensure that projects remain economically viable, helping scale sustainable technologies and ensuring long-term sustainability.
5) Interdisciplinary community networks: These networks bring together individuals from various backgrounds and disciplines, such as academia, civil society, and the general public. The goal is to promote sustainability, share knowledge, and raise awareness. Interdisciplinary collaboration ensures a more holistic and comprehensive approach to addressing global sustainability challenges.

Incorporating these networks, the 5N.BG.7PS model is pivotal in aligning SME operations with global sustainability objectives. It is designed to guide the creation of hybrid solutions that blend technological, environmental, and societal considerations, supporting SMEs in their transition to the SME X.0 paradigm. This model exemplifies how SMEs can leverage interdisciplinary collaboration and strategic governance to thrive amidst disruption and contribute to achieving global sustainability goals.

The following figure represents the 5N.BG.7PS model, illustrating the interconnected roles of political, technical, organizational, economic, and interdisciplinary community networks in driving sustainable development and innovation.

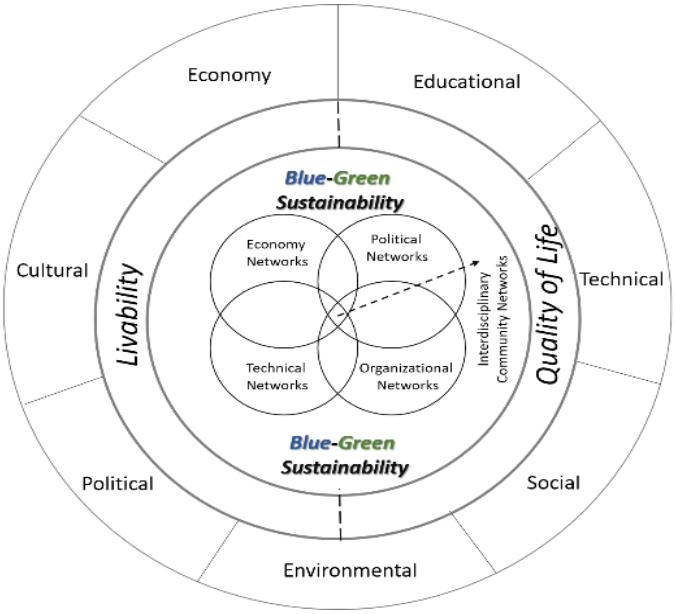


Figure 10. The 5N.BG.7PS model (Prof. H. Mattiello, 2017–2019).

Figure 10 presents a visual representation of the 5N.BG.7PS model, illustrating the interconnected roles of political, technical, organizational, economic, and interdisciplinary community networks in driving sustainable development and innovation.

The X.0 wave theory provides a comprehensive framework that is essential for understanding the rapid transformation of industries and societies through digitalization and sustainability. It offers a roadmap for businesses, governments, and educators to navigate the shifting landscape, emphasizing adaptability, technological innovation, and cross-sectoral collaboration. The 5N.BG.7PS model plays an instrumental role in this process by facilitating the integration of different sectors to foster resilience, growth, and sustainable development in the face of increasingly complex global challenges.

In your article, this model would seamlessly support the examination of how SMEs, when transitioning to the SME X.0 model, can better incorporate sustainability and innovation into their strategic frameworks, ensuring long-term success in a rapidly evolving business environment. By aligning this model with the 7PS and the broader X.0 wave theory, SMEs are better equipped to anticipate future trends, adapt to new technologies, and lead the charge towards sustainable growth.

The 5N.BG.7PS model is a key component in the transition to SME X.0, providing a comprehensive framework for navigating the complexities of sustainable growth and governance. By emphasizing the integration of five critical networks—political, technical, organizational, economic, and interdisciplinary community networks—The model addresses the multifaceted challenges SMEs face in the modern business landscape. In the context of the article, these networks play a pivotal role in fostering collaboration across sectors and disciplines, enabling SMEs to align their operations with the global sustainability agenda. The political networks ensure that regulatory frameworks support sustainable practices, while technical networks drive innovation through the development of cutting-edge technologies. Organizational networks translate these innovations into actionable strategies, supported by economic networks that provide the necessary financial resources. Finally, interdisciplinary community networks bring together diverse perspectives, ensuring that sustainability efforts are holistic and inclusive. This model is integral to the SME X.0 paradigm, offering a roadmap for businesses to adapt to the evolving technological, societal, and environmental demands of the future.

2.8. The nine pillars of sustainable governance model (9PSG)

The Nine Pillars of Sustainable Governance (9PSG) model is a comprehensive framework that integrates various interrelated components to promote sustainable governance. This model is designed to navigate the complexities of achieving sustainability in governance, addressing both the structures of governance and the practical implementation of sustainable practices across different sectors. The key components of the 9PSG model include (as shown in **Figure 11**):

1) D3 revolutions—Digitalization, Decarbonization, and Decentralization: These revolutions are integral to the evolution of governance and sustainability in the digital era [40,45].

2) Transparency & clarification planning—Ensuring transparency and clarity in governance processes and strategies [45].
3) Commitment expertise & mutual trust—A focus on fostering collaboration and trust-building in governance structures, which is essential for the implementation of sustainable practices [40,45].
4) i-Livability and quality of life—Prioritizing the livability of urban spaces, enhancing the quality of life for all stakeholders [45,50–52].
5) Networks—Emphasizing the importance of organizational, political, technical, economic, and interdisciplinary networks to foster collaboration and innovation [45,50–52].
6) Sustainability compass—A focus on aligning strategy, process management, environmental stewardship, and social responsibility for a balanced approach to sustainability [40,45,50–52].
7) HR talent & succession planning—Developing and retaining talent for effective governance, a crucial element for sustaining long-term governance goals [40,45,50–52].
8) Seven Pillars Sustainability model (7PS)—Incorporating cultural, environmental, social, economic, technical, educational, and political considerations, in alignment with global sustainability agendas [45,50–52].
9) 3D-sociecoenvironment business model—Focusing on environmental responsibility, social choice, and economic efficiency in a balanced, sustainable approach [45,50–52].

In recent years, scholars have increasingly recognized the importance of digital technologies in fostering sustainable governance. The incorporation of Hybrid SMEs (small and medium enterprises) and SME X.0 frameworks are central to this discussion, as they represent the shift towards integrating sustainability into the business strategies of SMEs [45,50–52]. The 9PSG model aligns with these frameworks by providing a structure for governance that emphasizes not only technological innovations but also the necessity of human capital development through HR talent and succession planning [40,45,50–52].

These elements work in unison to promote sustainable governance, ensuring that decision-making processes are inclusive, transparent, and focused on long-term sustainability goals. The 9PSG model can be applied across various sectors, including sustainable management, by addressing the critical pillars of governance, collaboration, and accountability.

Figure 11 illustrates the Nine Pillars of Sustainable Governance (9PSG) model, demonstrating how each pillar contributes to sustainable governance, supporting sectors such as sustainable management, collaboration, and accountability in governance systems.

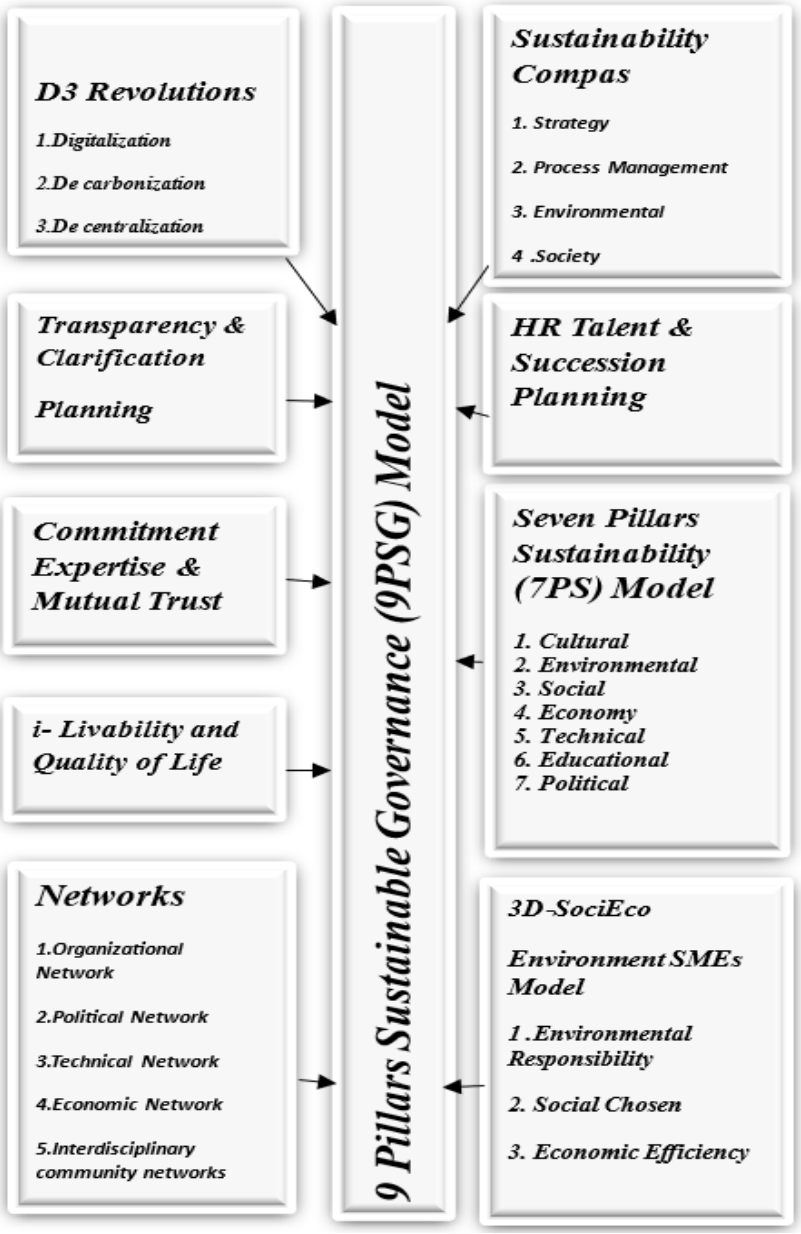


Figure 11. Nine pillars of sustainable governance (9PSG) model (Prof. H. Mattiello, 2017–2019).

Application of the 9PSG model in sustainable management: The 9PSG model can be effectively applied to promote sustainable management and the transition toward a Blue-Green clean technologically innovative economy. Here's how each pillar of the model supports this objective:

1) D3 revolutions:
   - *Digitalization* enables the monitoring and management of resources using innovative technologies.
   - *Decarbonization* supports the use of renewable energy in treatment and distribution processes.
   - *Decentralization* promotes localized solutions like rainwater harvesting and sustainable irrigation systems. See **Figures 12** and **13**.

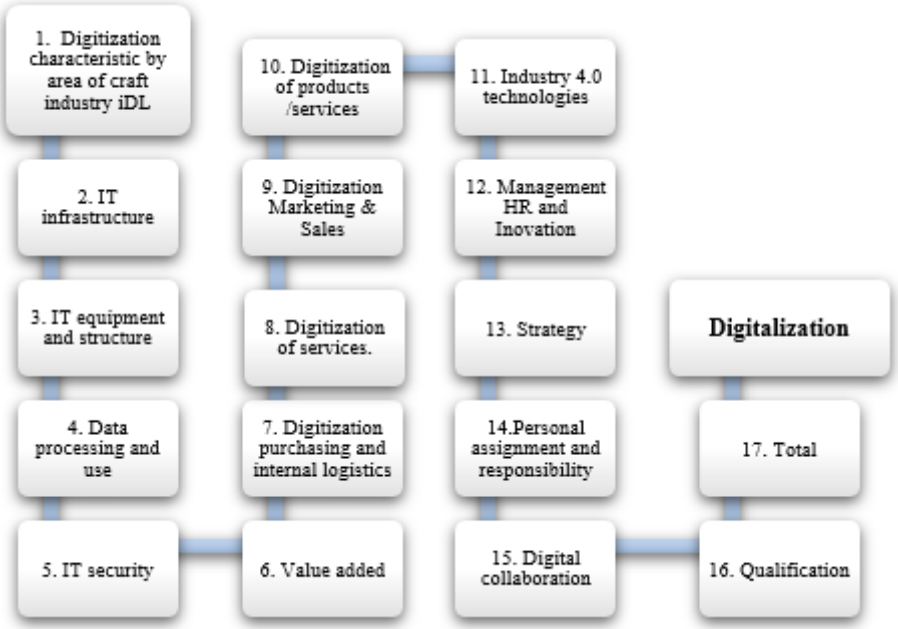


Figure 12. Digitalization dimensions [40].

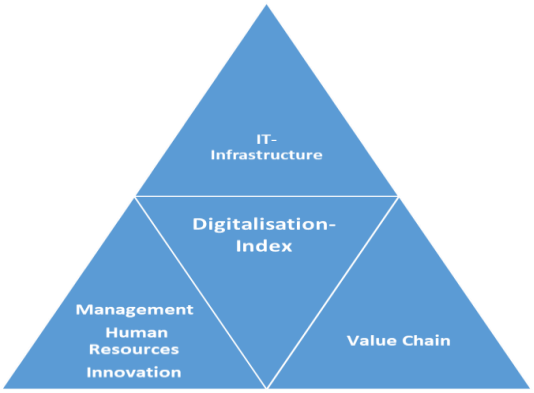


Figure 13. Digitization index by industry [40].

2) Transparency & clarification planning:
   - Developing transparent policies ensures the equitable use of natural resources and fosters trust among stakeholders.
   - Clear communication of availability and usage promotes responsible consumption and conservation.
3) Commitment expertise & mutual trust:
   - Encouraging partnerships between government agencies, private companies, and communities builds expertise and trust in sustainable management solutions.
4) Livability and quality of life:
   - Sustainable management ensures access to clean, safe life, contributing to better health and well-being.

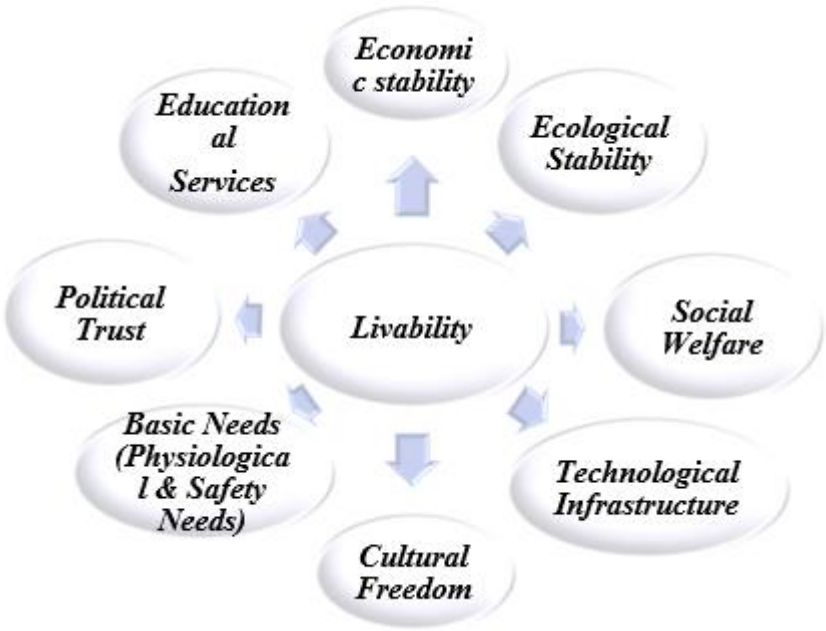


Figure 14. Aspects of liveability (Prof. H. Mattiello, 2017–2019).

Figure 14 illustrates the fundamental relationship between livability and sustainability. Based on the 7PS model, Prof. Mattiello defines eight key aspects that collectively shape a sustainable and high-quality life. These aspects serve as the pillars of a well-functioning society, ensuring stability, progress, and well-being:

(1) Basic Needs – Ensuring access to essential physiological and safety needs, such as food, water, shelter, and security, as the foundation for human survival.
(2) Cultural Freedom – Upholding individual and collective rights to cultural expression, diversity, and identity, fostering social harmony and inclusivity.
(3) Ecological Stability – Maintaining environmental balance through responsible resource management, conservation efforts, and sustainable practices.
(4) Social Welfare – Providing equitable access to healthcare, social security, and community support systems to enhance overall well-being.
(5) Economic Stability – Promoting financial security, job opportunities, and economic resilience to support long-term prosperity.
(6) Technological Infrastructure – Ensuring the availability of modern technology and digital connectivity to drive innovation and societal development.
(7) Educational Services – Facilitating lifelong learning, knowledge dissemination, and skill development to empower individuals and communities.
(8) Political Trus**t** – Establishing transparent governance, ethical leadership, and public confidence in institutions to maintain social cohesion and stability.

By integrating these eight dimensions, the 7PS model highlights how livability serves as the foundation of sustainability, emphasizing the need for a balanced and holistic approach to societal development.

5) Networks (5N.BG.7PS model):
   - Strong networks across organizational, political, technical, economic, and community sectors encourage collaboration and innovation in sustainable management practices. See **Figure 10**.
6) Sustainability compass:

- A sustainability strategy ensures resource management practices balance environmental, social, and economic considerations.
- Process management tools ensure the efficient and effective implementation of sustainable practices.
- Environmental and social factors ensure equitable access and conservation of natural resources.

7) HR-talent & succession planning:
   - A skilled workforce ensures the sustainable implementation and management of business practices, addressing both current and future challenges.
8) Seven Pillars Sustainability model (7PS):
   - Cultural, environmental, social, economic, technical, educational, and political factors ensure that sustainable management practices are aligned with sustainability goals and respect diverse values and needs. See **Figures 15–17**.

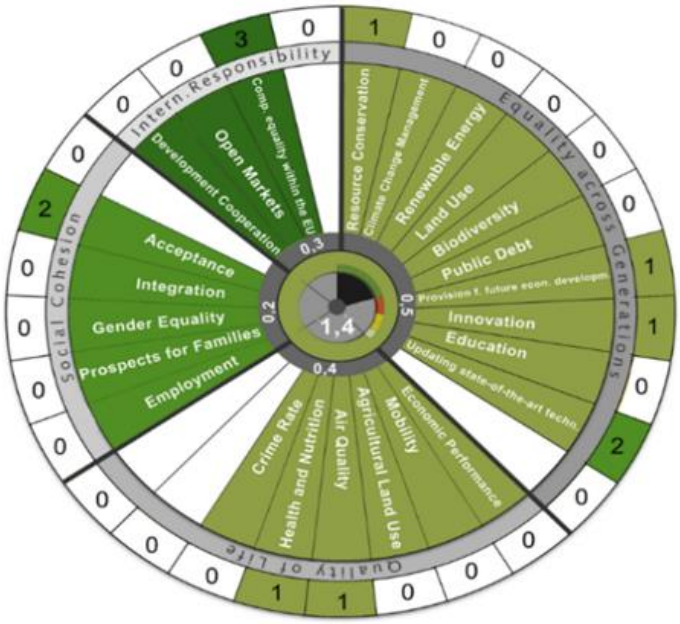


Figure 15. Research project FHM-NZBA: The entrepreneurial sustainability compass criteria [11,12].

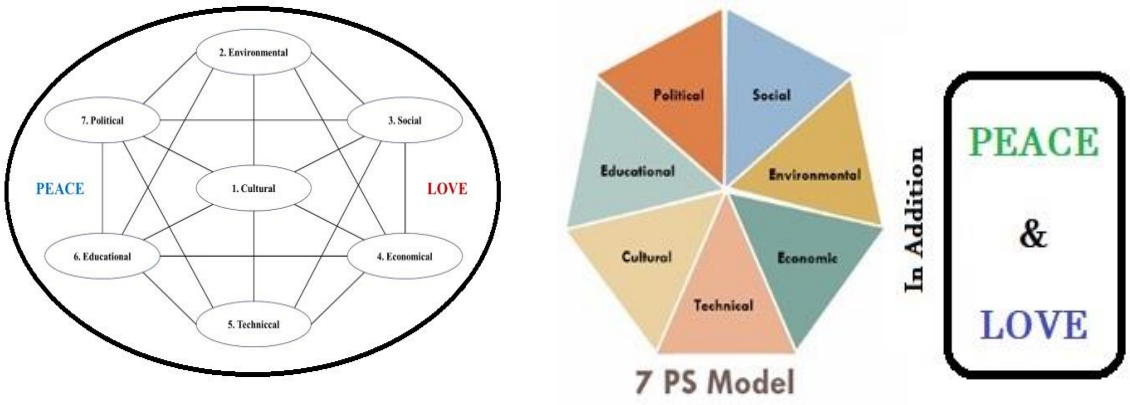


Figure 16. Seven Pillars of Sustainability (7PS) model (Prof. H. Mattiello, 2017–2019).

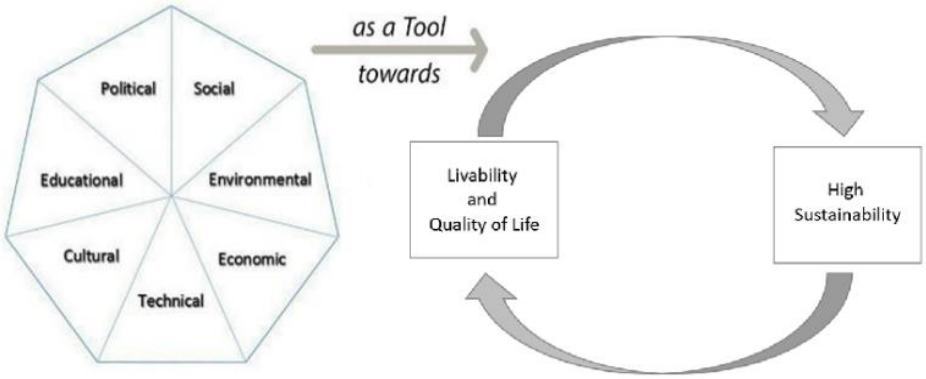


Figure 17. Relation among quality of liveability and life & 7 Pillars of Sustainability (Prof. H. Mattiello, 2017–2019).

9) 3D-sociecoenvironment business model:
   - *Environmental responsibility* focuses on protecting business ecosystems.
   - *Social considerations* promote fair access to natural resources.
   - *Economic efficiency* ensures the financial viability of sustainable management projects.

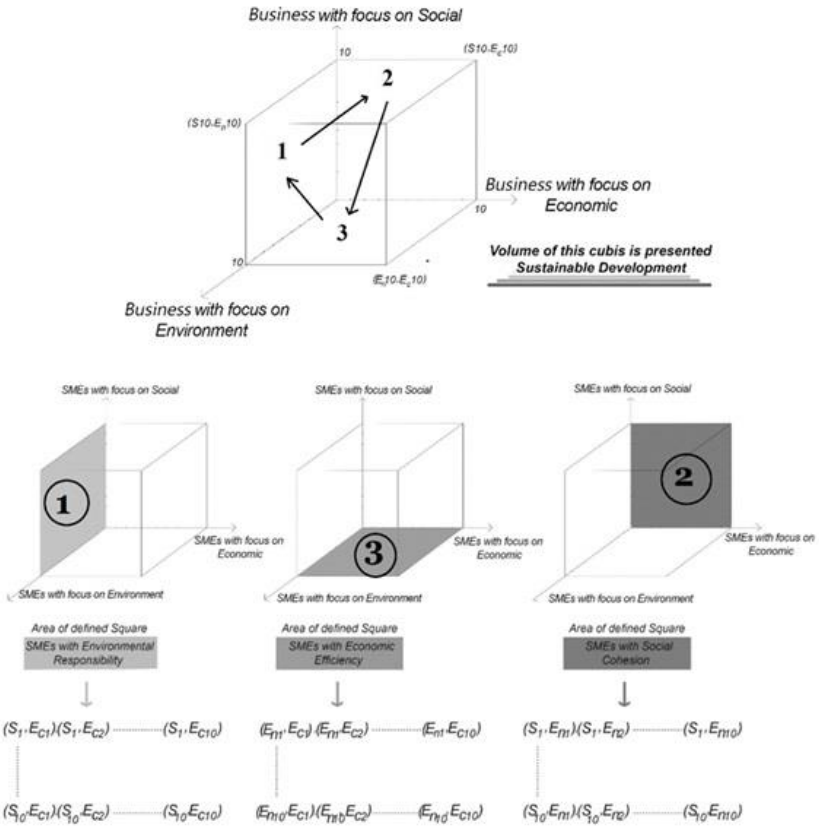


Figure 18. 3D Socio-eco-environment SMEs indexes model (Prof. Mattiello, 2017).

Figure 18 illustrates the 3D Socio-Eco-Environment SMEs Indexes Model, which tracks how small and medium enterprises (SMEs) can integrate these principles into their operations. This model provides valuable insights into how SMEs can evaluate and enhance their contributions to sustainable development, fostering an

environment where economic growth as 3rd priority, social equity as 2nd priority, and environmental health as first priority go hand in hand.

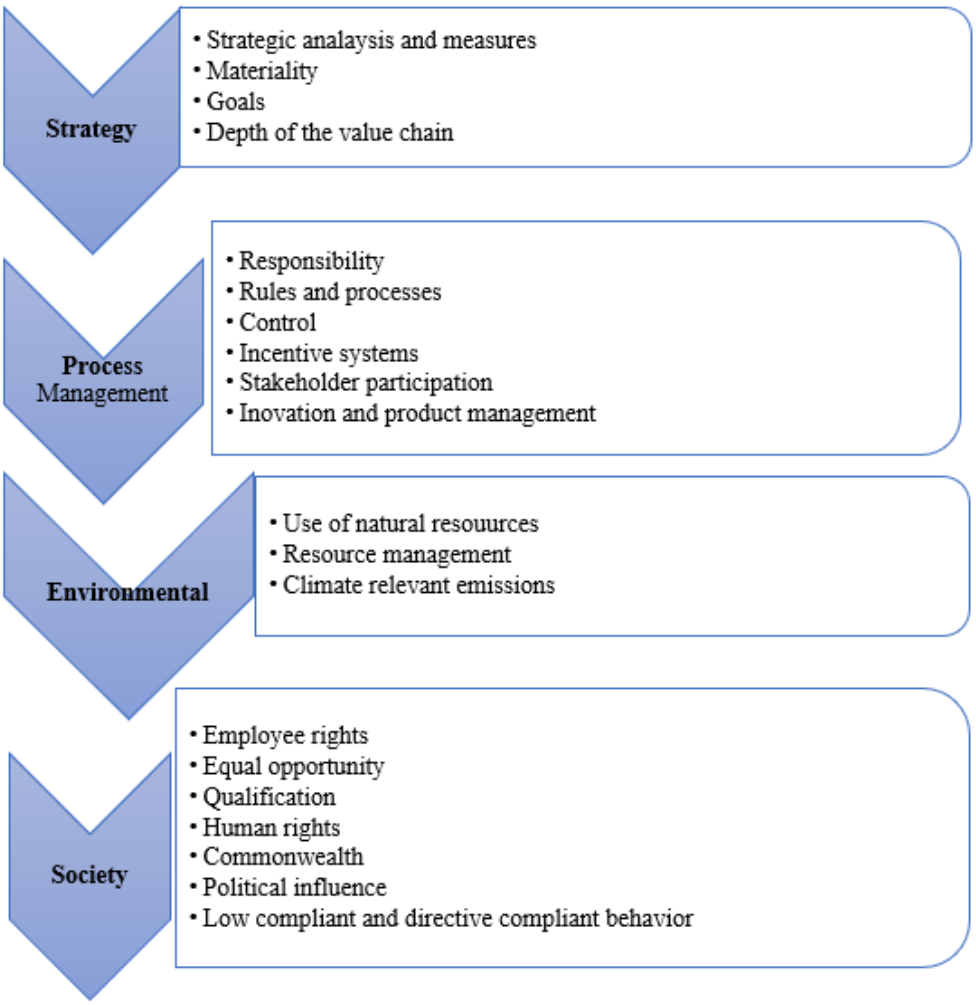


Figure 19. Research project FHM-NZBA: Development of a standard benefits model for systematic evaluation of the benefits of laws and regulations in terms of sustainable growth) [40,45].

Figure 19 illustrates the proposed model and the key evaluation criteria used to assess the impact of regulations, offering insights into how businesses, governments, and other stakeholders can measure the effectiveness of policies in fostering sustainable growth.

By integrating these pillars into sustainable governance frameworks, the 9PSG model supports the realization of a sustainable, innovative, and technologically advanced sustainable management system that serves both current and future generations.

2.9. Sustainable future

Creating a sustainable future is one of the most pressing global challenges, requiring coordinated efforts between governments, businesses, and communities. The Sustainable Development Goals (SDGs), established in 2015, offer a comprehensive framework with 17 targets aimed at ensuring global sustainability. However, progress

toward these goals has been slow, highlighting the urgent need for innovative strategies and systemic transformation.

Despite these challenges, the vision of a sustainable world has gained momentum, particularly among younger generations, policymakers, businesses, and investors. However, achieving sustainability demands more than aspirations—it requires a radical transformation in how societies produce, consume, and manage resources. Technology, entrepreneurship, and strategic policymaking serve as powerful enablers in converting green initiatives into tangible, lasting solutions. The X.0 wave theory recognizes sustainability as an evolving process embedded in economic, technological, and cultural progress, shaping future societies through innovation-driven resilience.

A truly sustainable future necessitates the protection and restoration of vital ecosystems, including forests, soil, and natural resources, by adopting smart resource management approaches. This requires industries and communities to integrate circular economy principles, reduce their carbon footprint, and transition toward renewable energy sources, such as solar, wind, and next-generation biofuels. While existing and emerging technologies provide viable pathways to sustainability, major shifts in production and consumption patterns are necessary to actualize a regenerative global economy.

However, realizing these shifts requires overcoming significant economic, social, and political barriers. Structural transformations, such as incentivizing sustainable business models, redefining supply chains, and enforcing robust environmental policies, are crucial. The integration of AI-driven resource optimization, smart grids, and climate-responsive urban planning within the X.0 wave framework illustrates the role of technological foresight in navigating the complexities of sustainable development.

Achieving a sustainable future is not merely an environmental goal but a fundamental requirement for the longevity of economies and civilizations. By fostering cross-sector collaboration, adopting ethically responsible innovation, and leveraging the principles of the X.0 wave theory, societies can achieve a balance between economic growth, technological advancement, and ecological preservation. The future of sustainability lies in reimagining progress, ensuring that technological evolution aligns with long-term planetary health and human well-being [45,50–53].

2.10. Digital transformation

The integration of advanced digital technologies—including IoT, AI, and big data analytics—into SME X.0 business models and governance structures to enhance efficiency, adaptability, and sustainability. In the context of your study, digital transformation enables SMEs to transition into hybrid, innovation-driven enterprises that align with global sustainability goals and the X.0 wave theory.

2.11. Sustainable development

A strategic approach that ensures SMEs achieve long-term economic growth while balancing social equity and environmental responsibility. Through frameworks such as 7PS and 9PSG, SME X.0 enterprises adopt sustainability as a core principle,

leveraging Smart Cyber Governance to minimize resource depletion, address climate challenges, and foster inclusive socio-economic progress.

2.12. IoT-driven governance

A governance model where SMEs leverage Internet of Things (IoT) technologies to enhance transparency, decision-making, and operational efficiency. This approach, embedded in Smart Cyber Governance, allows real-time monitoring of resources, predictive analytics for risk management, and automated sustainability compliance, ensuring SMEs remain agile and responsive to emerging global challenges.

2.13. Business model innovation

The redesign of SME structures and processes to incorporate sustainability, technological agility, and governance transformation. Rooted in the X.0 wave theory, business model innovation in SME X.0 involves integrating 7PS-driven decision-making, leveraging IoT technologies, and fostering interdisciplinary networks (5N.BG.7PS) to create adaptive, resilient, and future-ready enterprises. Each of these concepts plays a crucial role in shaping SME X.0 as a hybrid, sustainability-focused enterprise capable of thriving in the face of digital disruptions and global sustainability imperatives.

3. Research method

The present research is applied in its purpose and descriptive in nature. It employs a mixed-method approach, integrating both qualitative and quantitative methodologies, within the Deductive-Inductive Framework, ensuring a holistic and comprehensive analysis.

3.1. Qualitative phase: Thematic analysis

In the qualitative phase, thematic analysis was used to identify, categorize, and understand key concepts related to Hybrid SMEs and SME X.0 through the lens of Smart Cyber Governance. The analysis was executed in three stages:

1) Text analysis: Reviewing relevant literature and extracting core themes related to SME X.0 and governance.
2) Text description: Identifying basic concepts and categories associated with the transformation of Hybrid SMEs.
3) Text combination: Synthesizing the identified concepts into thematic networks, contributing to a deeper understanding of Hybrid SMEs/SME X.0 and their governance.

In-depth, semi-structured interviews were conducted with domain experts to enrich the thematic analysis. The interview data and secondary data from document analysis were coded, categorized, and organized into thematic networks using NVivo 12 software. The reliability of the findings was evaluated using Cohen's Kappa test (0.787) and the CVR coefficient (0.53), as shown in **Table 3**, ensuring the robustness of the qualitative analysis.

Table 3. Validity and reliability in the qualitative section.

Reliability		**Validity**	
Value	**The tool used**	**Value**	**The tool used**
0.787	Cohen's Kappa	0.53	CVR coefficient

In the quantitative stage, in order to confirm the results of the qualitative analysis, fuzzy Delphi method was used. This method was carried out to confirm the results of qualitative analysis and determine the antecedents and consequences of Hybrid SMEs/SME X.0 through Smart Cyber Governance, and the most important factors and consequences of Hybrid SMEs/SME X.0 were determined. The Delphi method includes a type of group process that emphasizes the mutual relationship between the researcher and a group of experts, and experts' opinions are usually collected through a questionnaire. Therefore, in the present study, a fuzzy Delphi questionnaire was designed and sent to academic and organizational experts for their opinion. The statistical population of the current research included 10 business and university sustainability experts and specialists in the qualitative phase, and 20 business and university experts in the quantitative phase, who were selected using a targeted sampling method. Based on the principle of data sufficiency, up to the stage of theoretical saturation, data and information needed for the research were collected through interviews. The general questions of the interview included the factors, antecedents and consequences related to the commodification of Hybrid SMEs/SME X.0 through Smart Cyber Governance. On the other hand, in the quantitative stage, using the results of the qualitative stage and the opinions of experts in the field of antecedents and consequences of Hybrid SMEs/SME X.0 a fuzzy Delphi questionnaire was designed and sent to the relevant experts.

3.2. Quantitative phase: fuzzy Delphi method

Following the qualitative analysis, the fuzzy Delphi method was applied to validate and refine the findings. This method is widely used to gather expert opinions through an iterative process aimed at reaching consensus on complex issues, such as the antecedents and consequences of Hybrid SMEs/SME X.0 in the context of Smart Cyber Governance.

The fuzzy Delphi process was carried out in two phases with a panel of 69 domain experts, including business practitioners, policymakers, and academic scholars specializing in SME sustainability and digital transformation. Expert opinions were solicited using a structured fuzzy Delphi questionnaire designed to gather insights on the critical factors influencing the development of SME X.0.

3.3. First phase: Expert panel and questionnaire development

The expert panel was initially selected through a targeted sampling approach. This included 10 experts from business and university sectors focusing on sustainability and SME digital transformation. The fuzzy Delphi questionnaire was based on the findings of the qualitative phase, and experts were asked to rate their level of agreement using linguistic variables: very little, little, medium, much, and very

much. These variables were then converted into triangular fuzzy numbers, as shown in next pages.

3.4. Second phase: Iterative feedback and refinement

In the second phase, the experts' responses from the first phase were analyzed to compute fuzzy averages, and feedback was provided to them. The questionnaire was revised based on the first round of feedback, and a second round of responses was gathered. The fuzzy averages were recalculated, and the results were used to assess whether consensus had been reached.

3.5. Integration of the 7PS and 9PSG models

The integration of the 7PS model (Seven Pillars of Sustainability) and the 9PSG model (Nine Pillars of Smart Governance) formed the backbone of the analysis in this study. These models provided a structured framework for understanding the governance and sustainability dimensions of Hybrid SMEs/SME X.0. They helped map out the various aspects of governance (political, economic, technological) and sustainability (environmental, social, governance) influencing the transformation of SMEs.

Each pillar in these models was used to analyze the factors identified through the qualitative phase and refined in the fuzzy Delphi phase. The 7PS model contributed to understanding how sustainability influences SME X.0, while the 9PSG model was pivotal in evaluating governance structures, policies, and smart technologies enabling this transformation.

3.6. Development of the 5N.BG.7PS model

The 5N.BG.7PS model was specifically developed for this study to address the needs of Hybrid SMEs undergoing digital transformation. This model is an extension of the existing 7PS framework and integrates additional components necessary for understanding the business governance transformation in SMEs.

The components of the 5N.BG.7PS model include:

- 5N: Five key areas of governance and strategic leadership (including human resources, technology adoption, business structure, financial management, and strategic planning).
- BG: The business governance dimension, which emphasizes leadership and policy frameworks that drive SME X.0.
- 7PS: Seven pillars focusing on sustainability and governance.

This model was tailored specifically to Hybrid SMEs, considering their unique needs and challenges in the context of digital governance.

4. Research findings

In this section, qualitative analysis using theme analysis in Nvivo 12 software will be discussed first. Then quantitative analyzes are performed using fuzzy Delphi technique.

4.1. Findings of the qualitative stage

In the qualitative phase, in order to identify the antecedents and consequences of Hybrid SMEs/SME X.0 through Smart Cyber Governance, relevant subjects were identified from the review and analysis of texts and semi-structured interviews. In this way, first, the texts related to Hybrid SMEs/SME X.0 were analyzed. Based on that, the interview questions were designed, and after providing the necessary explanations to the interviewees, the interview process was carried out. Then, the interview texts were analyzed using the theme analysis method and with the help of NVivo 12 software. After analyzing the texts and conducting interviews, the basic themes were extracted. The antecedents and consequences of Hybrid SMEs/SME X.0 through Smart Cyber Governance based on basic topics are stated in the table. According to **Table 4**, the antecedents obtained from the analysis of texts and semi-structured interviews include 8 basic topics. Also, the consequences include 8 positive consequences that can be seen in the table. **Tables 4–7** show the fuzzy averages for the second stage survey, indicating the expert consensus on various antecedents and consequences related to Hybrid SMEs/SME X.0.

Table 4. Antecedents and consequences of Hybrid SMEs/SME X.0.

Consequences		**Antecedents**	
Factors	**code**	**Factors**	**code**
Environmental responsibilities	C1	Cultural-educational factors	A1
Social responsibilities	C2	Individual-managerial factors	A2
Increase transparency	C3	Planning and foresight factors	A3
Increase responsiveness	C4	structural mechanism (capacity for development, implementation and testing)	A4
Customer Satisfaction	C5	Environmental uncertainty	A5
energy and resource saving	C6	Political and strategic factors	A6
future planning	C7	Factors based on high technologies	A7
financial focus	C8	Economic factors	A8

4.2. Findings of the quantitative stage

Findings of the quantitative stage After analyzing various texts and conducting a semi-structured interview using NVivo 12 software, 16 themes were identified in the form of antecedents and consequences of Hybrid SMEs/SME X.0. The fuzzy Delphi method was used to check the validity of the identified topics. The subjects counted were designed in the form of a fuzzy Delphi questionnaire with the aim of obtaining the opinion of experts. The relevant experts express their level of agreement through verbal variables: very little, little, medium, much, and very much. Then, these variables are defined as triangular fuzzy numbers. **Table 5** shows how to convert verbal variables into triangular fuzzy numbers and deterministic fuzzy numbers.

Table 5. Triangular fuzzy numbers and definitive numbers.

De-fuzzified value	Triangular fuzzy number	Verbal variables
0.0625	(0, 0, 0/25)	very low
0.2500	(0, 0/25, 0/50)	Low
0.5000	(0/25, 0/50, 0/75)	Medium
0.7500	(0/50, 0/75, 1)	Much
0.9375	(0/75, 1, 1)	very much

It is worth mentioning that the de-fuzzified value was calculated using the relationship [54], which is stated below:

Relationship 1) ¼ $(a_{i1}, 2a_{i2}, a_{i3})$.

Based on the above relationship, a_{i1}, the lower limit of the triangular fuzzy number; a_{i2}, the middle limit of the triangular fuzzy number; and a_{i3}, the upper limit of the triangular fuzzy number.

A) First stage survey: In the first stage of the fuzzy Delphi technique, the identified subjects were given to the experts in the form of a questionnaire. According to the proposed options and the defined linguistic variables, the results of the survey of the questionnaire answers were analyzed to obtain the fuzzy average of the subjects. **Table 6** shows the fuzzy average of each of the identified topics.

Table 6. The average opinion of experts in the first stage survey.

Fuzzy average	Codes	Fuzzy average	Codes
(0/59, 0/84, 0/94)	C1	(0/49, 0/74, 0/94)	A1
(0/53, 0/79, 0/93)	C2	(0/41, 0/66, 0/88)	A2
(0/51, 0/76, 0/90)	C3	(0/74, 0/73, 0/90)	A3
(0/59, 0/84, 0/95)	C4	(0/46, 0/71, 0/91)	A4
(0/49, 0/74, 0/89)	C5	(0/43, 0/68, 0/88)	A5
(0/50, 0/75, 0/94)	C6	(0/35, 0/60, 0/83)	A6
(0/46, 0/71, 0/85)	C7	(0/29, 0/51, 0/74)	A7
(0/46, 0/69, 0/84)	C8	(0/35, 0/60, 0/83)	A8

After the end of the first stage survey, it is necessary to conduct the second stage survey so that the results obtained from both stages can be compared and the result determined.

B) Second stage survey: In the second stage survey, as in the first stage, the answers given to the topics are counted, and their fuzzy average is calculated. **Table 7** shows the relevant values for the fuzzy average.

Table 7. The average opinion of experts in the second stage survey.

Fuzzy average	Codes	Fuzzy average	Codes
(0/68, 0/93, 0/99)	C1	(0/65, 0/81, 0/98)	A1
(0/60, 0/85, 0/98)	C2	(0/35, 0/59, 0/83)	A2
(0/60, 0/85, 0/95)	C3	(0/56, 0/81, 0/91)	A3
(0/66, 0/91, 0/99)	C4	(0/40, 0/65, 0/86)	A4

Table 7. (*Continued*).

Fuzzy average	Codes	Fuzzy average	Codes
(0/60, 0/84, 0/93)	C5	(0/51, 0/76, 0/93)	A5
(0/58, 0/83, 0/98)	C6	(0/55, 0/80, 0/99)	A6
(0/53, 0/78, 0/99)	C7	(0/30, 0/55, 0/80)	A7
(0/38, 0/63, 0/86)	C8	(0/44, 0/69, 0/90)	A8

After the end of the second stage survey, it is necessary to analyze the difference of the de-fuzzified average of the antecedents and consequences of the commoditization of Hybrid SMEs/SME X.0. If there is a difference between the de-fuzzified averages in the first and second stages. If it is less than 0.1, the polling process is stopped). **Table 8** shows the different values of the de-fuzzified average.

Table 8. The difference between the de-fuzzified mean of the first and second stages.

The difference between the average of the first and second stages	The de-fuzzified average of the first stages	The de-fuzzified average of the second stages	Codes
0.066	0.791	0.725	A1
0.065	0.588	0.653	A2
0.069	0.775	0.706	A3
0.059	0.641	0.700	A4
0.079	0.741	0.662	A5
0.090	0.784	0.694	A6
0.038	0.550	0.512	A7
0.084	0.678	0.594	A8
0.078	0.878	0.800	C1
0.060	0.819	0.759	C2
0.078	0.812	0.734	C3
0.066	0.869	0.803	C4
0.087	0.800	0.713	C5
0.069	0.803	0.734	C6
0.082	0.766	0.684	C7
0.047	0.622	0.669	C8

Based on the above table, the difference of the de-fuzzified average in the first and second stages is less than 0.1, and therefore the experts reached a consensus about the antecedents and consequences of Hybrid SMEs/SME X.0. At this point, the survey stops.

4.3. Data analysis: Integration of qualitative and quantitative data

The qualitative and quantitative data were combined and analyzed through a process of triangulation to ensure a cohesive and integrated interpretation of the research findings. First, the qualitative data was analyzed through thematic analysis, as described earlier, and then validated through the fuzzy Delphi process.

The quantitative data obtained through the fuzzy Delphi method was used to refine the themes and identify the most critical factors and strategies for SME X.0 transformation. The final integration of findings was achieved by combining both datasets, providing a comprehensive and evidence-based framework that addressed the research questions and objectives.

The triangulation of these methods ensured that the data was comprehensive, robust, and reliable, offering actionable insights into the governance and sustainability strategies required for the successful transformation of Hybrid SMEs into SME X.0.

5. Result and discussion

5.1. Result

The evolution of SME X.0 marks a significant transformation in sustainability-driven business models, necessitating collaboration between governments, businesses, and communities. Emerging trends and initiatives—such as artificial intelligence, smart policymaking, digital entrepreneurship, sustainable development goals, and civic engagement—shape the trajectory of SME ecosystems. This research explores the antecedents and consequences of Hybrid SMEs/SME X.0 through Smart Cyber Governance, leveraging a mixed-methodological approach that integrates qualitative thematic analysis and the quantitative fuzzy Delphi technique.

The results reveal key antecedents and outcomes of SME X.0, validated through expert insights and statistical analyses, which align with key trends identified in the research of Mattiello [40,45,52,53], Kanbara [55] and others.

Antecedents of SME X.0:

1) Cultural-educational factors:

The role of knowledge-driven governance, talent development, and strategic foresight in fostering adaptability within SMEs has been widely acknowledged in Mattiello [40,45,52,53], who emphasized the need for a comprehensive understanding of technological evolution in strategic management. Similarly, Mattiello [40,45,52,53] also argue that aligning education and knowledge systems with innovation is a key driver for SME success in the digital age. Our findings confirm that SMEs with robust educational infrastructures are better positioned to adapt to the X.0 transformation.

2) Individual-managerial factors:

Leadership capabilities, change management, and the entrepreneurial mindset are critical for navigating technological disruptions. Srinivasa et al. [56] discuss the centrality of leadership and managerial adaptability in their study on Society 5.0. Our findings expand on this by showing that the managerial factors identified in Mattiello [40,45,52,53] are instrumental in ensuring that SMEs transition successfully into SME X.0 models.

3) Planning and foresight factors:

The importance of long-term sustainability alignment, scenario planning, and proactive governance mechanisms is consistent with the conclusions of Kanbara [55], who emphasizes the need for strategic foresight in managing emerging challenges. This study similarly confirms that SMEs with strong foresight mechanisms are more successful in aligning with sustainability goals.

4) Structural mechanisms:

Srinivasa et al. [56] identify flexibility in structural mechanisms as crucial for fostering innovation in SMEs. Our research supports this by identifying how SMEs that engage in iterative innovation cycles see greater success in adapting to new technological advancements.

5) Environmental uncertainty:

Geopolitical dynamics, economic fluctuations, and climate risks have been highlighted by Srinivasa et al. [56] as significant challenges to SME stability in their work on Society 5.0. Our results show that SMEs adopting proactive strategies for dealing with these uncertainties are more resilient in the face of global disruptions.

6) Political and strategic factors:

Governmental policies and regulatory frameworks play a pivotal role in enabling SME transitions. Kanbara [55] discusses how regulatory frameworks in Society 5.0 are essential for fostering the growth of SMEs in complex socio-economic environments. Our findings align with this, showing that SMEs in environments with strong institutional support exhibit more significant growth in the X.0 transition.

7) Technology-based factors:

The integration of IoT, AI, big data, and automation has been a key enabler of operational efficiency and sustainability. Mattiello [40,45,52,53] underscore the importance of technological integration for SMEs in Japan's Society 5.0 framework, and our study corroborates this by showing how the adoption of these technologies leads to enhanced operational performance in SMEs.

8) Economic factors:

Financial sustainability and the market adaptability of SMEs are frequently cited as crucial drivers for SME success. Srinivasa et al. [56] explore how SMEs' financial strategies and adaptability to green technologies play a role in their sustainable development. Our study mirrors these findings, showing that the adoption of green technologies and the diversification of revenue streams are essential for long-term sustainability.

Consequences of SME X.0 through Smart Cyber Governance:

1) Environmental responsibilities:

Our results highlight the strengthened commitment to sustainability, carbon footprint reduction, and responsible resource management as key consequences of SME X.0. This aligns with Kanbara [55], who discusses the importance of carbon reduction and sustainable practices in Society 5.0 frameworks.

2) Social responsibilities:

Enhanced Corporate Social Responsibility (CSR) and workforce well-being have been integral to SME X.0 outcomes. This finding is consistent with Srinivasa et al. [56], who explore how SMEs can leverage digital governance for greater social engagement and well-being. Our results further show how these social responsibilities are amplified by effective Cyber Governance.

3) Increased transparency:

Increased transparency via data-driven governance is another significant outcome identified in the study. This finding supports the work of Mattiello [40,45,52,53], who emphasizes that digital governance fosters transparency and accountability, particularly in sustainable business models.

4) Increased responsiveness:

Our study found that SMEs benefit from more agile decision-making processes and enhanced stakeholder engagement. This is echoed in Srinivasa et al. [56], who argue that responsive SMEs outperform less agile competitors in dynamic environments, particularly in the context of Society 5.0.

5) Customer satisfaction:

Customer satisfaction and the digital transformation of customer experiences have been widely documented in the literature. Srinivasa et al. [56] also find a direct relationship between technological adoption and improved customer engagement. Our study reaffirms this link, demonstrating how SMEs can significantly enhance customer satisfaction by embracing digital transformation.

6) Energy and resource efficiency:

The adoption of smart energy management systems and resource optimization is a central finding in our study. This is in line with Srinivasa et al. [56], who explore the role of IoT in achieving resource efficiency in SMEs, particularly in the context of sustainable business practices.

7) Future planning and strategic development:

Future strategic planning for sustainability aligns with the work of Kanbara [55], who discusses how proactive planning is essential for SMEs in navigating future uncertainties. Our research confirms that SME X.0 companies are more likely to incorporate long-term sustainability into their strategies.

8) Financial focus:

Financial sustainability remains a central focus of our study, corroborating the findings of Mattiello [40,45,52,53], who argues that strategic investments, risk management, and revenue diversification are key for SMEs' long-term success.

These findings confirm that integrating the X.0 wave theory with the 7PS and 9PSG frameworks offers a robust roadmap for fostering innovation, resilience, and sustainability within SME ecosystems. Our results align with and extend the work of Mattiello [40,45,52,53], Kanbara [55], Srinivasa et al. [56], and others, emphasizing the necessity of strategic foresight, adaptive governance, and cross-sector collaboration to enable SME X.0 to thrive in an increasingly complex global landscape.

5.2. Discussion

Presently, we are in the Fourth wave (Digitalization Age)—The period of the occurrence of I4.0, influenced by digitalization and automatization procedures. It does not only cause huge changes in production but also in every aspect of life. The concept of the X.0 wave (Age of Tomorrow) was invented in 2010 and further developed until today. Due to this concept, there are three factors for tomorrow's shock: knowledge, technology, and business (KTB). For 100 years, business development has been proceeding; however, mankind is not prepared for tomorrow. The author's model is pointing out the main infrastructure of the edge of tomorrow and tomorrow's shocks.

Figure 20 highlights the key infrastructures that will define the edge of tomorrow and the shocks that are to come. This model serves as a framework for understanding

the interplay between knowledge, technology, and business in shaping future developments and their impact on society.

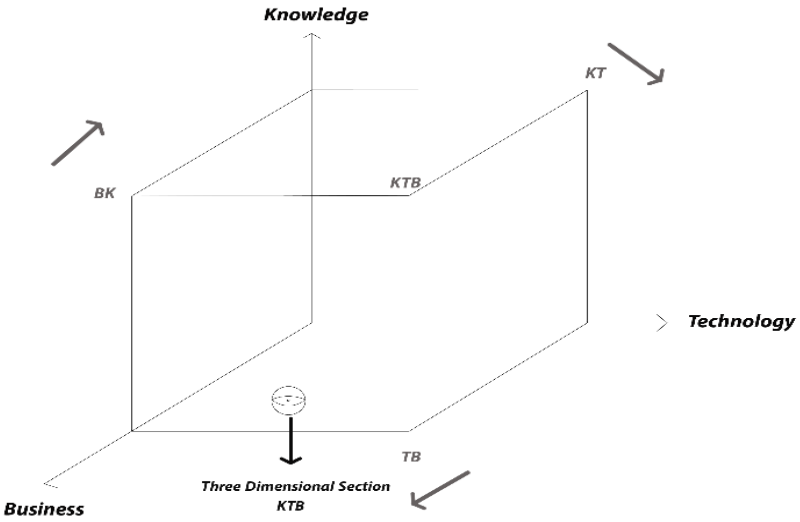


Figure 20. Knowledge, technology, business (KTB) model (Prof. Mattiello, 2010-17).

The global business landscape is undergoing a profound shift as SMEs transition toward SME X.0, driven by digital transformation, governance innovation, and sustainability imperatives. Positioned within the Fourth wave (Digitalization Age), contemporary enterprises are reshaping traditional production and business operations through automation, IoT, and AI-driven ecosystems. However, the forthcoming X.0 wave (Age of Tomorrow), conceptualized in 2010, introduces new paradigms of business, knowledge, and technological advancements, presenting both unprecedented opportunities and challenges for SMEs.

This study positions SME X.0 within the Knowledge, Technology, Business (KTB) model, emphasizing that tomorrow's business shocks will emerge from the convergence of these three factors. The accelerating pace of digitalization, alongside escalating socio-environmental concerns, necessitates that SMEs adopt transformative governance strategies and innovation-driven sustainability frameworks. The X.0 wave theory underscores the imperative for SMEs to evolve into hybrid, technology-integrated, and sustainability-oriented entities capable of navigating tomorrow's complexities.

Key takeaways from this discussion include:

- Strategic integration of sustainability and digital transformation: The synergy between Smart Cyber Governance and the 7PS sustainability model enables SMEs to address climate risks, resource depletion, and economic uncertainties proactively.
- The role of the 9PSG framework in governance evolution: Future-ready SMEs must leverage the Nine Pillars of Sustainable Governance to enhance resilience, regulatory compliance, and stakeholder engagement.

- Leveraging IoT-driven business models: Digital ecosystems, powered by AI, blockchain, and real-time data analytics, offer SMEs enhanced agility, operational efficiency, and strategic decision-making capabilities.
- Fostering an adaptive organizational culture: The integration of cultural-educational drivers within SME X.0 emphasizes the need for continuous learning, workforce upskilling, and leadership adaptability.
- Navigating policy and institutional frameworks: Policymakers must provide supportive regulatory environments and incentives to facilitate the seamless transition of SMEs into hybrid, sustainability-focused enterprises.

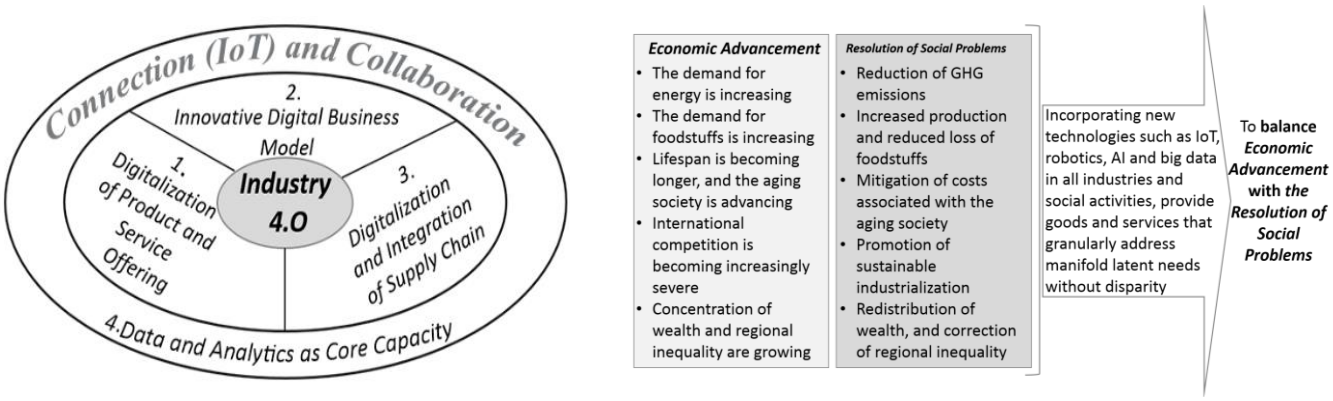
The X.0 wave theory proposes that we are currently in the fourth wave of human civilization, the Digitalization Age or Industry 4.0, and that a fifth wave, the Age of Tomorrow, is on the horizon. This fifth wave will be characterized by the convergence of knowledge, technology, and business and will bring about significant changes to every aspect of life.

Industry 4.0 is focused on the intelligent and smart networking of products and processes based on five technological fields: embedded systems, smart factories, strong networks, cloud computing, and IT security. The benefits of Industry 4.0 include reducing costs, improving environmental friendliness, sustainability, mass production, customer services and products, and reducing the processes of releasing new products to the market. However, adjusting leaders, managers, entrepreneurs, and workers to new methods and processes is a significant challenge that requires education and training. As it was mentioned, in the second half of the 20th century, through developing industrialization, I4.0 has emerged. I4.0 was introduced by the German government, founded on technological changes in manufacturing and a policy framework for companies in order to survive in global competitiveness.

- *I4.0 plays significant roles in the success of organizations. The main benefits of I4.0 are:*
- *Reducing costs, including production costs, logistic costs, and quality management costs;*
- *Creating a more friendly and effective environment;*
- *Sustainable energy management;*
- *Improving mass production concerned with economically cost;*
- *Improving customer services and products;*
- *Reducing the processes of releasing new products to market.*

Specifically, it may impact the company's value chain and enhance its operations. The main challenge of I4.0 is about adjusting leaders, managers, entrepreneurs, laborers, and generally capital to utilizing new methods and processes based on I4.0 and creating significant changes. To conquer this challenge, education and training play vital roles. In other words, qualified employees and adjusting to a new business model and the development of new revenue models founded on I4.0 are needed to achieve privileges from it.

In particular, it could influence the value chain of the company and improve its function. The below figure presents the involvement of I4.0 in a company's value chain [19–25].



(a) **(b)**

Figure 21. (a) Involvement of I4.0 in a company's value [21]; **(b)** advantages of society 5.0 [25].

The rapid evaluation and improvement of ICT and other kinds of high technologies like digitalization make significant changes in industry, society, and education. Society 5.0 concept is one of the ideas created through these evaluations by Japan. Basically, society 1.0 is a hunting society emerging on the birth of human' beings. At 13,000 BC, through the development of irrigation techniques, society 2.0, named Agrarian Society, was started. Industrial society, as a society 3.0 founded on the invention of steam power machines and mass production, emerged at the end of the 18th century. Society 4.0 is an information society via improving technology in the second half of the 20th century. Furthermore, society 5.0 as a super smart society has emerged from the 21st century.

Society 5.0, on the other hand, is a Japanese concept that emerged in the 21st century and aims to balance economic development and social sustainability in order to achieve sustainable development. Society 5.0 considers every aspect of life, such as mobility, manufacturing, food production, reducing disasters, education, finance, public services, cyberspace, and the efficiency of organizations, regions, and cities.

Empowering & Shaping the Future Sustainable for Building 7PS Sustainable Hybrid SMEs/SME X.0 through Smart Cyber Governance requires an understanding of these concepts and how they can be applied to create a sustainable future. By combining the principles of Industry 4.0 and Society 5.0, we can create educational, sustainable, smart SMEs that will be able to adapt to the changes of tomorrow. The expected results include reduced costs, improved environmental friendliness and sustainability, improved mass production, and improved customer services and products. Ultimately, the goal is to achieve a sustainable future for all [26,27].

Figure 21 illustrates the evolution of societal structures and technological integration. In **Figure 21a**, it shows the involvement of Industry 4.0 (I4.0) in a company's value, emphasizing the transformative impact of digitalization on business value creation. **Figure 21b** highlights the advantages of Society 5.0, a Japanese concept that envisions a super-smart society by leveraging advanced technologies to achieve balanced economic development and social sustainability.

By combining Industry 4.0 with Society 5.0, we can build sustainable, smart SMEs capable of adapting to future challenges and fostering a sustainable, efficient future for all.

5.3. Limitations

While this study provides a comprehensive framework for SME X.0 transformation, several limitations must be acknowledged:

1) Scope of empirical validation: Although the research employs mixed-method approaches, including thematic analysis and fuzzy Delphi techniques, broader cross-cultural validations are needed to assess the applicability of the proposed models across different regions and industries.
2) Technology adoption disparities: The implementation of Smart Cyber Governance and IoT-driven sustainability frameworks varies significantly across SMEs, depending on their financial capacity, regulatory environment, and digital infrastructure.
3) Dynamic nature of global challenges: The research primarily focuses on current global risks, but evolving economic, political, and technological uncertainties may require continuous adaptation and refinement of the proposed models.
4) Limitations in expert selection: Although the Delphi study engaged 69 domain experts, a larger and more diverse panel could enhance the generalizability of the findings.

Considering the industrial and social implications in times of challenges and crises and making the world a better place to live, the 5th wave theory forces SMEs to achieve sustainability in order to prepare for future concerns at the edge of tomorrow (2020–2030) [28].

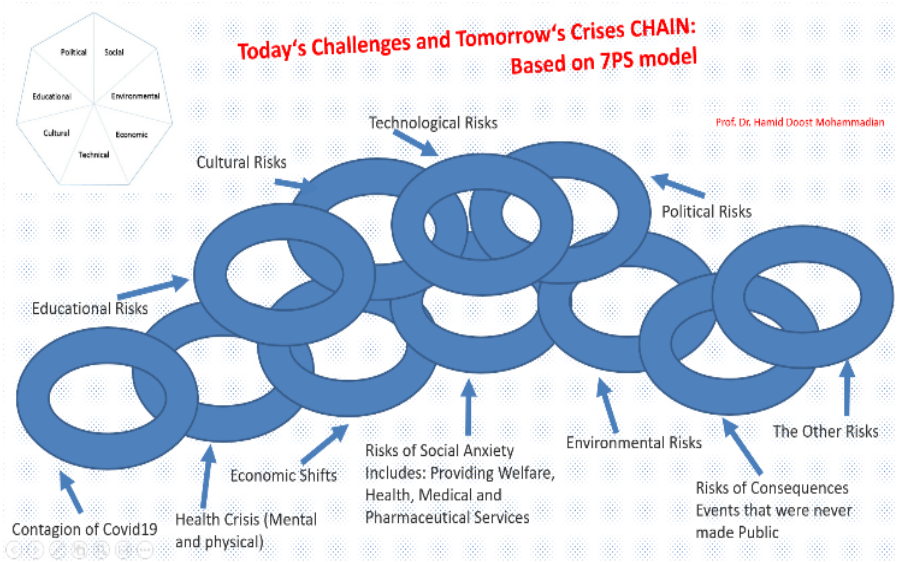


Figure 22. Tomorrow's crises chain at the first edge of tomorrow [5,10].

Figure 22 illustrates Tomorrow's Crises Chain, highlighting interconnected risks across various sectors, including sustainability, health, environment, technology, and cascading effects. These risks represent the fragile state of our global landscape, with each area having the potential to trigger further disruptions if not properly managed.

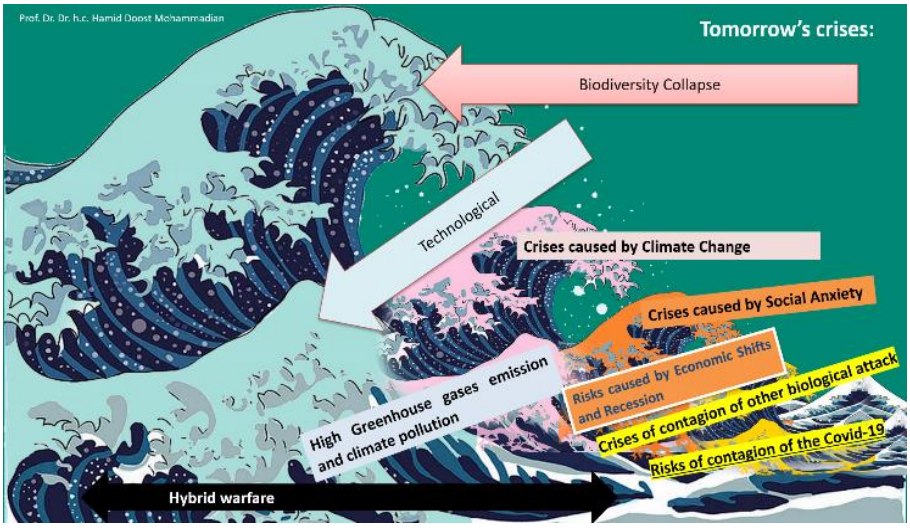


Figure 23. Tomorrow's crises wave at the first edge of tomorrow [5,10].

In **Figure 23**, the Tomorrow's Crises Wave concept is presented, illustrating how crises may unfold over time, building upon one another and escalating in severity. The wave emphasizes the need for future leadership that is equipped to anticipate, address, and mitigate these interconnected crises.

Figures 22 and **23** depict the evolving nature of future crises at the first edge of tomorrow.

Hybrid SMEs/SME X.0 through Smart Cyber Governance is an important concept that emphasizes the need for innovation, sustainability, and collaboration between governments, businesses, and communities. The X.0 wave theory, cyber security governance, and the 7PS model are some of the key frameworks that can be used to achieve sustainable development.

Building Hybrid SMEs/SME X.0 through Smart Cyber Governance is an important concept in the age of digital transformation. Smart Cyber Governance emphasizes specific aspects of different types of attack vectors, privacy impacts, and considerations for transformative frameworks to manage cybersecurity risks. It is essential for businesses, especially SMEs, to manage cybersecurity risks and protect sensitive information from cyber threats. Smart Cyber Governance includes processes and best practices to help assess, plan, design, and deliver effective and efficient governance, processes, and compliance.

The author's concept of tomorrow's SMEs, or Hybrid SMEs/SME X.0, should entail sustainable development criteria such as job preparation plans, vocational training, entrepreneurship, marketing, and creating a business environment. These businesses should be the right custodians to implement these plans and should be the auxiliary arm and mastermind of the executive part of governance.

In order to build Hybrid SMEs/SME X.0 through Smart Cyber Governance, businesses can follow these steps:

Develop a comprehensive cybersecurity governance policy that includes clearly defined risk management strategies, technical controls, administrative policies, and more.

Implement the right tools, skills, and resources to detect threats, irregularities, and other indicators of potential breaches or attacks, and activate reactive protocols quickly based on detected issues.

Conduct regular cybersecurity assessments to identify vulnerabilities and areas for improvement.

Train employees on cybersecurity best practices and ensure that they understand their role in maintaining a secure environment.

Use cybersecurity ratings to enjoy a clear overview of the security posture of the entire ecosystem.

Create a culture of cybersecurity awareness and responsibility throughout the organization.

Continuously monitor and update cybersecurity policies and procedures to stay ahead of emerging threats.

The findings of this study reinforce the transformative potential of SME X.0 in aligning business strategies with global sustainability goals. As SMEs adapt to the Age of Tomorrow, the adoption of holistic frameworks such as the X.0 wave theory, 7PS, and 9PSG will be pivotal in shaping resilient, innovation-driven, and socially responsible enterprises. Future research should further explore the intersection of digital transformation, sustainability governance, and SME competitiveness, ensuring that business models remain agile, sustainable, and future-proof in an increasingly volatile world.

6. Conclusion and future suggestions

6.1. Conclusion

The integration of Prof. Hamid Mattiello's X.0 wave theory with the 7PS and the Nine Pillars of Sustainable Governance (9PSG) provides a structured and strategic roadmap for transforming conventional SMEs into SME X.0. By leveraging Smart Cyber Governance and advanced technological frameworks, SMEs can enhance resilience, adaptability, and sustainability, aligning with global development goals.

This study highlights the pivotal role of governance innovation, digital transformation, and sustainability-driven strategies in shaping the future of SMEs. The findings underscore the necessity of dynamic business models that incorporate cultural, economic, technological, and governance dimensions, enabling SMEs to navigate contemporary global challenges such as climate change, resource depletion, socio-economic disparities, and digital disruptions.

Key takeaways from this research include:

- The role of education and culture in SME X.0: The accumulation of human capital, strategic foresight, and adaptability are essential drivers of sustainable business transformation.
- The impact of Smart Cyber Governance: Advanced IoT technologies, digital transparency, and network-based governance models are crucial for ensuring accountability and efficiency in SME operations.

- The importance of supply chain sustainability: Green supply chain management and environmental responsibility play a fundamental role in achieving sustainability in SME X.0 frameworks.
- Social responsibility and leadership in SME X.0: Corporate Social Responsibility (CSR) and ethical leadership significantly impact sustainable SME ecosystems, fostering long-term success and societal well-being.

Through the integration of smart governance models, hybrid SMEs can thrive in highly dynamic environments, ensuring high-quality service delivery and sustainable growth. This research contributes to the ongoing discourse on SME evolution, offering practical frameworks and empirical validation to support policymakers, business leaders, and academics in fostering resilient and sustainable SMEs.

Thinking globally and acting regionally: The X.0 wave approach.

Based on the 7PS know-how and 9PSG governance framework, sustainable resource planning for SMEs X.0 requires active cooperative partnerships with:

(1) Governments;
(2) Strategic planners and policy architects;
(3) Resource managers and industry experts;
(4) Digital transformation facilitators;
(5) Politicians and regulatory bodies;
(6) Universities, researchers, and academic institutions;
(7) SMEs, corporate entities, and financial institutions;
(8) Communities, societies, and urban development stakeholders.

The X.0 wave theory underscores the reinforcement of the "Knowledge Triangle," integrating innovation, entrepreneurship, and university-business cooperation to drive sustainable transformation in SMEs. This theory envisions a structured approach to leveraging digitalization, decarbonization, and decentralization to enhance resilience, efficiency, and competitiveness in SME ecosystems.

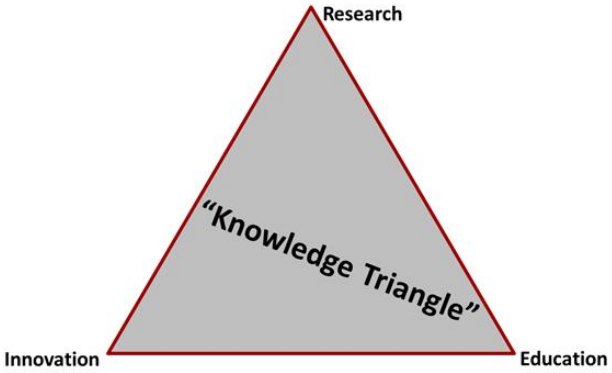


Figure 24. Knowledge triangle and expected impact of the X.0 wave/age theory [34,35,53].

Figure 24 shows The Trinity of the Knowledge Triangle and the Projected Impact of the X.0 Wave/Age Theory, highlighting how innovation, research, and education drive sustainable transformation in SMEs.

The Knowledge Triangle—comprising innovation, research, and education—plays a critical role in fostering sustainable transformation within SMEs. By

integrating these elements with entrepreneurship and university-business cooperation, the X.0 wave framework outlines a structured approach to leveraging key forces such as digitalization, decarbonization, and decentralization. This framework is designed to enhance resilience, efficiency, and competitiveness, empowering SMEs to thrive in the evolving digital age.

The X.0 wave theory presents a transformative roadmap for SMEs, positioning them at the forefront of sustainable innovation and governance. By integrating the 7PS and Nine Pillars of Sustainable Governance (9PSG), the framework ensures that SMEs X.0 contribute to a resilient, equitable, and technologically advanced future.

Table 9 below illustrates the key subjects and strategic components that form the foundation for implementing the X.0 Wave framework within SME ecosystems. This table captures a comprehensive overview of the areas that SMEs X.0 must focus on to ensure long-term sustainability, competitiveness, and resilience. Each subject highlights the critical components necessary for SMEs to adapt to the evolving demands of the digital age, emphasizing the integration of innovative, resource-efficient, and socially responsible practices.

How to do that?

Table 9. Implementing the X.0 wave framework for SME X.0.

Row	Subject	Logo
1	Blue-Green Sustainable Energy: The X.0 wave fosters new, more efficient sustainable energy systems, emphasizing digitalized, decentralized, and green solutions. SMEs X.0 leverage renewable energy integration and resource-efficient innovations.	
2	Infrastructure and smart ecosystems: Future-proof infrastructure underpins SME resilience. Smart infrastructure aligns SMEs with digitalization trends, ensuring operational sustainability.	
3	Cross-validation and digital sandboxing: SMEs X.0 leverage sandbox environments for cross-validation, enhancing adaptability and scalability across regions. This global collaboration accelerates sustainability and innovation.	
4	Business, marketing, and technological innovation: Digital transformation and strategic foresight drive SME X.0 success. Marketing and technological innovations are key to adapting to tomorrow's shocks and fostering sustainable competitive advantages.	

Table 9. (*Continued*).

Row	Subject	Logo
5	Blue-Green sustainable mobility: Whether it's commuting to work, popping to the shops, or seeing friends, connected transportation systems offering flexibility, effectiveness, and efficiency are key to the happiness of quality of livability and citizens' lives. The 5th wave is looking for the most efficient and Blue-Green sustainable alternatives, such as electric bikes and buses, to reduce CO_2 emissions and noise pollution, as well as improve quality of livability and citizens' lives (high sustainability).	
6	Water, wastewater & circular waste management: Sustainable water and waste management practices are pivotal for SME X.0, ensuring efficient resource utilization and alignment with global sustainability goals.	
7	Circular economy and resource efficiency: The X.0 Wave promotes circular economic models, emphasizing reuse, recycling, and resource optimization within SME X.0 ecosystems.	
8	Health, labor, and social welfare security: Digital governance in SME X.0 fosters inclusive growth, social well-being, and labor security through automation, AI-driven monitoring, and CSR-oriented approaches.	

6.2. Future suggestions

Building on the insights derived from this research, several key areas warrant further exploration to enhance the transition of SMEs into the SME X.0 paradigm. These future directions aim to deepen our understanding of sustainable governance, digital transformation, and strategic adaptation within SME ecosystems.

(1) Expanding the SME X.0 framework with AI and advanced analytics

While this study has emphasized IoT-driven governance, future research should investigate the integration of artificial intelligence (AI), machine learning (ML), and big data analytics within the SME X.0 framework. These technologies can enhance decision-making, predictive analysis, and resource optimization, contributing to a more resilient and adaptive SME ecosystem.

(2) Longitudinal analysis of SME X.0 evolution

A long-term empirical study tracking SMEs as they transition into the SME X.0 model would provide valuable insights into the practical challenges and benefits associated with this shift. By assessing the gradual impact of 7PS and 9PSG frameworks over time, researchers can refine strategic roadmaps and governance models for improved implementation.

(3) Cross-cultural comparative studies of SME X.0 implementation

The adaptability of SME X.0 across different cultural and economic landscapes remains an area for further exploration. Conducting comparative studies across Western, non-Western, and TORN (TORN stands for Transitional, Obscured, and Resilient Nations, representing cultures and regions in transition that are navigating between traditional and modern frameworks, facing unique challenges in adopting sustainable SME governance.) cultures can shed light on region-specific drivers and barriers to adoption, enabling a more nuanced approach to sustainable SME governance.

(4) Smart Cyber Governance and regulatory frameworks

Given the increasing reliance on digital ecosystems, future research should explore the development of regulatory frameworks that ensure ethical, secure, and sustainable Cyber Governance for SMEs. Establishing global best practices for SME X.0 within legal and institutional frameworks will be crucial for ensuring compliance and ethical AI deployment.

(5) Integration of the 5N.BG.7PS model in policymaking

Future studies should assess the role of political, technical, organizational, economic, and interdisciplinary community networks in influencing SME X.0 adoption. By integrating the 5N.BG.7PS model into policy recommendations, researchers can provide actionable insights for governments and international organizations to foster SME resilience and sustainable growth.

(6) Blockchain and decentralized systems for SME X.0

Blockchain technology holds significant potential for enhancing transparency, accountability, and security in SME operations. Future research should investigate the role of decentralized digital ledgers in streamlining supply chain management, financial transactions, and smart contracts within the SME X.0 framework.

(7) SME X.0 and the circular economy

Aligning SME X.0 with circular economy principles can further enhance sustainability efforts. Future research should explore how SMEs can implement closed-loop production cycles, resource efficiency strategies, and waste reduction initiatives within the X.0 wave framework.

(8) Human-centric approaches and workforce readiness

As digital transformation accelerates, the impact of SME X.0 on workforce dynamics needs further exploration. Future studies should analyze the implications of automation, AI, and IoT on employment, skill development, and job satisfaction, ensuring a balanced approach between technological innovation and human-centric business practices.

(9) Developing industry-specific SME X.0 adaptation strategies

Different industries face unique challenges in adopting SME X.0. Future research should develop sector-specific adaptation models tailored to manufacturing, healthcare, finance, and other key industries. Customizing the X.0 wave theory application will maximize its effectiveness in diverse SME environments.

(10) Measuring societal impact and SDG alignment

Further exploration is needed to assess the broader societal impacts of SME X.0, particularly in relation to the UN Sustainable Development Goals (SDGs). Establishing robust measurement frameworks to evaluate economic, social, and

environmental outcomes will enable SMEs to align their growth strategies with global sustainability imperatives.

(11) Expansion of the Nine Pillars of Sustainable Governance (9PSG):

Future studies should explore how the 9PSG framework can be further refined to enhance governance mechanisms within SME X.0 ecosystems. This includes strengthening policy coherence, stakeholder engagement, and ethical AI integration to ensure robust decision-making processes that align with global sustainability objectives.

(12) Integration of the knowledge transfer and benchmarking (KTB) model:

The KTB model, focusing on cross-sectoral knowledge exchange and adaptive benchmarking, should be examined as a strategic tool to facilitate SME X.0 adoption. By leveraging best practices from high-performing SMEs and multinational enterprises, this model can drive continuous learning, innovation, and competitiveness.

(13) Hybrid governance and policy innovations for SME X.0:

Research should further investigate hybrid governance models that merge public-private collaborations, regulatory sandboxes, and data-driven policy frameworks. These models can support SMEs in navigating regulatory complexities while ensuring compliance with sustainability standards and digital transformation requirements.

(14) Cross-cultural adaptation of SME X.0 models:

Given the diverse socio-economic landscapes of SMEs across different regions, comparative studies should assess how the SME X.0 framework, along with 7PS, 9PSG, and KTB, can be tailored to various cultural and economic contexts. This will ensure that sustainability-driven business transformation is inclusive and adaptable.

(15) AI-driven decision-making for sustainability and growth:

Future research should explore the role of AI-powered analytics, machine learning, and blockchain in enhancing transparency, predictive governance, and sustainability reporting for SME X.0. AI-driven decision-making could significantly improve risk management and long-term strategic planning.

(16) Interdisciplinary research on SME X.0 resilience:

To better understand the resilience factors of SME X.0, interdisciplinary studies combining business strategy, environmental science, digital ethics, and socio-economic policy should be encouraged. Such research can help create holistic frameworks that balance technological progress with human-centric values.

(17) Deepening the 5N.BG.7PS model in industry-specific contexts:

Future studies should apply the 5N.BG.7PS model to industry-specific case studies, particularly in high-impact sectors such as green manufacturing, fintech, agritech, and digital health. This would provide tailored insights into how SMEs in different industries can leverage political, technical, organizational, economic, and interdisciplinary networks for sustainable growth.

(18) Strengthening public-private partnerships (PPPs) within SME X.0:

The role of PPPs should be further examined in fostering sustainable development, innovation funding, and technology transfer for SMEs. Governments and international organizations can play a crucial role in creating incentives that support SME X.0 adoption at scale.

(19) Measuring long-term impacts of SME X.0 transformation:

Longitudinal studies should be conducted to assess the long-term economic, social, and environmental impacts of SME X.0 adoption. This research could track key performance indicators such as energy efficiency, digital inclusivity, job creation, and social responsibility metrics.

(20) Establishing SME X.0 as a global standard for sustainable business models:

Finally, collaborative efforts should aim to formalize SME X.0 as an internationally recognized business model, integrating it into global sustainability rankings, regulatory frameworks, and policy recommendations. This would enhance the adoption of SME X.0 principles across different economic and regulatory landscapes.

Future research should continue refining the SME X.0 paradigm by integrating technological advancements, regulatory insights, and cultural perspectives. By addressing these areas, scholars, policymakers, and business leaders can foster a resilient, adaptive, and sustainability-driven SME landscape, ensuring long-term economic and societal benefits.

Key questions:

1) How can the X.0 wave theory, alongside the 7PS and 9PSG frameworks, facilitate the transition of conventional SMEs into SME X.0?
2) What are the essential drivers and outcomes of SME X.0, and how do they contribute to sustainable growth?
3) In what ways can Smart Cyber Governance enhance transparency, innovation, and sustainability within SME ecosystems?

Key results:

- Integration of the X.0 wave theory with the 7PS and 9PSG frameworks offers a structured roadmap for the evolution of SMEs into SME X.0, emphasizing strategic foresight and technological agility.
- Key antecedents include cultural-educational 7PS drivers and organizational adaptability, while identified outcomes highlight enhanced sustainability, efficiency, and customer satisfaction.
- Validation using fuzzy Delphi methods confirms the practical applicability of these frameworks in addressing real-world SME challenges.

Key impacts:

1) Strategic sustainability alignment: Establishes a comprehensive framework that bridges SME development with global sustainability imperatives.
2) Governance transformation: Demonstrates the pivotal role of Smart Cyber Governance in fostering transparency, innovation, and societal resilience.
3) Policy and practice guidance: Provides practical recommendations for policymakers and business leaders to promote resilience and sustainability in SMEs.
4) Societal contributions: Encourages the formation of SME ecosystems that enhance public service delivery and long-term societal welfare.

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