The Effectiveness Of Digitalization Components In Industry 4.0 On The Sustainable Development Of Technology-Based Businesses

Abolghasem Arabiun[1]
Director of Technological Entrepreneurship Department , Faculty of Entrepreneurship, University of Tehran, Iran.
arabiun@ut.ac.ir
0000-0002-6542-0933

Elahe Hosseini
Department of Business Management, Faculty of Economics, Management & Accounting, Yazd University, Yazd, Iran
elahe.hosseini@stu.yazd.ac.ir
0000-0003-3478-5320

Hasan Ahmadi
Director of Technological Entrepreneurship Department, Faculty of Entrepreneurship, University of Tehran, Iran.
hassan.ahmadi@ut.ac.ir

Abstract

Digitalization in Industry 4.0 and sustainable development have been considered crucial for businesses and industries. Thus, business managers and experts in technology-based organizations should identify influential components for implementing these two concepts and recognizing their correlation. It helps these organizations develop the necessary capabilities and impact on automating and improving business performance. This research intends to identify the digitalization components in Industry 4.0 for the sustainable development of technology-based businesses. This applied research is qualitative in terms of methodology, and the research components were identified through semi-structured interviews with experts using the 5W1H method. Then, the researchers used a three-stage coding process (open, axial, selective) for data analysis. The results indicated the identification of several components, such as inner and outer organizational (e.g., environmental factors, organizational factors, and barriers), business regeneration (e.g., process transformation, business restoration, and instrument transformation), digital transformation (e.g., technology pressure, market scope, competition, and development), sustainable development (e.g., economic, environmental, and social sustainability), as well as digital transformation, knowledge, intelligent decision-making factors (e.g., innovation, capabilities, and decision-making approach).

Keywords: *Digitalization, Digital Transformation, Industry 4.0, Automation, Sustainable Development, Technology-based Business.*

[1] . Corresponding author

Introduction

Organizations tend to change their path and develop their business leadership style according to new challenges (Kwiotkowska et al., 2022). Contemporary businesses may face two fundamental challenges: 1. digital transformation and the emergence of innovative opportunities based on Industry 4.0 and 2. sustainability and sustainable development (Jørgensen & Pedersen, 2018). Companies may face the former challenge by the transformations resulting from digitization and respective innovative opportunities. Adopting digital technologies and digitization has had a significant impact on all organizational dimensions recently (Aagaard & Aagaard, 2019). Digital transformation technologies have had substantial influences and led to unique innovations in business models across all industries due to their disruptive nature (Gupta, 2018). Research findings indicate that G20 countries encompass digital leadership capabilities to develop digital inclination, innovation, and competition in Industrial 4.0, which can make them global leaders in digitization (Cahyadi & Magda, 2021). Despite the widespread implementation of technology during the COVID-19 pandemic, organizations indicated little interest in developing and utilizing digital technologies for digital and online service delivery in our country. Given the fast-paced changes caused by digitalization and the impact of the COVID-19 pandemic, many Iranian businesses have been focusing on innovation and restructuring their business models using digital technologies. Hence, it can help gain a competitive advantage (Shahabi et al., 2022).

Sustainability is the other challenge that businesses face, which requires them to provide appropriate and transparent responses to their stakeholders regarding economic, social, and environmental issues (Rezaei & Mirizdi, 2022). Business sustainability has become increasingly popular (Cahyadi et al., 2022), as it aligns with the principles of sustainable development and sustainability strategies (Szromek, 2021). Many international and national stock exchanges have mandated reporting on the sustainability of businesses by enacting appropriate laws and regulations (Rezaei & Mirizdi, 2022). Iran is a developing country, and developing and highlighting business sustainability are regarded as crucial factors and driving forces of economic development (Shirmohammadi et al., 2020). Nonetheless, it has not been investigated attentively in Iran. Hence, only a few companies have taken the initiative to prepare sustainability reports (Abdi et al., 2019).

Sustainability is considered a primary requirement for businesses, at the international level, seeking to adapt to their surrounding environment and address social, environmental, and economic challenges as a key strategic issue (Nosratabadi et al., 2019). These organizations

ensure the compatibility of their products and services by preserving the environment and society(Hosseini & Rajabipoor Meybodi,2023). Eventually, it can result in a sustainable competitive advantage (Eikelenboom & de Jong, 2019). Research indicates that sustainability has become the focus of academic literature and policymakers, supporting sustainable business models seriously. It has become challenging for organizational managers and decision-makers (Bergmann & Utikal, 2021). Consequently, managers often face ambiguities in achieving sustainability and creating balance simultaneously (Clinton & Whisnant, 2019). Given that digital transformation technology competencies can facilitate sustainability, these two topics have not been emphasized concurrently (Aluchna & Rok, 2018). Thus, it is essential to investigate the interactions and compatibility between digitalization measures as well as the economic, social, and environmental aspects of sustainability measures to pursue digital sustainability modifications in organizations (Eikelenboom & de Jong, 2019). Hence, companies are required to examine efficient competencies and capabilities that facilitate revisiting business models so that they include sustainability factors and necessary capabilities while facing digital transformations (Brenner, 2018). McKinsey Institution published an article entitled "Why Digital Strategies Fail" in 2018. It was asserted that only 8% of businesses trust their business models to be economically viable in the existing digital era, indicating its significance for organizations. Nonetheless, it leads to a crucial question: which components are effective and reliable in digitalization and the sustainable development of technology-based businesses in Industry 4.0?

Research Literature

Despite the significance of Industry 4.0 in sustainable industrial development, few studies have focused on examining the role of Industry 4.0 technologies within the sustainable development framework (Asadi, 2022). Industry 4.0 is an extended and interdisciplinary topic, addressing conceptual, methodological, technological, and commercial domains. The digital transformation in production and other fundamental sectors of the economy has been established recently. Hence, it requires investigating various challenges and opportunities. Commonly, existing research demonstrates the need for more applied studies in organizations with varying sizes and underlying sectors (Lemstra & de Mesquita, 2023). The revolutionary nature of Industry 4.0, similar to previous industrial revolutions, leads to a significant transformation in manufacturing industries. Besides, this trend can influence the structures of the customers, organizations, and their products. Since Industry 4.0 encompasses the

comprehensive digitalization of industries and customer markets, such transformations include the advent of intelligent production and the digitization of the entire value channels. Industries that fail to follow this trend are prone to be eliminated from the competition cycle. Despite the variations in the challenges of implementation and adaptation of Industry 4.0, it is necessary to further investigate this area because of the widespread impact of such a revolution (Ostadi et al., 2023).

Industry 4.0 sustainability literature is still in its early stages, it is expected to witness a limited understanding of related sustainable production functions. The literature review indicates that only a few studies have explained the empirical applications of Industry 4.0 for sustainable production (Sharma et al., 2021). Hence, the digitalization of businesses creates opportunities within entrepreneurial ecosystems, providing numerous benefits for businesses. These opportunities include interacting with new players, achieving extensive knowledge resources, reducing risks, and legitimizing businesses at various levels (Sadeghi Ordoubadi et al., 2023). This transformation is so influential that even the world's largest companies have been eliminated from the market in recent years. According to Statista Website, companies like Nokia once supplied over 50% of the mobile phone market demand lost their customers and market share by failing to adapt to new business models and technologies as well as neglecting market changes (HosseiniNasab et al., 2021). Digital transformation is considered an intra-national concept. Thus, many state and private organizations worldwide are moving toward developing such plans and initiatives. For instance, the Ministry of Economy and Finance has obliged the banks to develop the digital transformation roadmap, indicating the necessity of this concept in our country (HosseiniNasab et al., 2021).

Given the prevalent impact of digital transformation on all organizations and industries (Lang & Rumsey, 2018) and the role of entrepreneurs in the recent economic and industrial growth of countries, the significance of promoting entrepreneurship is undeniable. Accordingly, technology-based companies can act as incentives for entrepreneurship (Fatehipour et al., 2021). Technology-based companies are regarded as primary contributors to social growth and wealth generation (Bergek & Norrman, 2008). They also contribute to the competitiveness of domestic and international economies. These companies, often referred to as knowledge-based companies, are supported by the Law on the Support of Knowledge-Based Companies and Institutions in Iran (Ghazinoori et al., 2016). There has been an outstanding tendency toward being recognized as a knowledge-based company with the emergence of over 4000 knowledge-based companies that generate 30 trillion tomans revenue annually and hire over a hundred thousand people. Besides, this trend has attracted more than 6000 applicants

for knowledge-based entrepreneurship and prepared the ground for a prosperous entrepreneurial ecosystem in the country (Karami, 2017). Technology-based businesses have become the focus of many policymakers in several countries because of their promising growth, job creation, and export potential (Tavakolian et al., 2019). Therefore, it is necessary for policymakers as well as national executive managers to identify and endorse the digitalization components in Industry 4.0 for the sustainable development of technology-based businesses. These managers' awareness of efficient and reliable digitalization components in Industry 4.0 can improve policies, programs, and business performance as well as the country's overall economy.

Digitalization

Digitalization is an ambiguous concept despite several related inquiries(Arabiun et al.,2024). It focuses on digital media and electronic communications, which is highlighted in economic and social domains. Digitalization has been associated with three components: 1. creating value at the cutting edge of the business world, 2. optimizing processes that impact customers' experiences with businesses or products, and 3. building foundations that support business activities (Dellarocas, 2003). The process of digitization has brought fundamental changes in the execution of business model performance based on contemporary knowledge (Schallmo & Williams, 2018). Digitalization aims to establish and provide new value to customers, along with improving or advancing the same ordinary services (Mazurek, 2020). Moreover, this phenomenon has the potential to transform the market in all industries or sectors(Arabiun et al.,2023). Digitalization is a process that crafts fundamental changes in the tasks, professions, procedures, organizations, and people's lives (Bartosik-Purgat, 2017). Digitalization can result in numerous benefits, such as higher efficiency and quality, stability of executed processes, higher levels of delivery, as well as more practical monitoring of operational activities and their impacts on the interaction with external stakeholders (including shorter response times and enhanced customer services) (Mazurek, 2020). Business digitalization leads to flexible and competitive production that aligns with the emerging realities of the digital world. Digital transformation is defined as leveraging new technology to improve production and expansion of the company's scope (Brozzi et al., 2021). Although business digitalization is technology-bound, the concept of digital transformation is not limited to technology and includes people (ŚledziewsKa et al., 2015). Digitalization of information processes and the emergence of electronic equipment to provide services (e.g., e-payment) can lead to the constant digital

transformation of companies, such as remote work opportunities (employee mobility), online activities (e-commerce), lower transaction costs, and synchronized activities. Nonetheless, verification of reliable documents is still challenging (Vásquez et al., 2018).

Industry 4.0

Despite the lack of a shared definition in the literature, Industry 4.0 is an accepted term for the concept of the Fourth Industrial Revolution. The crucial role of the Internet in production and service delivery led to the onset of the fourth industrial revolution, with the fundamental impact of various technologies in the growth and development of Industry 4.0 (Saniuk & Saniuk, 2018). Imminent industrial platforms have been frequently addressed in industry and education, employing numerous innovations to describe such platforms. However, successful development of these systems is essential to establish a competitive advantage among manufacturing companies and national economies (Kusiak, 2018). The results of the literature review indicate that "Industry 4.0" is recognized as the most prominent instance of such platforms in Europe (Galati & Bigliardi, 2019). While some researchers have defined Industry 4.0 in various disciplines and areas, the underlying idea behind Industry 4.0 is the "Fourth Industrial Revolution," highlighting rapid technological advancements in recent years (Masood & Sonntag, 2020). Shafiq et al. (2015) defined Industry 4.0 as “the facilitator of the digitalization of traditional industries, aiming to conduct mass customization of products through information technology. It also intends to provide other services, such as enabling automatic and flexible adaptation in the production chain, tracking parts and products, facilitating connections among parts, products, and machinery, and implementing human-machine interaction (HMI) paradigms. Hence, it results in achieving production optimization based on the Internet of Things (IoT) in smart companies and introducing new categories of services and interactional-commercial models in the value chain (Shafiq et al., 2015, 2016).

Ultimately, Industry 4.0 aims to create intelligent companies where production technologies are enhanced and transformed by cyber-physical systems, IoT, and cloud computation (Zhong et al., 2017). It is recommended to start from the pre-first Industrial Revolution era to have an efficient introduction to the Fourth Industrial Revolution. Handicraft industries flourished before 1760 AD, resulting in the emergence of various markets. At that time, goods and products were mainly sold in markets, where buyers approached sellers to express their demand for products (Turner, 2021). Crafts (2021) argued that the First Industrial Revolution was inspired by the introduction of machinery (Crafts, 2021). The following industries were

significantly influenced by the First Industrial Revolution: textile, agriculture, mining, glass production, transportation, and similar sectors (Lasi et al., 2014).

The second industrial revolution emerged in the 1870s and continued until 1914 AD. This stage focused on the development of electricity, oil, and steel; thus, it led to innovations in faster transportation and the advent of railway transportation. The implementation of electricity in production processes is considered another transformative innovation during this era (Kocdar et al., 2021). Electric generators replaced steam engines; moreover, fast-paced electronic communications and mass production evolved during the Second Industrial Revolution. The third industrial revolution was founded based on the rapid expansion of electronic communications and the production of microelectronics. The introduction of information technologies and automation processes contributed significantly to economic development and production growth (Taalbi, 2018). The fourth industrial revolution was rooted in the relationship between physical components and digital technologies, which was initiated in 2011 AD (Majiwala et al., 2020). In this era, manufacturing/production systems are interconnected using computer technologies (Catal & Tekinerdogan, 2019). The fourth industrial revolution led to several technologies, such as the Internet of Things, artificial intelligence, robotics, 3D printers, robots, and drones (Li et al., 2017). Manufacturing industries can effectively implement Industry 4.0 through real-time data transfer and customized production as it involves timely interactions between humans, objects, machinery, and systems (de Sousa Jabbour et al., 2018). Industry 4.0 can be defined as a concept where emerging physical, biological, and digital technologies integrate to generate transformation in organizations, value chains, business models, production, distribution, and consumption (Radziwill, 2018).

Sustainable Development

According to the World Commission on Environment and Development (WCED), sustainable development should meet the existing needs without compromising future generations' competencies to meet their own needs (WCED, 1978). The concept of sustainable development was first introduced by the former Prime Minister of Norway and the head of the UN Environment Commission at the United Nations Conference on the Environment in 1987. He proposed a definition for sustainable development that remained in vogue for 25 years. It must establish comprehensive strategies in economic, social, and environmental dimensions over time. Following 28 years of effort and multiple meetings, the 2030 Agenda for Sustainable

Development was finally adopted by all United Nations countries in 2015, providing a shared framework for peace and prosperity for people and the planet. This agenda encompasses 17 Sustainable Development Goals (SDGs), and there is an urgent request for action from all the developed and developing countries. Planning to end poverty and other deprivations must be accompanied by strategies that improve health and education, reduce inequality, and inspire economic growth. All these measures will address climate change and seek to preserve oceans and forests.

SDGs must translate into a strong commitment for all stakeholders and every country must participate in advancing prosperity and protecting the Earth to acknowledge the 2030 Agenda. The six primary areas to achieve these goals include health, education, social protection, food security and sustainable agriculture, infrastructure (access to low-carbon energy and related infrastructure, drinking water and hygiene, transportation, and telecommunication), and ecosystem and biodiversity services (Safiri & Kolahi, 2023). Sustainable development emerged due to the negative environmental and social consequences of biased economic development approaches following the Industrial Revolution, which manipulated human perception of growth and progress. Sustainable development is a process that envisions a desirable future for societies whose living conditions and resources address human needs without compromising the integrity, beauty, and stability of fundamental systems.

Sustainable development suggests solutions for structural, social, and economic patterns of development to address natural resource depletion, ecosystem destruction, pollution, climate change, unexpected population growth, injustice, and diminishing quality of life for present and future generations. The sustainable development process aligns with existing and future demands related to resource exploitation, investment direction, technology development, and institutional changes. Sustainable development has been highlighted since the 1990s; it refers to one aspect of human development related to the environment and future generations. It prepares the ground for improving and addressing social and cultural deficiencies in advanced societies. Hence, sustainable development should encourage balanced, proportional, and collaborative progress in the economic, social, and cultural dimensions of all societies, especially developing countries (Gholami et al., 2023). Recently, sustainable development has been the center of attention and one of the most significant challenges. Sustainable development is resonated in the intelligent exploitation of resources within a framework consisting of environmental, economic, and social factors. It aims to prevent resource depletion and improve the quality of life while preserving the quality of life for future generations (Mirzaei et al., 2023).

Technology-Based Businesses

Technology-based businesses or enterprises consider innovation as their primary source and experience rapid growth(Tajpour et al.,2022). These companies develop various types of innovations in 1. New products or services, 2. Production method, 3. Novel supply and distribution, 4. Changes in the workplace and organizational management, and 5. Innovative consumption or application patterns (Rezvani et al., 2011). Technology-based businesses introduce new products to the market (Grinstein & Goldman, 2006). They are considered fundamental drivers of innovation with significant research and development capabilities. Their economic influence can be interpreted as creating new workplaces, accelerating innovation and technology, supporting economic growth, and changing economic structures. The major competitive advantage of these companies lies in their innovation capacity, which helps them develop and introduce new products to the market. They seek knowledge and technology transfer with collaborating organizations since they have a growing role in employment over time (Halmosi, 2020).

Many researchers believe that technology-based companies differ from other companies in many aspects and characteristics. Nevertheless, all researchers acknowledge that such companies emphasize technology and innovation activities (Rezvani et al., 2011). Technology-based businesses contribute to social growth and wealth generation (Bergek & Norrman, 2008). Given their innovative and entrepreneurial nature, they play a critical role in the competitiveness of local and international economies. Similar companies, known as knowledge-based, are supported by Iran Law to support knowledge-based companies and institutions (Ghazinoori et al., 2016). Knowledge-based companies are newly established and independent companies with high-level technologies, allocating a significant share of their resources to research and development. In other words, a large part of their workforce consists of individuals with high scientific and technical capacities, formed by an entrepreneur or a group of entrepreneurs (Khyatyan et al., 2015). Knowledge-based companies are launched to create, develop, and promote new technologies (Saputra et al., 2018).

Research Methodology

Researchers employed the library (journals and articles) data collection procedure to review the related literature. Then, semi-structured interviews were conducted to collect qualitative data on the components of Industry 4.0 digitalization using the 5W1H technique. The data were

analyzed through a three-stage coding process (open, axial, and selective coding) using the Maxqda 2020 software. The research focuses on identifying Industry 4.0 digitalization components in the sustainable development of technology-based businesses in Isfahan province, Iran from May to November 2023. The research population encompasses experts and managers of technology-based businesses in Isfahan province, who have related knowledge or experience. The sampling continued until theoretical saturation was reached, where new samples could not have significant contributions to the theoretical accountability of the research. In other words, new variables had insignificant impacts on expanding the ultimate hypothesis. The following criteria were employed to achieve purposeful theoretical saturation: holding a Master's degree or higher, being over 25 years old, having more than 5 years of executive research experience, and working as specialists or higher positions.

Results

Researchers examined the semi-structured interviews to identify the components of Industry 4.0 digitalization in the sustainable development of technology-based businesses. Then, relevant concepts were extracted by integrating meaningful statements into conceptual categories. These concepts were categorized into different codes based on their content and structure.

Descriptive Statistics

Pertinent to the research objective, the authors selected experts and managers of technology-based businesses in Isfahan province. Then, nine individuals were interviewed. The descriptive statistics of demographic variables revealed that 11% of the respondents were female and 89% were male. Besides, 56% of the participants held a Master's degree and 44% had a PhD. The average age was 34 years, and the average executive-research experience was 11 years. Finally, 22% of the respondents were specialists, 56% were managers, and 22% were senior managers.

Inferential Statistics

Open Coding

Researchers conducted open coding to investigate the collected data as smaller conceptual components. This phase is regarded as open coding because researchers have no limitations in defining the concepts (Baghban & Qorbi, 2022). The interview data are documented in the following tables. These semi-structured interviews were conducted until they resulted in no new information and code. The following table includes some parts of the interviews along with the corresponding codes.

Table 1. Samples of verbal evidence extracted from interviews for prelimanery coding

	Verbal evidence	**Primary codes**
A1	The technology and product roadmaps, extracted form examining competitiors and business pioneers, could determine achieving Industry 4.0 digital technologies.	Technology roadmap product roadmap
A2	Globalization refers to integration into international market, particularly developing countries. For this purpose, companies are required to implement advanced technologies in their products, which leads to the transformation of production processes, human resource allocation, organizational strategy and structure, and etc.	Globalizaiton Organizaitonal transformation

Researchers reviewed the content several times to avoid the extraction of excessive primary codes. Then, those primary codes were classified based on their content. In other words, open codes were re-evaluated and conceptual codes were formulated. These concepts represent several primary codes with shared content.

Axial Coding

After conducting an in-depth assessment of the extracted concepts (codes) and recognizing similarities and differences between those codes, researchers developed a broader classification (components). Hence, corresponding concepts were classified into a unified component. As a result, extracted themes and codes with similar semantics were classified into sub-components. There were some correspondences between various sub-components; thus, they were integrated under a more abstract category and formed primary components.

Selective Coding

Researchers can formulate a theory based on the outcomes of a comprehensive data analysis. The proposed theory should comprise a set of relationships, leading to the most acceptable explanation of the research concern. The theory was formulated to integrate all data sources

and establish a coherent and systematic set of relationships between concepts and components. This process was performed regardless of the degree of theory abstraction. Selective coding, which is the final stage of data analysis, aims to select the axial component and integrate other components accordingly (Nouri & Mehrmohammadi, 2012).

Table 2. The results of selective coding

Components	Axial concepts	Selected codes
Causal conditions		
Digital transformation	Technology pressure	Technology advancement Technology roadmap Replaceing outdated technologies Technological demands Technology elevation
	Market demand	Customers' expectations Social responsibility Customers' demand
	Competition and development	Industry competition Globalization Business needs Comprehensive development Expansion of digital transformation Product roadmap Increased costs of product development
Interveinig conditions		
Intelligent knowledge and decision-making	Innovation and capabilities	Technological innovations Digital skills Integrating digitalization capabilities Investment in knowledge workers
	Decision-making approach	Support of executive management Mutual decision-making
Strategic conditions		
Business regeneration	Process transformation	Process transformation Process intelligence
	Business regeneration	Infrastructure enhancement Business model transformation Organizational transformation
	Tool transformation	Implementing advanced technologies
Contextual conditions		
Internal and external organizational factors	Environmental factors	Sanctions impact Censorship Society culture Environmental laws
	Organizational factors	Organizational inclination Organizational culture Virtual workplace Digital organization Digital workplace
	Impediments	Job threats Inexperienced executive management Unbalanced digital capabilities Resistance to change Limitations in technology development resources On-site workplace

Consequences		
Economic sustainability	Increased investment efficiency	Reducing resource costs Reducing product development costs Reducing production costs Reducing the planning risks for the production line
	Competition success	Persistent competitive advantage
	Integration and automation of production	Data integration Production autonomy Reducing breakdowns Production flexibility
	Improvement of customer experience	Company brand Improving customer experience Enhancing product quality
Environmental sustainability	Reducing environmental impacts	Managing product life cycle Reducing environmental costs Minimizing waste Redicing malproduction Reducing carbon emissions
Social sustainability	Developing labor market	New job opportunities Increasing employment for individuals with higher education
	Promoting motivation	Increasing workplace safety Providing technology to employees

Discussion and Conclusion

Industry 4.0 transforms the manufacturing industry and the value-generating economy. Considerable positive advertisements have been created around sustainable development outcomes through Industry 4.0. There are remarkably high expectations from Industry 4.0 to create opportunities for sustainable production. However, the lack of comprehensive understanding of the respective processes leads to a fundamental barrier for businesses pursuing digitalization and sustainable philosophy (Ching et al., 2022). Managers of technology-based enterprises can leverage the benefits of implementing Industry 4.0 for the sustainability of their businesses. It also highlights influential components of digitalization.

The component of digital transformation encompasses three core dimensions: technological pressure, market demand, and competition and development. The “technological pressure” concept includes the following selected codes: technology advancement, technology roadmap in the organization, replacing outdated technologies with new ones, organization’s

technological demands, and technology elevation. This concept implies that technology-based businesses are bound to the recent technological advancements. Respectively, Gupta (2018) and Johnson (2018) concluded that digital transformation technologies have had a considerable impact on businesses across all industries, leading to distinct innovations in business models through conceptual revisions (Gupta, 2018; Johnson, 2018). Arjmandi et al. (2022) also asserted that industrial revolutions resulted in significant changes in technology and production patterns (Arjmandi et al., 2023). The concept of "market demand" includes the following selected codes of customers' expectations and needs. It highlights customers' desire for technology-based businesses associated with Industry 4.0. Arjomandi et al. (2022) demonstrated that the dynamic development process related to the fourth industrial revolution stems from the adaptability of customers' demands (Arjmandi et al., 2023). Consequently, researchers believe that digitalization aims to create and implement new value for customers instead of improving the values they have received before (Mazurek, 2020). The concept of "competition and development" includes the following selected codes: industry competition, globalization, business needs, expansion of digital transformation, product roadmap, and increased costs of product development. This concept assumes that businesses must align with the requirements of the new digital reality due to the fluctuating economic landscape. Researchers assert that business digitalization helps achieve more flexible and competitive production that aligns with the realities of the modern digital world and results in a fundamental improvement in businesses by implementing new technologies (Emara & Zhang, 2021).

The component of intelligent knowledge and decision-making includes two core concepts: "innovation and capabilities" as well as "decision-making approach". The former encompasses the following selected codes: technological innovations, employees' digital skills, and investment in knowledge workers. Implementing Industry 4.0 methods and technologies in businesses requires new professional skills (Lemstra & de Mesquita, 2023). Motyl and Filippi (2021) highlighted that Industry 4.0 can lead to central transformation in careers. It requires a professional engineer with new skills; thus, educational institutions have incorporated respective subjects into their programs. For this purpose, it is necessary to invest in professors, experts, and laboratory equipment (Motyl & Filippi, 2021).

The component of business regeneration encompasses three core concepts: process transformation, business regeneration, and tool transformation. Accordingly, Schallmo and Williams (2018) argued that digitization processes result in underlying changes in the execution and performance of business models based on newly created knowledge (Schallmo

& Williams, 2018). The concept of "process transformation" contains the following selected codes: process transformation and automation. Mazurek (2020) asserted that digitalization leads to several benefits, such as higher efficiency, quality, and stability of executed processes as well as enhanced delivery and monitoring of operational activities and their impacts. It also reduces the response time in interactions with external stakeholders and improves customer service (Mazurek, 2020). Similarly, Mergel et al. (2019) described digital transformation as an interminable change beyond other projects, such as electronic automation of organizational processes. They argued that digital transformation reflects continuous improvement in organizational processes, products, and services (Mergel et al., 2019). The concept of "business regeneration" includes the following selected codes of infrastructure enhancement, business model transformation, and organizational transformation. Accordingly, Tumbas et al. (2018) highlighted that "digitization" has been addressed in many organizations in recent years, incorporating several topics, such as digital innovation, digital strategy, digital strategy, digital transformation, as well as digital platforms and infrastructure (Tumbas et al., 2018). Moreover, Mergel et al. (2019) concluded that the concept of transformation is beyond the electronic automation of organizational procedures. Digital transformation is a process that restructures organizational structures through the influence of external factors, such as technologies and management approaches (Mergel et al., 2019). The concept of "tool transformation" includes the following selected code: implementing advanced technologies. Accordingly, researchers have found that digital transformation involves exploiting innovative digital technologies, such as mobile computing, social media, data analytics, and the Internet of Things. It aims to transform and enhance organizational functions, like customer experience, greater functional efficiency, and new business models (Horlacher et al., 2016). Given the unstable economic condition, businesses must align with the requirements of the new digital reality. It is also necessary to access digital tools for decision-making, management, and data analysis processes. Therefore, most business support has been delivered using digital tools (Oliveira et al., 2021).

The component of internal and external organizational factors encompasses the following three core concepts: environmental factors, organizational factors, and impediments. The concept of "environmental factors" includes the following elected codes: society's culture and environmental laws. Respectively, research findings indicate that international sustainability is considered a fundamental requirement for businesses to integrate into their environment. It also develops a strategic orientation by addressing social, environmental, and economic challenges

(Nosratabadi et al., 2019). These organizations attempt to synchronize their products and services with environmental and societal preservation objectives to attain a sustainable competitive advantage (Eikelenboom & de Jong, 2019). The concept of "organizational factors" includes the following selected codes: organizational inclination, organizational culture, and digital organization. Researchers asserted that continuous digital transformation involves highlighting remote job opportunities (employee mobility), online activities (e-commerce and online business), lower transaction costs, and similar responsibilities. Such features are delivered by digitizing transmitted information and providing electronic services (e-payment) (Vásquez et al., 2018). Information transfer within organizations should be carried out through the new digital economic measures instead of outdated physical communication (cash, checks, invoices, loading bills, reports, meetings, and calls) (Ballestar et al., 2020). The concept of "impediments" includes the following selected codes of job threats, inexperienced executive management, employees' unbalanced digital capabilities, resistance to change, and limitations in technology development resources. Mukhuty et al. (2022) investigated sustainable development. They found numerous impediments concerning individuals, including resistance to change, gaps in employees' digital capabilities, job threats that increase social-economic inequalities, lack of industry collaboration, leadership challenges, and organizational culture (Mukhuty et al., 2022).

The component of economic sustainability encompasses four fundamental concepts: increased investment efficiency, competition success, integration and automation of production, and improvement of customer experience. The concept of "increased investment efficiency" includes the following selected codes: reducing resource costs, product development costs, production costs, and planning risks for the production line. Ghaithan et al. (2021) argued that the digitalization of Industry 4.0 technologies contributes to reduced production and delivery time, minimal production and transportation costs, higher customer satisfaction, and promoted market share and organizational profits (Ghaithan et al., 2021). Industry 4.0 and digital technologies, such as cyber-physical systems and the industrial Internet of Things, are expected to help reduce operational costs related to various production activities (Gouda & Saranga, 2020). The concept of "competition success" includes the selected code of persistent competitive advantage. Researchers emphasize that many businesses seek to innovate and modify their business models to attain a competitive advantage through digital technologies (Shahabi et al., 2022). The concept of "integration and automation of production" involves following selected codes: reducing breakdowns and increasing production flexibility.

Similarly, Ghaithan et al. (2021) demonstrated that Industry 4.0 technologies facilitate production flexibility (Ghaithan et al., 2021). Other researchers also concluded that business digitalization can lead to highly flexible and competitive production, which is aligned with the realities of the emerging digital world. Digital transformation refers to exploiting new technologies to seek a fundamental improvement in production and business development (Emara & Zhang, 2021). The concept of "improving customer experience" includes the following selected codes: improving customer experience and enhancing product quality. There is a direct relationship between Industry 4.0 technologies and product quality (Ghaithan et al., 2021). The digitalization of Industry 4.0 technologies leads to higher customer satisfaction (Ghaithan et al., 2021). Besides, it results in better service delivery (Mazurek, 2020).

The component of environmental sustainability encompasses the fundamental concept of reducing environmental impacts. The concept of "reducing environmental impacts" includes several selected codes, such as managing product life cycle, reducing environmental costs, minimizing waste, and reducing carbon emissions. Sustainable development of products requires significant resources, information, and technology. Industry 4.0 supports the sustainable development of products by facilitating life cycle assessment for new products (Leng et al., 2020). The dual technology of digital and simulation of the entire product life cycle transforms the brainstorming phase of the sustainable development of products (Tao et al., 2018). Computational design with higher efficiency and additional productive technologies enhance the effectiveness of proposing product sustainable development concept (Dev et al., 2020). Moreover, the intelligent production features of Industry 4.0 enrich the commercialization of products' sustainable development by improving efficiency and productivity capabilities (Lin, 2018). Given its impact on the environmental dimension, Industry 4.0 technologies facilitate allocating raw materials, water, energy, and labor time through the real-time availability of data and data sharing among supply chain stakeholders. It further helps minimize resource depletion, greenhouse gas emissions, and waste production (Ghaithan et al., 2021). Industry 4.0 is also expected to contribute to environmental sustainability by promoting value-creation activities, green energy, and material resources (Machado et al., 2020).

The component of social sustainability includes two fundamental concepts of developing the labor market and enhancing motivation. Industry 4.0 can enhance employees' relative performance through real-time information transfer, communication clarity, task automation,

intersectoral collaboration, improved human-machine interaction, and simplified production operations (Strandhagen et al., 2022). Higher employee productivity usually leads to greater profit margins, improved working conditions, and a healthier business network (Jacobs et al., 2016). The concept of "developing labor market" contains the following selected codes: creating new job opportunities and increasing employment for individuals with higher education. Given the social sustainability dimensions, Industry 4.0 is expected to improve working conditions and create new job opportunities (Sartal et al., 2020). Besides, digital transformation influenced by Insudtry 4.0 significantly increases the complexity of production systems (Bag et al., 2021). Despite the undeniable loss of jobs due to automation, Industry 4.0 results in newly created jobs. Manufacturers and managers investing in digital transformation are expected to include new professional profiles in their workforce, such as software engineers, information technology specialists, and multi-skilled machine operators (Gualtieri et al., 2021). Given the proper management of new job opportunities within Industry 4.0, the process can reduce job and income inequality (Sung, 2018). The concept of "promoting motivation" includes the selected code of providing technology to employees. From a social standpoint, implementing Industry 4.0 technologies in organizations improves working conditions, provides safe working conditions for employees, offers new technologies to individuals, and consequently increases motivation (Ghaithan et al., 2021). Therefore, managers and business experts, especially in technology-oriented businesses, are required to understand the influential components to exploit these competencies and develop necessary capabilities and impacts on digitization and improving business performance. This research aimed to identify and validate the role of digitization components of Industry 4.0 in the sustainable development of technology-oriented businesses. The findings confirmed the influence of intrinsic and extrinsic organizational factors (environmental factors, organizational factors, and impediments) and business restructuring (process transformation, business regeneration, and tool transformation) on digital transformation (technology pressure, market attraction, and enhancement) and sustainable development (economic sustainability, environmental sustainability, and social sustainability). Besides, it approved the impact of digital transformation and intelligent decision-making (innovation, skills, and decision-making methods) on sustainable development. Eventually, the research model is formulated as follows:

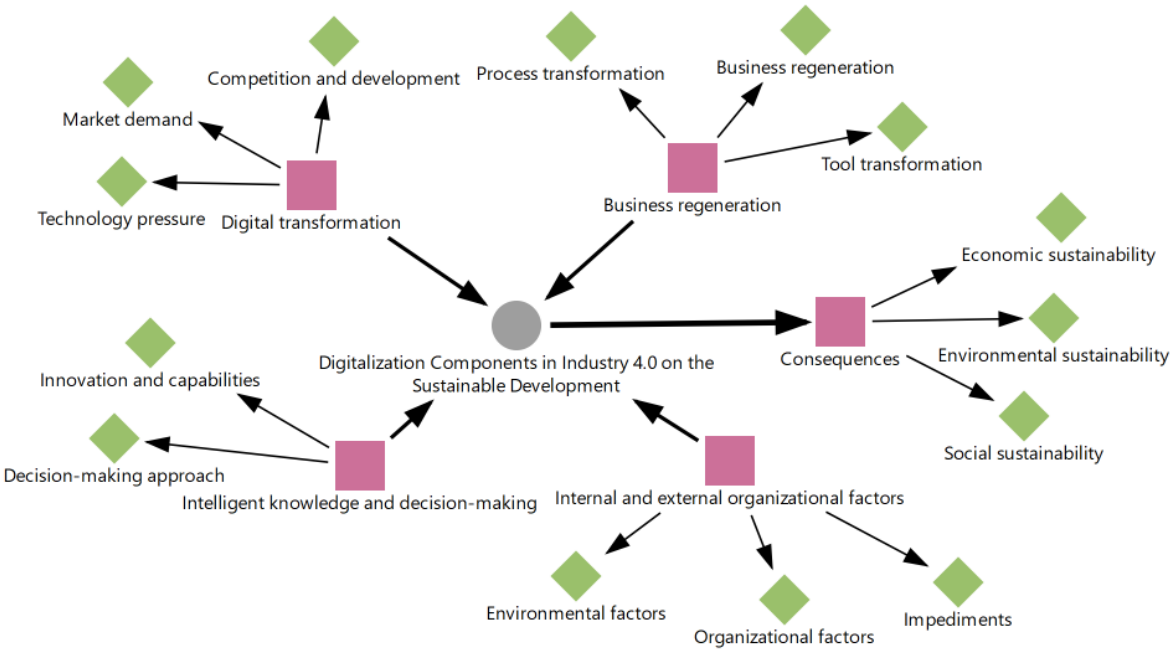

Figure 1. The output of Max qda software

Empirical Recommendations

This research sought to identify the digitalization components of Industry 4.0 for the sustainable development of technology-based businesses. Thus, research findings highlight the following recommendations:

- ✓ It is suggested to conduct a comprehensive and integrative evaluation and restructuring of various dimensions of the business, such as the model, processes, infrastructure, and related technologies to pursue business digitalization.
- ✓ It is recommended to implement business restructuring to improve the customer experience.
- ✓ Business restructuring expenses should be considered as a long-term investment.
- ✓ Businesses are recommended to design and implement digitalization and sustainable development plans comprehensively and concurrently to prevent future conflicts.
- ✓ Given the diversity of businesses and industries in terms of sectors, levels, and regions, it is suggested to observe the structure and outcomes of similar businesses. And then, plan for a digital transformation procedure based on the strengths and weaknesses.
- ✓ Businesses are recommended to revisit sustainable development objectives while developing technological innovations and digital capabilities among their employees.

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