sustainability

MDPI

Article

Industry 4.0 and Management 4.0: Examining the Impact of Environmental, Cultural, and Technological Changes

Aylin Yılmaz Gezgin [1,*] and Mustafa Atilla Arıcıoğlu [2]

[1] Vocational School of Social Sciences, Karamanoğlu Mehmetbey Univesity, Karaman 70100, Türkiye
[2] Faculty of Political Science, Necmettin Erbakan University, Konya 42090, Türkiye; maaricioglu@gmail.com
* Correspondence: aylinyilmaz@kmu.edu.tr

Abstract: Environmental, cultural, and technological developments, along with Industry 4.0 technologies—one of the most significant topics of recent years—have led to a paradigm shift in management functions and practices. These changes raise questions about the necessity of discussing the emergence of a new revolution in management, referred to as Management 4.0. Accordingly, the purpose of this exploratory sequential mixed-methods study is to examine the impact of environmental, cultural, and technological developments on management functions through Industry 4.0 technologies and to explore the underlying elements of the qualitative findings in depth. To address the research problem, 401 business managers participated in the quantitative phase of the study, while 10 business managers took part in the qualitative phase. The quantitative phase also included scale development. The study discusses the prediction of Management 4.0 and evaluates its feasibility. The findings from the quantitative research indicate that Industry 4.0 technologies play a mediating role between environmental changes and management functions. Meanwhile, the qualitative findings suggest that environmental, cultural, and technological developments are shaping a new cultural environment, necessitating adaptation to a new order. As a result of these changes, employees are expected to take part in decision-making processes. In terms of management functions, key developments include enhanced planning and coordination, the rise of platform-based business models, increased collaboration with competitors, the adoption of a modern management approach, and more frequent monitoring and control. Furthermore, the study reveals that although business managers in Turkey recognize the necessity of adopting Industry 4.0 technologies, their widespread implementation remains limited. This study contributes to the literature by introducing the concept of Management 4.0 and developing the Management 4.0 Foresight Scale.

Keywords: Management 4.0; Industry 4.0; digitalization; technology

check for updates

Academic Editors: Yan Yan, Jingjing Zhang and Yinghuan Wang

Received: 2 February 2025
Revised: 13 April 2025
Accepted: 14 April 2025
Published: 16 April 2025

Citation: Yılmaz Gezgin, A.; Arıcıoğlu, M.A. Industry 4.0 and Management 4.0: Examining the Impact of Environmental, Cultural, and Technological Changes. *Sustainability* **2025**, *17*, 3601. https://doi.org/10.3390/su17083601

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

As a result of technological advancements worldwide, rapid changes are occurring, leading to paradigm shifts. The foundation of these shifts lies in transformations in environmental factors, the rapid evolution of cultural and cognitive norms, and the increasing complexity of the environment due to technological advancements [1–4]. Consequently, the complexity of environmental changes has intensified, characterized by an accelerated pace of transformation, the emergence of environmental uncertainties, and increased interconnectivity among various actors. To provide a more comprehensive analysis, it is essential to examine how adaptive systems respond to these dynamics and leverage this multifaceted complexity to enhance their resilience and effectiveness in evolving conditions [5]. In this

context, perceptions of the environment, business operations, and employees' work habits are undergoing significant changes. The increasing collaboration among environmental stakeholders and shifts in employees' business attitudes have led to cultural transformations. As a result, new ways of thinking have emerged, reshaping the assumptions and understandings that define cultural contexts [6,7]. The impact of technological advancements extends beyond tools and equipment; it also reshapes how businesses operate and redefines the role of human beings. Historically, this evolution has progressed from hunters to farmers, from farmers to sailors, from sailors to merchants, and from merchants to bankers [8]. Tsvetkov et al. (2019) [9], in one of the key studies in the field, discuss digital management, arguing that paradigm shifts in management have led to the emergence of a new management approach. Similarly, Mulgan (2021) [10] moves away from traditional management models, emphasizing the significance of smart management applications. Oswald and Müller (2018) [11] highlight the prediction of Management 4.0, the importance of network structures, and the role of technology in modern management [12]. Indeed, this research began with the fundamental question of whether predicting Management 4.0 is a valid discussion in light of these transformations.

With the rapid changes in the business world, companies are transforming their management approaches and sustainability strategies. Moreover, they must reconsider their management methods to overcome barriers to sustainability. When sustainability is defined as minimizing the negative impact of business processes on the environment, economy, and society, everything from biodiversity to climate justice demands action. Since the 18th century, industrial revolutions have largely failed to provide a positive response to these challenges. This reality is something all consumers, especially large corporations, must acknowledge. A key aspect of this research is to identify and clarify the nature of this connection.

Management 4.0 is envisioned as the counterpart of Industry 4.0 technologies in the field of management and business [13]. It represents a management approach in which flexible structures and agile teams replace traditional hierarchical systems, moving toward platform-based models [14–17]. With the proliferation of networks, the increasing interconnection of environmental actors, and the growing importance of information sharing, discussions surrounding the concept of Management 4.0 have gained momentum [18,19]. In the ecosystem shaped by networked systems, decision making is guided by collective intelligence, which emerges from human–machine collaboration [20]. Within the framework of Management 4.0, platforms powered by real-time data enable a continuous control mechanism that spans from the planning phase to the monitoring and evaluation processes [21]. This approach not only facilitates the monitoring of physical processes but also fosters the creation of a virtual environment, further distancing management from traditional hierarchical paradigms [22]. With the ability of autonomous machines to make decisions, a decentralized management approach is becoming increasingly prevalent [23]. Despite technological advancements, the importance of human skills remains evident in the Management 4.0 vision, emphasizing the need for teams with diverse skill sets [24]. Additionally, collective intelligence plays a crucial role in generating innovative ideas, while organizational power sources are diversified through customized cultural frameworks [25]. Employees in a Management 4.0 environment are expected to possess data literacy and the ability to manage data effectively. Since this approach fosters continuous development, adaptability is a key requirement for employees [26]. Management 4.0 envisions the integration of data, people, machines, and devices into a cohesive system [27]. The ability to interpret data accurately, make reliable predictions, and develop strategic plans based on these insights is essential for effective decision making [28]. At the core of the Management 4.0 framework lies human–machine collaboration within an interconnected

ecosystem, leading to the emergence of new skill sets and capabilities [29]. Industry 4.0, as the latest major industrial revolution, has initiated a paradigm shift, driving radical corporate transformation. However, there is limited research in the literature on whether management functions play a mediating role in the adoption of Industry 4.0 technologies. This study explores the relationship between Industry 4.0 and management, drawing on the work of Sulich and Zema (2020) [30]. An exploratory sequential mixed-methods design was employed, with data collected through surveys and interviews with managers from companies listed in the Istanbul Chamber of Industry's (ISO 1000) ranking of large industrial firms in Turkey.

In this study, a scale comprising five dimensions and 72 items was developed to assess environmental change, cultural change, technological change, Industry 4.0 technologies, and management functions. The newly developed "Management 4.0 Foresight" scale was administered to 401 participants. The quantitative data analysis examined the mediating role of Industry 4.0 technologies in the relationship between management functions and environmental, cultural, and technological changes. The results revealed that Industry 4.0 technologies serve as a mediator only between environmental changes and management functions. This finding suggests that the advancement of these technologies influences the rate of change in the business environment, the level of uncertainty, and the interconnection between actors and management functions. These results highlight the critical impact of emerging technologies on business management. To further explore these critical impacts, qualitative data analysis was conducted as the second phase of the exploratory sequential mixed-methods approach. For this analysis, nine open-ended questions were designed, and in-depth interviews were conducted with 10 business managers.

The qualitative data analysis revealed that the new cultural environment shaped by Industry 4.0 technologies has led to significant transformations in the business landscape. To adapt effectively to this evolving environment, businesses must move away from classical management approaches and embrace modern management models. This study contributes to both the academic literature and the business world in several ways. First, it introduces a new scale that assesses the impact of Industry 4.0 technologies on management functions and "Management 4.0". Existing studies on this topic predominantly rely on qualitative analysis methods [31–33]. Second, the influence of Industry 4.0 technologies on management perceptions and employees remains unclear. The newly developed scale, which separately evaluates environmental, cultural, and technological changes, aims to provide deeper insights into how these technologies affect both management practices and employees. In this context, the combined findings from quantitative and qualitative analyses offer valuable guidance for both managers and employees, helping them navigate the evolving business environment shaped by Industry 4.0.

The third contribution of this study is its exploration of how changing environmental, cultural, and technological contexts influence business managers' expectations of both employees and other managers. To address these evolving expectations, policymakers must create opportunities for businesses as well as current and future employees. Therefore, the findings of this study not only shed light on the impact of Industry 4.0 technologies on management functions but also offer valuable insights for the political system by informing the development of education policies tailored to these emerging needs.

2. Materials and Methods

2.1. Theoretical Background

Technological advancements, environmental changes, and cultural differentiation are reshaping the nature of competition, driving paradigm shifts [34]. These shifts create new resources and opportunities, fostering further developments in business and manage-

ment [35]. The Fourth Industrial Revolution is a transformative process that impacts entire systems, with technological advancements playing a central role in driving this paradigm shift [36]. Industry 4.0 represents a revolution in which disruptive and advanced technologies facilitate smart transformation, enabling strategic changes through the interaction of humans, machines, sensors, and devices [37–39]. Industry 4.0 involves the enhancement of self-adjusting systems designed to achieve intelligent outcomes by continuously adapting based on data-driven insights [40].

Industry 4.0 encompasses ten technological breakthroughs: First, cyber–physical systems that bridge the virtual and real worlds [41]; the Internet of Things, a network system for machine–device–sensor interaction, which is the paradigm of new technology [42]; big data technology, which facilitates the acquisition, storage, and management of data [43]; artificial intelligence, which transfers human characteristics to machines through simulations [44]; augmented reality, which visualizes data and transfers it to the real world through animations [45]; 3D printers that perform additive manufacturing by combining personalized and mass production [46]; simulation modeling that brings the virtual world and the real world closer together [22]; cloud computing technology that allows remote data access and storage [47]; horizontal and vertical integration systems that enable machine-to-machine communication [48]; and cybersecurity technology that ensures secure communication between objects and machines [49].

Several studies examine the effects of Industry 4.0 technologies on management and organization. Dobrowolska and Knop (2020) [50] highlighted that competition and sustainability issues have undergone significant changes due to Industry 4.0 technologies. Sulich and Zema (2020) [30] noted that paradigm shifts have occurred in management as a result of Industry 4.0 technologies. Mohelska and Sokolova (2018) [51] pointed out that Industry 4.0 innovations have led to changes in organizational culture and capabilities, thus necessitating new management approaches. Saucedo-Martínez et al. (2018) [31] emphasized the importance of managing information properly and noted that innovations in information management have led to improvements in management. Shamim et al. (2016) [36] suggested that managerial skills are changing, raising the question of how management should evolve. As highlighted by these studies, Industry 4.0 technologies underscore the need for new management approaches.

Industry 4.0 applications distinguish themselves from previous revolutions by making decisions based on information and involving machines as partners in decision making [52]. Industry 4.0 applications specifically affect business functions through smart factory systems [40], a departure from traditional business models [53], machine-supported learning and decision making [45], and the provision of more efficient improvements [54].

Looking at the history of management, it is evident that technological developments have brought radical changes to the fields of business and management. The paradigm shift described by Kuhn (2017) [55] suggests that strategic shifts occur as ways to transform businesses. This leads to the emergence of new managerial approaches [2]. Following the innovations introduced by Industry 4.0 technology in the field of management, the concept of "Management 4.0" is now being discussed. Before introducing the term "Management 4.0", there were discussions about Pre-Management 1.0, Management 1.0, Management 2.0, Management 3.0, and Management 4.0. The industrial revolution had a significant impact on management. It is known that there were studies and practices in management before the industrial revolution [56]. In management history, the innovations brought about by the industrial revolution are seen as new developments because management has evolved as a result of environmental changes, cultural differentiation, and technological advancements [57]. It is widely accepted that management was formalized as a science during the industrial revolution [58]. Management practices and studies before the industrial

revolution are referred to as "Pre-Management 1.0". During the "Pre-Management 1.0" period, religion had a dominant influence over management, authority was concentrated in one person, and the foundations of labor division and hierarchical order within organizations were established [56]. Following the industrial revolution, new theories emerged in management due to cultural, economic, and social revitalization [59]. During this period, a new production system emerged, efficiency studies were conducted, and workshops were transformed into factories [13,17]. This era is referred to as "Management 1.0". In the "Management 1.0" period, management emerged as a profession and employees were provided with only technical skills and expected to perform intensive work [60,61]. Bureaucratic organizations gained prominence in organizational structuring, and management activities were carried out within the framework of the chain of command [62]. As organizations interact with the environment, they become part of a complex system [63]. With the development of systems theory, paradigm shifts occurred in management [64], and this period is known as the "management jungle theory", referring to diversity in management [65]. The period in which many theories were developed and studies on adapting to the environment through feedback were intensive [66] is called "Management 2.0". In the "Management 2.0" period, managers assumed coaching roles that added guiding and empowerment features for their employees [67]. Instead of a strict chain of command, a process emerged where employees were given more authority, and a participative management approach became widespread [68]. The interaction of management with the environment helped the development of scientific theories.

With the emergence of the digitalization phenomenon, flexibility, leadership, vision, and collaboration practices are integrated into an understanding of "agility" [69,70]. This is a process in which information becomes a key power and the importance of people is increasing [71]. This period is referred to as "Management 3.0" and characterized by a quantum approach [72]. With the quantum approach, hierarchy disappears and cooperation gains importance [11]. There is a shift towards the distribution of management tasks, rather than them being dominated by a single individual [73]. New talent emerges, and revolutionary changes occur in organizational structures [74].

With the emergence of Industry 4.0 technologies, differentiations have occurred in management functions [75]. Industry 4.0 technologies bring about organizational and managerial changes by creating a paradigm shift in management functions [55,76]. The impact of Industry 4.0 technologies on planning functions is evident. Due to changing environmental conditions, it is no longer sufficient to manage these conditions intuitively and instinctively [77]. Therefore, it is necessary to gather regular information and make improvements based on this information [25]. Managers should, therefore, rely on technology when making decisions and predictions [27]. In particular, they should be able to make decisions using various algorithms [78]. With cyber–physical systems technology, organizations become interconnected, which affects the coordination function [23]. These connected organizations obtain outputs as a result of smart applications [79]. With the advent of Industry 4.0 technologies, organizations are shifting toward decentralization and moving away from hierarchical structures [80]. Machines are participating in decision making, and changes in organizational functions occur with the emergence of employee–machine cooperation [81]. Big data and artificial intelligence technologies provide the right information at the right time, enhancing flexibility in decision making [40]. Thus, the executive function derives its power from accurate information [82]. In management functions, Industry 4.0 technologies make their effectiveness felt [83]. Finally, in the control function, faster and more accurate information enables punctual process controls [84]. This allows management to solve problems instantly [85]. Technological advancements drive significant changes in management and organizational practices [86]. In response

to environmental shifts, technological progress, and cultural transformations, concepts such as "new management approach" or "paradigm shift in management" highlight the limitations of traditional management models [72]. The studies in the literature related to the prediction of "Management 4.0" are summarized in Table 1.

Table 1. Literature review on Management 4.0 Foresight.

Literature Study	Study Subject	Methodology of the Study	Key Findings
Alpaslan and Kutanis (2007) [87]	It studies management experience revolutions in parallel with industrial revolutions. He discusses paradigm shifts in management based on three industrial revolutions.	A qualitative study method was used. Literature review was used as a data collection technique.	This section mentions the turning points that are effective in the emergence of revolutions in management. After each industrial revolution, paradigm shifts are experienced in management, management style, and organizational power sources.
Bersin Deloitte (2016) [12]	After the Industrial Revolution, it is understood that the first management revolution took place, when management became science and industrial enterprises were established. As hierarchical leaders came to the forefront, a transition to an era in which managers ruled the kings was achieved. In the 1990s, as it became important to collaborate with employees, a new era was ushered in, in which servant leadership played a leading role.	The qualitative study method was preferred. Data were obtained through a literature review.	The paradigm shifts that occurred in management as a result of industrial revolutions were expressed.
Tsvetkov et al. (2019) [9]	In line with the developments caused by digitalization and the opportunities offered by the network economy, the concept of Digital Management is put forward. It claims that management has experienced a paradigm shift after the industrial revolution.	A qualitative research method was preferred.	It mentions the conditions of digital management. The importance of the inter-network of things and cyber–physical systems in the field of management and efficiency is emphasized.
Oswald and Müller (2018) [11]	Management 1.0 covers the period from the industrial revolution to the emergence of complexity theory. The management 2.0 phenomenon is defined within the period from the beginning of complexity theory to the emergence of the agile manifesto. The management 3.0 phenomenon deals with the period from the beginning of the agile manifesto within the framework of the possibilities offered by network theories. The prediction of Management 4.0 is discussed within the process of the effects of recent technological developments on the field of management from the effects provided by network theory.	A qualitative research method was preferred.	It includes detailed studies on the prediction of Management 4.0. It shares the evolutionary process of Management 4.0.
Mulgan (2021) [10]	In this study, a discussion of a new management model starts with the opportunities offered by technology and changes in the environment. In this regard, a model proposal is presented on smart management applications using the triggered hierarchy model.	A qualitative research method was preferred.	Changing environmental conditions and technological developments have led to the emergence of smart management practices.
Davutoğlu (2021) [88]	This research accepts the milestone of the concept of management as Classical Management, starts the first classification from here, and introduces the concepts of "Digital Management" and "Techno Management" after the Industry 4.0 revolution that emerged after 2011. With Techno Management, a new formation is experienced, and the evolutionary process of management is discussed.	A qualitative research method was preferred.	The organizational structure situation after Industry 4.0 was evaluated. It is emphasized that new structuring is needed in an organizational structure.
Güleryüz (2021) [89]	The organizational structure situation after Industry 4.0 was evaluated. It is emphasized that new structuring is needed in an organizational structure.	A qualitative research method was preferred.	With the industrial revolution, the work of management has become digitalized and the work of control and management has become easier.

In predicting Management 4.0, this study adopts the framework proposed by Oswald and Müller (2018) [11] to classify revolutions. This model advances changes and developments in management through the following:

The prediction of Management 4.0 suggests that with the expansion of networks [90] and the increased interconnection of organizations, information can be shared more seamlessly [91]. Industry 4.0 technologies are transforming the nature of work through human–machine collaborations, enabling innovation through shared knowledge [19,92,93]. As new cultures, management practices, managerial approaches, and organizational structures emerge, traditional management methods are gradually being phased out [56]. Increased efficiency and flexibility are achieved through smart networks, real-time monitoring, and intelligent audits [94]. With machines collecting data, employees' tasks become simpler and a greater emphasis is placed on human cognitive skills [95].

In the "Management 4.0" vision, flexible networks, agile teams, and platforms emerge as key components of the paradigm shift in management [14]. As predicted in Management 4.0, there is a shift toward platform-based organizational structures [40]. Cloud-based platforms support the management planning function [15], enabling processes to be monitored and, more importantly, continuously audited. With the rise of platforms, traditional hierarchical models are being replaced [16]. Through coordinated connections, organizations are moving away from rigid hierarchies, adopting an ecosystem approach based on collaborative management [96]. In this ecosystem approach, self-organization is encouraged, as activities are activated without a strict chain of command or continuous control mechanisms [97]. This concept is often referred to in the literature as smart management practices [10]. Within the framework of Management 4.0, employees are expected to possess meta-competence skills, including the ability to manage data, interpret algorithms, embrace continuous development, think integratively, empathize, and adapt to new work cultures [26,27,29,82,98].

In the "Management 4.0" vision, the roles and responsibilities of managers are evolving [24]. Managers are now expected to act as career coaches [16], fostering areas of responsibility for employees while promoting collaboration [99]. Artificial intelligence is assuming lower-level management tasks, leading to a shift in the responsibilities of managers [8]. Within the Management 4.0 framework, sources of organizational power include autonomous authority, human–machine partnerships, the advantages offered by platforms, and new ways of thinking [100]. Collective intelligence is driven by both human cognitive abilities and the technical capabilities of machines [10,101]. By harnessing this collective power, organizations can create environments that are continuously developing and learning [102].

2.2. Hypothesis Development

2.2.1. The Mediating Role of Industry 4.0 Technologies in Environmental Changes and Management Functions

Environmental changes lead to differences in the functioning and scope of management activities. Although emerging waves of change introduce innovations to the scope of management functions, they also alter the direction of activities. There have been developments in the field of management in the environment [103–106].

Although Industry 4.0 technologies bring changes to the environment, they also impact management functions. The possibilities offered by these technologies affect the functioning of environmental factors, leading to changes in management styles and managerial areas [107–111].

H1: *Environmental changes lead to shifts in management functions.*

H2: *Industry 4.0 technologies mediate the relationship between environmental changes and management functions.*

2.2.2. The Mediating Role of Industry 4.0 Technologies in Cultural Changes and Management Functions

Intellectual differences in society, demographic changes, diverse business models, and cultural differentiation offer new opportunities for basic management functions. Consequently, changes in cultural norms influence business practices and management [112–114].

Among Industry 4.0 technologies, artificial intelligence applications are reshaping the way people conduct business, big data technology influences decision-making processes in management, human–machine collaboration is becoming significant as machines join work teams, and a new cultural environment is emerging. These changes suggest that cultural differentiation is occurring through Industry 4.0 technology and is impacting management functions [115–119].

H3: *Cultural changes lead to shifts in management functions.*

H4: *Industry 4.0 technologies mediate the relationship between cultural changes and management functions.*

2.2.3. The Mediating Role of Industry 4.0 Technologies in Technological Changes and Management Functions

Industry 4.0 technologies enable technological advancements in both disruptive and advanced dimensions. As a result, they bring changes to management functions [120,121]. Thanks to Industry 4.0 technologies, control mechanisms can now be activated at every stage of management functions. Long-term planning lags behind technological developments, making short-term planning more necessary after the advent of Industry 4.0 technologies. Forecasting in management becomes more accurate and efficient with technological advancements. Technological developments are transforming management functions through Industry 4.0 technologies [122–129].

H5: *Technological developments lead to changes in management functions.*

H6: *Industry 4.0 technologies mediate the relationship between technological changes and management functions.*

2.3. Theoretical Model and Variable Identification

The hypotheses presented in this research were examined using an exploratory sequential mixed-design approach. The quantitative method is a research approach supported by the positivist/postpositivist paradigm, focusing on the process of storing, analyzing, and interpreting digital data [130]. Research problems are addressed through research questions. The qualitative procedure is a type of research endorsed by executive management [131]. It involves the analysis of narrative data using iterative techniques and inductive connections. The approach of using mixed research methods is grounded in pragmatism [132]. A research program in this approach involves collecting data obtained through both qualitative and quantitative methods, integrating findings and inferences [133]. Both quantitative methods and qualitative processes have limitations when used separately [134]. By combining both approaches, explanations of social events and phenomena are made stronger and more meaningful [135,136]. The reason for choosing a mixed-methods approach was to allow for in-depth investigation and to integrate quantitative data with qualitative insights.

The aim was to ensure that the quantitative findings were not merely complemented but enriched by the qualitative data [137,138].

In the first stage, quantitative analysis was conducted, followed by qualitative analysis in the second stage. The quantitative analysis involved a survey of 401 participants who are managers of enterprises in the Istanbul Chamber of Industry 1000 (ISO 1000). Previous studies have examined the impact of Industry 4.0 technologies on management functions using qualitative analysis methods. Therefore, a scale was developed for the quantitative analysis in this study. The scale codes used in the questionnaire and the sources referenced are provided in Appendix A.

The questionnaire consists of five dimensions and includes a total of 72 items. The first dimension is environmental changes, which is further divided into three sub-dimensions: "the pace of environmental change", "the uncertainty of the environment", and "the interconnectedness of environmental actors". The second dimension is cultural changes, with two sub-dimensions: "continuous learning and a creative environment" and "employee participation in decisions and fostering innovation". The third dimension is technological changes, comprising two sub-dimensions: "the abundance of information and access to real data" and "human-machine collaboration and innovation". The fourth dimension is management functions, and the fifth dimension is Industry 4.0 technologies.

Three theoretical models were employed for the quantitative analysis. Model 1 illustrates the mediating effect of Industry 4.0 technologies on environmental changes and management functions. Model 2 demonstrates the mediating effect of Industry 4.0 technologies on cultural changes and management functions. Model 3 highlights the mediating effect of Industry 4.0 technologies on technological changes and management functions. The theoretical models of the study are presented in Figures A1–A3 in Appendix B. These models were developed following validity, reliability, and factor analyses. Table 2 provides a detailed explanation of the variables used in the models.

Table 2. Description of variables used in models.

Models	Variable Code	Description
Model 1	UE	Uncertainty of the Environment
	SEC	Speed of Environmental Change
	IPA	Interconnectedness of Peripheral Actors
	END	Toward Industry 4.0 Technologies
	MF	Management Functions
Model 2	CC_CLC	Cultural Situation: Creating an Environment for Continuous Learning and Creativity
	CC_EEP	Cultural Situation: Ensuring Employee Participation in Decisions and Building Employees' competences
	END	Toward Industry 4.0 Technologies
	MF	Management Functions
Model 3	TD_UAI	Technological Developments: Understanding the Abundance of Information and Providing Ease of Access to Real
	TD_PHM	Technological Developments: Providing Human–Machine Partnership and Gaining Innovation
	END	Toward Industry 4.0 Technologies
	MF	Management Functions

The second stage of the analysis involved transitioning to a mixed research method to explore the study in more depth after scale development. In this phase, semi-structured interviews were conducted with 10 business managers. Nine open-ended questions were asked during the interviews. The full list of questions is provided in Appendix C.

To align with the research purpose, the study group was determined using a purposive sampling method [139]. This sampling method was chosen because it focused on managers who provided the most statistically significant quantitative data. Another key characteristic of the sample was that the managers selected had knowledge of Industry 4.0 technologies and actively used them in their businesses. The interviews were conducted between 1 December 2022 and 20 January 2023, either in the participants' personal offices or through online meetings.

The qualitative research phase was analyzed through three main themes: cultural, environmental, and technological changes; management functions; and employee expectations as a result of these changes. Codes were applied to ensure systematic data analysis [140]. The themes and corresponding literature codes are presented in Appendix D.

2.4. Scale Development Stages

2.4.1. Face and Content Validity of the Scale

After determining the item pool for the content validity of the Management 4.0 Foresight Scale, three managers were consulted to assess the face validity of the items within each dimension. Based on their feedback, aspects such as the comprehensibility, length, readability, and answerability of the scale were evaluated, along with ensuring that the draft was not visually overwhelming. These revisions helped ensure the surface validity of the scale.

For the content validity of the developed scale, an Expert Opinion Form was prepared to gather feedback from five experts: one academic, one linguistics expert, and three administrators. In this form, each item in the scale was rated as "appropriate", "appropriate but should be corrected", or "not appropriate, should be removed".

The content validity ratio and content validity index were calculated using the information and feedback provided by the experts. The content validity ratio ranges from −1 to +1. For an item to be included in the ^{scale}, more than 50% of the experts must rate it as "appropriate" [141]. The validity of each item in the scale was calculated using the following formula [142]:

$$CSR = NG/(N/2) - 1$$

CSR: Coverage Validity Ratio

NG: Number of experts who agree with the item

N: Total number of experts who expressed an opinion on the item.

The Content Validity Index, which shows the validity of the scale as a whole, was calculated with the formula:

$$CGI = (CKGO)/MS$$

CGI: Content Validity Index

∑CGO: Sum of content validity ratios of remaining items

MS: Number of items remaining

After obtaining expert opinions, it was found that each item had a CGV value ranging from 0.60 to +1. The CVI of the whole scale was 0.93. It is stated that a content validity index above 0.80 is an acceptable value.

2.4.2. Pilot Application

A questionnaire survey was conducted with 111 business managers, including online interviews with participants from 1000 ISO 1000 businesses. As a result of the pilot study, item validity, reliability analyses, and factor analyses were performed using SPSS 25.0 and AMOS 24.0. These analyses revealed changes and similarities within the dimensions of the scales, leading to the merging of certain item dimensions. Specifically, in the cultural

change scale, the dimensions of continuous learning and creativity were combined. In the technological developments scale, the dimensions of human–machine partnership and innovation were merged. Additionally, in the technological developments scale, the dimensions of the abundance of information and access to real data were combined. Finally, in the management functions scale, the dimensions of planning, organizing, coordination, execution, and control were consolidated into a single dimension. The scales of Industry 4.0 technologies and management functions are now treated as a single dimension.

2.4.3. Reliability of the Scale

In the reliability analysis of the "Management 4.0 Foresight" scale, Cronbach's Alpha (α) value was examined to assess the internal consistency of the dimensions, as presented in Table 3.

Table 3. Reliability coefficients for the dimensions of the Management 4.0 Foresight Scale.

Dimension	Cronbach's Alfa
Environmental Change Dimension	0.841
Cultural Changes Dimension	0.846
The Technological Development Dimension	0.837
Management Functions Dimension	0.875
Industry 4.0 Technology Dimension	0.848

According to Hair et al. (2014) [143] and Büyüköztürk (2011) [139], the minimum acceptable value for Cronbach's alpha, which indicates the reliability coefficient, is 0.70, with 0.60 being the critical threshold for exploratory research. The Cronbach's alpha values of the scale developed in this study ranged from 0.83 to 0.87, demonstrating that the reliability of the five dimensions is ensured.

2.4.4. Explanatory Factor Analysis Results

The results of the exploratory factor analysis of the scale developed for this research are presented in Appendix E. In addition, the Kaiser–Meyer–Olkin (KMO) test was applied to assess the suitability of the dimensions used in the scale for factor analysis. A KMO value between 0.5 and 1.0 is considered acceptable for factor analysis, while values below 0.5 suggest that factor analysis may not be suitable for the dataset [144].

When analyzing the results of the environmental change dimension, the KMO value was found to be 0.867, and Bartlett's Sphericity test yielded an acceptable chi-square value of $\chi^2(66) = 1313.292$, $p < 0.05$, indicating that the sampling adequacy was sufficient for factor analysis. In the factor analysis results, SEC 4 was removed from the scale due to its factor loading being below 0.40. The remaining 12 items were grouped into 3 sub-dimensions, which together explained 54.949% of the total variance. In multi-factor designs, an explained variance above 40% is generally considered sufficient [145].

The KMO value for the cultural change dimension was found to be 0.885. Additionally, Bartlett's Sphericity test revealed an acceptable chi-square value of $\chi^2(66) = 1311.209$, $p < 0.05$. In the exploratory factor analysis conducted to determine the factor structure of the cultural change scale, five items were removed due to their factor loadings being below 0.40 (CC_CLC2, CC_CLC7, CC_EEP1, CC_EEP4, and CC_EEP7). The remaining 12 items were grouped into 2 sub-dimensions, which together explained 47.406% of the total variance.

Technological change dimension's KMO value was found to be 0.894. In addition, when the results of Bartlett's Sphericity test were analyzed, the chi-square value obtained was $\chi^2(66) = 1155.276$, $p < 0.05$, which is considered acceptable. In the exploratory factor analysis conducted to determine the factor structure of the technological development scale,

four items were removed due to low factor loadings (TD_UAI1, TD_UAI5, TD_PHM6, and TD_PHM2). The remaining 12 items were grouped into two sub-dimensions, which together explained 45.324% of the total variance.

For the management function dimension, the KMO value was found to be 0.922. Additionally, the results of Bartlett's Sphericity test revealed an acceptable chi-square value of $\chi^2(120) = 1933.564$, $p < 0.05$. In the exploratory factor analysis conducted to determine the factor structure of the management function scale, 16 items were grouped into a single dimension, explaining 37.036% of the total variance. In single-factor designs, explaining more than 30% of the variance is generally considered sufficient [139,145].

For the Industry 4.0 technology dimension, the KMO value was found to be 0.901. The results of Bartlett's Sphericity test revealed an acceptable chi-square value of $\chi^2(45) = 1112.751$, $p < 0.05$. In the exploratory factor analysis conducted to determine the factor structure of the Industry 4.0 technology scale, 10 items were grouped into a single sub-dimension, explaining 42.5627% of the total variability.

2.4.5. Confirmatory Factor Analysis Results

The results of the confirmatory factor analysis for the five dimensions of the Management 4.0 Foresight Scale are presented in Table 4. The critical goodness-of-fit values of the structural model are indicated in the last column of the table, following the guidelines of Hair et al. (2014) [143]. When the critical value thresholds and the model goodness-of-fit values for the dimensions are compared, it can be observed that the model fits of each sub-dimension meet the required critical values.

Table 4. Confirmatory factor analysis results of scale dimensions.

	Environmental Change Dimension	Cultural Changes Dimension	The Dimension of Technological Changes	Management Functions Dimension	Industry 4.0 Technology Dimension	Critical Values
CMIN/DF	2.741	3.012	1.785	2.510	2.233	≤5
RMSEA	0.066	0.071	0.044	0.061	0.056	≤0.08
GFI	0.946	0.936	0.963	0.924	0.964	≥0.80
AGFI	0.918	0.905	0.946	0.901	0.944	≥0.80
CFI	0.930	0.915	0.962	0.915	0.960	≥0.80
TLI	0.909	0.895	0.953	0.902	0.949	≥0.80
IFI	0.931	0.916	0.963	0.916	0.960	≥0.80
SRMR	0.044	0.049	0.038	0.041	0.036	≤0.10

3. Results

3.1. Correlation Analysis Results

The results of the correlation analyses for the three models established in the context of the main purpose of the research are presented in Tables 5–7. According to the correlation analyses, environmental changes have a positive and significant relationship with the mediator variable, Industry 4.0, and the dependent variable, management functions, at the 0.01 significance level. When examining the subdimensions of cultural change in Model 2, both subdimensions show a positive and significant relationship with the mediator variable and the dependent variable at the 0.01 significance level. In the final model, the subdimensions of technological changes were found to have a positive and significant relationship with Industry 4.0 and management functions at the 0.01 significance level.

Table 5. Correlation analysis of environmental change sub-dimensions with Industry 4.0 and management functions.

		SEC	UE	IPA	Industry 4.0	MF
SEC	Pearson Correlation Sig. (2-tailed)	1				
UE	Pearson Correlation Sig. (2-tailed)	0.551 ** 0.000	1			
IPA	Pearson Correlation Sig. (2-tailed)	0.486 ** 0.000	0.600 ** 0.000	1		
END	Pearson Correlation Sig. (2-tailed)	0.446 ** 0.000	0.497 ** 0.000	0.535 ** 0.000	1	
MF	Pearson Correlation Sig. (2-tailed)	0.475 ** 0.000	0.498 ** 0.000	0.586 ** 0.000	0.748 ** 0.000	1

** The correlation is significant at the 0.01 level (2-tailed).

Table 6. Correlation analysis of cultural change sub-dimensions between Industry 4.0 and management functions.

		CC_CLC	CC_EEP	Industry 4.0	MF
CC_CLC	Pearson Correlation Sig. (2-tailed)	1			
CC_EEP	Pearson Correlation Sig. (2-tailed)	0.702 ** 0.000	1		
END	Pearson Correlation Sig. (2-tailed)	0.605 ** 0.000	0.682 ** 0.000	1	
MF	Pearson Correlation Sig. (2-tailed)	0.607 ** 0.000	0.723 ** 0.000	0.748 ** 0.000	1

** The correlation is significant at the 0.01 level (2-tailed).

Table 7. Correlation analysis of technological change sub-dimensions between Industry 4.0 and management functions.

		TD_UAI	TD_PHM	Industry 4.0	MF
TD_UAI	Pearson Correlation Sig. (2-tailed)	1			
TD_PHM	Pearson Correlation Sig. (2-tailed)	0.727 ** 0.000	1		
END	Pearson Correlation Sig. (2-tailed)	0.669 ** 0.000	0.591 ** 0.000	1	
MF	Pearson Correlation Sig. (2-tailed)	0.737 ** 0.000	0.736 ** 0.000	0.748 ** 0.000	1

** The correlation is significant at the 0.01 level (2-tailed).

3.2. Structural Equation Analysis Results

Before examining whether Industry 4.0 technologies have a mediating effect on environmental, cultural, and technological changes and management functions, the model fits of the three structural equation models were assessed. Table 8 presents the model fit values for the three models. All three models met the critical value ranges established by Hair et al. (2014) [143].

Table 8. Model fit values of Models 1, 2, and 3.

	Model 1	Model 2	Model 3	Critical Values
CMIN/DF	1.896	1.955	1.954	≤5
RMSEA	0.047	0.049	0.051	≤0.08
GFI	0.820	0.815	0.821	≥0.80
AGFI	0.807	0.808	0.808	≥0.80
CFI	0.883	0.879	0.877	≥0.80
TLI	0.875	0.871	0.869	≥0.80
IFI	0.884	0.880	0.878	≥0.80
SRMR	0.051	0.050	0.050	≤0.10

Emerson (2023) [146] states that the eta squared (η^2) statistic can be used as a measure of effect size in regression analyses. Effect size is expressed as small, medium, and large according to values of 0.01, 0.06, and 0.14, respectively [147,148].

When the effect size results of the variables in our study are analyzed, IPA ($\eta^2 = 0.1285$) has a large effect, while the UE ($\eta^2 = 0.0936$) and SEC ($\eta^2 = 0.0252$) variables have medium and small effects, respectively.

While the variable CC_CLC ($\eta^2 = 0.1071$), which shows cultural change, has a medium effect, it can be said that the variable CC_EEP ($\eta^2 = 0.1372$) has a large effect since it is very close to 0.14.

In the technological changes model, the UAI ($\eta^2 = 0.1204$) variable can be considered to have a large effect since it is close to 0.14, while the effect size of the PHM ($\eta^2 = 0.1543$) variable is found to be large. It can be stated that the variable END ($\eta^2 = 0.1308$), which shows Industry 4.0 technologies, is close to a large effect.

According to Baron and Kenny (1986) [149], before examining the mediation effect of a variable, a significant relationship must first be established between the independent and dependent variables. In the second step, if the significant relationship between the independent and dependent variables found in the first step becomes completely insignificant with the mediator variable, it indicates a full mediation effect. However, if the significance persists but the coefficient decreases, it indicates a partial mediation effect.

In this context, Table 9 presents the results of the relationships between the independent and dependent variables across the three models. Based on the analysis results, a significant relationship exists between environmental changes and management functions, as the significance level is less than 0.05. Therefore, hypothesis H1 is accepted ($\beta = 0.768$, $p < 0.05$). In Model 2, a significant relationship is found between cultural changes and management functions, as the significance level is less than 0.05. Thus, hypothesis H3 is accepted ($\beta = 0.879$, $p < 0.05$). In Model 3, a significant relationship is found between technological changes and management functions, as the p-value is less than 0.05 ($\beta = 0.943$, $p < 0.05$). Based on this result, hypothesis H5 is accepted.

The mediation effect of Industry 4.0 technologies on the three models is presented in Table 10. According to the analysis results, Industry 4.0 has a mediating effect between environmental changes and management functions because the confidence interval does not include zero and the significance level is less than 0.05 (0.317, 0.605). Therefore, hypothesis H2 is supported. After confirming the mediating role, the next step was to examine whether the direct effect was significant to determine the type of mediation. The results showed that the direct effect was significant but the coefficient decreased ($\beta = 0.288$, $p < 0.05$), indicating that the mediator has a partial mediation effect.

Table 9. Relationship between independent and dependent variables in Models 1, 2, and 3.

Models	Estimate (β)	Standard Error	t	*p*	Result
(H1) (Model 1)	0.768	0.110	8.130	***	Acceptance
(H3) (Model 2)	0.879	0.150	8.257	***	Acceptance
(H5) (Model 3)	0.943	0.183	7.732	***	Acceptance

*** The correlation is significant at the 0.001 level (2-tailed).

Table 10. Mediating variable effect of Industry 4.0 on Models 1, 2, and 3.

Models	Impact	Estimate (β)	Standard Error	t	*p*	Result
(H2) (Model 1)	Direct Impact	0.275	0.086	3.700	***	Acceptance
	Indirect Impact	0.493	Confidence Interval (0.378–0.616)		0.007	Acceptance
(H4) (Model 2)	Direct Impact	0.533	0.191	3.947	***	Acceptance
	Indirect Impact	0.348	Confidence Interval (−0.002–0.599)		0.099	Rejection
(H6) (Model 3)	Direct Impact	0.727	0.200	5.314	***	Acceptance
	Indirect Impact	0.214	Confidence Interval (−0.010–0.346)		0.154	Rejection

*** The correlation is significant at the 0.001 level (2-tailed).

However, since the confidence interval for the mediation effect of Industry 4.0 between culture and management functions includes zero, according to Hayes and Preacher (2010) [150] there is no mediating variable effect. Furthermore, because the *p*-value indicating the significance level of the analysis is greater than 0.05, there is no mediating variable effect of Industry 4.0 between culture and management functions (0.099 > 0.05). Therefore, hypothesis H4 is rejected.

Similarly, since the confidence interval for the mediation effect of Industry 4.0 between technological changes and management functions includes zero and the *p*-value is greater than 0.05, there is no mediation effect. Hence, hypothesis H6 is rejected.

3.3. Qualitative Data Analysis Results

The reliability of the qualitative research was ensured by comparing the codings made by two independent coders based on the K1 document at the code existence level. Both coders performed their coding independently, without knowledge of each other's work. Consensus, which reflects the level of agreement between coders, is considered a key indicator of reliability in qualitative research. Out of 20 coded sections, 17 were consistent, while 3 showed inconsistencies. This resulted in an 85% consensus rate between the coders. According to Miles and Huberman (1994) [151], a consensus rate above 80% ensures the reliability of the study.

3.3.1. Participant Information

A total of ten managers participated in the qualitative phase of the study. To ensure confidentiality, participants were labeled from P1 to P10. Detailed participant information is provided in Appendix F, where the first column lists participant numbers, the second column indicates the sector in which each company operates, and the third column specifies the participant's job position.

The participants hold the following positions within their respective organizations: two Planning Managers, two Human Resources Managers, two Business Managers, one Marketing Manager, one Technology Manager, and one Customer Team Manager. In terms of educational background, three managers hold a bachelor's degree, while seven have a master's degree. Regarding sector distribution, 3 out of 10 managers are from the textile sector, while the remaining 7 managers represent various other industries.

3.3.2. Hierarchical Code-Sub-Code Notation for the Themes of Cultural, Technological, and Environmental Changes

Eleven codes were developed for the theme of Cultural/Technological/Environmental Changes, which is a central theme of this research. These codes include: adaptation to the new order, new cultural environment, technology and culture compatibility, continuous learning, trust-tolerant environment, presenting new ideas, acceptance of change by senior management, following the change, adaptation to the company plan, easy communication, and recruitment in alignment with the new culture. Table 11 provides the codes associated with these themes along with the participants' responses.

Table 11. Results of the cultural, technological, and environmental changes theme.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Total
Adaptation to the New Order	1	1		1	2	2	1	1	2	1	12
A New Cultural Environment	1	1	1	1		1	1	1	1	1	9
Harmony between Technology and Culture	1	2		3	1			1	1		9
Continuous Learning	1	1				1				1	4
Trust-Tolerant Environment						2	1		1		4
New Ideas		1		1		1	1				4
Top Management Acceptance of Changes		1					1	1	1		4
Tracking Change								2	1		3
Compliance with the Company Plan				1		2					3
Easy Communication		2			1						3
Recruitment for the New Culture		1									1

The participants' views on the theme of Cultural/Technological/Environmental Changes centered around the codes "adaptation to the new order" and "new cultural environment". Participants P6 and P9 shared the following insights regarding adaptation to the new order:

P6 stated: *"Yes, I do. The company's mission, values, and goals are shaped by this changing cultural environment. The better and stronger the employees perceive this, the more realistic and effective the company's mission and plans will be. I can say that culture changes our management approach to achieving our goals. These changes form the foundation of the relationship between the manager and the managed".*

P9 mentioned: *"It enables us to advance further in the sector within the enterprise. In this regard, we prioritize technological developments and national or international studies. We*

consistently examine these developments and conduct R&D. For personnel development, we stay aligned with evolving technology and provide them with training both externally and within the company".

Another code under the theme of Cultural/Environmental Change was new cultural environment. Participants emphasized that with the development of technology, a new corporate culture has emerged. Participants P7 and P10 shared the following perspectives:

P7 stated: *"Businesses or sectors like ours are part of every field of life. It has also benefited our business, resulting in the formation of a new culture. Of course, the business is not independent of life and current events, so I can say that the cultural changes we've experienced have fostered a new business culture built on trust and tolerance".*

P10 mentioned: *"It created new cultures. Regular training and educational programs have started being offered to employees. With the changing and developing structures, our perspectives are constantly evolving in both our personal lives and within our organization".*

In the theme of Cultural/Environmental Changes, participants also referenced the code of technology and cultural harmony, highlighting how they have integrated developing technology into their corporate culture. Participants P2 and P8 shared the following insights:

P2 shared: *"Technology has transformed our management style into a holistic, integrated, and systematic approach. With these advancements, we are distinct from previous administrations. Technology has made our management more systematic and future-focused, enabling us to make more radical decisions and implement these decisions long term".*

P8 noted: *"With the development of technology, there have certainly been corresponding shifts in management practices. One of the most noticeable examples of this is the emergence of new working models enabled by technological advancements. For instance, while management models like Waterfall were common in the past, new models have gained prominence with the infrastructure support provided by technology. The support offered by programming tools allows us to use them much more actively. Of course, there are many such positive examples".*

3.3.3. Hierarchical Code-Subcode Representation of the Management Function Theme

Six codes were created under the planning function category. These codes are as follows: being systematic in decision making, planned/coordinated work, staff expressing their opinions, participation in decisions, long-term planning, and efficient work. Table 12 presents these codes along with the responses of the participants.

Table 12. Results of planning function theme.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Total
Systematic decision making		2					2	1	1		6
Planned/coordinated	1	1					2		1	1	6
Personnel Expressing Their Opinions	1						1				2
Employee Participation in Decisions	1						1				2
Long-Term Planning	1					1					2
Working Efficiently										1	1

In the planning category, participants strongly emphasized the importance of systematic decision making. They noted that the decision-making process has become more structured and systematic. Participants P2 and P7 highlighted the following insights:

P2: *"Technology has made our management style more systematic and future-focused, allowing us to make more radical decisions and implement them in a long-term, systematic manner".*

P7: *"I can say that everything has gained an automatic and systematic dimension; Industry 4.0 technologies are like our hands and feet. You may have heard rumors about technology replacing human labor with machines, but this is a misunderstanding. In fact, this labor shortage is more about using information technologies mentally rather than physically".*

In the planning category, another key code mentioned by participants was planned/coordinated work. Participants emphasized that they prioritize a structured and coordinated approach in their operations. Participants P1 and P7 shared the following insights:

P1: *"Our priority is for employees to adapt to this new order. It's true that new technologies are used continuously and dynamically, but these are changes we can only fully appreciate through long-term planning and teamwork. It is crucial for us that our employees consistently perform their duties in the best and most honest way".*

P7: *"There are many effects, but the first thing that comes to mind is efficiency. Technological advancements, particularly in terms of time-saving and efficiency, have been very beneficial in our sector. As a result, I can say that everything has become more systematic, especially in the decision-making and coordination stages of planning, now happening in an orderly manner".*

In the organizing category, seven codes were created. These are the rise of platforms, the emergence of new working models, the use of machines, the use of less manpower, reductions in the number of personnel, flexible structures, and the movement away from rigid bureaucracy. Table 13 presents the codes and participant responses for the organizational function.

Table 13. Results of the organization function theme.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Total
The Rise of Platforms	1	1			2	1				2	7
Emergence of New Working Models	1							4			5
Working with Machines	1		1			2	1				5
Working with less manual labor					1	1	1				3
Decrease in the amount of Personnel										1	1
Flexible Structures		1									1
Moving Away from Rigid Bureaucracy		1									1

In the organizing category, respondents strongly emphasized the rise of platforms. They stated that technology has facilitated the emergence of platforms, making communication easier and improving access to markets. Participants P5 and P10 shared the following:

P5: *"Let me put it this way, we can access products in terms of marketing. It is easier in terms of market and marketing. Therefore, a more competitive environment is created. For example, a product is sold for 10 or 8 Lire or 7 Lire. However, for more competitive labor, there are discussions about whether they sell for 7 Lire or 6 Lire. The negative aspects are in this way, and the positive aspect is that we can sell more quickly. I think the consumer can reach some things more quickly".*

P10: *"It played a positive role in communication. We got rid of landline phones and provided direct conversations on WhatsApp for faster access to everyone. It made it faster and easier to reach the staff. In the classical system in our machines, tooling and labor were more tiring and costly in terms of management, but now that tooling is automatic in our machines, productivity has increased,*

time has shortened, and production has increased. In this way, the change provided convenience for management and personnel".

Another code in the organizing category was the emergence of new working models. Participants noted that the development of new working models was driven by the emergence of a new culture within organizations. Participants P1 and P8 shared the following:

P1: *"I mean, I can say that I think partially, for example, that the culture is not what it used to be. This is obvious, and it is inevitable that a new culture will emerge within the organization. However, the drink of our culture is tea. This is a culture change within the organization. It also impacts management. When you think about it like this, of course, many things come out".*

P8: *"With the development of technology, of course, there have been related developments in management approaches. One of the most obvious examples of this is the emergence of new working models through the opportunities provided by technology. For example, while management models like Waterfall were common in the past, new models have come to the fore with the infrastructure support provided by technological tools. The support provided by programming helps us to use them much more actively. Of course, there are many such examples in a positive way".*

In the organizing category, participants also discussed the code related to working with machines. They mentioned that machines have increasingly replaced human labor in production. Participants P6 and P7 shared the following:

P6: *"The point is that using the latest machinery in the business will provide us with profitability in the long run, but there is also the cost of service and the return to customers. It is very important to maintain the balance. We need to move forward without disrupting the plan and coordination in order to avoid falling behind in management and making losses. This is the essence of the technology-based management approach".*

P7: *"I can say that everything has become automated and systematic; Industry 4.0 technologies are our hands and feet. You must have heard the rumors that technology is taking away the labor force, that machines are replacing the labor force. There is a misunderstanding among the public; there is no such thing. On the contrary, this labor shortage is based on using information technologies mentally, not physically".*

Six distinct codes emerged under the coordination category: flexibility/transparency, cooperation with competitors, faster movement, cooperation within the team, faster communication, and all departments being connected. These codes reflect the various aspects of coordination that participants associated with technological and organizational changes. Participant responses highlighted the increased flexibility, transparency, and efficiency brought about by advancements in technology and Industry 4.0 tools. Table 14 summarizes the codes alongside participant responses.

Table 14. Results of coordination function theme.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Total
Flexibility/Transparency		1			1	1	1	1		3	8
Collaboration with Competitors	1	1		1		1		1	1		6
Moving Faster			1		1		1	1		2	6
Team Collaboration	2				1		1				4
Faster Communication										2	2
Connectivity of All Departments		1									1

In the coordination category, participants emphasized the importance of flexibility and transparency. They stated that they had adopted flexible and transparent management

practices in line with technological advancements. Participants P2 and P10 shared the following insights:

P2: *"These methods provide flexibility and transparency, which are the most important aspects. These qualities are connected to all other departments, enabling the business to achieve total quality and efficiency to the extent that these technologies are utilized. With this approach, we can foster harmonization both within the team and across departments or even with competitors".*

P10: *"With these developments, our employees have increased their contributions to the company and have begun using their time more effectively".*

Another theme in the coordination category was cooperation with competitors. Participants indicated that they collaborated and exchanged ideas with their competitors. Participants P1 and P6 shared the following remarks:

P1: *"There is no issue with our communication with competitors, and we exchange ideas when evaluating job applications. We all have a voice at special HR meetings held across Turkey. Poor communication could lead to negative outcomes for the sector".*

P6: *"We cooperate with our competitors, and competition motivates us. Through this collaboration, we continually contribute new content to the sector".*

In the coordination category, participants also highlighted the concept of moving faster. They emphasized that technological advancements help save time. Participants P5 and P8 shared the following insights:

P5: *"If five people are needed to perform a task in-house, with the new systems, it can now be done by three. However, explaining this can sometimes be challenging".*

P8: *"For example, with these changes in social life, our online management features have improved significantly. Many new methods have been developed to address the shortcomings of traditional models. We have gained speed, remote work has been supported to enable people to work more efficiently under various conditions, and we are gradually adapting to this new form of management".*

Nine codes were identified under the execution category. These are modern management approach, digital management, the absence of a classical management approach, teamwork, innovation, distribution of authority, a holistic management perspective, moving away from the traditional management model, and everyone taking responsibility as a manager in their own work. The participants' responses corresponding to the codes within the execution function are presented in Table 15.

Table 15. Results of the executive function theme.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Total
Modern Management Approach	1	1	1	1	2	1	1	1	1	1	11
Digital Management	1		1	1	1	1		1	1		7
Lack of Classical Management Approach	1	1		1		1	1	1			6
Teamwork	2						1	1		1	5
Innovation				1	1				1		3
Distribution of Authority	1									1	2
Holistic Management Perspectives			1								1
Departure from the Traditional Management Model								1			1
Everyone Becoming a Manager in Their Own Business					1						1

In the execution category, participants frequently shared their thoughts on the modern management approach. They stated that they had adopted this new style of management. Participants P3 and P7 provided the following insights:

P3: *"We have no rigid practices or policies in our company. We fully embrace a modern management approach, as its foundation lies in seeking support from employees during the decision-making process and involving them in management".*

P7: *"I can say we follow a modern management approach, but when necessary, the traditional model is still inevitable in business operations. Of course, it's not the same as before, but maintaining a balance between the top and bottom levels of management is essential and should align with this understanding".*

Another theme in the execution category where participants shared their opinions was digital management. They stated that technological advancements had led them to adopt more digital activities. Participants P3 and P4 expressed the following views:

P3: *"Industrial techniques and technologies provide us with the knowledge needed to carry out production and technical activities. As a result, our management approach is based on this understanding. Robot technologies and automation applications now shape our industrial management practices".*

P4: *"Clearly, management has acquired a digital dimension. We observe its impact at every stage, from production to customer engagement. While each aspect deserves separate consideration, management itself is also becoming digitalized. For instance, we can easily manage a team member remotely. We frequently hold international meetings, and a manager from marketing, sales, or another department can efficiently inform and coordinate their team—even while on a flight".*

In the execution category, participants also discussed the decline of the classical management approach. They noted that while traditional methods were still utilized, they were often integrated with modern practices. Participants P4 and P2 shared the following insights:

P4: *"I believe that we should not completely move away from the traditional order, even in a predominantly modern environment. However, this is a form of traditional management that incorporates new elements. Unlike before, we no longer have rigid rules and taboos".*

P2: *"One of the core principles of our management approach is centered on dismantling traditional and existing management methods. Our foundation dates back to before the 1980s, and we employ a methodology where new practices are constantly tested. Of course, our current approach is influenced by the past, but when we examine the company's history, we see that we evolved because the main vision of our founders was to break down many traditional sub-areas, including management, and enhance them through innovation. If we fail to move beyond the past and rigid bureaucracy, I don't believe we can succeed in today's conditions, either nationally or globally. If this persists, we risk regressing by 30 or 40 years".*

Three codes were identified under the control category. These are more frequent control, faster and more accurate record-keeping, and more frequent reporting. The responses provided by the participants corresponding to the control function codes are shown in Table 16.

Table 16. Results of the control function theme.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Total
More Frequent Checks	1	1	1						1		4
Fast and Accurate Registrations										1	1
More Frequent Reporting									1		1

In the control category, participants noted that controls had become more frequent after the changes. Participants P1 and P3 provided the following insights:

P1: *"I believe that Industry 4.0 will no longer rely on people for management control, but rather on machine data and systems".*

P3: *"We can continuously monitor changes. However, to prevent confusion, we establish a plan for managing these changes. We designate a person to serve as a role model for this process. This person becomes the pioneer, responsible for everything from follow-up to implementation and dissemination".*

Another theme in the control category where participants shared their opinions was the increased speed and accuracy of records. Participants mentioned that they were able to act faster and more accurately in product tracking and record-keeping. Participant P10 shared the following insight on the topic:

P10: *"Industry 4.0 is utilized in our company. It is actively integrated into both our programs and workforce. This makes it easier to use our programs more efficiently and track received products. For instance, it's used to track how much product is purchased from foreign countries and from which companies these transactions occur. With Industry 4.0, we can access records of all transactions made within our company more quickly and accurately".*

3.3.4. Hierarchical Code-Subcode for the Theme of Expectations from Employees as a Result of Changes

Within the scope of the research, five codes were identified under the theme "Expectations from Employees as a Result of Changes". These are employee participation in decisions, commitment to work, employees in a continuous learning environment, continuous development, and agile management. The codes related to employee expectations as a result of the changes, along with the responses provided by the participants, are presented in Table 17.

Table 17. Theme expectations of employees as a result of changes.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Total
Employee Participation in Decisions		2		1		1	2	1	2		9
Work Commitment	2	1	2	1							6
Continuous Improvement		1	2		1	1		1			6
Provide a Continuous Learning Environment for Employees									2	2	4
Agile Management		1					1	1			3

In the theme "Expectations from Employees as a Result of Changes", participants strongly emphasized the importance of employee participation in decision making. Participants P6 and P7 shared the following insights:

P6: *"Yes, the suggestion and complaint boxes are a great idea for us. At the same time, everyone here, especially in-house staff, can express their complaints and requests more easily since they can do so anonymously. We also reward those who develop and implement new ideas within the organization, starting with a quarter gold and continuing up to two salary bonuses. The fact that there is a reward at the end encourages more suggestions from our employees".*

P7: *"Of course, there is. We are a company that thrives on innovation. We conduct both internal customer and customer satisfaction surveys. As you know, the internal customer surveys are aimed at our staff, and we benefit greatly from this feedback. In particular, senior management*

and our board members support us every month, helping us determine how we can incorporate these requests into our operational flow. While it may take more time to find the best ideas from many suggestions, we are satisfied with this process".

Another code under the theme of employee expectations as a result of changes was work engagement. Participants mentioned that they expect employees to show respect for their work. Participants P1 and P3 shared the following insights:

P1: *"Yes, we have our own expectations, like everyone else, but if I provide too many details, I might violate confidentiality agreements within the company. Let me put it this way: If everyone plans their work well and produces content that benefits the organization, it will be advantageous for us. I should say that both we and our employees benefit from this, or rather, we support it".*

P3: *"We have clear expectations for our employees. We want them to demonstrate high levels of loyalty. If they approach their work with passion, the rest will follow. We encourage creativity, and in the near future, we plan to offer training first to department managers and white-collar employees, and later to blue-collar employees, to instill this mindset. We must also remember that life changes go hand in hand with this process".*

Another code under the theme "Expectations from Employees as a Result of Changes" was continuous development. Participants mentioned that employees should continually improve to keep up with changes. Participants P3 and P5 shared the following insights:

P3: *"If you are generous with rewarding employees, new and useful ideas become an attractive force. A highly motivated employee not only performs their job very well but also brings active and valuable ideas. There is no need to tell an employee who is passionate about their work to produce; they are already productive. We are a company that has gained a strong reputation in the sector by working this way. When a company becomes well-known, it creates an environment where successful people will work passionately. This, of course, opens the door to many opportunities".*

P5: *"We adopt modern principles. Using general methods is not appropriate for us in this sector, and we ensure this without disrupting the overall order. Of course, we aim to adopt a modern approach. We are striving to keep up with new systems and stay aligned with modernization. We make sure to keep ourselves up-to-date".*

4. Discussion

The purpose of this study is to examine the impact of environmental, cultural, and technological changes on the field of management and to identify paradigm shifts driven by Industry 4.0 technologies. These changes influence management functions, leading to transformations in management practices and related processes. The study was conducted using an exploratory sequential mixed-methods design. The primary objective is to analyze how environmental, cultural, and technological changes affect management functions through Industry 4.0 technologies. Following this approach, a scale development study was carried out in the quantitative phase, followed by interviews in the qualitative phase. Since no existing scale was available for predicting Management 4.0, a new scale was first developed. Subsequently, to gain deeper insights into the research topic, qualitative data were collected through interviews.

4.1. Theorical Implications

As environmental actors become more interconnected, environmental uncertainties increase, the environment grows more complex, and environmental changes occur at an accelerating pace, the way businesses operate has also evolved [4,9]. The nature of employees' work and their organizational structures are adapting in response to these shifting environmental conditions. Additionally, their perception of the environment is evolving alongside these structural changes and is further facilitated by Industry 4.0 technologies. Furthermore, technological advancements that enhance employee collaboration encourage

a human–machine partnerships, allowing machines to participate in decision-making processes [18]. This shift moves management away from a model in which the highest-paid individuals make decisions toward a more inclusive approach, where both employees and machines contribute to decision making [25]. Consequently, the value of human cognition is becoming increasingly recognized and the need to leverage human cognitive abilities is growing [20]. Since Industry 4.0 technologies drive significant transformations in environmental dynamics and the pace of change, it is crucial to prioritize short-term planning in management activities rather than relying solely on long-term strategies [31].

Cultural advancements, cognitive revitalization, and shifts in ways of thinking are transforming work structures and management styles. In particular, customized business cultures are gaining prominence, and Industry 4.0 technologies are driving significant cultural shifts. Organizations are increasingly adopting structures that continuously evolve, fostering a cultural environment of constant improvement. To adapt to this transformation, it is crucial for organizations to provide training that emphasizes continuous innovation and development [51]. As a result, employees are expected to engage in ongoing self-improvement. Moreover, people, machines, data, and devices are regarded as integral talents within the business, contributing to the emergence of a diverse range of capabilities. This phenomenon is a direct outcome of the human–machine collaboration.

Technological advancements drive significant changes in the fields of management and organization [8]. As a result, various organizational developments have emerged, including the rise of freelance work, human–machine collaboration, platform-based growth in organizational structures, increased career coaching by managers, greater employee participation in decision making, the dissolution of rigid hierarchical systems, and the adoption of modern management approaches [29,119].

4.2. Practical Implications

The first key finding of the study is that environmental, cultural, and technological changes are giving rise to a new cultural environment, making adaptation to this new order essential. The second theme relates to management functions. The findings regarding the planning function within the management functions theme are as follows: the most frequently emphasized aspect of the planning function is the importance of being planned and coordinated. In the literature, greater emphasis is placed on systematic decision making within the planning function [25]. Within the organization function, the rise of platform-based structures is the most emphasized aspect, followed by increased collaboration between humans and machines. Industry 4.0 technologies play a crucial role in promoting platform-based organizational structures [16]. In the coordination category, the most frequently highlighted factors are flexibility, transparency, and cooperation with competitors. Industry 4.0 technologies facilitate collaboration between the physical and virtual worlds. In the implementation category, modern management approaches and digital management were the most emphasized concepts. Industry 4.0 technologies prioritize data management, making it essential not only to manage people but also to manage machines and data effectively. Since traditional management approaches are insufficient for this, adopting modern management practices is imperative [82]. In the control category, control mechanisms were emphasized more frequently. With Industry 4.0 technologies, intelligent control systems have emerged, enabling real-time monitoring and instant reporting [25]. These technologies have driven fundamental changes in certain aspects of management functions while introducing partial changes in others. The interviews indicate that managers are aware of Industry 4.0 technologies and their implications. The third theme focuses on expectations from employees, with the most frequently mentioned aspects being employee participation in decision making and continuous improvement.

Employees expressed concerns about potential job losses due to Industry 4.0 technologies and uncertainty regarding their benefits. However, recent research highlights that continuous improvement environments enhance employees' skills and that technology can be leveraged to strengthen specific competencies [152].

Industry 4.0 technologies prioritize human–machine interaction, and managers benefit from these technologies in the decision-making process [100]. The analysis results align with the literature, as managers emphasize the importance of systematic decision making with the assistance of Industry 4.0 technologies. Algorithms facilitate risk estimation and prediction, leading managers to anticipate improvements in planning and coordination. The most emphasized topics within the organization category are the rise of platforms and collaboration with machines. According to the literature, organizational structures change after the adoption of Industry 4.0 technologies [18]. With the implementation of these technologies, organizational change occurs rapidly, making it impossible to maintain bureaucratic structures [101]. As organizational structures evolve, platforms emerge. Employees collaborate with machines as colleagues, adopting a mindset that supports human–machine partnerships. Industry 4.0 technologies accelerate internal interactions within the enterprise and bring about changes in coordination processes [126]. By encouraging cooperation between units within and across enterprises, they allow organizations to act more flexibly and transparently [40]. Flexibility, particularly during the coordination phase, provides significant advantages. The shift towards a modern management approach, driven by the integration of human, machine, and data management, is emphasized. Recent technological advancements underscore the need to abandon traditional management approaches, especially in the executive functions of enterprises. With the control mechanism now active in all management functions, feedback is continuously gathered throughout the management process. As a result, more frequent checks lead to fewer errors. Consequently, Industry 4.0 technologies foster employee participation in decision making. This shift is expected to empower employees with greater decision-making authority. Additionally, these technologies create an environment conducive to continuous learning.

With Industry 4.0 technologies, flexible structures have become increasingly important, as rigid bureaucracy is no longer sufficient and the traditional hierarchical model has become outdated. The human–machine partnership fosters collective intelligence, ushering in an era where cognitive abilities take center stage. As a result, businesses require more machine power and less human labor. Additionally, Industry 4.0 technologies have led to the rise of platforms within organizational structures, contributing to a shift away from rigid bureaucratic systems.

As departments and stakeholders within an enterprise become increasingly interconnected through Industry 4.0, cyber–physical systems facilitate seamless communication by linking all processes. This results in greater flexibility and transparency in business operations. As businesses move away from traditional management models, collaboration, rather than individual leadership, is becoming more prominent. Industry 4.0 technologies advocate for a digital management approach in the execution function, introducing a modern management paradigm. Furthermore, Industry 4.0 technologies support more frequent control and the ability to receive instant reports. With data-driven dynamics, businesses can conduct more frequent surveillance and audits. This enhanced control mechanism, integrated at every stage of the management process, minimizes errors and enables the early identification of risks.

4.3. Sustainability Implications

In today's organizational dynamics, sustainability has evolved into a holistic approach that encompasses not only environmental performance but also technological transforma-

tion and the strategic management of human resources. This is where the Management 4.0 paradigm emerges as a key driver of sustainable transformation.

Modern sustainability approaches indicate that technological integration enhances business resilience. For example, research by Saucedo-Martinez et al. (2018) [31] reveals that Industry 4.0 technologies strengthen the ability of organizations to adapt to environmental changes by supporting short-term planning strategies. Human–machine collaboration stands out as the most critical component of sustainable governance. Davenport and Redman (2020) [20] emphasize that integrating human cognitive abilities with technological systems fosters more flexible, transparent, and efficient decision-making processes. This approach enables organizations to optimize not only their economic performance but also their social and environmental responsibilities. Additionally, Mohelska and Sokolova (2018) [51] highlight that a culture of continuous learning and innovation is a fundamental driver of sustainable organizational development. By focusing on enhancing employees' digital capabilities, the Management 4.0 paradigm strengthens the potential of human resources to create sustainable value. Research by Ghobakhloo (2018) [119] and Lee (2019) [29] further demonstrates that digital platforms and flexible organizational structures support sustainable performance. Shifting away from traditional hierarchical models toward networked and self-organizing systems increases organizational agility and adaptability. In conclusion, the Management 4.0 paradigm views sustainability as a dynamic interaction between technology, people, and the environment. This approach empowers businesses to develop a strategic vision capable of addressing both present and future challenges.

As highlighted in the Management 4.0 framework, the evolution of management practices has been profoundly shaped by environmental, cultural, and technological changes. With the rapid advancements brought by Industry 4.0 technologies, businesses are adapting to new paradigms that emphasize digital transformation, automation, and human–machine collaboration. However, alongside these developments, sustainability has become a critical factor in shaping the future of management. Sustainable management involves integrating environmental, social, and economic responsibilities into decision-making and organizational processes. In the context of Management 4.0, this means leveraging Industry 4.0 technologies to develop more sustainable business models. The adoption of smart technologies enables organizations to optimize resource utilization, reduce waste, and enhance operational efficiency. Real-time monitoring systems and data analytics facilitate predictive decision making, allowing businesses to minimize their environmental footprint while improving productivity. Culturally, Industry 4.0 fosters a shift toward a sustainability-conscious workforce. Organizations increasingly emphasize continuous learning, innovation, and adaptive work structures that contribute to long-term sustainability. The rise of platform-based business models and flexible work environments further supports social sustainability by promoting inclusion, collaboration, and knowledge sharing. From a technological perspective, Management 4.0 enhances sustainability by integrating cyber–physical systems that improve coordination and resource management. Intelligent control systems and AI-driven insights help organizations balance short-term adaptability with long-term sustainability goals. Additionally, as businesses transition from rigid bureaucratic models to more dynamic and interconnected structures, they gain the agility needed to address sustainability challenges such as climate change, supply chain disruptions, and social inequalities.

This highlights that while businesses acknowledge the transformative potential of Industry 4.0, sustainability considerations must be more explicitly integrated into their strategic planning. As organizations transition to Management 4.0, aligning technological advancements with sustainability goals is crucial. This alignment will ensure that digital transformation not only enhances efficiency but also contributes to a more resilient and re-

sponsible global economy. In conclusion, sustainability and Management 4.0 are inherently interconnected. By incorporating sustainability into Industry 4.0-driven management practices, businesses can address critical environmental and social challenges while achieving long-term success. Future research should focus on the role of Industry 4.0 in advancing corporate sustainability performance and explore how businesses can effectively balance technological innovation with sustainable development.

5. Conclusions

As a result of the findings obtained, it is necessary to discuss the "Management 4.0 Forecast". In the Management 1.0 framework, large factory organizations dominate the organizational structure. During this period, the driving force is the Industrial Revolution and management is regarded as a science. Various management applications and tools are utilized to enhance efficiency. Management 2.0 introduces an interaction between organizations and their environment, highlighting the need for adaptation. This phase includes intensive studies on management applications. Management 3.0 emerges with digitalization, emphasizing agility as a core principle. While flexibility and speed are crucial in this period, sustainability has become an essential factor.

In the Management 4.0 paradigm, a new dimension emerges in the field of organization and management. Thanks to network structures, the scientific and technological paradigms are converging, leading to a state of interconnectedness. While network structures continue to play a crucial role in organizational processes, flat hierarchies and self-organizing structures gain prominence. In the execution phase, not only humans but also data, machines, and devices are actively involved. Data from machines, insights generated by algorithms, and outputs from artificial intelligence applications are reshaping management processes. In this era, managers no longer act as supervisors and controllers but rather as consultants and career coaches. The most significant development in the Management 4.0 framework is the transformative power of human–machine collaboration. This partnership fosters collective intelligence, which enhances synergy and contributes to management through autonomous systems. The integration of humans and machines strengthens collaboration and connectivity, making coordination—a fundamental management function—continuous and dynamic. It is evident that coordination is undergoing radical changes in this new management paradigm.

In light of the findings and discussions, the concept of "Management 4.0" has been explored in depth. As management evolves, changes in management functions are driven by environmental, cultural, and technological shifts. Industrial revolutions, in particular, have had a profound impact on groundbreaking developments in the field of management. For instance, the First Industrial Revolution brought significant transformations to management styles, organizational power resources, and organizational structures.

This research explores whether a paradigm shift has occurred in management functions. Based on the findings, it can be concluded that the study makes a significant contribution to the field, as no similar studies have been identified in the existing literature. Furthermore, the analysis of the changes brought about by Industry 4.0 technologies in management, framed within the concept of "Management 4.0 Foresight", introduces a novel perspective to the literature. Currently, no scale for "Management 4.0 Foresight" exists in Turkey. This research addresses this gap by conducting a scale development study during the quantitative phase, thus contributing to the field of application.

The concept of "Management 4.0 Foresight" is discussed in relation to the findings obtained from both quantitative and qualitative research methods conducted with business managers in Turkey. As a result of these findings, a new capability emerges with the human–machine partnership, leading to the realization of smart organizational struc-

tures. As management processes become more interconnected, an ecosystem approach becomes predominant.

However, a contradiction exists between the findings in the literature and the coding outcomes from this study. While the literature suggests that long-term planning will be insufficient due to the sudden and radical changes brought about by Industry 4.0 technologies, managers emphasize the need for long-term planning. In contrast, ISO 1000 business managers in Turkey continue to stress the ongoing importance of long-term planning, viewing it as essential despite the shifting dynamics.

Furthermore, concepts that align with "Management 4.0 Foresight," such as moving away from bureaucratic approaches, adopting flat hierarchical structures, supporting self-organizing structures, and moving away from traditional management models, are not yet widely implemented in Turkish enterprises. Therefore, when examining the progression of management paradigms, it is evident that Turkey is situated between Management 2.0 and Management 3.0.

Limitations and Suggestions for Future Studies

The research sample was selected from ISO 1000 companies, which are believed to be capable of utilizing Industry 4.0 technologies. The study is limited to Turkey, which defines its scope. Furthermore, the limited use of Industry 4.0 technologies in Turkey is another limitation of the study. Additionally, there is no existing scale for predicting Management 4.0, and applying such a scale across different sectors and countries may yield varying results, which is also a limitation.

Since Industry 4.0 technologies are not yet widely used in Turkey, they do not fully align with some of the characteristics of the Management 4.0 vision. It is recommended to apply the scale in different countries worldwide, both to expand its usage and to obtain diverse results. One of the research findings indicates that the organizational structure influences the growth of platforms. For future studies, it may be beneficial to modify the organizational structure in Turkey and compare it with data from other countries. Additionally, predictions regarding Management 4.0 could be explored in other performance types, allowing for a cross-country comparative analysis.

Author Contributions: Conceptualization, A.Y.G. and M.A.A.; Methodology, A.Y.G. and M.A.A.; Software, A.Y.G.; Validation, A.Y.G. and M.A.A.; Formal Analysis, A.Y.G.; Investigation, A.Y.G.; Resources, A.Y.G.; Data Curation, A.Y.G.; Writing—Original Draft Preparation, A.Y.G.; Writing—Review and Editing, M.A.A.; Visualization, A.Y.G.; Supervision, M.A.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are available within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Management 4.0 Foresight Scale.

Questions	Reference	Code
Environmental Changes Determine the Rate of Environmental Change		
Economic, social, technological, and cultural changes are occurring very rapidly.	[78]	SEC1
It is more important than anything else to follow changes in the business environment.	[31]	SEC2
The markets in the business world are constantly renewing.	[71]	SEC3
Changes in the business environment occur at short intervals.	[12]	SEC4
Competition in the business environment is high and fierce.	[43]	SEC5
Understanding the Ambiguities of the Environment		
Economic, social, technological, and cultural changes cause the business environment to be uncertain.	[84]	UE1
Changes in technological, social, political, and commercial forces cause paradigm shifts in the environment.	[4]	UE2
Developments after industrial revolutions have caused the business environment to be uncertain.	[10]	UE3
Changes in the environment require a new management understanding.	[82]	UE4
Interconnectedness of Environmental Actors		
Social, political, and economic actors in the business become interconnected.	[90]	IPA1
The business continues its activities within the ecosystem.	[91]	IPA2
The actors in the business care about being together and connected.	[153]	IPA3
Systems and connections emerge as a result of technological and digital developments.	[22]	IPA4
Cultural Change		
Cultural Situation: Toward a Continuous Learning and Creative Environment		
Following changing environmental factors, the business determines appropriate cultural environments.	[154]	CC_CLC1
After the changing environmental factors, the business seeks to keep up with these changes and search for new capabilities.	[155]	CC_CLC2
The business is open to continuous learning and development.	[117]	CC_CLC3
Continuous learning environments allow businesses to create a new working culture.	[156]	CC_CLC4
Business cares about the emergence of new ideas.	[117]	CC_CLC5
It is important to be creative in cultural environments after technological development.	[40]	CC_CLC6
Advances in the business environment contribute to research and development activities.	[40]	CC_CLC7
The business expects its employees to be open to cooperation and to have empathy.	[157]	CC_CLC8
Cultural Situation: Ensuring Employee Participation in Decisions and Providing Innovation to Employees		
With a changing environment, the organization seeks employees to participate in decisions in the work culture.	[25]	CC_EEP1
After cultural change, the expectations of the organization from the employees change.	[154]	CC_EEP2
The business wants employees to acquire knowledge and share this knowledge with the business.	[158]	CC_EEP3
The business expects its employees to develop soft skills (such as empathy, integrated thinking).	[156]	CC_EEP4
After cultural change, the organization expects employees to be able to manage uncertainty.	[10]	CC_EEP5
After cultural change, the organization expects employees to assume different roles and skills.	[159]	CC_EEP6

Table A1. *Cont.*

Questions	Reference	Code
After cultural change, employees tend to develop cognitive skills.	[159]	CC_EEP7
Employees of an organization can discover innovations more easily through the technology they use.	[45]	CC_EEP8
The organization wants its employees to be good algorithm readers.	[45]	CC_EEP9
Technological Changes		
Technological developments: Abundance of Information and Access to Real Data		
The amount of information will increase following technological developments.	[115]	TD_UAI1
Accessibility of information will become easier after technological developments.	[115]	TD_UAI2
Digitization of information will be beneficial after technological developments.	[112]	TD_UAI3
After technological developments, more accurate information about the business environment will be collected.	[40]	TD_UAI4
As a result of technological developments, businesses can easily access real data.	[40]	TD_UAI5
Accurate information obtained after technological advances will enable smart audits.	[40]	TD_UAI6
Technological advancements change the nature of work as they provide access to real-world data.	[160]	TD_UAI7
The ease of access to real data changes how employees work.	[160]	TD_UAI8
Technological Developments: Human–Machine Partnership and Innovation		
As a result of technological developments, human–machine cooperation emerges.	[161]	TD_PHM1
As a result of technological developments, human–machine cooperation strengthens the collective mind.	[10]	TD_PHM2
As a result of technological developments, humans and machines can perform joint analyses.	[10]	TD_PHM3
As a result of technological developments, human–machine partnership plays a role in decision making.	[162]	TD_PHM4
As a result of technological developments, the management processes of the enterprise are automated.	[47]	TD_PHM5
Technological developments provide benefits to businesses by providing environmental feedback.	[93]	TD_PHM6
Technological advancements radically change the way things are done and the way they do business.	[163]	TD_PHM7
Technologies give businesses important capabilities by providing appropriate human resources and machine partnerships.	[162]	TD_PHM8
Measuring Management Functions		
Good planning means being able to make good decisions.	[25]	MF1
Businesses plan to make future predictions.	[82]	MF2
Business plans to make rational decisions.	[85]	MF3
Business decisions are made based on intuition.	[31]	MF4
There is a formal structure in which authorities and responsibilities are predetermined.	[164]	MF5
There is a mechanism to ensure coordination between departments and employees.	[164]	MF6
There is an understanding of decentralized management instead of centralized management.	[164]	MF7
The division of labor and specialization are important in an enterprise.	[164]	MF8
The enterprise is governed by certain rules and regulations, and coordination is ensured in line with these rules.	[164]	MF9
Managers delegate authority to their employees and empower them.	[76]	MF10
Having employees with different organizational and operational skills forms important collaborations.	[164]	MF11
In business management, managers gather all the relevant authorities together.	[164]	MF12
A business interacts with its environment and organizes itself according to this environment.	[12]	MF13
The technology used in the enterprise controls employee motivation and performance.	[165]	MF14
The enterprise conducts self-organization and control activities without the need for a control mechanism.	[115]	MF15
The control function maintains businesses under constant supervision.	[49]	MF16

Table A1. *Cont.*

Questions	Reference	Code
Toward Industry 4.0 Technologies		
Artificial intelligence is changing the functioning of the management function of businesses.	[155]	END1
The Internet of Things is changing the functioning of the management function of businesses.	[124]	END2
Augmented Reality is changing the functioning of enterprises' management functions.	[125]	END3
Three-dimensional printers are changing the functioning of enterprises' management functions.	[110]	END4
Cyber–physical systems are changing the functioning of enterprise management functions.	[109]	END5
Big data are changing the functioning of enterprises' management functions.	[111]	END6
Cloud computing is changing the functioning of enterprise management functions.	[10]	END7
Simulation changes the functioning of enterprises' management functions.	[83]	END8
Horizontal–vertical integration changes the functioning of enterprises' management functions.	[52]	END9
Cybersecurity is changing the functioning of enterprise management functions.	[49]	END10

Appendix B

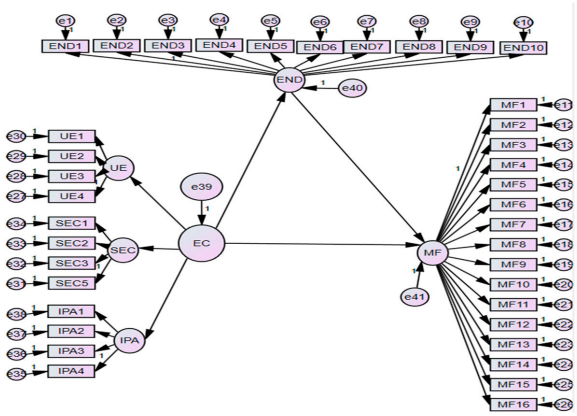


Figure A1. Mediating effect of Industry 4.0 technologies on environmental changes and management functions (Model 1).

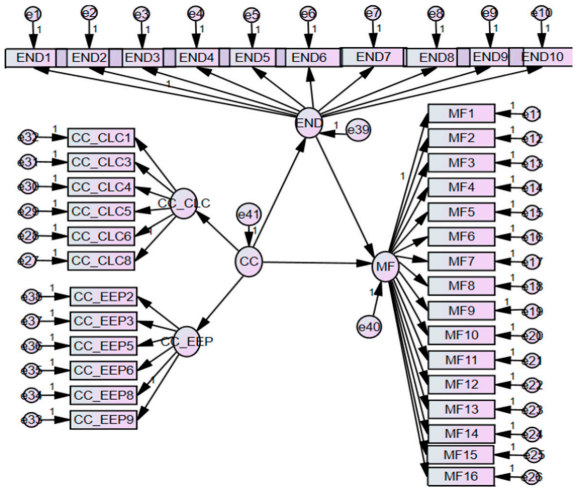


Figure A2. Mediating effect of Industry 4.0 technologies on cultural changes and management functions (Model 2).

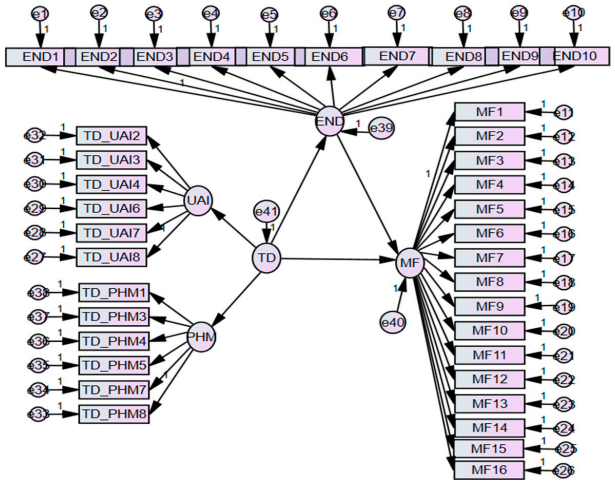


Figure A3. Mediating effect of Industry 4.0 technologies on technological changes and management functions (Model 3).

Appendix C

Table A2. Interview questions.

Questions
1. How do you think the phenomenon of technological development, which includes action in the global context, expresses a change in management understanding? Can you address these changes? 2. Do you think that environmental and cultural changes that occur in ongoing life change the context of management understanding? Can you evaluate this change in 3. Can you evaluate the positive and negative effects of cultural, environmental, and technological changes on management understanding through your own examples?
4. Considering technological and environmental changes, how would you evaluate your communication with competitors? 5. When you think about your business and management approach, do you have a company policy that supports and implements new ideas? If so, can you talk to me about this understanding? 6. When you consider the changing cultural and technological conditions, do your expectations from your employees cause the role distribution to change in parallel with this change? Can you provide information about your expectations from your employees? 7. Considering the changes experienced, do you think that they cause a difference in planning and coordination functions? Can you provide information for both cases? (Yes/No) 8. When you think about your executive function in your business, which traditional or modern management approaches do you think you have adopted? Can you briefly talk about this approach? 9. Can you provide detailed information about how the Industry 4.0 phenomenon has affected your management approach.

Appendix D

Table A3. Themes, codes, and sources.

Themes	Code	References
Cultural/Environmental/Technological Changes	Adaptation to the New Order	[27]
	Technology and Culture Adaptation	[156]
	The New Cultural Environment	[26]
	Continuous Learning	[154]
	Top Management Acceptance of Change	[117]
	Trust-Tolerance Environment	[82]

Table A3. *Cont.*

Themes	Code	References
	Tracking Change	[19]
	Compliance with the Company Plan	[166]
	Recruitment for the New Culture	[167]
	Easy Communication	
Planning Function	Being Planned/Coordinated	[27]
	Systematic Decision Making	[14]
	Staff Expressing Opinions	[22]
	Participation in Decisions	[88]
	Long-Term Planning	[15]
	Working Efficiently	[25]
Organizing Function	The Rise of Platforms,	[107]
	Emergence of New Working Models	[23]
	Working with Machines	[125]
	Less Manpower	[124]
	Reduction in the Number of Personnel and Flexible Structures	[42]
	Moving Away from Rigid Bureaucracy	[119]
Coordination Function	Flexibility/Transparency	[36]
	Cooperation with Competitors	[79]
	Moving Faster	[109]
	Team Collaboration	[52]
	Faster Communication	[110]
	Interconnectedness of All Departments	[90]
Executive Function	Modern Management	[76]
	Digital Governance	[42]
	Lack of a Classical Management Approach to Teamwork	[26]
	Bringing Innovation	[14]
	Delegation of Authority	[111]
	Holistic Management Approach	[82]
	Departure from Traditional Management Models	[168]
	Everyone Gets a Chance to Become a Manager	[153]
Control Function	Check More Often	[27]
	Faster Records Accuracy	[128]
	More Frequent Reporting	[111]
Expectations of Employees as a Function of Changes	Employee Participation in Decisions	[156]
	Continuous Improvement	[157]
	Work Engagement	[117]
	Continuous Learning Environment for Employees	[40]
	Agile Management	[116]

Appendix E

Table A4. Explanatory factor analysis results for the environmental change dimension.

	Factors			
	Uncertainty of the Environment	**Rate of Change in the Environment**	**Environmental Actors Connected**	**Total Item Correlation**
SEC1		0.719		0.463
SEC2		0.750		0.406

Table A4. *Cont.*

	Factors			
	Uncertainty of the Environment	**Rate of Change in the Environment**	**Environmental Actors Connected**	**Total Item Correlation**
SEC3		0.664		0.416
SEC5		0.498		0.476
UE1	0.711			0.632
UE2	0.595			0.565
UE3	0.771			0.538
UE4	0.705			0.542
IPABB1			0.619	0.589
IPABB2			0.744	0.422
IPABB3			0.561	0.489
IPABB4			0.721	0.544

Table A5. Explanatory factor analysis results for the cultural change dimension.

	Factors		
	Continuous Learning and Creative Environment	**Employee Participation in Decisions and Building Competencies**	**Total Item Correlation**
CC_CLC1	0.590		0.631
CC_CLC3	0.578		0.464
CC_CLC4	0.728		0.483
CC_CLC5	0.746		0.542
CC_CLC6	0.577		0.461
CC_CLC8	0.604		0.490
CC_EEP2		0.685	0.463
CC_EEP3		0.632	0.481
CC_EEP5		0.510	0.542
CC_EEP6		0.727	0.489
CC_EEP8		0.526	0.553
CC_EEP9		0.697	0.574

Table A6. Explanatory factor analysis results for the dimensions of technological development.

	Factors		
	Abundance of Information and Real Data	**Man–Machine Partnership and Innovation**	**Total Item Correlation**
TD_UAI2	0.585		0.430
TD_UAI3	0.667		0.438
TD_UAI4	0.672		0.567
TD_UAI 6	0.631		0.466
TD_UAI7	0.606		0.503
TD_UAI8	0.589		0.581
TD_PHM1		0.567	0.551
TD_PHM3		0.508	0.495
TD_PHM4		0.641	0.535
TD_PHM5		0.779	0.518
TD_PHM7		0.633	0.413
TD_PHM8		0.596	0.513

Table A7. Explanatory factor analysis results for the management functions dimension.

	Factors	
	Management Function Factor Distribution	**Total Item Correlation**
MF1	0.569	0.519
MF2	0.602	0.524
MF3	0.578	0.513
MF4	0.551	0.495
MF5	0.622	0.544
MF6	0.553	0.466
MF7	0.582	0.516
MF8	0.620	0.525
MF9	0.579	0.503
MF10	0.633	0.562
MF11	0.642	0.556
MF12	0.548	0.481
MF13	0.698	0.641
MF14	0.575	0.492
MF15	0.641	0.564
MF16	0.713	0.641

Table A8. Explanatory factor analysis results for the Industry 4.0 technologies dimension.

	Factors	
	Industry 4.0 Technology Factor Distribution	**Total Item Correlation**
END1	0.682	0.580
END2	0.641	0.539
END3	0.643	0.540
END4	0.621	0.518
END5	0.621	0.518
END6	0.664	0.558
END7	0.604	0.502
END8	0.638	0.532
END9	0.687	0.586
END10	0.714	0.614

Appendix F

Table A9. Qualitative analysis participant information.

Participant No.	Sector	Position	Education Status
P1	Fast Consumption	Human Resources Manager	Bachelor's Degree
P2	Textile	Planning Manager	Bachelor's Degree
P3	Chemistry	Marketing Manager	Graduate Degree
P4	Textile	Public Relations Manager	Bachelor's Degree
P5	Textile	Business Manager	Graduate Degree
P6	Paper and Forest Products	Customer Team Manager	Graduate Degree
P7	Oil	Planning Manager	Bachelor's Degree
P8	Aviation	Technology Manager	Graduate Degree
P9	Food	Human Resources Manager	Graduate Degree
P10	Automotive	Business Manager	Graduate Degree

References

1. Toffler, A. *Future Shock*; Random House: New York, NY, USA, 1996.
2. Grove, A.S. *Only Paranoids Survive. How Can We Overcome the Moments of Crisis That All Companies and Managers Will Experience?* 1st ed.; Dinçkal, Ö.; Lekesizalın, F., Translators; Sistem Publishing: Istanbul, Turkey, 1997.
3. Fişek, K. *Yönetim (Management)*; Kilit Publications: Ankara, Turkey, 2012.
4. Sung, T.K. Industry 4.0: A Korea perspective. *Technol. Forecast. Soc. Change* **2018**, *132*, 40–45. [CrossRef]
5. Falegnami, A.; Tomassi, A.; Gunella, C.; Amalfitano, S.; Corbelli, G.; Armonaite, K.; Fornaro, C.; Giorgi, L.; Pol-lini, A.; Caforio, A.; et al. Defining conceptual artefacts to manage and design simplicities in com-plex adaptive systems. *Heliyon* **2024**, *10*, 24. [CrossRef] [PubMed]
6. Yeke, S. *Mental and Cultural Transformation in Businesses, New Name of Transformation with Business Functions: Industry 4.0*; Zafer Aykanat, Z., Ed.; Gazi Bookstore: Ankara, Turkey, 2021; pp. 39–54.
7. Alvesson, M.; Sveningsson, S. *Changing Organizational Culture: Cultural Change Work in Progress*; Routledge: Oxfordshire, UK, 2015.
8. Newman, D.; Blanchard, O. *Human/Machine: The Future of Our Partnership with Machines*; Kogan Page Publishers: London, UK, 2019.
9. Tsvetkov, V.; Shaytura, S.V.; Ordov, K.V. Digital management railway. In *International Scientific and Practical Conference on Digital Economy (ISCDE 2019)*; Atlantis Press: Dordrecht, The Netherlands, 2019.
10. Mulgan, G. *Big Mind: How Collective Intelligence Can Change Our World*; Princeton University Press: Princeton, NJ, USA, 2021.
11. Oswald, A.; Müller, W. *Management 4.0: Handbook for Agile Practices, Release 2.0*; BoD–Books on Demand: Norderstedt, Germany, 2018; Volume 2.
12. Bersin, J.; Mallon, D.; Barnett, L.; Hines, J. *Predictions for 2017 Everything Is Becoming Digital*; Research Report; Deloitte Consulting LLP: London, UK, 2016.
13. Hrinchenko, Y. Implications of the "Industry 4.0" concept on management practice. *J. Appl. Manag. Invest.* **2021**, *10*, 31–42.
14. Aghina, W.; De Smet, A.; Weerda, K. Agility: It rhymes with stability. *McKinsey Q.* **2015**, *51*, 2–9.
15. Rüßmann, M.; Lorenz, M.; Gerbert, P.; Waldner, M.; Justus, J.; Engel, P.; Harnisch, M. Industry 4.0: The future of productivity and growth in manufacturing industries. *Boston Consult. Group* **2015**, *9*, 54–89.
16. Deloıtte. The Evolution of Work. 2018. Available online: https://www2.deloitte.com/us/en/insights/focus/technology-and-the-future-of-work/evolution-of-work-seven-new-realities.html (accessed on 12 February 2025).
17. Ford, M. *The Rise of the Robots: Technology and the Threat of Mass Unemployment*; Duran, C., Translator; Kronik Bookstore: Istanbul, Turkey, 2019.
18. Moeuf, A.; Lamouri, S.; Pellerin, R.; Eburdy, R.; Tamayo, S. Industry 4.0 and the SME: A technology-focused review of the empirical literature. In Proceedings of the 7th International Conference on Industrial Engineering and Systems Management IESM, Saarbrücken, Germany, 11–13 October 2017.
19. Maskuriy, R.; Selamat, A.; Maresova, P.; Krejcar, O.; David, O.O. Industry 4.0 for the construction industry: Review of management perspective. *Economies* **2019**, *7*, 68. [CrossRef]
20. Davenport, T.H.; Redman, T.C. Digital transformation comes down to talent in 4 key areas. *Harv. Bus. Rev.* **2020**, *2*, 2–6.
21. Nagy, J.; Oláh, J.; Erdei, E.; Máté, D.; Popp, J. The Role and Impact of Industry 4.0 and the Internet of Things on the Business Strategy of the Value Chain—The Case of Hungary. *Sustainability* **2018**, *10*, 3491. [CrossRef]
22. Roblek, V.; Meško, M.; Krapež, A. *A Complex View of Industry 4.0*; Sage Open: Thousand Oaks, CA, USA, 2016.
23. De Smet, A.; Kleinman, S.; Weerda, K. The helix organization. *McKinsey Q.* **2019**, *4*, 1–10.
24. O'Shea, L. *Future Histories: What Ada Lovelace, Tom Paine, and the Paris Commune Can Teach Us About Digital Technology*; Verso Books: London, UK; New York, NY, USA, 2021.
25. Zheng, P.; Wang, H.; Sang, Z.; Zhong, R.Y.; Liu, Y.; Liu, C.; Mubarok, K.; Yu, S.; Xu, X. Smart manufacturing systems for Industry 4.0: Conceptual framework, scenarios, and future perspectives. *Front. Mech. Eng.* **2018**, *13*, 137–150. [CrossRef]
26. Rogers, D. *The Digital Transformation Roadmap: Rebuild Your Organization for Continuous Change*; Columbia University Press: New York, NY, USA, 2020.
27. Luca, M.; Kleinberg, J.; Mullainathan, S. Algorithms need managers, too. *Harv. Bus. Rev.* **2016**, *94*, 20.
28. Chernov, A.V.; Chernova, V.A.; Komarova, T.V. The usage of artificial intelligence in strategic decision making in terms of fourth industrial revolution. In Proceedings of the 1st International Conference on Emerging Trends and Challenges in the Management Theory and Practice (ETCMTP 2019), Moscow, Russia, 24–25 October 2019.
29. Lee, E.A. *The Creative Partnership Between Human and Technology Digital Spirit*; Uysal, A.; Uysal, G., Translators; Koç University Press: Istanbul, Turkey, 2019.
30. Sulich, A.; Zema, T. Role of the Management in the World Driven by the Industry 4.0. In *Education Excellence and Innovation Management: A 2025 Vision to Sustain Economic Development during Global Challenges, Proceedings of the International Business Information Management Association (IBIMA), Granada, Spain, 4–5 November 2020*; 2020.

31. Saucedo-Martínez, J.A.; Pérez-Lara, M.; Marmolejo-Saucedo, J.A.; Salais-Fierro, T.E.; Vasant, P. Industry 4.0 framework for management and operations: A review. *J. Ambient Intell. Humaniz. Comput.* **2018**, *9*, 789–801. [CrossRef]
32. Piccarozzi, M.; Aquilani, B.; Gatti, C. Industry 4.0 in management studies: A systematic literature review. *Sustainability* **2018**, *10*, 3821. [CrossRef]
33. Al-Okaily, M.; Younis, H.; Al-Okaily, A. The impact of management practices and industry 4.0 technologies on supply chain sustainability: A systematic review. *Heliyon* **2024**, *10*, e36421. [CrossRef]
34. Kotler, P.; Caslione, J.A. *Chaotics: The Business of Managing and Marketing in the Age of Turbulence*; Amacom's: Hertogenbosch, The Netherlands, 2009.
35. Westerman, G.; Bonnet, D.; McAfee, A. *Leading Digital: Turning Technology into Business Transformation*; Harvard Business Press: Cambridge, MA, USA, 2014.
36. Shamim, S.; Cang, S.; Yu, H.; Li, Y. Management approaches for Industry 4.0: A human resource management perspective. In Proceedings of the 2016 IEEE congress on evolutionary computation (CEC), Vancouver, BC, Canada, 24–29 July 2016.
37. Preuveneers, D.; Joosen, W.; Ilie-Zudor, E. Trustworthy data-driven networked production for customer-centric plants. *Ind. Manag. Data Syst.* **2017**, *117*, 2305–2324. [CrossRef]
38. Lu, Y. Industry 4.0: A survey on technologies, applications and open research issues. *J. Ind. Inf. Integr.* **2017**, *6*, 1–10. [CrossRef]
39. Lin, D.; Lee, C.; Lau, H.; Yang, Y. Strategic response to Industry 4.0: An empirical investigation on the Chinese automotive industry. *Ind. Manag. Data Syst.* **2018**, *118*, 589–605. [CrossRef]
40. Schwab, K. The Fourth Industrial Revolution, Crown Currency. 2017. Available online: https://www.weforum.org/about/the-fourth-industrial-revolution-by-klaus-schwab/ (accessed on 1 February 2025).
41. Sanders, A.; Elangeswaran, C.; Wulfsberg, J.P. Industry 4.0 implies lean manufacturing: Research activities in industry 4.0 function as enablers for lean manufacturing. *J. Ind. Eng. Manag.* **2016**, *9*, 811–833. [CrossRef]
42. Lee, I.; Lee, K. The Internet of Things (IoT): Applications, investments, and challenges for enterprises. *Bus. Horiz.* **2015**, *58*, 431–440. [CrossRef]
43. McAfee, A.; Brynjolfsson, E. *Machine, Platform, Crowd: Harnessing Our Digital Future*; WW Norton & Company: New York, NY, USA, 2018.
44. Nilsson, N.J. *Artificial Intelligence Past and Future*; Doğan, M., Translator; Boğaziçi University Publishing House: Istanbul, Turkey, 2018.
45. Porter, M.E.; Heppelmann, J.E. Why every organization needs an augmented reality strategy. *Harv. Bus. Rev.* **2017**, *85*, 2–18.
46. Machado, C.G.; Winroth, M.P.; Ribeiro da Silva, E.H.D. Sustainable manufacturing in Industry 4.0: An emerging research agenda. *Int. J. Prod. Res.* **2020**, *58*, 1462–1484. [CrossRef]
47. Frank, A.G.; Dalenogare, L.S.; Ayala, N.F. Industry 4.0 technologies: Implementation patterns in manufacturing companies. *Int. J. Prod. Econ.* **2019**, *210*, 15–26. [CrossRef]
48. Elbestawi, M.; Centea, D.; Singh, I.; Wanyama, T. SEPT learning factory for industry 4.0 education and applied research. *Procedia Manuf.* **2018**, *23*, 249–254. [CrossRef]
49. Cheng, J.Y.J.; Groysberg, B. *Why Boards of Directors Are Not Interested in Cyber Threats*; Digital Transformation-Cyber Security, Optimist Publishing: Istanbul, Turkey, 2017.
50. Dobrowolska, M.; Knop, L. Fit to Work in the Business Models of the Industry 4.0 Age. *Sustainability* **2020**, *12*, 4854. [CrossRef]
51. Mohelska, H.; Sokolova, M. Management approaches for Industry 4.0–the organizational culture perspective. *Technol. Econ. Dev. Econ.* **2018**, *24*, 2225–2240. [CrossRef]
52. Crnjac, M.; Veža, I.; Banduka, N. From concept to the introduction of industry 4.0. *Int. J. Ind. Eng. Manag.* **2017**, *8*, 21. [CrossRef]
53. Fu, H.; Manogaran, G.; Wu, K.; Cao, M.; Jiang, S.; Yang, A. Intelligent decision-making of online shopping behavior based on internet of things. *Int. J. Inf. Manag.* **2020**, *50*, 515–525. [CrossRef]
54. Reischauer, G. Industry 4.0 as policy-driven discourse to institutionalize innovation systems in manufacturing. *Technol. Forecast. Soc. Change* **2018**, *132*, 26–33. [CrossRef]
55. Kuhn, T.S. *The Structure of Scientific Revolutions*; Kuyaş, N., Translator; Kırmızı Yayınları: Istanbul, Turkey, 2017.
56. Wren, D.A.; Bedeian, A.G. *The Evolution of Management Thought*; John Wiley & Sons: Hoboken, NJ, USA, 2023.
57. Taylor, F.W. *Principles of Scientific Management*, 7th ed.; Adres Yayınları: Ankara, Turkey, 2014.
58. Baransel, A. *Çağdaş Yönetim Düşüncesinin Evrimi: Klasik ve Neo-Klasik Yönetim ve Örgüt Teorileri (The Evolution of Contemporary Management Thought: Classical and Neoclassical Management and Organization Theories)*; Istanbul Üniversity: Istanbul, Turkey, 1993.
59. Lewis, P.S.; Goodman, S.H.; Fandt, P.M.; Campbell, C.R. *Instructor's Manual to Accompany Management: Challenges in the 21st Century*; West Publishing Company: Eagan, MN, USA, 1995.
60. Boulding, K.E. General systems theory—The skeleton of science. *Manag. Sci.* **1956**, *2*, 197–208. [CrossRef]
61. Fayol, H. *Genel ve Endüstriyel Yönetim (Administration Industrielle et Generale)*; Çolakoğlu, A., Translator; Adres Publications: Ankara, Turkey, 2013.
62. Mouzelis, N.P. *Organization and Bureaucracy*; Akın, H.B., Translator; Çizgi Bookstore: Konya, Turkey, 2001.

63. Schieve, W.C.; Allen, P.M. *Self-Organization and Dissipative Structures: Applications in the Physical and Social Sciences*; University of Texas Press: Austin, TX, USA, 1982.
64. Koontz, H. The Management Theory Jungle Revisited. *Acad. Manag. Rev.* **1980**, *5*, 175. [CrossRef]
65. Harford, T. *Fifty Inventions Shaping the Modern Economy*; Zararsız, T., Translator; Pegasus Publications: Istanbul, Turkey, 2019.
66. Hammer, M.; Champyr, J. Business process reengineering. *Nicholas Brealey* **1993**, *444*, 730–755.
67. Werner, M. The great paradox: Responsibility without empowerment. *Bus. Horiz.* **1992**, *35*, 55–58. [CrossRef]
68. Thomas, K.W.; Velthouse, B.A. Cognitive Elements of Empowerment: An "Interpretive" Model of Intrinsic Task Motivation. *Acad. Manag. Rev.* **1990**, *15*, 666.
69. Rigby, D.K.; Sutherland, J.; Takeuchi, H. The secret history of agile innovation. *Harvard Business Review*, 20 April 2016.
70. Bernstein, A.; Gulati, R. Agile Solutions. *Harvard Business Review*, 2021.
71. Nonaka, I. The knowledge-creating company. *Harvard Business Review*, 2007.
72. Kilmann, R.H. *Quantum Organizations*; Davies-Black: New York, NY, USA, 2001.
73. Sendjaya, S.; Cooper, B. Servant Leadership Behaviour Scale: A hierarchical model and test of construct validity. *Eur. J. Work. Organ. Psychol.* **2011**, *20*, 416–436. [CrossRef]
74. Leavy, B. Effective leadership today–character not just competence. *Strategy Leadersh.* **2016**, *44*, 20–29. [CrossRef]
75. Sousa, M.J.; Rocha, Á. Strategic Knowledge Management in the Digital Age. *J. Bus. Res.* **2019**, *94*, 223–226. [CrossRef]
76. Brynjolfsson, E.; McAfee, A. *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*; WW Norton & Company: New York, NY, USA, 2014.
77. Drucker, P. *Management Challenges for the 21st Century*; Routledge: Oxfordshire, UK, 2012.
78. Sheik, I.; Singh, P.K. Industry 4.0: Managerial roles and challenges. *Int. J. Innov. Eng. Res. Technol.* **2020**, 378–381.
79. Almada-Lobo, F. The Industry 4.0 revolution and the future of Manufacturing Execution Systems (MES). *J. Innov. Manag.* **2015**, *3*, 16–21. [CrossRef]
80. Li, G.; Hou, Y.; Wu, A. Fourth Industrial Revolution: Technological drivers, impacts and coping methods. *Chin. Geogr. Sci.* **2017**, *27*, 626–637. [CrossRef]
81. Rahwan, I.; Cebrian, M.; Obradovich, N.; Bongard, J.; Bonnefon, J.F.; Breazeal, C.; Crandall, J.W.; Christakis, N.A.; Couzin, I.D.; Jackson, M.O.; et al. Machine behavior. *Nature* **2019**, *568*, 477–486. [CrossRef]
82. Davenport, T. *Big Data at Work: Dispelling the Myths, Uncovering the Opportunities*; Harvard Business Review Press: Cambridge, CA, USA, 2014.
83. Gaspar, M.; Julião, J. Impacts of Industry 4.0 on Operations Management: Challenges for Operations Strategy. In Proceedings of the 7th International Conference on Industrial Engineering and Applications, Bangkok, Thailand, 16–18 April 2020.
84. Alcácer, V.; Cruz-Machado, V. Scanning the industry 4.0: A literature review on technologies for manufacturing systems. *Eng. Sci. Technol. Int. J.* **2019**, *22*, 899–919. [CrossRef]
85. Lindebaum, D.; Vesa, M.; Hond, F.D. Insights from "The Machine Stops" to Better Understand Rational Assumptions in Algorithmic Decision Making and Its Implications for Organizations. *Acad. Manag. Rev.* **2020**, *45*, 247–263. [CrossRef]
86. Castells, M. *The Rise of the Network Society*; Ebru Kılıç, E., Translator; Istanbul Bilgi University Publications: Istanbul, Turkey, 2005.
87. Alpaslan, S.; Kutanis, R. Comparison of Industrial and Information Society Management Metaphors. *Akad. İncelemeler Derg.* **2007**, *2*, 49–71.
88. Davutoğlu, N.A. Industry 4.0 and The Management Paradox. *Manag. Political Sci. Rev.* **2021**, *3*, 53–67.
89. Güleryüz, Ö. *Industry 4.0 and Changing Managerial Roles*; Dokuz Eylul University: İzmir, Turkey, 2021.
90. Barabasi, A.L. *Bağlantılar, İş Hayatında ve Günlük Yaşamda*; Elhuseyni, N., Translator; Optimist Yayıncılık: Istanbul, Turkey, 2010.
91. Morçöl, G.; Wachhaus, A. Network and complexity theories: A comparison and prospects for a synthesis. *Adm. Theory Prax.* **2009**, *31*, 44–58. [CrossRef]
92. Davies, R.; Coole, T.; Smith, A. Review of socio-technical considerations to ensure successful implementation of Industry 4.0. *Procedia Manuf.* **2017**, *11*, 1288–1295. [CrossRef]
93. Sony, M.; Naik, S. Industry 4.0 integration with socio-technical systems theory: A systematic review and proposed theoretical model. *Technol. Soc.* **2020**, *61*, 101248. [CrossRef]
94. Poonpakdee, P.; Koiwanit, J.; Yuangyai, C. Decentralized network building change in large manufacturing companies towards Industry 4.0. *Procedia Comput. Sci.* **2017**, *110*, 46–53. [CrossRef]
95. Fountaine, T.; McCarthy, B.; Saleh, T. Building the AI-powered organization. *Harv. Bus. Rev.* **2019**, *97*, 62–73.
96. Goncharuk, A.G. Wine value chains: Challenges and prospects. *J. Appl. Manag. Invest.* **2017**, *6*, 11–27.
97. Ahuja, G.; Soda, G.; Zaheer, A. The Genesis and Dynamics of Organizational Networks. *Organ. Sci.* **2012**, *23*, 434–448. [CrossRef]
98. Pradeep, A.K.; Appel, A.; Sthanunathan, S. *AI for Marketing and Product Innovation: Powerful New Tools for Predicting Trends, Connecting with Customers, and Closing Sales*; John Wiley & Sons: Hoboken, NJ, USA, 2018.
99. Bertoncel, T.; Erenda, I.; Meško, M. Managerial early warning system as best practice for project selection at a smart factory. *Amfiteatru Econ.* **2018**, *20*, 805–819. [CrossRef]

100. Lodgaard, E.; Dransfeld, S. Organizational aspects for successful integration of human-machine interaction in the industry 4.0 era. *Procedia Cirp* **2020**, *88*, 218–222. [CrossRef]
101. Schuh, G.; Anderl, R.; Gausemeier, J.; Ten Hompel, M.; Wahlster, W. Industrie 4.0 maturity index. *Manag. Digit. Transform. Co.* **2017**, *61*.
102. Ziaei Nafchi, M.; Mohelská, H. Organizational culture as an indication of readiness to implement industry 4.0. *Information* **2020**, *11*, 174. [CrossRef]
103. Whysall, Z.; Owtram, M.; Brittain, S. The new talent management challenges of Industry 4.0. *J. Manag. Dev.* **2019**, *38*, 118–129. [CrossRef]
104. Li, Y.; Dai, J.; Cui, L. The impact of digital technologies on economic and environmental performance in the context of industry 4.0: A moderated mediation model. *Int. J. Prod. Econ.* **2020**, *229*, 107777. [CrossRef]
105. Bakkalbaşı, İ.O. A Dıscussıon About the Emergence and First Representatives Of Management Science. *Marmara Univ. J. Econ. Adm. Sci.* **2017**, *39*, 431–452.
106. Parsons, T. *The Social System*; Turner, B., Ed.; Routledge: London, UK, 2013.
107. Jamali, D. Changing management paradigms: Implications for educational institutions. *J. Manag. Dev.* **2005**, *24*, 104–115. [CrossRef]
108. Deloıtte. Building Your Digital DNA Digital Transformation in Progress. Deloittle Digital, 2015. Available online: https://www.deloitte.com/be/en/services/consulting/research/building-your-digital-dna.html (accessed on 1 February 2025).
109. Hoffman, E.; Rüsch, M. Industry 4.0 and the current status as well as future prospects on logistics. *Comput. Ind.* **2017**, *89*, 23–34. [CrossRef]
110. Rifkin, J. *The Zero Marginal Cost Society: The Internet of Things, the Collaborative Commons, and the Eclipse of Capitalism*; Macmillan: New York, NY, USA, 2015.
111. Tiwari, K.; Khan, M.S. Sustainability accounting and reporting in the industry 4.0. *J. Clean. Prod.* **2020**, *258*, 120783. [CrossRef]
112. Mckinsey. *Big Data the Next Frontier for Innovatıon, Competition, and Creativity*; McKinsey Global Instıtute Company: New York, NY, USA, 2011.
113. Berber, A. *Klasik Yönetim Düşüncesi: Geleneksel ve Klasik Paradigmalarla Klasik ve Neo-Klasik Örgüt Teorileri (Classical Management Thought, Traditional and Classical Paradigms, and Classical and Neo-Classical Organization Theories)*; Alfa Publications: Istanbul, Turkey, 2013.
114. Özcan, K.; Barca, M. Evolutionary Dynamic of Administrative Thought: Environmental Determinism or, Ideational Advancement. *Amme İdaresi Derg.* **2010**, *43*, 1–31.
115. Pereira, A.; Romero, F. A review of the meanings and the implications of the Industry 4.0 concept. *Procedia Manuf.* **2017**, *13*, 1206–1214. [CrossRef]
116. Davenport, T.H.; Ronanki, R. Artificial intelligence for the real world. *Harv. Bus. Rev.* **2018**, *96*, 108–116.
117. Goodwin, T. *Dijital Darwinizm: İş Dünyasının Dijital Sonrası Çağa Uyum Kılavuzu*; Siyah Kitap Yayınevi: Istanbul, Turkey, 2019.
118. Wang, C.L.; Ahmed, P.K. The development and validation of the organisational innovativeness con-struct using confirmatory factor analysis. *Eur. J. Innov. Manag.* **2004**, *7*, 303–313. [CrossRef]
119. Ghobakhloo, M. The future of manufacturing industry: A strategic roadmap toward Industry 4.0. *J. Manuf. Technol. Manag.* **2018**, *29*, 910–936. [CrossRef]
120. Oberer, B.; Erkollar, A. Leadership 4.0: Digital leaders in the age of industry 4.0. *Int. J. Organ. Leadersh.* **2018**, *7*, 404–412. [CrossRef]
121. Kumar, S.; Bhatia, M.S. Environmental dynamism, industry 4.0 and performance: Mediating role of organizational and technological factors. *Ind. Mark. Manag.* **2021**, *95*, 54–64. [CrossRef]
122. Carnall, C.A. *Managing Change in Organizations*; Pearson Education: London, UK, 2007.
123. Ekebring, O.; Eriksson, M. *Managing a Transformation Toward Industry 4.0: A Study of the Bus Manufacturing Industry*; Karlstad University: Karlstad, Sweden, 2020.
124. Meissner, H.; Ilsen, R.; Aurich, J.C. Analysis of Control Architectures in the Context of Industry 4.0. *Procedia CIRP* **2017**, *62*, 165–169. [CrossRef]
125. Bongomin, O.; Ocen, G.G.; Nganyi, E.O.; Musinguzi, A.; Omara, T. Exponential Disruptive Technologies and the Required Skills of Industry 4.0. *J. Eng.* **2020**, *2020*, 4280156. [CrossRef]
126. Mohanta, B.; Nanda, P.; Patnaik, S. Management of VUCA (Volatility, Uncertainty, Complexity and Ambiguity) Using machine learning techniques in industry 4.0 paradigm. In *New Paradigm of Industry 4.0: Internet of Things, Big Data & Cyber Physical Systems*; Springer: Cham, Switzerland, 2020; pp. 1–24.
127. Atzori, L.; Iera, A.; Morabito, G. The internet of things: A survey. *Comput. Netw.* **2010**, *54*, 2787–2805. [CrossRef]
128. Kruse, W.; Hogrebe, F. *Industrie 4.0 "braucht, Verwaltung 4.0"*; Behörden Spiegel: Berlin, Germany, 2013.
129. Albers, A.; Gladysz, B.; Pinner, T.; Butenko, V.; Stürmlinger, T. Procedure for defining the system of ob-jectives in the initial phase of an industry 4.0 project focusing on intelligent quality control systems. *Procedia CIRP* **2016**, *52*, 262–267. [CrossRef]

130. Teddlie, C.; Tashakkori, A. Mixed methods research. In *The Sage Handbook of Qualitative Research*; Sage: Thousand Oaks, CA, USA, 2011; Volume 4, pp. 285–300.
131. Lincoln, Y.S.; Guba, E.G. *Naturalistic Inquiry*; Sage: Thousand Oaks, CA, USA, 1985.
132. Johnson, R.B.; Onwuegbuzie, A.J. Mixed Methods Research: A Research Paradigm Whose Time Has Come. *Educ. Res.* **2004**, *33*, 14–26. [CrossRef]
133. Creswell, J.W.; Clark, V.L.P. *Designing and Conducting Mixed Methods Research*; Sage Publications: Thousand Oaks, CA, USA, 2018.
134. Morse, J.M. Principles of mixed methods. In *Handbook of Mixed Methods in Social & Behavioral Research*; Sage Publication: Thousand Oaks, CA, USA, 2003; Volume 189.
135. Creswell, J.W.; Tashakkori, A. Developing publishable mixed methods manuscripts. *J. Mix. Methods Res.* **2007**, *1*, 107–111. [CrossRef]
136. Teddlie, C.; Yu, F. Mixed methods sampling: A typology with examples. *J. Mix. Methods Res.* **2007**, *1*, 77–100. [CrossRef]
137. Greene, J.C. Toward a methodology of mixed methods social inquiry. *Res. Sch.* **2006**, *13*, 93–98.
138. Plano Clark, V.L. Mixed methods research. *J. Posit. Psychol.* **2017**, *12*, 305–306. [CrossRef]
139. Büyüköztürk, Ş. *Sosyal Bilimlerde Analiz (Data Analysis for Social Sciences)*; Pegem Kitabevi: Ankara, Turkey, 2011.
140. Kuckartz, U.; Rädiker, S. Introduction: Analyzing qualitative data with software. In *Analyzing Qualitative Data with MAXQDA*; Springer: Berlin/Heidelberg, Germany, 2019; pp. 1–11.
141. Lawshe, C.H. A Quantitative Approach to Content Validity. *Pers. Psychol.* **1975**, *28*, 563–575. [CrossRef]
142. Ayre, C.; Scally, A.J. Critical values for Lawshe's content validity ratio: Revisiting the original methods of calculation. *Meas. Eval. Couns. Dev.* **2014**, *47*, 79–86. [CrossRef]
143. Hair, J.F.; Black, W.C.; Babin, B.J.; Anderson, R.E.; Tatham, R.L. *Multivariate Data Analysis, Essex: Pearson New International Edition, 7th ed*; Pearson Education Limited: London, UK, 2014.
144. Altunışık, R.; Coşkun, R.; Bayraktaroğlu, S.; Yıldırım, E. *Sosyal Bilimlerde Araştırma Yöntemleri: SPSS Uy-Gulamalı (Research Methods in Social Sciences: SPSS Applied)*; Sakarya yayıncılık: Sakarya, Turkey, 2007.
145. Tavşancıl, E. *Tutumların Ölçülmesi ve Spss ile Veri Analizi*; Nobel Yayınları: Ankara, Turkey, 2005.
146. Emerson, R.W. Regression and Effect Size. *J. Vis. Impair. Blind.* **2023**, *117*, 191–192. [CrossRef]
147. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed.; Routledge: New York, NY, USA, 1998.
148. Olejnik, S.; Algina, J. Measures of effect size for comparative studies: Applications, interpretations, and limitations. *Contemp. Educ. Psychol.* **2000**, *25*, 241–286. [CrossRef] [PubMed]
149. Baron, R.M.; Kenny, D.A. The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *J. Personal. Soc. Psychol.* **1986**, *51*, 6. [CrossRef] [PubMed]
150. Hayes, A.F.; Preacher, K.J. Quantifying and Testing Indirect Effects in Simple Mediation Models When the Constituent Paths Are Nonlinear. *Multivar. Behav. Res.* **2010**, *45*, 627–660. [CrossRef] [PubMed]
151. Miles, M.B.; Huberman, M.A. *Qualitative Data Analysis: An Expanded Sourcebook*, 2nd ed.; Sage: Thousand Oaks, CA, USA, 1994.
152. Makridakis, S. The forthcoming Artificial Intelligence (AI) revolution: Its impact on society and firms. *Futures* **2017**, *90*, 46–60. [CrossRef]
153. Ben-Daya, M.; Hassini, E.; Bahroun, Z. Internet of things and supply chain management: A literature review. *Int. J. Prod. Res.* **2019**, *57*, 4719–4742. [CrossRef]
154. Ermut, N.K. Yeni Çalışma Kültürünün Yeniden Düşünülecekler Listesi. *Harvard Business Review*, 2021.
155. Özdoğan, D. *Endüstri 4.0, Dördüncü Sanayi Devrimi ve Endüstriyel Dönüşümün Anahtarları*; Pusula 20 Yayıncılık: Istanbul, Turkey, 2018.
156. Aydın, A.D. Agility Panel. *Harvard Business Review*, 2020.
157. Brown, T. Design thinking. *Harvard Business Review*, 2008.
158. Tupa, J.; Simota, J.; Steiner, F. Aspects of Risk Management Implementation for Industry 4.0. *Procedia Manuf.* **2017**, *11*, 1223–1230. [CrossRef]
159. Chang, Y.H.; Yeh, Y.J.Y. Industry 4.0 and the need for talent: A multiple case study of Taiwan's companies. *Int. J. Prod. Dev.* **2018**, *22*, 314–332. [CrossRef]
160. Klingenberg, C.O.; Borges, M.A.V.; Antunes, J.A.V., Jr. Industry 4.0 as a data-driven paradigm: A systematic literature review on technologies. *J. Manuf. Technol. Manag.* **2021**, *32*, 570–592. [CrossRef]
161. Götz, M.; Jankowska, B. Clusters and Industry 4.0 do they fit together. *Eur. Plan. Stud.* **2017**, *25*, 1633–1653. [CrossRef]
162. PricewaterhouseCoopers. Yapay Zekâ Öngörüleri Raporu. 2018. Available online: www.pwc.com (accessed on 1 February 2025).
163. Wilson, H.J.; Daugherty, P.R. Collaborative intelligence: Humans and AI are joining forces. *Harv. Bus. Rev.* **2018**, *96*, 114–123.
164. Koçel, T. *İşletme Yöneticiliği*; Beta Kitabevi: Istanbul, Turkey, 2018.
165. Cummings, T.G. Self-Regulating Work Groups: A Socio-Technical Synthesis. *Acad. Manag. Rev.* **1978**, *3*, 625. [CrossRef]
166. Dalenogare, L.S.; Benitez, G.B.; Ayala, N.F.; Frank, A.G. The expected contribution of Industry 4.0 technologies for industrial performance. *Int. J. Prod. Econ.* **2018**, *204*, 383–394. [CrossRef]

167. Zanella, A. Internet of things for smart cities. *IEEE Internet Things J.* **2014**, *1*, 22–32. [CrossRef]
168. Bhardwaj, S.; Jain, L.; Jain, S. Cloud computing: A study of infrastructure as a service. *Int. J. Eng. Inf. Technol.* **2010**, *2*, 60–63.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.