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# Identification and prioritization of industry 4.0 maturity dimensions in the banking service digital supply chain

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**Abstract** The transformations resulting from the fourth industrial revolution and the expansion of digital technologies have reshaped the structure and traditional patterns of financial service delivery, paving the way for the development of digital banking and the emergence of the financial technology ecosystem. Under such conditions, the banking service supply chain has also undergone fundamental changes, and enhancing the maturity level of technologies related to Industry 4.0 has become a strategic necessity for increasing efficiency, innovation, and competitiveness in banks. However, the dimensions and factors affecting Industry 4.0 maturity in the banking service supply chain have rarely been identified and prioritized in an integrated manner. Therefore, the objective of this study is to identify and rank the dimensions and components of Industry 4.0 maturity in the banking service supply chain with an emphasis on digital banking and financial technologies. This research was conducted using a mixed-method approach. In the qualitative phase, using grounded theory and analyzing in-depth interviews with 14 experts in digital banking, financial technologies, and the banking service supply chain, the conceptual model of the study was extracted, consisting of six main dimensions and 50 components. In the quantitative phase, the relationships among the dimensions of the model were tested using structural equation modeling based on data collected from 168 valid questionnaires. Furthermore, in order to determine the relative importance and prioritize the dimensions and components, the Bayesian best–worst method (Bayesian BWM) was applied with the participation of 10 experts. The findings of the study indicate that among the six dimensions of the model, the causal conditions dimension has the highest importance, followed respectively by strategies, contextual conditions, intervening conditions, consequences, and the core phenomenon. At the component level, the digital ecosystem, technical infrastructure, assessment of the current status of the banking supply chain, legal infrastructure, and evaluation of information technology infrastructure maturity were identified as the most influential factors. The results suggest that the development of technological infrastructures, the strengthening of legal frameworks, and the formation of an integrated digital ecosystem play a decisive role in enhancing the maturity of Industry 4.0 technologies and improving the efficiency of the banking service supply chain. The findings of this research can serve as a basis for policymaking and decision-making by managers and planners in the banking system in the path toward the development of digital banking and technological transformation.

**Keywords:** Fourth Industrial Revolution, Digital Banking, Financial Technologies (FinTech), Banking Service Supply Chain, Bayesian Best–Worst Method (Bayesian BWM).

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## 1 Introduction

In recent decades, the rapid advancement of information and communication technologies and the emergence of advanced digital technologies have led to fundamental transformations in the structure of various industries. These transformations, known as the fourth industrial revolution (Industry 4.0), are characterized by technologies such as the internet of things (IoT), artificial intelligence (AI), big data, cloud computing, blockchain, and advanced data analytics, and they have transformed production methods, service delivery, and business models across many economic sectors [1]. Among different industries, the banking sector, as one of the main pillars of the financial system, has been influenced by these developments more than many other fields and has been compelled to reconsider its structures, processes, and service delivery methods. In such an environment, the use of digital technologies has become one of the key factors in improving efficiency, enhancing service quality, and strengthening the competitive advantage of banks [2]. One of the most important manifestations of this transformation is the emergence of the digital banking paradigm. Digital banking refers to the integrated use of advanced technologies to provide financial services on digital platforms, with the aim of delivering faster, smarter, more secure services that are aligned with customers' changing needs [3]. The development of digital banking has caused many traditional banking processes to be redesigned in digital and data-driven forms, and has enabled banks to interact with customers through smart and multiple channels. As a result, banks are compelled to pursue digital transformation strategies at different organizational levels and to utilize the capacities of new technologies to improve customer experience, increase organizational agility, and enhance operational efficiency [4]. Alongside the expansion of digital banking, the rapid development of financial technologies (FinTech) has also played a significant role in transforming the banking industry. By leveraging technological innovations, FinTech companies have been able to provide a wide range of financial services with greater speed, transparency, and efficiency, thereby reshaping patterns of competition in financial markets [5]. Many studies show that interaction and collaboration between banks and FinTech firms can lead to the development of innovation, increased efficiency of financial services, and improved customer experience [6]. Under such circumstances, the traditional structure of banking service delivery has gradually given way to a network of interactions among various actors in the financial ecosystem, in which banks, FinTech companies, information technology firms, technology infrastructure providers, payment companies, regulatory bodies, and other related institutions collaboratively participate in value creation for customers. Within this framework, financial service delivery can be analyzed in the form of the banking service supply chain. The banking service supply chain consists of the aforementioned set of activities, resources, and various actors that play a role in the process of designing, developing, delivering, and supporting financial services, and that, through interaction with one another, provide financial services [7]. Consequently, understanding developments in the banking industry and the path toward digital banking development requires attention to the interactions among the various components of this chain and examination of the factors affecting its technological capabilities. In this regard, the concept of Industry 4.0 maturity has attracted attention as one of the analytical frameworks for understanding the level of organizational readiness in the face of technological change. The dimensions associated with this concept can identify the key areas of digital transformation, technological capacities, and organizational capabilities required for leveraging new technologies. However, in many studies conducted so far, the primary focus has been on identifying components or examining digital transformation trends, while less attention has been paid to the relative importance of different dimensions in this field. A review of the research literature shows that a considerable number of studies in the field of digital banking and the fourth industrial revolution have addressed issues such as technology adoption, the introduction of FinTech innovations, and the examination of digital transformation trends in financial services [8]. Nevertheless, only limited research has examined which dimensions related to Industry 4.0 maturity are of greater importance within the framework of the banking service supply chain. This issue is important because banks face resource constraints on the path toward digital transformation and therefore need to concentrate their technological investments in areas that have the greatest impact on the development of digital services and the enhancement of their competitiveness. Under such conditions, the use of multi-criteria decision-making (MCDM) methods can help analyze the relative importance of different dimensions of digital transformation [9].

One of the novel methods in this field is the Bayesian best-worst method (Bayesian BWM), which, by reducing the number of pairwise comparisons and increasing the consistency of expert judgments, enables a more accurate determination of the weights and priorities of criteria [10]. The application of this method can lead to the identification of dimensions whose prioritization plays a more effective role in advancing digital transformation in the banking industry. The importance and necessity of this research can be considered from three perspectives. First, from a theoretical perspective, this study contributes to the development of the literature related to digital transformation and the Fourth Industrial Revolution in the field of financial services by focusing on the banking service supply chain, an area that has received less attention compared with manufacturing industries. Second, from a practical perspective, the findings of the study can help bank managers and financial organizations identify priority areas in the path toward digital banking development and direct their resources purposefully toward these areas. Third, from a managerial and policy perspective, the findings of this study can be useful for policymakers and supervisory bodies in the banking system in designing programs and strategies for technology development in the banking industry. Accordingly, the present study was conducted with the aim of identifying and explaining the dimensions of Industry 4.0 maturity in the banking service supply chain and its role in the development of digital banking and financial technologies. In this regard, the antecedents, core dimensions, and consequences related to Industry 4.0 maturity in the context of the banking service supply chain were first identified, and the relationships among them were examined. In the next step, the relative importance and priority of the identified dimensions were determined using the Bayesian Best-Worst Method, in order to provide a clear picture of the key factors influencing digital transformation in the banking industry. The innovation of this study lies in its systematic mixed-method approach and its reliance on a six-dimensional paradigmatic model to extract, validate, and prioritize the dimensions, relationships, and priorities influencing Industry 4.0 maturity. Such a comprehensive undertaking has been either overlooked or only partially addressed in similar extant literature. This study distinguishes itself from previous research in digital banking and FinTech in three primary ways: First, while many prior studies have predominantly focused on FinTech adoption, customer experience, digital innovation acceptance, or operational efficiency, the present research specifically examines Industry 4.0 maturity within the banking service supply chain. In doing so, it transcends the purely technological layer to encompass infrastructure, regulatory requirements, organizational actors, and the broader digital ecosystem. Second, this research employs a rigorous triangulation of Grounded Theory (GT), Partial Least Squares Structural Equation Modeling (PLS-SEM), and the Bayesian Best-Worst Method (Bayesian BWM). This methodological synergy facilitates a cohesive analytical trajectory from conceptual discovery to empirical validation and strategic prioritization a depth rarely achieved in studies that rely on a single qualitative or quantitative approach. Third, rather than merely describing the current state, this study provides actionable insights for regulators, bank executives, data analysts, product owners, and other stakeholders in the financial ecosystem. It offers pragmatic outputs for policymaking, strategic design, and managerial decision-making. Consequently, the core distinction of this study resides in the design and presentation of an integrated Industry 4.0 maturity model. By synthesizing theoretical, empirical, and managerial perspectives within a networked, multi-actor ecosystem of digital banking and FinTech, this research provides a comprehensive framework for understanding and navigating digital transformation.

## 2 Theoretical background and literature review

### 2.1 Fourth revolution industry

Technological transformations have always been one of the main forces shaping economic, social, and organizational structures [10]. The history of industrial transformations shows that technological advances are not limited to developing new tools for production and service delivery; rather, they fundamentally transform the patterns of organizing economic activities and the modes of interaction within societies. Some of these transformations, due to the breadth of their impact and their ability to alter the foundations of production systems and value creation, have been referred to as “industrial revolutions” [11]. The fourth industrial revolution, or Industry 4.0, as the most recent stage of industrial transformation, is founded on the extensive integration of advanced digital technologies with industrial and service processes. Unlike previous industrial revolutions that were mainly based on the emergence of new energy sources, the fourth industrial revolution is rooted in the expansion of digitalization and is built on the convergence of technologies such as the Internet of Things, big data, artificial intelligence, machine learning, cloud computing, and blockchain. By enabling intelligent connectivity among systems, advanced data analytics, and process automation, these technologies have brought about fundamental changes in modes of production and service delivery, creating the conditions for enhanced productivity, innovation, and organizational flexibility [12]. The research literature emphasizes that the implications of Industry 4.0 extend beyond the manufacturing sector and have also profoundly affected service industries especially financial services and banking. In these industries, data has become a strategic resource, and decision-making, customer interactions, and service design are increasingly becoming intelligent and personalized [13]. In recent years, many industries, including manufacturing, transportation, healthcare, and financial services, have moved toward the adoption of fourth industrial revolution technologies. Among them, the banking industry given its data-driven nature is one of the domains with the greatest potential for leveraging these technologies [14].

### 2.2 Digital banking

Digital banking refers to the integrated use of digital technologies to deliver financial services through smart and digital channels and platforms. The main goal of digital banking is to provide financial services that are faster, more accurate, and better tailored to customers’ needs [15]. In digital banking, many banking services are offered via online platforms, mobile applications, and intelligent systems, which significantly reduces the need for in-person visits to bank branches [16]. Research shows that digital banking can bring multiple benefits for banks and customers, including lower operational costs, higher service delivery speed, improved customer experience, and greater access to financial services. However, the successful implementation of digital banking requires the development of technological infrastructure, changes in organizational structures, and the enhancement of employees' skills [17]. Recent studies emphasize that digital banking, on the one hand, can strengthen financial inclusion, but on the other hand, if the digital divide, digital financial literacy, infrastructure, and regulation are not taken into account, it may lead to inequality in benefiting from services. For this reason, in the recent literature, future trends in digital banking have been linked to themes such as security, regulation, trust, and fairness in access [18].

## 2.3 Financial technologies

Financial technologies, or fintech, refer to the use of modern technologies to provide innovative financial services. Fintech companies, by leveraging digital technologies, offer services such as digital payments, digital asset management, online lending, and crowdfunding. Owing to their high flexibility and reliance on new technologies, these companies have been able to play an important role in transforming the financial industry. The expansion of fintechs has led banks, in order to maintain their competitiveness, to move toward cooperating with these companies. Such cooperation can lead to the development of innovation in financial services, improved operational efficiency, and increased customer satisfaction [19].

## 2.4 Bayesian best-worst method

The best–worst Method (BWM) is a modern multi-criteria decision-making (MCDM) technique introduced by Rezaei. In this method, decision-makers first identify the best and the worst criteria and then conduct pairwise comparisons between these criteria and the remaining ones. Compared with many other MCDM techniques, this method requires fewer comparisons while providing higher consistency in decision-makers' judgments. The Bayesian best–worst method (Bayesian BWM) is a probabilistic extension of the BWM in which the weights of criteria are estimated as probability distributions rather than fixed values. This allows uncertainty in human judgments to be incorporated into the model [20]. In recent years, the Bayesian best–worst method has been applied in various fields such as supply chain management, project management, technology assessment, and strategic decision-making, and it is recognized as an efficient method for determining the weights and priorities of decision criteria [21].

## 2.5 Literature review

In recent years, numerous studies have examined digital transformation in the banking industry, the role of financial technologies, and the application of fourth industrial revolution technologies in financial services. Some of these studies have focused on the dimensions of digital banking and bank–FinTech collaboration, while others have concentrated on evaluating digital maturity in organizations or applying multi-criteria decision-making methods to prioritize technological indicators. Gomber et al. [5], through a comprehensive review of FinTech literature, showed that financial technologies play a significant role in transforming the structure of financial services and creating new business models in the banking industry. Their findings indicated that interaction between banks and FinTech firms can foster innovation in financial services and improve customer experience. Salamatitaba et al. [15], by examining emerging trends in banking, showed that the development of digital technologies can fundamentally transform financial service delivery. Khosroanjom et al. [10] identified strategic indicators for implementing digital banking and demonstrated that developing IT infrastructure, innovating financial services, and improving customer experience are among the most important success factors in digital banking. Similarly, Thakor [19], in a study on the future of banking in the FinTech era, argues that digital technologies have substantially altered the competitive landscape of the banking sector, making it necessary for banks to invest in modern technologies to maintain their market position. Heidarzadeh-Aghdam et al. [8] designed a model for the formation of a FinTech-based banking services market in Iran, highlighting the role of collaboration between banks and FinTech companies in the development of modern financial services. Shah-Hosseini et al. [17] examined factors affecting collaboration between banks and FinTech companies and found that technological infrastructure development, regulatory support, and organizational culture are the most critical factors enabling such collaborations. In another study, Siddiqi and Rivera [18], through a systematic review of FinTech literature, examined the financial technology ecosystem and found that interactions among various factors such as banks, FinTech companies, and regulatory bodies play a crucial role in developing digital financial services. Additionally, Filgueiras et al. [4], by investigating the application of Fourth Industrial Revolution technologies in the banking industry, found that technologies such as artificial intelligence, the internet of things, and big data can significantly enhance the efficiency and sustainability of banking services. In another study, Bigdeli et al. [3], using a system dynamics approach, examined performance management in the banking service supply chain and demonstrated that coordination among different actors in the supply chain plays an important role in improving the efficiency of financial services. Yashodha et al. [21], in a study titled "The future of digital banking and financial inclusion in 2025," examined the role of digital banking in expanding access to financial services. Using an analytical–descriptive approach and literature review, the study explored dimensions such as digital banking, FinTech, and financial inclusion. Results showed that the development of digital platforms and mobile banking services can increase access to financial services by reducing geographical and cost-related barriers, thereby strengthening financial inclusion. However, factors such as the digital divide, cybersecurity, privacy, and users' digital literacy remain major challenges to the broad and sustainable adoption of digital banking. Kandpal et al. [9], in their study titled "Digital Finance and the Future of Banks and Financial Services," examined the consequences of expanding digital technologies and Industry 4.0 on the banking system and financial services. Their analytical and literature-based study indicates that digital transformation and the rise of data-driven technologies have made data a strategic resource in banking, leading to increasingly intelligent, data-driven, and personalized decision-making processes, customer interactions, and financial service design. The study further suggests that integrating digital technologies with financial services can enhance banks' efficiency, innovation, and competitiveness, playing a pivotal role in shaping the future of the banking industry.

Despite these studies, a review of the literature reveals that most research has examined topics such as digital banking, financial technologies, or digital transformation in the banking industry separately. Very few studies have comprehensively explored the dimensions of Industry 4.0 maturity within the banking service supply chain and its relationship with digital banking development. Moreover, in many studies, the dimensions of digital transformation have been analyzed conceptually or descriptively, while quantitative evaluation of the relative importance of these dimensions using multi-criteria decision-making methods has received less attention.

Accordingly, the present study aims to integrate concepts from the fourth industrial revolution, digital banking, financial technologies, and banking service supply chain management. Using the Bayesian best–worst method, it seeks to identify and prioritize the dimensions of Industry 4.0 maturity in the banking industry.

## 2.6 Research gap

A critical review of the extant literature reveals a significant disconnect between the rapid global advancements of Industry 4.0 and the theoretical frameworks governing digital banking. While existing studies have extensively explored digital banking, FinTech integration, and digital transformation, these endeavors have largely been conducted in isolation. Research in this domain has historically suffered from a "siloed" approach, focusing either on technology adoption or specific service outcomes, while failing to integrate these concepts into a cohesive framework within the context of the banking service supply chain. Furthermore, a substantial portion of the literature on Industry 4.0 maturity models has been predominantly derived from manufacturing industries, often lacking the contextual nuance required for financial ecosystems. This creates a critical theoretical gap: the absence of native, service-oriented frameworks that can accommodate the unique regulatory requirements, organizational structures, and multi-actor dynamics of the banking industry particularly in emerging markets. Methodologically, there is a lack of rigorous, quantitative approaches to prioritize the multidimensional factors influencing digital maturity. Most studies rely on descriptive analysis or qualitative trends, neglecting the application of advanced multi-criteria decision-making (MCDM) methods to identify the relative importance of digital drivers. Consequently, bank managers and policymakers face ambiguity regarding where to concentrate their resource-constrained investments to maximize competitiveness. This research addresses these critical gaps by synthesizing the fragmented literature into a comprehensive Industry 4.0 maturity framework specifically tailored for the banking service supply chain. Additionally, it bridges the gap between theoretical models and practical implementation by validating the developed framework within a real-world financial ecosystem, utilizing Bank Mellat as a representative empirical setting. Finally, by employing the Bayesian best-worst method (BWM), this study provides a precise, data-driven prioritization of digital maturity dimensions, successfully shifting the academic discourse from mere theoretical description to actionable, strategic insight.

## 3 Methods

The conceptual model of the present study was developed and validated through a sequential mixed-methods approach, structured across two primary stages: qualitative and quantitative.

The rationale for adopting this mixed-methods design is rooted in the logic of exploration, validation, and prioritization. Initially, the dimensions and components of Industry 4.0 maturity were extracted from field data using grounded theory (GT). Subsequently, the resulting conceptual model was empirically tested via partial least squares structural equation modeling (PLS-SEM) to evaluate the causal and structural relationships between constructs. Finally, Bayesian best-worst method (BWM) was employed to determine the relative weight and ranking of the identified dimensions, accounting for the inherent uncertainty in expert judgments and facilitating more precise managerial prioritization. This methodological sequence transitions the research from conceptual discovery to robust decision-making support. In the qualitative phase, the systematic grounded theory approach of Strauss and Corbin was utilized to identify the dimensions and components affecting Industry 4.0 maturity within the banking service supply chain (BSSC). A total of 14 experts were selected via non-probability purposive (judgmental) sampling, based on criteria such as executive experience in digital banking, proficiency in Industry 4.0 technologies, managerial tenure, or relevant research expertise. The inclusion of both academic and industry practitioners enhanced data richness and ensured the alignment of the extracted concepts with the practical realities of digital banking. Data collection through semi-structured interviews continued until theoretical saturation was achieved. Data analysis followed the three-stage coding logic of open, axial, and selective coding. During open coding, initial concepts were extracted from the interview transcripts; axial coding organized these concepts into main categories; and selective coding established the links between these categories to formulate the final paradigm model. To ensure the trustworthiness and credibility of the qualitative findings, several strategies were employed, including continuous data comparison, peer debriefing, member checking (participant feedback), and supervision by the research committee. Furthermore, interviews were extended beyond the initial saturation point to confirm the stability and consistency of the concepts, thereby strengthening the analytical robustness of the qualitative model. The results of this phase led to the identification of six main dimensions and 50 components, organized within a coherent paradigm model. Within this framework, causal conditions represent the factors necessitating the transition toward Industry 4.0 maturity in the BSSC, while the core phenomenon is defined as the dimensions of Industry 4.0 maturity in the banking service supply chain and the development of digital banking, around which all other categories are integrated. Furthermore, strategies refer to the managerial policies and actions adopted by banks and BSSC actors to realize this transformation, supported by contextual conditions that encompass the institutional, infrastructural, and technological environments facilitating these measures. Additionally, intervening conditions include facilitating or constraining factors that influence the maturity process, ultimately leading to consequences that signify the outcomes and performance achievements resulting from Industry 4.0 maturity. The conceptual coherence of these relationships within the GT paradigm framework confirms the theoretical validity of the qualitative model, which subsequently served as the foundation for the measurement instrument in the quantitative phase (Figure 1).

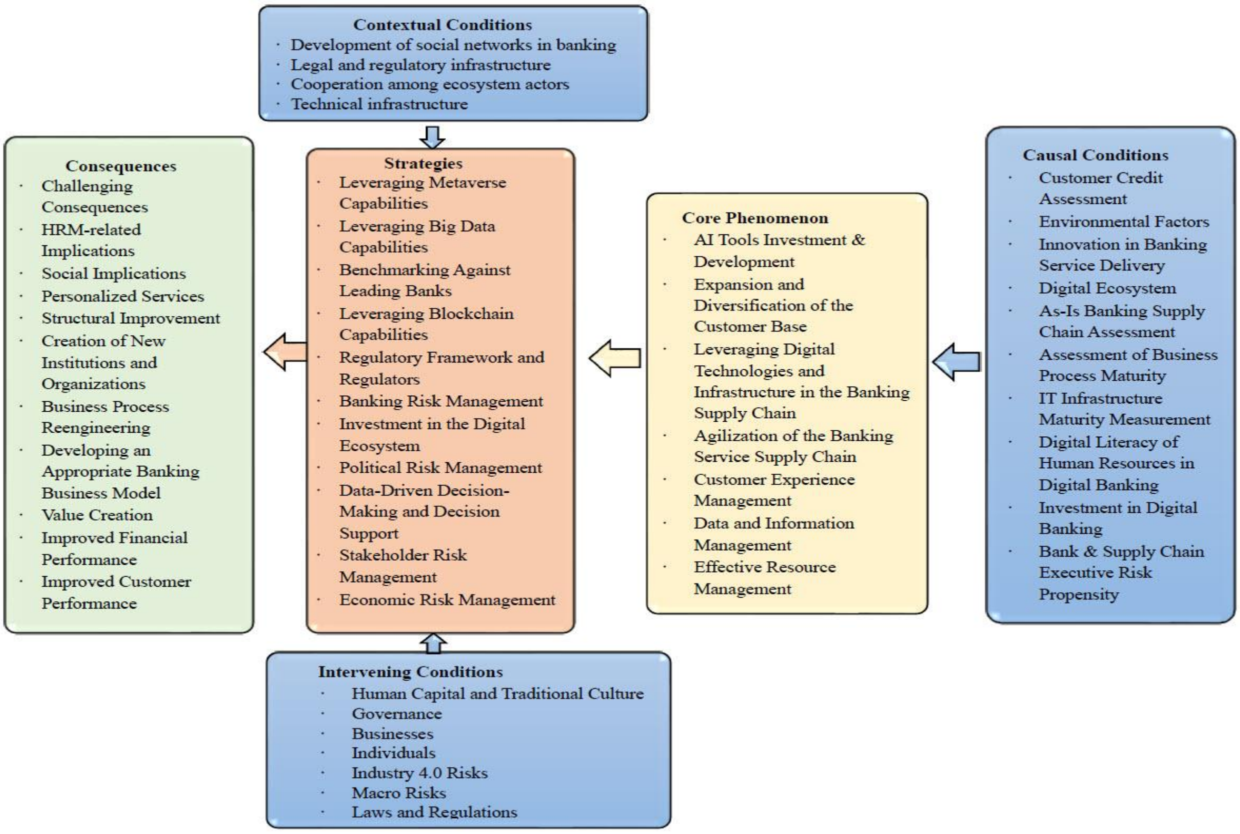


**Fig. 1.** Designed conceptual model framework

In the quantitative phase, a structured questionnaire was developed based on the categories derived from the grounded theory analysis to empirically test the relationships among the dimensions identified in the qualitative phase. To determine the adequacy of the sample size for Partial Least Squares Structural Equation Modeling (PLS-SEM), the “10-times rule” was employed. According to this rule, the minimum required sample size should be at least ten times the largest number of structural paths directed toward any single construct in the model. Since the construct with the highest number of incoming paths in the conceptual model had 11 incoming paths, the minimum required sample size was estimated at 110 respondents. To ensure an adequate sample size, 180 questionnaires were distributed using non-probability purposive (judgmental) sampling among qualified managers and specialists with sufficient knowledge of, and professional experience in, digital banking and the banking service supply chain (BSSC). Following data screening, 12 questionnaires were excluded due to incomplete responses. Consequently, 168 valid questionnaires were retained for the final analysis. This number substantially exceeded the minimum sample size requirement and was therefore considered adequate for conducting the structural analyses.
The descriptive analysis of the respondents’ demographic characteristics indicated that 71.4% of the participants were male and 28.6% were female. Regarding educational attainment, 50% of the respondents held a master’s degree, 32.7% held a bachelor’s degree, and 17.3% held a doctoral degree. This demographic composition reflects the respondents’ high level of academic and professional expertise and demonstrates the suitability of the sample for the specialized nature of the research topic. The evaluation of the research model was conducted in two stages. First, the measurement model was assessed to examine the quality, reliability, and validity of the measurement instrument. The assessment included factor loadings,

convergent validity as measured by the average variance extracted (AVE), discriminant validity using the Fornell–Larcker criterion and the Heterotrait–Monotrait ratio (HTMT), Cronbach's alpha, and composite reliability (CR). The results indicated that the measurement indicators satisfied the established criteria for PLS-SEM and that the constructs demonstrated acceptable levels of reliability and validity. Second, the structural model was evaluated in terms of path significance, explanatory power, and predictive adequacy. The empirical findings demonstrated that all hypothesized relationships among the constructs were statistically significant at the 95% confidence level ($t$>1.96t). Moreover, the overall structure of the model exhibited an appropriate level of model fit and satisfactory empirical validity. These findings indicate that the proposed six-dimensional model possesses not only strong theoretical coherence but also adequate capacity to explain the causal and structural relationships underlying the development and assessment of Industry 4.0 maturity in the Banking Service Supply Chain.

**Table 1** Results of the significance of relationships between the variables

| **Path** | **Path coefficient** | **T_value** | **Sig.** |
|---|---|---|---|
| Causal Conditions → Core Phenomenon | 0.614 | 10.472 | **0.00** |
| Core Phenomenon → Strategies | 0.517 | 7.715 | **0.00** |
| Contextual Conditions → Strategies | 0.225 | 3.805 | **0.00** |
| Intervening Conditions → Strategies | 0.250 | 4.094 | **0.00** |
| Strategies → Outcomes | 0.621 | 12.313 | **0.00** |

**Table 2** Results of path coefficients and significance of the relationships in the structural model

| Effect | Path effect | T stat. | Result |
|---|---|---|---|
| Causal Conditions → Core Phenomenon | 0.614 | 10.472 | **Relationship Confirmed** |
| Contextual Conditions → Strategies | 0.225 | 3.805 | **Relationship Confirmed** |
| Intervening Conditions → Strategies | 0.250 | 4.094 | **Relationship Confirmed** |
| Core Phenomenon → Strategies | 0.517 | 7.75 | **Relationship Confirmed** |
| Strategies → Outcomes | 0.621 | 12.313 | **Relationship Confirmed** |

### 3.1 Ranking the dimensions and components of the model using the Bayesian best–worst method

Following the identification and clarification of the model's dimensions and components in the previous research stages and the final verification of its conceptual framework, the Bayesian best–worst method (Bayesian BWM) was utilized to determine the relative importance and rank the extracted elements. This method was selected for its robustness in managing the uncertainties inherent in human judgment and its capacity to aggregate opinions from multiple experts simultaneously. In this stage, 10 key experts in the fields of digital banking, information technology, and the banking service supply chain (BSSC) participated; these individuals were purposively selected based on criteria such as specialized knowledge, decision-making experience, and proficiency in digital transformation issues. The required data were collected through pairwise comparisons (Best-to-Others and Others-to-Worst) and subsequently analyzed using computational codes implemented in MATLAB. To ensure computational precision, the Bayesian approach facilitates the reduction of individual biases and, by leveraging probabilistic distributions, provides more accurate weight estimations compared to deterministic methods. This feature is particularly significant in the highly interactive and complex environment of digital banking, thereby enhancing the validity of the findings. In the following sections, the ranking results for the main dimensions of the model are presented first, followed by a detailed report on the prioritization of all individual components.

## 4 Results

In this stage, the six main dimensions of the research model, including “causal conditions,” “core phenomenon,” “strategies,” “contextual conditions,” “intervening conditions,” and “consequences,” were provided to 10 experts. The experts were first asked to determine the most important and the least important dimension. Then, using a 1–9 scale, pairwise comparisons were conducted between the most important dimension and the other dimensions, as well as between the other dimensions and the least important dimension. The data obtained from these pairwise comparisons were used as inputs to the Bayesian BWM model and served as the basis for calculating the final weights and ranking the dimensions.

**Table 3** Weight and ranking of basic model dimension

| **Dimension Name** | Symbol | Weight | Rank |
|---|---|---|---|
| **Causal Conditions** | C1 | 0.3115 | 1 |
| **Core Phenomenon** | C2 | 0.0908 | 6 |
| **Strategies** | C3 | 0.2313 | 2 |
| **Contextual Conditions** | C4 | 0.1477 | 3 |
| **Intervening Conditions** | C5 | 0.1189 | 4 |
| **Outcomes** | C6 | 0.0981 | 5 |

The results of the Bayesian best–worst method (BWM) analysis show that the weights of the criteria represent the probability of superiority and the relative importance of each dimension compared to the other dimensions. According to these results, the “causal conditions” dimension, with a weight of 0.3115, ranked first, confirming the high importance of the main drivers and underlying factors in shaping the maturity of the Fourth Industrial Revolution in the banking service supply chain. Next, the “strategies” dimension, with a weight of 0.2331, ranked second, indicating the fundamental role of policies and managerial actions in advancing this transformation. In addition, the “contextual conditions” dimension, with a weight of 0.1477, ranked third, reflecting the impact of infrastructures, institutional settings, and technological capabilities in facilitating the implementation of digital transformation strategies in the banking system. As shown in Figure 1, C1 is, with 100 percent probability (probability of 1), greater than criteria C4, C5, C6, and C2, and with a probability of 0.94 it is greater than criterion C3. The magnitude percentages of the other criteria are also indicated in this figure.

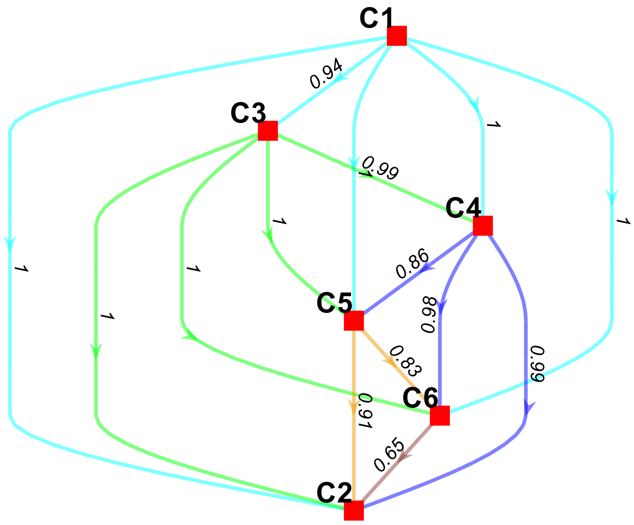


**Fig. 2.** Magnitude of dimensions (criteria) relative to one another

## 4.1 Ranking of Model Components

To determine the final weight of the model components, first the weights of the main dimensions were calculated using the Bayesian Best–Worst method, and then the relative weight of the components within each dimension was obtained. In the final step, to derive the overall weight of the components, the weight of each dimension was multiplied by the relative weight of its corresponding components. The results of this procedure formed the basis for the final ranking of the components, and their complete list, along with the corresponding weights and ranks, is presented in the relevant table. A review of the findings shows that some components have a considerably greater share in explaining the maturity of the Fourth Industrial Revolution in the banking service supply chain and therefore appear in the higher levels of the ranking.

**Table 4** Ranking of model components results

| Component Name | Code | Final Weight | Final Rank | Cumulative Weight (%) |
|---|---|---|---|---|
| **Digital Ecosystem** | C14 | 7.314% | 1 | 7.314% |
| **Technical Infrastructure** | C44 | 5.715% | 2 | 13.029% |
| **Assessment of the Current State of the Banking Supply Chain** | C15 | 5.171% | 3 | 18.199% |
| **Legal Infrastructure** | C42 | 4.589% | 4 | 22.788% |
| **Measurement of IT Infrastructure Maturity** | C17 | 3.807% | 5 | 26.595% |
| **Banking Risk Management** | C36 | 3.249% | 6 | 29.844% |
| **Utilization of Metaverse Capabilities and** | C31 | 3.198% | 7 | 33.043% |

| Features | | | | |
|---|---|---|---|---|
| **Assessment of Business Process Maturity in the Supply Chain** | C16 | 3.053% | 8 | 36.095% |
| **Human Resources and Traditional Organizational Culture in Banks** | C51 | 3.008% | 9 | 39.103% |
| **Economic Risk Management** | C311 | 2.690% | 10 | 41.793% |
| **Collaboration Within Ecosystem Components** | C43 | 2.530% | 11 | 44.323% |
| **Risks Related to Industry 4.0** | C55 | 2.344% | 12 | 46.667% |
| **Development and Investment in the Use of AI Tools** | C21 | 2.318% | 13 | 48.985% |
| **To be continue in the Appendix. A** | | | | |

According to the ranking results, the component "Digital Ecosystem" ranks first with a weight of 7.314%, highlighting the key role of coordination, collaboration, and synergy among various actors within the digital ecosystem in enhancing the maturity of the Fourth Industrial Revolution. The "Technical Infrastructure" component ranks second with a weight of 5.715%, indicating the importance of having appropriate technological platforms for the development and implementation of emerging technologies in the banking industry. The "Assessment of the Current State of the Banking Supply Chain" ranks third with a weight of 5.171%, reflecting the necessity of accurately understanding the current condition of the supply chain and its readiness to move toward digital transformation. Next, the "Legal Infrastructure" component ranks fourth with a weight of 4.589%, emphasizing the role of legal and regulatory frameworks in supporting innovation and emerging technologies in the banking industry. The "Measurement of Information Technology Infrastructure Maturity" ranks fifth with a weight of 3.807%, underscoring the importance of continuously evaluating the status of IT infrastructure in order to effectively guide the path of digital transformation. Overall, the ranking results indicate that components related to the development of the digital ecosystem, strengthening technological infrastructures, and assessing the current situation are among the most important factors influencing the advancement of the Fourth Industrial Revolution maturity in the banking services supply chain. These components can provide an appropriate direction for focusing executive actions and policymaking aimed at advancing digital transformation in the banking industry. An examination of the weight distribution also shows that the top five components Digital Ecosystem, Technical Infrastructure, Assessment of the Current State of the Banking Supply Chain, Legal Infrastructure, and Measurement of IT Infrastructure Maturity collectively account for approximately 26.6% of the total weight. This notable concentration of weight at the top of the distribution indicates that a limited number of components exert the greatest influence on the maturity of the Fourth Industrial Revolution within the banking services supply chain. Consequently, their role in designing and implementing digital transformation programs is highly critical.

Furthermore, the results reveal that the first 14 components in the table account for more than 50% of the total importance among the 50 components. This finding indicates a strong concentration of importance among a relatively small set of key factors. From a managerial perspective, this result is particularly significant, as it suggests that policymakers and banking managers can achieve the greatest impact in accelerating digital transformation within the banking system by focusing on a set of key factors, including the development of the digital ecosystem, strengthening technological and legal infrastructures, assessing the current situation, risk management, and fostering innovation.

## 5 Discussion and conclusion

This study aimed to identify, explain, and prioritize the dimensions and mechanisms influencing Industry 4.0 maturity in the banking service supply chain, with an emphasis on the development of digital banking and financial technologies. The conceptual model was initially developed through qualitative analysis and grounded theory, and was subsequently validated and prioritized using quantitative data through partial least squares structural equation modeling and the Bayesian best–worst method (Bayesian BWM). This section interprets the findings and discusses their theoretical and managerial implications. The findings indicate that Industry 4.0 maturity in the banking service supply chain is not a one-dimensional or purely technological phenomenon; rather, it emerges from the simultaneous interaction of technological, organizational, institutional, and environmental factors. The structural equation modeling results confirm that the development of technological infrastructure, the adoption of data-driven technologies, the implementation of intelligent processes, and the alignment of organizational strategies with digital orientation play decisive roles in Industry 4.0 maturity. Accordingly, investment in emerging technologies such as artificial intelligence, blockchain, and the internet of things alone is insufficient to achieve genuine maturity. The development of organizational capabilities, process redesign, enhancement of employees' digital literacy, establishment of data governance, and cultivation of a digital mindset are also essential prerequisites for this transformation. The Bayesian Best–Worst Method results also clarified the relative importance of the identified components. Based on the estimated weights, certain components were more important than others. The digital ecosystem, technical infrastructure, assessment of the current state of the banking service supply chain, legal infrastructure, and the maturity of information technology infrastructure emerged as critical elements of the model. This finding suggests that digital transformation in banks should be pursued simultaneously at three levels: internal organizational capabilities, institutional requirements, and ecosystem interactions. From a theoretical perspective, this study makes several distinctive contributions to the existing literature. First, it presents an integrated model that explains the causal conditions, central phenomenon, strategies, contextual conditions, intervening conditions, and consequences of Industry 4.0 maturity in the banking service supply chain within a coherent framework. Second, the combination of grounded theory, structural equation modeling, and Bayesian BWM provides a multidimensional and systematic understanding of the mechanisms underlying digital maturity in the banking industry. This integrated approach not only identifies the relationships among the constructs but also enables the determination of the relative importance of dimensions and components, an issue that has received limited simultaneous attention in many previous studies. From a practical perspective, the findings offer clear implications for bank managers, information technology managers, FinTech companies, and financial-sector regulators. The following managerial recommendations are directly derived from the qualitative model, the results of partial least square structural equation modeling (PLS-SEM), and the prioritization results of the Bayesian best–worst method (Bayesian BWM). Accordingly, to facilitate the practical application of the research findings, the following recommendations are proposed.

**Development of the digital ecosystem**

The findings revealed that the digital ecosystem is one of the major causal factors in Industry 4.0 maturity and occupies a high rank in the prioritization of components. This finding indicates that banks will not achieve sustainable value creation without establishing effective and structured interactions with FinTech firms, technology companies, intermediary platforms, government institutions, customers, and other actors in the banking service supply chain. Therefore, in the short term, banks should prioritize the development of open and standardized application programming interfaces (APIs) and secure connectivity with FinTech firms operating in the payment and lending technology sectors. In the medium term, the formation of interbank consortia to share non-competitive infrastructures, improvement of transparency in collaboration among stakeholders, and movement toward the Banking-as-a-Service (BaaS) model can enhance agility, scalability, and innovation within the banking ecosystem.

**Investment in artificial intelligence, big data, and advanced analytics**

The findings indicate that the development of and investment in artificial intelligence tools and data and information management play a driving role within the central phenomenon dimension. Moreover, the use of big data capabilities within the strategies dimension represents an important component for improving the performance and intelligence of the banking service supply chain. Accordingly, in the short term, banks can deploy intelligent chatbots, automated response systems, and recommender systems to personalize services and improve customer responsiveness. In the medium term, the application of machine-learning algorithms for credit assessment, credit-risk prediction, fraud detection, customer-behavior analysis, and the design of personalized services can strengthen banks' operational intelligence. In this regard, establishing a big data platform to aggregate and analyze customer, transaction, digital-channel, risk, branch, and operational data is essential. Furthermore, the controlled and authorized integration of internal banking data with reliable external data can improve analytical accuracy and enhance the effectiveness of strategic decision-making. The outputs of big data analytics should also be utilized in service design, marketing, risk management, managerial decision-making, and customer-experience improvement.

**Modernization of technical infrastructure and establishment of data governance**

The findings demonstrate that technical infrastructure, as a contextual condition, is a fundamental component that provides the basis for implementing digital banking strategies. In addition, data and information management, as part of the central phenomenon, plays an important role in linking technology, digital strategies, and managerial decision-making. Therefore, technical infrastructure modernization and the establishment of data governance should be pursued as complementary rather than separate initiatives. In the short term, banks should develop a comprehensive data-governance framework that includes the definition of data ownership, improvement of data quality, assurance of security, specification of access levels, protection of confidentiality, and management of the data life cycle. Moreover, the development of data catalogs, data dictionaries, data-exchange standards, managerial dashboards, and the cleansing of inconsistent data should be prioritized. In the medium term, the gradual redesign or replacement of legacy, costly, and incompatible systems; transition toward microservices architecture; adoption of cloud computing; and alignment of technical architecture with the requirements of open banking, artificial intelligence, big data, blockchain, and digital services are recommended. In addition, banks should continuously monitor indicators such as system response time, service availability, frequency and duration of outages, service recovery time, processing capacity, and infrastructure resilience. Investment in cybersecurity, business continuity, and infrastructure sustainability is also essential to mitigate operational risks and maintain customer trust.

**Strengthening digital human capital and a learning culture**

The findings indicate that the digital literacy of human resources constitutes an enabling causal condition for transforming technological investments into effective performance. In other words, without improving the digital skills of managers and employees, the effective utilization of intelligent systems, data analytics tools, and digital platforms will face substantial limitations. Therefore, the development of digital human capital should be addressed concurrently with technological modernization. In the short term, capacity-building programs should be implemented for managers and employees in data-driven thinking, data analytics, technology management, cybersecurity, and digital service design. In the medium term, reviewing the organizational structure and establishing specialized roles—such as data analysts, product owners, customer-experience specialists, cybersecurity specialists, and digital-risk specialists—can strengthen banks' organizational transformation capabilities. Creating a culture of continuous learning, reducing resistance to change, and gradually replacing traditional culture with a culture of innovation and cross-functional collaboration are further prerequisites for a successful transition to digital banking.

**Agile regulation and constructive engagement with the regulator**

The model findings indicate that laws and regulations, while providing the necessary foundation for digital activities, may become barriers to innovation when they lack flexibility. Therefore, active and continuous engagement among banks, FinTech firms, and regulators is strategically necessary to formulate rules that are aligned with technological developments. The role of government in governing the digital ecosystem and promoting transparency in relationships among stakeholders also emerged as a notable finding of this study. In the short term, the active participation of banks and FinTech firms in regulatory sandboxes can facilitate the assessment of innovative business models in a controlled environment. In the medium term, the development of supervisory technology (SupTech) and regulatory technology (RegTech) solutions can improve transparency, facilitate supervision, reduce compliance costs, and enable more effective management of regulatory risks. Regulators can also facilitate the development of financial innovations by formulating flexible frameworks for open banking, secure data sharing, digital identity verification, and cooperation between banks and FinTech firms.

**Process redesign and customer experience management**

The findings indicate that process redesign within the strategies dimension and customer experience management within the central phenomenon dimension play important roles in realizing the consequences of digital maturity. Furthermore, improved customer performance was identified as a major consequence of the successful implementation of digital strategies. Therefore, banks should view business-process redesign as a key mechanism linking technological capabilities to customer value creation. In the short term, banks should identify and prioritize high-frequency, time-consuming, costly, and high-friction processes; eliminate redundant steps; reduce repetitive controls; and remove unnecessary manual interventions. Establishing cross-functional teams comprising business, information technology, risk, legal, and customer-experience units can also enhance the effectiveness of process redesign.

In the medium term, the design of an integrated omnichannel customer journey is essential to ensure that customers experience seamless and consistent service across branches, internet banking, mobile banking, call centers, and other channels. In addition, the development of a customer-experience dashboard, including indicators such as customer satisfaction, complaint rate, service-delivery time, churn rate, digital-service usage, and the net promoter score, can enable the continuous monitoring of service quality. The integrated analysis of customer feedback across different channels and the development of personalized services based on customer-behavior analysis and artificial intelligence models can strengthen banks' competitive position. In conclusion, this study demonstrates that Industry 4.0 maturity in the banking service supply chain is a multidimensional and dynamic process that depends on the reciprocal interaction of technology, organizations, regulatory institutions, and the financial innovation ecosystem. Achieving such maturity requires banks to invest simultaneously in digital ecosystem development, data-driven intelligence, technical infrastructure modernization, data governance, digital human-capital development, agile regulation, process redesign, and customer-experience enhancement. Future studies are recommended to test the proposed model in other financial-service sectors, compare public and private banks, and examine the model across different countries in order to enhance the generalizability of the findings and further advance the literature in this field.

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**Appendix A.**

| Component Name | Code | Final Weight | Final Rank | Cumulative Weight (%) |
|---|---|---|---|---|
| Innovation in Banking Services | C13 | 2.237% | 14 | 51.222% |
| Use of Big Data Capabilities | C32 | 2.235% | 15 | 53.457% |
| Investment in Digital Banking | C19 | 2.174% | 16 | 55.631% |
| Data-Driven Decision-Making | C39 | 2.093% | 17 | 57.725% |
| Environmental Factors | C12 | 1.959% | 18 | 59.684% |
| Benchmarking Leading Banks | C33 | 1.956% | 19 | 61.640% |
| Development of Social Networks | C41 | 1.936% | 20 | 63.576% |
| Use of Digital Technologies and Infrastructure in the Banking Supply Chain | C23 | 1.923% | 21 | 65.499% |
| Digital Literacy of Human Resources in Digital Banking | C18 | 1.916% | 22 | 67.415% |
| Laws and Regulations | C57 | 1.873% | 23 | 69.288% |
| Utilization of Blockchain Capabilities | C34 | 1.851% | 24 | 71.138% |
| Risk-Taking Level of Senior Managers in Banks and the Supply Chain | C110 | 1.797% | 25 | 72.936% |
| Human-Resource-Related Outcomes | C62 | 1.758% | 26 | 74.694% |
| Investment in the Digital Ecosystem | C37 | 1.748% | 27 | 76.442% |
| Customer Credit Scoring | C11 | 1.723% | 28 | 78.165% |
| Regulatory Bodies | C35 | 1.576% | 29 | 79.740% |
| Political Risk Management | C38 | 1.462% | 30 | 81.202% |
| Improvement of Customer Performance | C611 | 1.401% | 31 | 82.603% |
| Individuals | C54 | 1.350% | 32 | 83.952% |
| Macro-Level Risks | C56 | 1.344% | 33 | 85.296% |
| Stakeholder Risk Management | C310 | 1.252% | 34 | 86.548% |
| Customer Experience Management | C25 | 1.226% | 35 | 87.773% |
| Governance | C52 | 1.105% | 36 | 88.878% |
| Agility of the Banking Service Supply Chain | C24 | 1.059% | 37 | 89.937% |

| | | | | |
|---|---|---|---|---|
| Data and Information Management | C26 | 1.031% | 38 | 90.968% |
| Social Outcomes | C63 | 0.963% | 39 | 91.931% |
| Structural Improvement | C65 | 0.895% | 40 | 92.826% |
| Businesses | C53 | 0.868% | 41 | 93.694% |
| Increase in Customer Diversity and | C22 | 0.824% | 42 | 94.518% |
| Business Process Reengineering | C67 | 0.778% | 43 | 95.296% |
| Value Creation | C69 | 0.743% | 44 | 96.038% |
| Challenging Outcomes | C61 | 0.720% | 45 | 96.758% |
| Effective Resource Management | C27 | 0.699% | 46 | 97.457% |
| Creation of New Institutions and | C66 | 0.657% | 47 | 98.115% |
| Personalized Services | C64 | 0.651% | 48 | 98.766% |
| Financial Performance Improvement | C610 | 0.651% | 48 | 99.417% |
| Creating an Appropriate Banking | C68 | 0.593% | 49 | 100% |

**Appendix B.** Participant characteristics in the qualitative section

| No | Field of Study | Degree | Work Experience (Years) | Gender | Age |
|---|---|---|---|---|---|
| 1 | Industrial Engineering | Ph.D. | 14 | Male | 38 |
| 2 | Industrial Engineering | Ph.D. | 18 | Male | 42 |
| 3 | Industrial Engineering | Ph.D. | 17 | Male | 44 |
| 4 | Financial Management | Ph.D. | 15 | Male | 40 |
| 5 | Industrial Management | Ph.D. | 22 | Male | 47 |
| 6 | Industrial Management | Ph.D. | 12 | Female | 35 |
| 7 | Industrial Management | Ph.D. | 25 | Male | 50 |
| 8 | Business Administration | Ph.D. | 27 | Male | 55 |
| 9 | Information Technology | Ph.D. | 23 | Male | 45 |
| 10 | Industrial Engineering | M.Sc. | 28 | Male | 57 |
| 11 | Information Technology | M.Sc. | 21 | Male | 47 |
| 12 | Computer Engineering | M.Sc. | 15 | Female | 37 |
| 13 | Computer Engineering | M.Sc. | 12 | Female | 36 |
| 14 | Information Technology | M.Sc. | 18 | Male | 45 |

**Appendix C.** Characteristics of participants in the ranking section

| No | Field of Study | Degree | Work Experience (Years) | Gender | Age |
|---|---|---|---|---|---|
| 1 | Industrial Engineering | Ph.D. | 17 | Male | 44 |
| 2 | Financial Management | Ph.D. | 15 | Male | 40 |
| 3 | Industrial Management | Ph.D. | 22 | Male | 47 |
| 4 | Industrial Management | Ph.D. | 12 | Female | 35 |
| 5 | Industrial Management | Ph.D. | 25 | Male | 50 |
| 6 | Business Administration | Ph.D. | 27 | Male | 55 |
| 7 | Information Technology | Ph.D. | 23 | Male | 45 |
| 8 | Industrial Engineering | M.Sc. | 28 | Male | 57 |
| 9 | Information Technology | M.Sc. | 21 | Male | 47 |
| 10 | Computer Engineering | M.Sc. | 15 | Female | 37 |