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Address: Qom, Ghadir Boulvard, Opposite to Yadgar Imam Stadium, Hazrat-e Masoumeh University.

Tel: +9825 – 33209030
Email: jkes@hmu.ac.ir
Website: http://kes.hmu.ac.ir

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Editor's Letter

Disruptive Technologies and the Development of Knowledge Economy

Dear Readers,

We are pleased to announce the publication of the inaugural issue of *Knowledge Economy Studies*, which features a collection of significant studies in the field of knowledge economy. This issue focuses on innovative technologies that are pivotal to the development of a knowledge-based economy, offering strategic insights for decision-makers and policymakers.

In today's world, the key divide between developed and developing countries is not access to natural resources but access to knowledge resources. Knowledge capital is increasingly recognized as essential for achieving national and organizational objectives, with competitive advantage in the information age reliant on managers' abilities to acquire, utilize, and protect knowledge assets. Recent years have seen significant investments in knowledge management, focusing on technologies that enhance knowledge processes within communities and organizations. The United Nations General Assembly's initiative, "The Future We Want," highlights the importance of sustainable development through equitable economic growth, creating opportunities, reducing inequality, and managing resources sustainably. Building a knowledge society is closely linked to disruptive technologies like artificial intelligence (AI), Blockchain, social media, cloud computing, the Internet of Things (IoT), and big data. Sustainable development depends on effective knowledge asset management, achievable through the adoption of digital technologies. We are witnessing the rise of a digital knowledge society, which promotes good governance at the national level, efficient management at the organizational level, and improved productivity for individuals. International organizations are working to bridge the digital divide between developed and developing nations regarding access to these transformative technologies. Establishing a digital knowledge society is essential for fostering equitable economic growth and social development globally. Thus, investing in disruptive technologies is a crucial strategy for nations aiming to enhance their technical capabilities and transition to a knowledge-based economy.

The studies featured in this issue encompass various domains, including artificial intelligence, Fintech, customer knowledge, and more, examining the potential of emerging technologies in the knowledge economy from diverse perspectives.

I hope that the articles in this issue will enhance the knowledge of researchers and practitioners in related fields and serve as a guiding light for future scholars in this domain. Finally, I would like to extend my heartfelt gratitude to the esteemed authors and dedicated reviewers whose commitment to scholarly excellence has made this journal a valuable resource in our field.

Warm regards,

Mona Jami Pour
Editor-in-Chief
Knowledge Economy Studies

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Exploring the Use of Explainable Artificial Intelligence (XAI) in Production and Operations: A Systematic Review

Seyed Mohammadbagher Jafari[1*] | **Alireza Payvar**[2]

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Seyed Mohammadbagher Jafari
Corresponding Author, Associate Professor, Faculty of Management & Accounting, College of Farabi, University of Tehran, Iran.
E-mail: sm.jafari@ut.ac.ir

Alireza Payvar
Ph.D. Candidate, Faculty of Management and Accounting College of Farabi, University of Tehran, Iran.
E-mail: alireza.payvar@ut.ac.ir

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ABSTRACT

Today, with the development of artificial intelligence, its application in different areas, including production and operations, has expanded. Explainable artificial intelligence (XAI) is a new research topic that has emerged with the development of artificial intelligence. This study aimed to investigate the applications of XAI in production and operations using the systematic review approach. For this purpose, a systematic review of the most recent studies published in the Science Direct, Scopus, and Emerald knowledge bases was conducted. After screening through different stages, 29 articles were reviewed and analyzed. The results showed that publications on XAI have been on an upward trend in recent years, with a significant increase observed from 2021 to 2024. Also, the fields of engineering, production, decision-making, and computer science are the major areas in which recent studies have been published. The results also suggested that the largest scope of XAI application was observed at the organizational level, followed by the industrial level. Based on the findings, the fields of production and operations, followed by logistics and supply chain, were the most frequently studied areas. Regarding the methods used, the SHAP method was the most commonly applied method in the XAI studies, followed by Integrated Gradient and SVM methods. In general, the results of this study showed that XAI is a new field of research that is gradually developing in terms of methodology and areas of application.

KEYWORDS

Artificial Intelligence, Explainable Artificial Intelligence, Production and Operations, Systematic Review.
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Introduction

In the digital age, various manufacturing and service sectors need to increase their customer access speed and enhance their understanding of businesses, governments, and communities. Accordingly, public and private organizations are adopting and applying emerging technologies to improve their efficiency and gain a competitive advantage. In this context, artificial intelligence (AI) plays a crucial role in achieving operational transformation within contemporary organizational structures. AI has become a fundamental aspect of today's business organizations. Technology companies and governments acknowledge the power of AI and attempt to develop machine learning, particularly deep learning, across a range of sectors, from health to national security. Moreover, civic groups, governments, and academic scholars are increasingly concerned with the impacts of AI on health, discrimination, racial differences, and the risks of applying AI in the military and governance settings. In fact, AI has demonstrated impressive applications across economic, healthcare, political, legal, social, security, and business sectors, and it is poised to have a close co-existence with human life in the near future. AI is generally defined as the ability to process and transform data into information to support purposeful behavior. Alongside advancements in technological innovation and the elimination of human-centered organizations, AI empowers companies to drive and manage innovation more efficiently.

AI has moved out of its infancy and is now in its youth, providing a variety of innovative and creative applications and services to businesses, people, and governments. Therefore, many service organizations, production companies, research institutes, and researchers have been drawn to this technology. In other words, AI has made significands tridents both in research and application across various fields, including the development of smart and networked vehicles, drones, agriculture, defense security, logistics, finance, industry, healthcare, robotics, energy, digital education, transportation, space exploration, and environmental management. These are among the most important areas in which AI is currently being seriously implemented.

Apart from these areas, both developed and developing countries- such as the USA, UK, France, Germany, Sweden, UAE, Lithuania, Mexico, Qatar, China, and Turkey- have made serious strides towards the optimal use of AI by developing strategic plans, infrastructures, and governance institutions.

Literature Review

Artificial Intelligence

AI is arguably one of the oldest disciplines of computer science, with its perceptual dimensions and functions designed to mimic the real world and create systems that think and learn like humans (Holzinger et al., 2019). AI has produced significant benefits and has successfully been applied in several areas of industry, including image classification, voice recognition, automated cars, and computer vision (Zhao et al., 2020). The main goal of AI is to solve human problems by modeling human capabilities- not only the physical

capabilities, but also the neural, mental, and perceptual capabilities. By modeling and imitating human perceptual functions, AI seeks to speed up progress in various fields such as medicine, transportation, economy, education, etc. Therefore, the closer the AI gets to replicating human intelligence, the more aligned it becomes to its goals.

An Analysis of theoretical foundations shows that research on the prioritization of applied areas of AI is a relatively new issue in the field of emerging technologies, despite the significant amount of research conducted on AI both domestically and internationally. One of the most recent studies is the research titled "Creativity and artificial intelligence" (Miller, 2019). In this research, creativity is considered as the main characteristic of human intelligence and the author believes that creativity presents considerable challenges for AI. The study suggests that AI techniques can be used in three ways to generate new ideas: by combining similar ideas, exploring potential conceptual spaces, and making changes that transforms previously impossible ideas into possible ideas. In another study, Zhang et al. (2022) investigated ethics and governance in AI. In this study, the authors suggest that researchers in machine learning (ML) and AI play an important role in the ethics and governance of AI, particularly in areas such as job creation, work force support, and career choice. Tolan et al. (2021) have addressed the impact of AI on community employment. By designing a framework for analyzing the impact of AI on employment, they ranked AI-related jobs and improved people's knowledge about employment opportunities in an AI-affected labor market (Tolan et al., 2021).

In Iran, some studies have been performed on AI, investigating the principles, techniques, and applications of AI. For example, Soroush and Monajemi (2018) in a study titled "Analysis and criticism of artificial intelligence in medicine from an epistemological perspective" addressed cognitive errors in medicine that led to the increased use of AI. They also reviewed medical epistemology, ultimately describing the following epistemological reasons for the failure of AI systems in this field of science: incorrect assumptions about the nature of knowledge, separation of knowledge from decision-making strategies, not paying attention to tacit knowledge, and separating knowledge from context (Soroush & Monajemi, 2018) .

Another study examined crime analysis using AI methods and data mining for the preemptive detection of crimes. This research examined the methods used by house bulgars, using neural networks - one of the existing AI methods- for the discovery and preemptive detection of crime (Keivanpour et al., 2009).

Many other studies have also examined the application of AI in various fields. For example, AI has been used to determine the maximum output discharge resulting from the fission of the earth dam (Babaeian et al., 2012), assist in medical decision-making with a focus on its advantages and challenges, optimize the operation of dam reservoirs, and improve energy consumption in Iran's transportation sector (Tahari-Mehrjerdi et al., 2012).

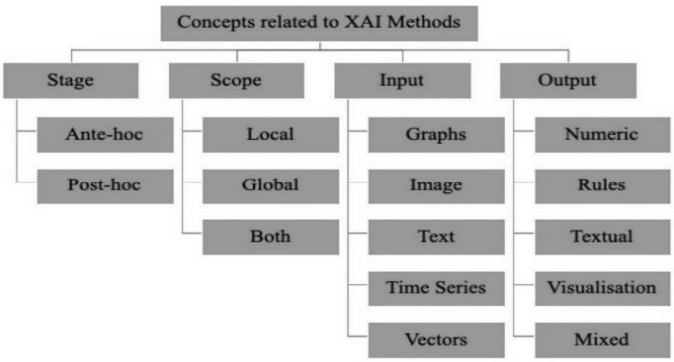
Explainable Artificial Intelligence (XAI)

Since 2020, explain ability has been identified as a key factor for the adoption of AI

systems in a wide range of contexts. Explainable Artificial Intelligence (XAI) has actually been developed to address the current limitations of AI systems. Explainable AI proposes the creation of a set of machine learning techniques that (1) generate more explainable models while maintaining high learning performance (e.g., greater predictive accuracy) and (2) enable humans to understand, trust, and effectively manage the emerging generation of AI partners. XAI also integrates findings from the social sciences (Miller, 2019) and the psychology of explanation.

The concept of explain ability relates to the relationship between decision-makers and humans. This interface is developed to be comprehensible to humans and accurately represents the decision-making process. In XAI, the interface between models and end users is called "explanatory", allowing the end user to understand the decisions made by the AI/ML model. Based on the literature, XAI concepts can be classified into different application areas such as stage, range, input, and output formats. Figure 1 summarizes the main concepts of XAI application development.

Figure 1.
Various Concepts on Methodological Development for XAI Derived from Studies by Villon and Longo



(Source: Vilone & Longo, 2020)

Artificial Intelligence and Production and Operations

The goal of AI is making computers smarter by processing large amounts of data, discovering hidden patterns and unknown correlations, learning from data, and finding the best possible solutions to real-world problems. Various tools are used to facilitate this process, including statistical tools, rule-based methods, machine learning (ML), deep learning (DL), reinforcement learning, probabilistic graphical models, soft computing, knowledge representation techniques like knowledge diagrams, game theory, and even traditional algorithms such as programming and search algorithms (Zhang & Lu, 2021).

AI is a set of tools used to process data, extract patterns, and learn from it. In academic literature, AI is also referred to by names such as big data analysis, data mining, predictive modeling, data science, pattern recognition, and data-driven systems, all of which aim to process large amounts of data, learn from it, and enhance computers' intelligence. AI offers the benefits of persistence, reliability, and cost-effectiveness, while also addressing uncertainty and accelerating the speed of problem solving or decision making (Chowdhury & Sadek, 2012). Today's manufacturing systems are increasingly becoming

complex, dynamic, and interconnected. Plant operations face nonlinear and stochastic challenges due to numerous uncertainties and interdependencies. Recent advances in AI have shown great potential to change production scope through advanced analytical tools for processing large volumes of generated data, commonly referred to as big data (Arinez et al., 2020).

AI solutions to existing problems have three important aspects: 1) optimal output, 2) input data, and 3) the modeling approach. AI begins by defining the desired outcome. To achieve that output successfully, the input data must be carefully defined. Understanding the type of input data is crucial to understanding how AI is used in problem-solving. Finally, the steps that are used in a given modeling approach, such as feature engineering, are determined to obtain the desired output from the input data (Subramaniyan et al., 2021).

Methodology

Given the large amount of information, inconsistent studies, contradictory results, and the reduction of time and capital, along with the need to identify research needs, a review study is necessary (Yarmohammadian et al., 2011). The method used in this research is a systematic review. One of the main features of a systematic review is its high stability, meaning that it is repeatable and follows several stages. Initially, the scope is very wide and highly sensitive, but in the later stages, it becomes more specific. This method is a powerful tool for the comprehensive analysis and diagnosis of relevant studies and answering the research questions (De Loë et. al., 2016).

In this study, a systematic review of applied research using one or more XAI methods has been conducted. While individual studies provide insights into one aspect of the larger picture, the value of a systematic review lies in combining discrete and synergistic results in an organized method, allowing researchers to obtain an overview of the subject under investigation (Sengers et al., 2019).

The process of conducting a systematic review in this study is based on Okoli and Shabram's (2010) guideline. Also, to ensure a more accurate selection of articles, the selection process outlined in Silva (2015) was adopted. Okoli and Shabram (2010) proposed a framework for illustrating the steps of conducting a systematic review, which has been widely adopted in systematic review studies. As shown in Figure 1, these steps are as follows: planning, selection, extraction, and implementation.

Given the importance of selecting the articles, the framework presented by Silva (2015) was used in the selection step. The selection process includes the following steps:

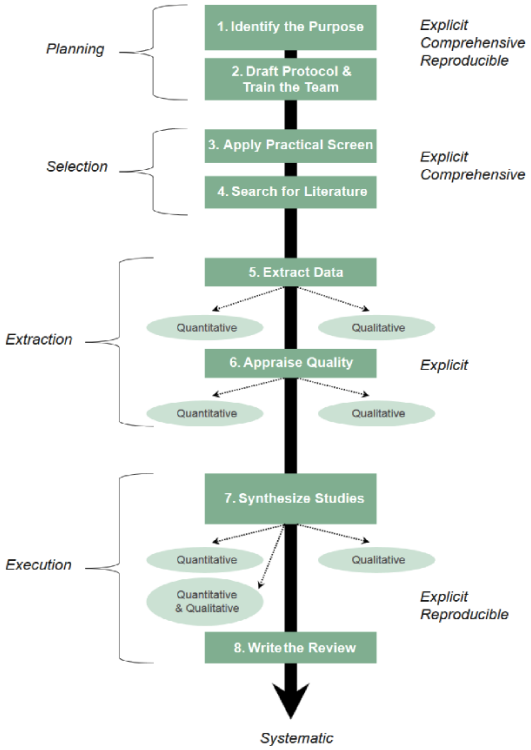
1. Identifying and extracting articles from scientific databases and removing duplicate records;
2. Screening through examining the title and abstract of the extracted articles, selecting relevant ones, and deleting unrelated ones.
3. Rescreening through reading the introduction and conclusion of the previously screened articles, selecting those that are relevant, and deleting unrelated ones.

4. The final evaluation of the articles through studying them, ensuring that they align with the research objectives, followed by the final selection of the related articles.

The combined application of these two frameworks and the overall process of conducting this study are illustrated in Figure 1. To determine the direction of article selection and analysis in a systematic review, the objectives and research questions must first be clarified (De Loë et al., 2016). Then, based on these goals, relevant articles are selected in order to answer the mentioned questions, and after several stages of screening and in-depth analysis of the relevant articles, final articles are selected.

Okoli and Schabram (2015) and Silva's (2015) selection steps for a systematic review are provided in Figure 2.

Figure 2.
A systematic Guide to Literature Review Development



(Source: Researcher's Findings)

In this study, to identify the prototype, the articles published in the journal of three databases-Science Direct, Scopus, and Emerald- were selected. These databases were selected for their maximum coverage, which led to achieving more comprehensive articles and obtaining more reliable and valid results (De Loë et al., 2016). The systematic review began by searching for articles whose title, abstract, or keywords were in English (last search date: 13th May 2024)

The literature search was performed using the following keywords: «XAI» ‹«Artificial Intelligence» ‹«Explainable» «AI», «Manufacturing» ‹«Production» ‹ «Operation». "AND" and "OR" were combined, and " * " wildcards were used to expand the search if necessary. A database of articles was then created, which included the following information:

- Citation information such as author/author name, year of publication, and journal name;
- Number of citations;
- The main approach of the paper in terms of practicality and theoretically (Vishnevskiy & Karasev, 2016);
- The context and scope of the study;
- The domain being investigated;
- Methods used and referred to in the paper;
- Nationality of authors;
- The country in which the study was conducted (in applied literature and case studies);
- The time horizon for applied studies;
- Objectives, methodology, and output of the paper

In the next step, the results of this search were combined and repeated items were removed. Titles and abstracts of the remaining articles were reviewed and irrelevant items were filtered out. In the next step, the introduction and conclusion of the remaining articles were studied, and a number of articles were excluded due to their lack of relevance to the research goals and questions. During the screening process, only studies that applied or combined explainable AI methods or focused on system design were considered. Accordingly, articles dealing with purely theoretical issues were also excluded.

To gain more accurate results, the remaining articles were evaluated through comparisons. At this stage, to assess the quality of articles, the criteria outlined by Quiñones and Rusu (2017) were used and the articles were evaluated in terms of:

Focusing on the use of one or more methods;

Following a clear and open process;

Being published in prestigious journals.

At this stage, 429 articles were identified. Based on the obtained quality score, the articles were evaluated in terms of the mentioned criteria, and the eligible ones were selected for in-depth study and analysis. Finally, 29 articles passed the screening process and were analyzed using systematic review techniques. The following table presents the questions used as the basis for screening and evaluation. Table 2 provides a sample of the papers that were selected in the final filter.

Table 1.
Research Questions

Category Questions	Questions
Methods	What methods of explainable artificial intelligence have been used in different years?
Year of publication	In what years have papers on XAI been published?
Scope/scale of application	What has been the scope of the research? (organization, industry, public)
Field of application	In what areas has each methods of XAI been used in the studies under investigation?
Topical Topics	What are the thematic topics of the journals in which the articles were published?

(Source: Researcher's Findings)

Table 2.
Sample of Selected Articles

Row	Title of the article	Year of publication	Authors	The method used	Magazine
1	Advancing solar energy integration: Unveiling XAI insights for enhanced power system management and Sustainable future	2024	M.K. Nallakaruppan, Nathan Shankar, Prahal Bhagavath Bhuvanagiri, Sanjeevikumar Padmanaban, Surbhi Bhatia Khan	LIME	Ain Shams Engineering Journal (Nallakaruppan, Shankar, Bhuvanagiri, Padmanaban, & Khan, 2024)
2	XAI-empowered Iota multisensory system for real-time milk adulteration detection	2024	Kashish Goyal, Parteek Kumar, Karun Verma	Shapley	Food Control (Goyal, Kumar, & Verma, 2024)
3	Harnessing explainable artificial intelligence for feature selection in time series energy forecasting: A comparative analysis of Grad-CAM and SHAP	2024	Van Zyl, Corne, Xianming Ye, and Raj Naidoo	Gradientweighted Class Activation Mapping (Grad-CAM) and Shapley Additive Explanations (SHAP),	Applied Energy (Van Zyl, Ye, & Naidoo, 2024)
4	Interpretable artificial neural networks for retrospective QbD of pharmaceutical tablet manufacturing based on a pilot-scale Developmental dataset	2023	Brigitta Nagy, Szabados-Nacsa, Fülöp, Anikó Nagyné, Dorián Galata, Attila Farka Alexandra Zsombor Kristóf Nagy, György Marosi Ágnes Gergő Turák László s, Lilla Mészáros,	Interpretable Artificial Neural Network	International Journal of Pharmaceutics (Nagy et al., 2023)
5	Fault Diagnosis using explainable AI: A transfer learning-based approach for rotating machinery exploiting augmented Synthetic data	2023	Lucas Costa Brito, Gian Antonio Susto, Jorge Nei Brito, Marcus Antonio Viana Duarte	Gradientweighted Class Activation Mapping (Grad-CAM) with 1D Convolutional Neural Network (1D CNN)	Expert Systems with Applications (Brito, Susto, Brito, & Duarte, 2023)

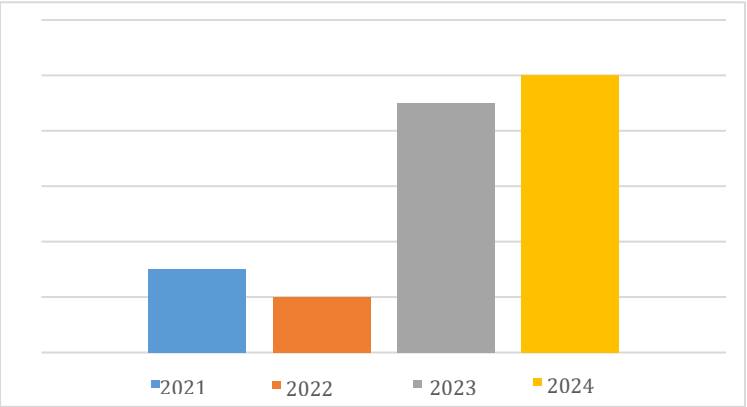
(Source: Researcher's Findings)

Findings

Year of Publication

One of the aims of this research is to study the publication years of the articles. As the chart below shows, there has been an upward trend in the publication of articles over the past few years, with a significant increase from 2021 to 2024. This indicates that AI is a relatively new field of study and highlights the growing interest of the scientific community in addressing this issue. The results are shown in Figure 3.

Figure 3.
Publication Year of the Articles

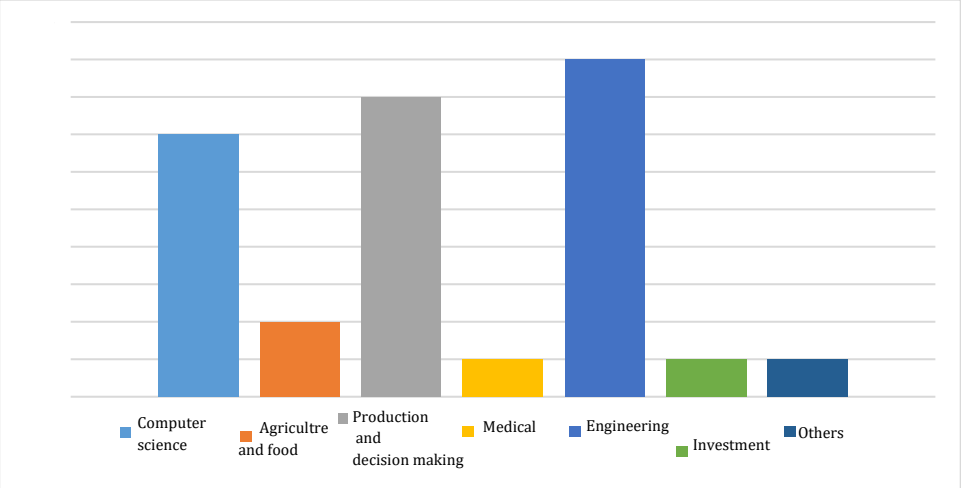


(Source: Researcher's Findings)

Thematic Topics of Journals

Another aim of this research is to identify the thematic focus of the journals in which the articles have been published. As shown in the diagram below, the most common thematic areas include engineering, production and decision-making, and computer science. The results are shown in Figure 4.

Figure 4.
Thematic Topics of Journals

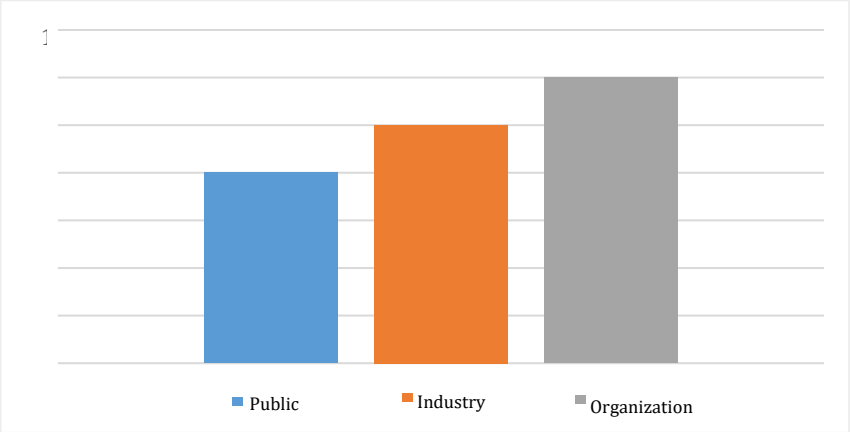


(Source: Researcher's Findings)

Scope and Scale of Application

Articles usually define the scope and application scale of their results, which can be at a micro (i.e., the organization), or macro level (i.e., the industry). In the reviewed articles, the most common application scope was the organization level, with 12 cases. This was followed by the industry level with 10 cases, and the general level with 8 cases. These findings suggest a greater interest in using XAI to solve the operational problems within organizations. The results are provided in Figure 5.

Figure 5.
Scope and Scale of Application

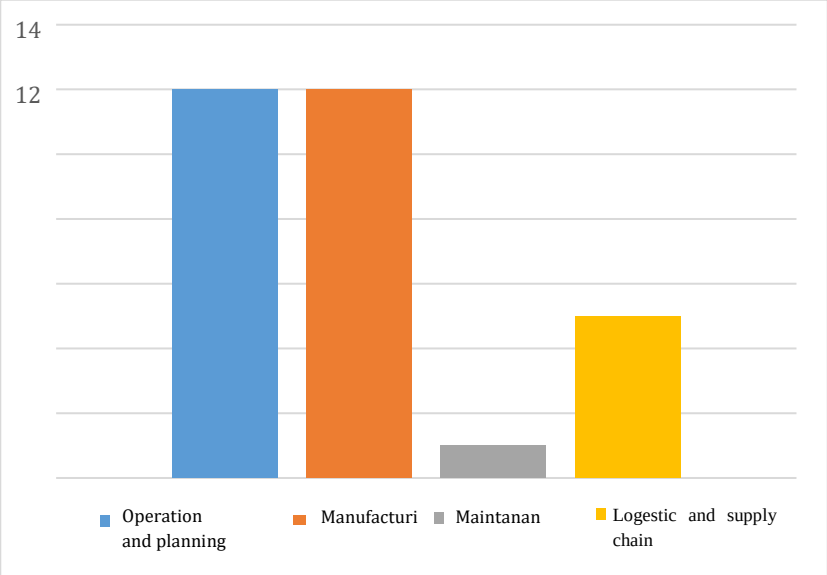


(Source: Researcher's Findings)

Field of Application

Another purpose of this research is to identify articles' field of application. According to the review, the most common field of application was production and operations with 24 cases. This was followed by logistics and supply chain with 5 items, and maintenance and repairs with 1 item. The results are shown in Figure 6.

Figure 6.
Field of Application

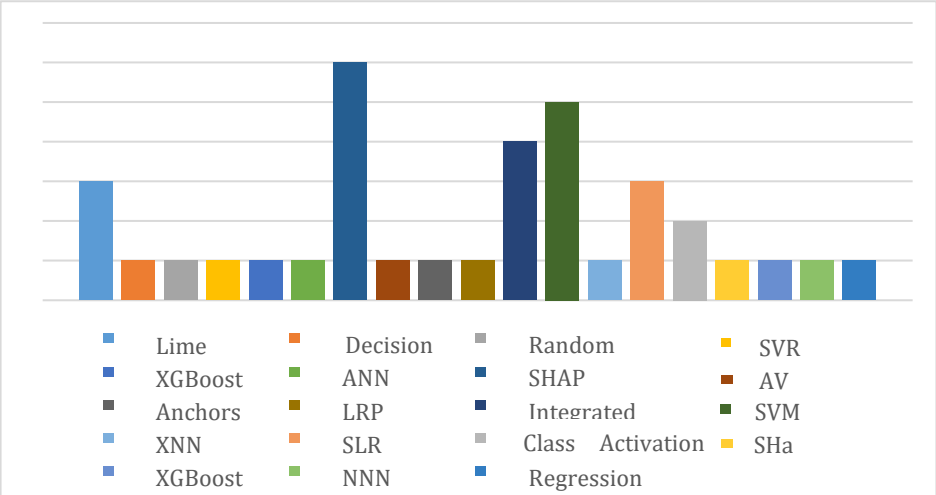


(Source: Researcher's Findings)

Methodology

The other objective of this study was to identify the techniques and methods used in the literature. According to the results, the Shap method with 6 cases was the most used method. Then, "Integrated Gradient" and "SVM" methods with 5 and 4 cases, respectively were the most commonly-used methods. The results are presented in Figure 7.

Figure 7.
Methods Used



(Source: Researcher's Findings)

Discussion and Conclusion

Regarding the period and publication years of articles, the results reveal that, researchers have mainly focused on XAI in recent years. The volume of published articles has significantly increased in the last two years compared to the previous years, indicating the novelty XAI. Accordingly, the number of studies in this field is expected to increase, alongside the development of applications, methods, and functional areas of XAI.

According to the results, XAI has been applied in fields such as engineering, food and agriculture, finance and investment, medicine, production and decision-making, and computer science. Although in some areas, such as engineering, its application has been more than in other areas, the diversity of fields suggest that we will see the use of AI in new fields.

Regarding the scope and scale of AI approaches, it could be said that because of the optimization nature of these methods, they are mostly used at the micro level (i.e. the organization) with operational goals. However, their application across the macro level (i.e. industry) is also significant. Also, the potential of their use at the general level is promising and they may expand into other fields in the future.

As for the methods and techniques used, the results revealed that a wide range of methods have been used in the literature. Several factors have been effective in choosing the appropriate method, including type of research strategy, previous experience, available financial resources, appropriateness with other methods, desired output, scope of the project, available knowledge and information, the time horizon of research, uncertainty, research approach (top-down or bottom-up), review period, technology, industry or organization characteristics, and the user group. These factors can justify the selection of appropriate method and technique for conducting research.

In general, the findings of this study suggest that we are likely to see a growing application of interpretable AI techniques and methods in various fields in the future.

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Designing and Implementing an Artificial Intelligence-Based Robo-Advisor to Assess Investors' Risk Tolerance: A Case Study of the S&P 500 Index

Samira Khonsha[1*] | **Hojjatollah Sadeqi**[2]

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Samira Khonsha
Corresponding Author, Instructor at Islamic Azad University, Zarghan, Ph.D. in Computer Engineering.
E-mail: khonsha.samira@gmail.com

Hojjatollah Sadeqi
Associate Professor, Department of Accounting and Finance, Faculty of Social Sciences and Humanities, Yazd University, Iran.
E-mail: sadeqi@yazd.ac.ir

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ABSTRACT

Financial services companies such as banks, brokerage firms, family offices, insurance companies, and trusts, provide advisory services to help clients achieve their investment goals. These services typically include offering investment solutions and discretionary portfolio management, where asset management is entrusted to financial experts. One of the main challenges in this field is recommending investment strategies that align with clients' needs and risk tolerance. In this study, a model was designed to assess investors' risk tolerance using advanced artificial intelligence (AI) and machine learning techniques. The model analyzed investors' demographic and financial data using regression algorithms to calculate their risk profiles. Then, an intelligent robo-advisor was designed to recommend the most suitable investment mix in S&P 500 companies' stocks based on individual investor profiles. The data for this study was extracted from the Federal Reserve's Survey of Consumer Finances (SCF), conducted between 2007 and 2009. The results of this research indicated that the use of AI and machine learning models can significantly improve the accuracy of assessing investors' risk tolerance. The proposed model, utilizing demographic and financial data from the SCF, successfully generated diverse risk profiles for investors. The designed robo-advisor intelligently analyzed these profiles and provided appropriate investment strategies for the S&P 500 index.

KEYWORDS

Artificial Intelligence, Investment Advisory, Investment Portfolio, Machine Learning, Risk Tolerance, Robo-Advisor.

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Introduction

In today's financial world, investment advisory plays a crucial role in helping investors achieve their financial goals. However, providing advice that accurately addresses investors' needs while considering their risk tolerance has always been a significant challenge in wealth management. The emergence of new technologies, particularly artificial intelligence (AI) and machine learning, has led to remarkable advancements in this field, giving rise to innovative solutions such as robo-advisors. Robo-advisors use advanced algorithms and analyze financial and demographic data to provide automated and personalized investment recommendations to investors, offering both simplicity and high accuracy (Torno et al., 2021; Grealish & Kolm, 2021).

As financial markets become increasingly complex and both retail and institutional investments expand, traditional financial advisory services face limitations. On one hand, the growing number of investors and, on the other, the diversity of investment behaviors, require financial advisors to evaluate investors' risk tolerance more accurately (Darskuviene & Lisauskiene, 2021). In this context, robo-advisors, with their ability to quickly and intelligently analyze financial and psychological data, can effectively manage these challenges and offer optimal recommendations to investors (Jung et al., 2019).

In this research, leveraging recent advancements in AI and machine learning, a new model for assessing investors' risk tolerance has been developed. This model analyzes data from the Survey of Consumer Finances (SCF) and uses regression algorithms to create personalized risk profiles for investors. Subsequently, by implementing an intelligent robo-advisor, appropriate investment strategies for stocks in the S&P 500 index are recommended. This study examines how this system can be integrated within investment advisory and portfolio management firms, evaluating its impact on the accuracy and efficiency of the financial advisory process.

Literature Review

Robo-advisors are digital platforms that provide algorithm-based, automated financial planning services, such as investment management. These services do not require human supervision due to their autonomous capabilities. Robo-advisors collect information about clients' financial situation and future goals. To do this, they are typically asked to respond to a survey or answer several online questions. The data entered is then used to provide tailored financial advice.

Robo-advisor software asks investors questions regarding their financial situation and goals, and based on their responses, algorithms are often employed to provide recommendations on buying, selling, or holding certain products. The advice generated depends on the client's input and the algorithmic logic used to determine which type of recommendation is appropriate based on the information. The tool can be represented as a decision tree, where the client follows a series of questions to arrive at a

recommendation. Some robo-advisors are fully automated, while others incorporate human interactions at certain stages of the advisory process.

Robo-advisors fundamentally change the investment advisory process. Beyond the nature of interaction, they also bring changes in the format of information and contracts. When investment decisions are made online, there is typically no human present to ensure that the investor has fully understood the information provided or that the responses given were appropriately evaluated. No one is available to briefly review the meaning of the content (Salo & Haapio, 2017). Table 1 provides a comparison between Robo-Advisors, Portfolio Management, and Mutual Funds.

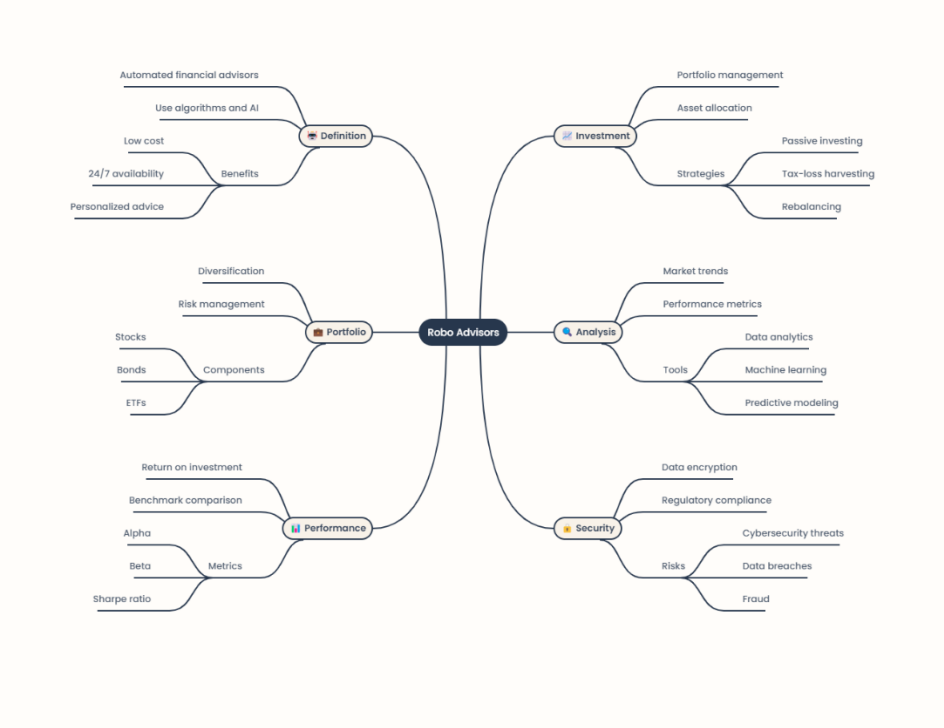
Table 1.
Comparison between Robo-Advisors, Portfolio Management, and Mutual Funds

Feature	Robo-Advisors	Portfolio Management	Mutual Funds
Definition	Automated platforms using algorithms to manage portfolios	Professional management of individual portfolios	Pooled investment vehicles managed by fund managers
Management Style	Algorithm-based, passive or hybrid strategies	Custom, personalized management by professionals	Active or passive strategies by fund managers
Customization	Limited, based on user inputs like risk tolerance	High, tailored to individual needs and goals	Limited, using the same portfolio for all investors in the fund
Fees	Low (0.25%–0.50% annually)	High (1%–2% or more annually)	Moderate (0.5%–2% annual expense ratio)
Investment Strategy	Primarily passive (index-based ETFs)	Can be both active or passive	Active or passive depending on the fund type
Minimum Investment	Low ($500 or less in some cases)	High (Typically $100,000 or more)	Varies (can be low or high, often $1,000–$3,000)
Human Interaction	Minimal or none, customer support available	High, direct contact with a portfolio manager	None or limited, no direct contact with fund managers
Accessibility	Easy, available to beginners with low capital	Less accessible, typically for high-net-worth individuals	Moderately accessible for individual investors
Transparency	High, with real-time portfolio updates	High, frequent reporting and direct insights	Moderate, detailed quarterly reports but no daily insights
Risk Level	Managed based on user's risk profile	Adjusted for individual risk tolerance	Depends on the fund's objective (can vary from low to high)
Tax Efficiency	Moderate, some tax-loss harvesting options	High, can be tailored for tax efficiency	Varies, generally less tax-efficient due to pooled structure
Rebalancing	Automatic, often periodically (e.g., quarterly)	Manual, based on professional judgement	Periodic, at the discretion of the fund manager
Suitable for	Beginners or investors preferring low-cost, automated solutions	High-net-worth individuals needing personalized service	Investors seeking diversification in a single product
Time Commitment	Minimal after setup	Requires regular consultation with manager	Minimal, once invested
Examples	Betterment, Wealthfront	Private wealth managers, financial advisors	Vanguard, Fidelity, BlackRock mutual funds

(Source: Researcher's Findings)

In the chart below, the various applications of robo-advisors are illustrated.

Figure 1.
The various applications of robo-advisors



(Source: https://mylens.ai/space/aq4phi8nnmt/story/robo-advisors-in-investment-M6yGWW?slide=10)

So far, limited research has been conducted on "robo-advisors". To gain a better understanding of the application of recommendation systems in finance, the keyword "in investment robo-advisors" was searched on Scopus on October 22, 2024, and the following outputs were obtained using the bibliometrix package in R. According to the Scopus database, there are only 177 documents on this subject, of which 89 are articles under this title. A summary of the descriptive statistics is as Table 2.

Table 2.
A summary of the descriptive statistics of robo-advisors

Results	Description
	Main Information About Data
2017:2024	Timespan
138	Sources (Journals, Books, etc.)
176	Documents
26.44	Annual Growth Rate %
2.69	Document Average Age
12.38	Average citations per doc
0	References
	Document Contents
631	Keywords Plus (ID)

Results	Description
486	Author's Keywords (DE)
	Authors
410	Authors
33	Authors of single-authored docs
	AUTHORS COLLABORATION
34	Single-authored docs
2.68	Co-Authors per Doc
18.18	International co-authorships %
	Document Types
89	article
1	article
26	book chapter
54	conference paper
1	retracted
5	review

(Source: Researcher's Findings)

In recent years, the number of published articles in this field has increased, with 22 articles published in 2020 alone. Additionally, the first article in this field was published in 1984.

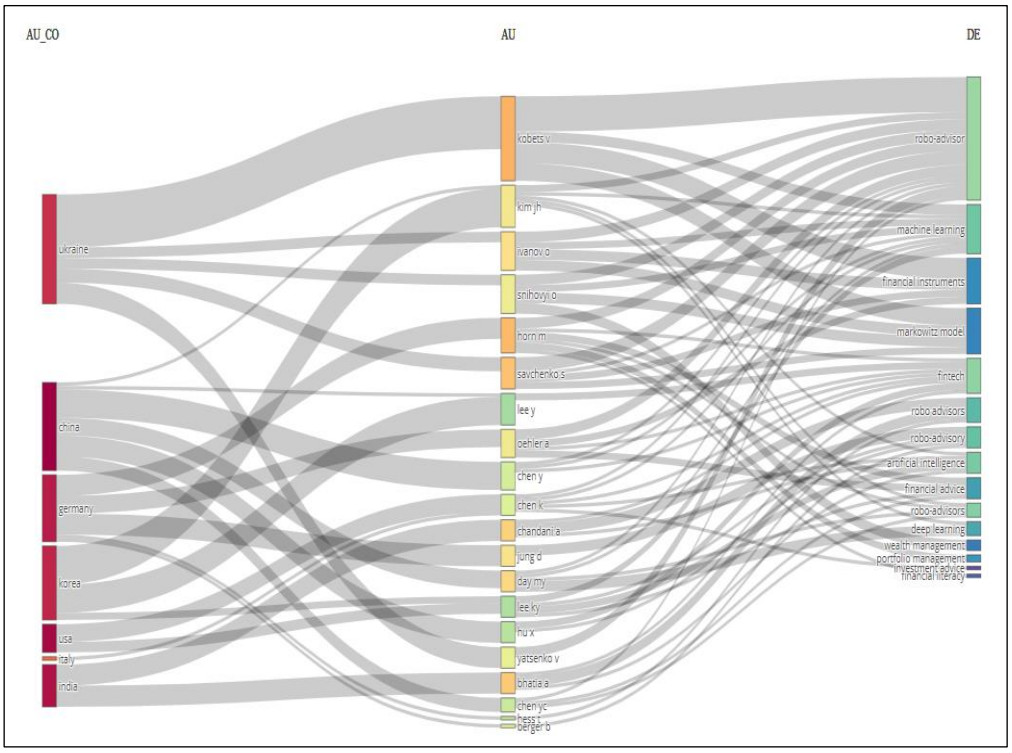
The Figure. 2 displays the most important keywords used in the articles, based on the frequency of their occurrence.

Figure 2.
The most important keywords

(Source: Researcher's Findings)

In this network, the connections between authors, keywords, and titles are presented in such a way that the keywords are displayed on the left, the titles in the center, and the authors of the top research in this field are shown on the right (Figure 3).

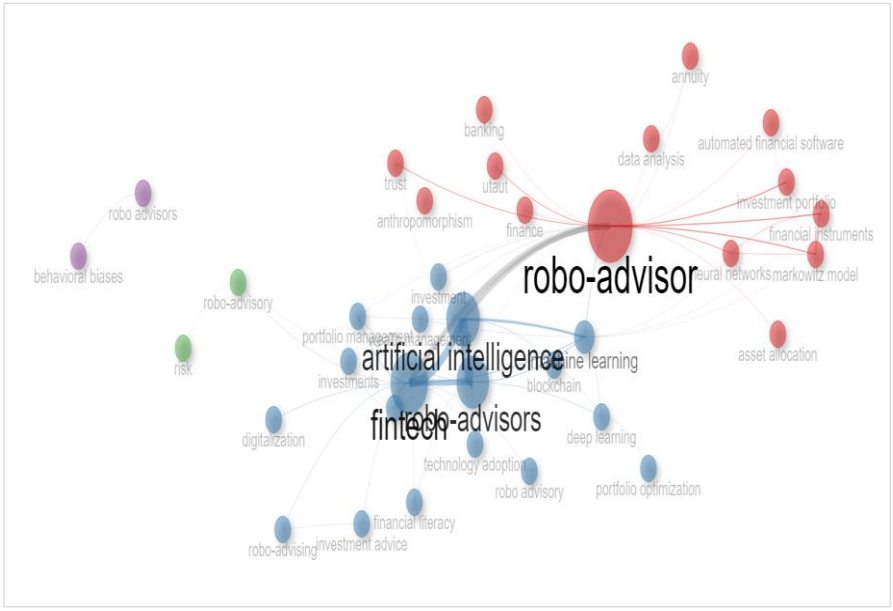
Figure 3.
The Importance of Robo-Advisors in the Conducted Research



(Source: Researcher's Findings)

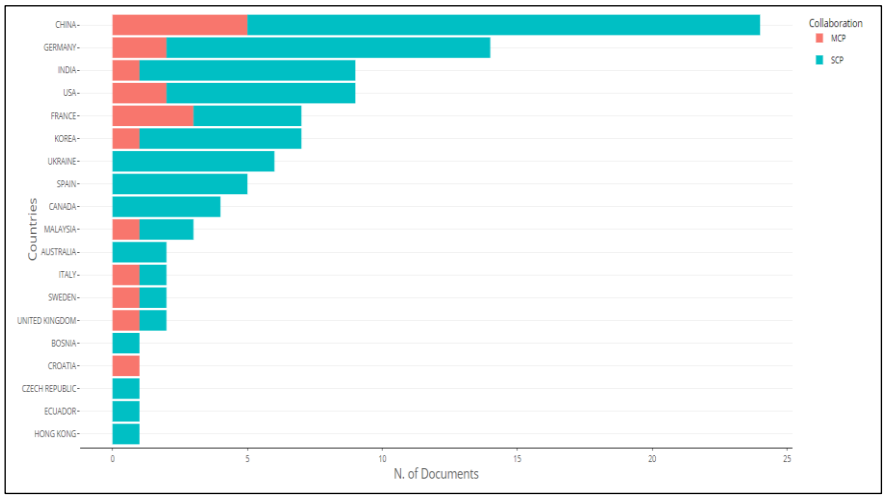
The network of keywords used in the articles is shown in the Figure 4 and Figure 5 shows Corresponding Author's Countries.

Figure 4.
The network of keywords used in the articles (Co-occurrence Network)



(Source: Researcher's Findings)

Figure 5.
Corresponding Author's Countries



(Source: Researcher's Findings)

Robo-advisors represent a transformative shift in investment management, utilizing AI to provide personalized financial advice and portfolio management with minimal human intervention. These platforms leverage big data analytics and machine learning to optimize investment strategies, adapt to real-time market conditions, and enhance investor confidence. However, challenges such as data inaccuracy and the risk of overfitting in the models must be addressed to improve their reliability and performance (Needhi et al., 2024; Ablazov et al., 2024).

Key Features of Robo-Advisors:

- *Personalized Investment Strategies*: Robo-advisors analyze individual financial goals and risk tolerance to create tailored investment plans (Ablazov et al., 2024).
- *Real-Time Data Integration*: By prioritizing real-time data, these platforms can adapt to market changes and provide timely recommendations (Needhi et al., 2024).
- *User-Friendly Interfaces*: Effective design and transparency are crucial for building user trust and encouraging adoption (Huang et al., 2024).

Challenges to Adoption:

- *Financial Literacy*: A lower level of financial literacy can hinder the acceptance of robo-advisory services (Suhaily et al., 2024).
- *Perceived Risks*: Concerns regarding data security and investment performance can discourrage potential users (Suhaily et al., 2024).

While robo-advisors offer significant advantages in democratizing investment management, their effectiveness relies on addressing users' concerns and enhancing thier trust in these automated systems.

The Table 2 captures the insights and findings of Robo-Advisors and their significance in the investment landscape, as outlined by various authors.

Table 3.
Insights and findings of Robo-Advisors

Authors	Insights	Key Findings
(Jeyadev, Ram, Mohamed, & Manokar, 2024)	Robo-Advisors utilize AI for strategic investment decisions, optimizing portfolios through big data analysis and deep learning.	- Real-time data integration enhances Robo-Advisors' performance. - Reduced reliance on historical data improves recommendation accuracy.
(Suhaily, Manaf, Amin, & Zakaria, 2024)	Factors influencing the adoption of Robo-Advisors include financial literacy, perceived risk, and trust.	- Key factors: financial literacy, perceived risk, perceived trust. - Informing interventions can boost financial engagement.
(Ablazov, Qodirov, Ibragimova, & Akhmedov, 2024)	Robo-Advisors enhance personal investment management using AI, offering tailored solutions compared to traditional human advisors.	- AI improves investment management efficiency and accessibility. - Robo-Advisors often outperform traditional human advisors in investment outcomes.
(Huang, Che, Zheng, & Li, 2024)	Robo-Advisors use AI algorithms for personalized investment plans, optimizing asset management and increasing user trust.	- Continuous use of smart advisors is crucial for long-term benefits. - Transparency and tailored financial services boost user trust and optimization.
(Adji, Karmawan, & Lusianah, 2024)	Robo-Advisors analyze market data and client profiles to create tailored portfolios, enhancing investor satisfaction.	- Positive relationship between Robo-Advisor use and investor satisfaction. - UTAUT variables impact investor satisfaction with Robo-Advisors.
(Liu, Xu, Qian, Zhong, & Qin, 2024)	Robo-Advisors manage investments primarily in index funds and ETFs, providing low costs and accessibility for various investors.	- AI enhances investment decision-making but presents challenges. - AI technology has significant potential in quantitative finance investments.
(Azzahra, & Rimenda, 2024)	Robo-Advisors help Millennials make informed investment decisions by facilitating risk profiling, financial planning, and rebalancing.	- Robo-Advisors effectively influence Millennials' investment decisions. - Risk profiling and rebalancing significantly impact investment choices.
(Bianchi, & Brière, 2024)	Robo-Advisors suggest investment strategies and rebalancing, increase investor attention and trading activities, and improve portfolio returns.	- Robo-Advisors increase investor attention and trading activity. - Following Robo-Advisor alerts leads to higher portfolio returns.
(Jiang, Qian, Fan, Ding, & Li, 2024)	Robo-Advisors, using modern portfolio theory algorithms, automate wealth management and offer personalized asset allocation and investment strategies.	- It highlights the transformative potential of AI in finance. - It recommends professional advice to manage compliance risks.
(Chen, 2023)	AI enhances Robo-Advisors by automating financial management, improving model efficiency, and enabling intelligent asset allocation based on risk preferences.	- Models demonstrate good profitability and risk control capabilities. - Models offers guidance for investors in quantitative investing.
(Fatima, & Chakraborty, 2024)	This study identifies performance optimism as a key factor influencing investors' adoption if Robo-Advisors, emphasizing AI's role in improving perceived effectiveness and reliability in financial decision-making.	- Trust, anxiety, performance optimism, and preference affect Robo-Advisors' adoption. - PLS-SEM with 445 investors shows significant variable roles.
(Nourahmadi et al., 2024)	Stock recommendation systems can help investors make informed decisions and achieve higher returns on investments.	- Collaborative filtering algorithms effectively identify valuable stocks for higher market returns. - Future research need to evaluate algorithm performance in diverse markets.
(Zarei et al., 2023)	It emphasizes the importance of designing and implementing intelligent financial robots, showcasing the role of machine learning algorithms in delivering personalized and efficient investment suggestions.	- This study provides a framework for developing intelligent robots in Iran, highlighting AI-driven approaches that enhance financial services.

(Source: Researcher's Findings)

The of AI in robo-advisors' Performance

AI plays a crucial role in enhancing the performance of robo-advisors by enabling personalized investment strategies, optimizing portfolio management, and improving user interaction. The integration of AI technologies allows these platforms to analyze vast amounts of financial data, leading to more informed decision-making and improved investment outcomes.

Personalized Financial Advice:

- AI algorithms analyze individual user data to tailor investment strategies, ensuring alignment with personal financial goals (Ablazov et al., 2024).
- Platforms like Wealthfront utilize AI to create customized asset management plans, enhancing user engagement and satisfaction (Huang et al., 2024).

Risk Assessment and Portfolio Management:

- AI enhances risk assessment by processing real-time market data, enabling robo-advisors to adapt to changing conditions and provide timely recommendations.
- Advanced machine learning techniques improve the accuracy of predictions related to market trends and consumer behavior (Beck, 2021).

User Experience and Trust:

- User interface design and transparency in AI operations are critical for building trust in robo-advisors (Huang et al., 2024).
- Continuous refinement of data integration methods helps maintain reliability and investor confidence (Needhi et al., 2024).
- Conversely, while AI significantly enhances the capabilities of robo-advisors, challenges such as data inaccuracy and the risk of overfitting in the models remain critical concerns that need to be addressed to ensure optimal performance and ethical standards in automated investment platforms (Needhi et al., 2024).

Comparison of Robo-Advisors and Traditional Financial Advisory Services

The emergence of robo-advisors has transformed the wealth management landscape, creating new opportunities and challenges for traditional investment advisors. Robo-advisors, which use algorithms and automation to provide personalized investment recommendations, are increasingly positioned as a low-cost alternative to human advisors. Uhl and Rohner (2018) argue that the competition between robo-advisors and traditional advisors is inherently unequal, particularly due to the scalability and affordability of robo-advisors, which allow them to serve a broader range of clients at lower costs. However, Meyll (2020) suggest that while robo-advisors can serve as a substitute for human financial advice, their capabilities in providing comprehensive financial planning and emotional support in complex financial situations are limited.

Moreover, the ability of robo-advisors to efficiently process large volumes of data has led to their acceptance among tech-savvy and cost-sensitive investors. Phoon and Koh

(2018) state that robo-advisors play an important role in democratizing access to wealth management, especially for individuals who do not meet the minimum asset requirements of traditional advisors. This shift has been particularly appealing to younger generations interested in technology-driven solutions. However, Lam (2016) believes that while robo-advisors excel in portfolio management through algorithms, they still fail to provide complex financial solutions that require human judgment.

Ultimately, while robo-advisors have successfully challenged traditional financial advisory services by offering low-cost and scalable solutions, they have specific limitations. Investors seeking straightforward portfolio management may benefit from robo-advisors, but those requiring comprehensive financial planning and personalized advice will continue to recognize the value of human advisors. (Figure 6)

Figure 6.
Comparison of robo-advisors and traditional advisor

Advisor Type	$ Cost	Investment Strategy	Availability	Personalization	Performance Tracking	Regulation
Robo-Advisor	Low fees, often 0.25%-0.50% of AUM	Algorithm-based, passive investing	24/7 online access	Limited, based on algorithms	Automated, real-time updates	Subject to financial regulations
Traditional Advisor	Higher fees, often 1%-2% of AUM	Personalized, active investing	Business hours, in-person meetings	High, tailored to individual needs	Manual, periodic updates	Subject to financial regulations

(Source: https://mylens.ai/space/aq4phi8nnmt/story/robo-advisors-in-investment-M6yGWW?slide=3)

Methodology

This research aims to develop a machine learning model to predict investor risk tolerance and to utilize this model in the robo-advisor dashboard. The data used for this research comes from the Survey of Consumer Finances (SCF) conducted by the Federal Reserve Board. This survey includes responses regarding household demographic statistics and net financial and non-financial assets for 2007 (before the crisis) and 2009 (after the crisis). This allows us to observe changes in the way each household allocated its resources after the 2008 global financial crisis.

The dataset contains 19,285 observations with 515 columns. The number of columns indicates the number of features.

The steps for preparing the predicted variables are as follows:

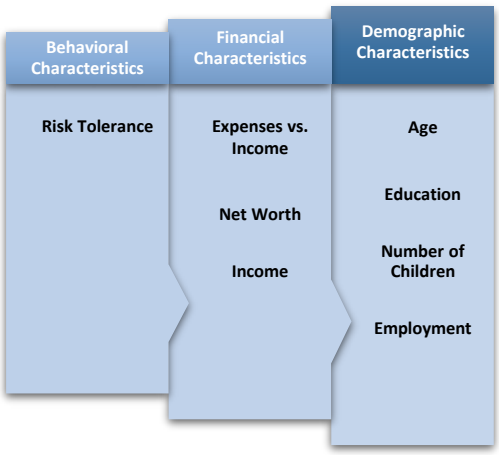
a) Calculating risky and risk-free assets for all individuals in the survey data. Risky and risk-free assets are defined as follows:

- *Risky assets*: Estimate investments in equity mutual funds, bonds, commodities, real estate, and human capital.
- *Risk-free assets*: Balances in checking accounts, savings, certificates of deposit, and other cash and cash equivalents.

b) Calculating the ratio of risky assets to the total assets of the investor and consider it as a measure of risk tolerance. In the financial literature, savvy investors do not change their risk tolerance when market conditions change. Therefore, investors who change their risk tolerance by less than 10% over time are considered savvy investors. However, this is a qualitative measure and is subject to change.

We will first calculate the risk tolerance for each of the years 2007 and 2009 and then consider the average of these as the measure of risk tolerance. In the next step, we will reduce the features. We will then use only these selected features.

Figure 7.
Flowchart



(Source: Researcher's Findings)

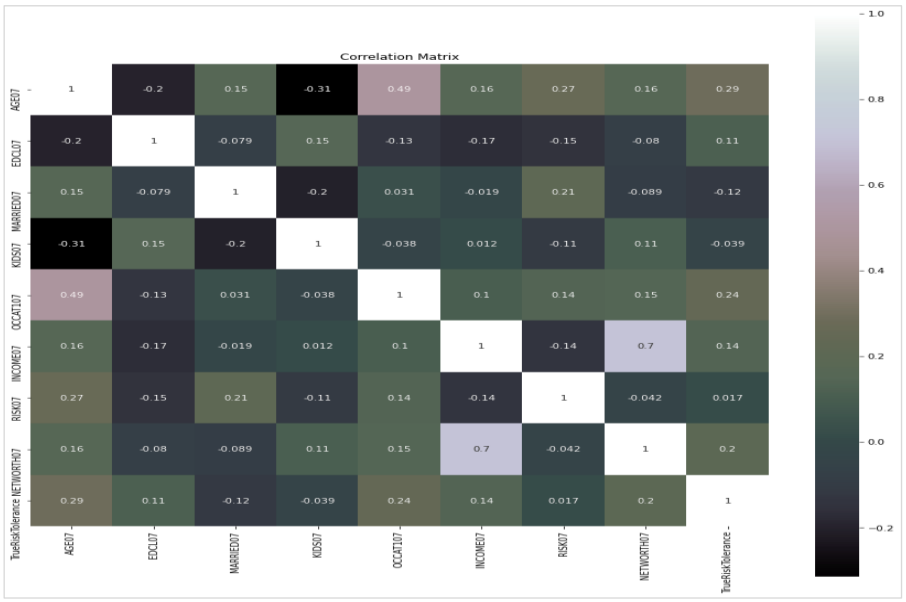
- *Age (AGE)*: Represents the age range of individuals, where 1 indicates an age under 35 years and 6 indicates an age over 75 years.
- *Education (EDUC)*: Represents the education level of individuals, where 1 indicates illiterate and 4 indicates a university degree.
- *Marital Status (MARRIED)*: Indicates the marriage status of individuals. There are two categories: 1 indicates married, and 2 indicates single.
- *Occupation (OCCU)*: Indicates the occupational group, where 1 represents managerial positions, and 4 indicates unemployed.
- *Number of Children (KIDS)*: Indicates the number of children.
- *Net worth Classification (NWCAT)*: Represents the classification of net worth, where 1 indicates net worth less than 25%, and 5 indicates net worth over 90%.
- *Income Level (INCCL)*: Indicates income, with 5 categories where 1 represents income under $10,000, and 5 represents income over $100,000.
- *Risk Tolerance (RISK)*: Indicates willingness to take risks on a scale of 1 to 4, where 1 indicates the highest level of risk tolerance.

These factors will be retained from the questionnaire, while the remaining items will be discarded.

The chart below shows the correlation between these features:

Figure 8.

Feature Correlations

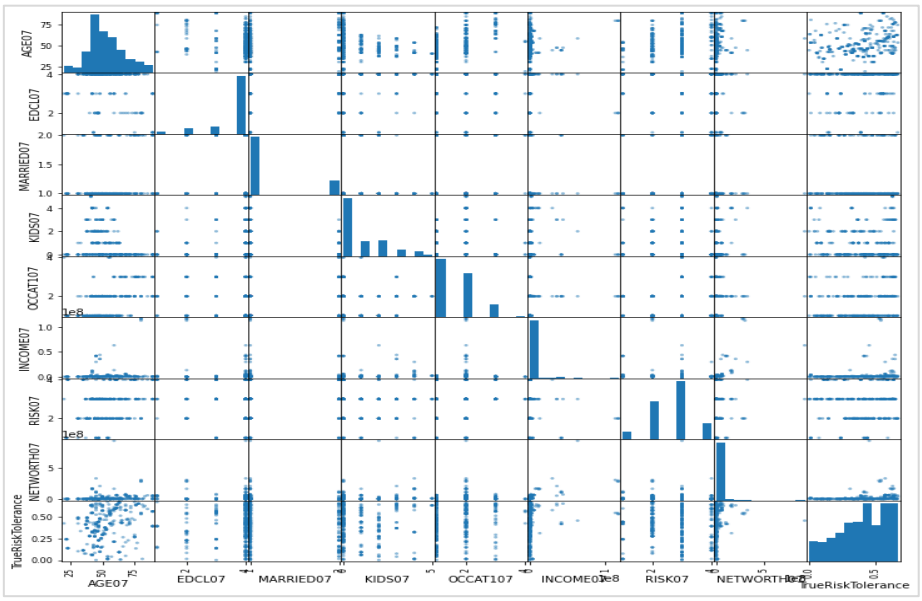


(Source: Researcher's Findings)

The above correlation chart shows that net worth and income have a positive relationship with risk tolerance. As the number of children and marital status increase, risk tolerance decreases. Additionally, a decrease in willingness to take risks correlates with a decline in risk tolerance. Conversely, there is a positive relationship between age and risk tolerance, meaning that as age increases, risk tolerance tends to rise.

Figure 9.

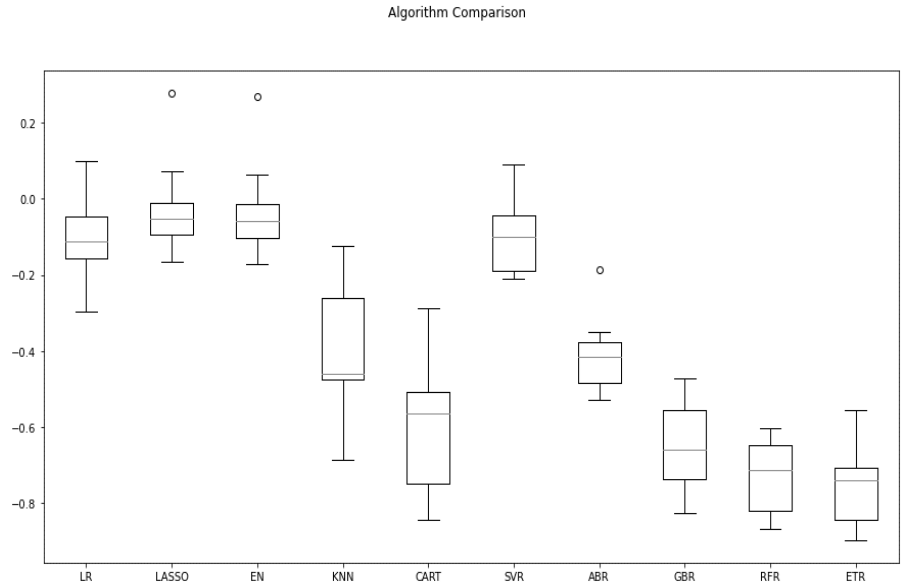
Scatter plot



(Source: Researcher's Findings)

In the next step, we evaluated the model and algorithm. To do this, the data were divided into two categories, namely training and testing datasets. 20% of the data were considered as the test set. The dependent variable was the level of risk tolerance, while the other variables were treated as independent variables. For evaluation, we used boosting models (AdaBoost and Gradient Boosting), bagging models (Random Forest and Extra Trees Regression), linear regression, LASSO, Elastic Net, K-Nearest Neighbors regression, Decision Tree Regression, and Support Vector Regression (SVR). We evaluated these methods using the K-fold cross-validation technique.

Figure 10.
Algorithms Comparison

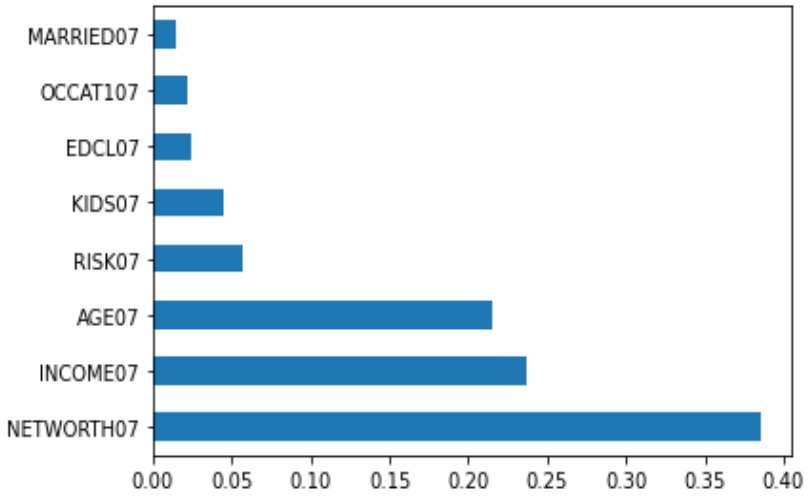


(Source: Researcher's Findings)

Non-linear models perform better than linear models, indicating a non-linear relationship between risk tolerance and other variables. Based on the results obtained, Random Forest regression emerges as one of the best methods, which we will use for further estimation of the model. For model tuning, we estimate the model over time periods of 50, 100, 150, 200, 250, 300, 350, and 400 days, with the results indicating that a 250-day window is the most suitable.

Ultimately, the model's accuracy, measured by the R^2 criterion, is found to be 0.76, while the error, calculated using the Mean Squared Error (MSE), is calculated at 0.0077. In the next step, we will determine the importance of each feature in the Random Forest model.

Figure 11.
The Importance of Each Feature



(Source: Researcher's Findings)

Based on the above chart, income and net worth, followed by age and risk preference, are the primary variables for risk tolerance. These variables are considered key indicators of risk tolerance in various studies.

Findings

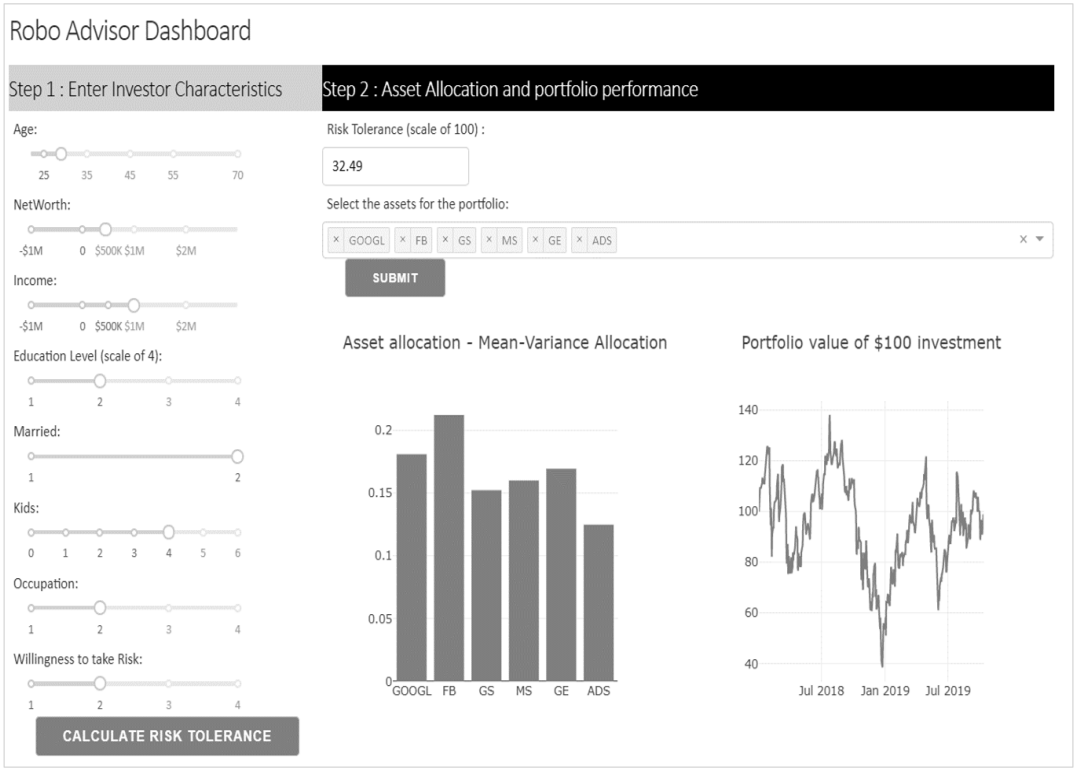
Then, we designed the Robo-Advisor dashboard using the Dash library in Python. It consists of two pages:

1. *Investor Characteristics Input*: The first section allows users to enter the the investor's characteristics .
2. *Asset Allocation and Portfolio Performance*: The second section uses the mean-variance method to focus on asset allocation and portfolio performance.

The input for this model comprises the same characteristics tested in the previous section. After submitting the input, the risk tolerance was calculated, and in the next step, the desired stocks were selected and introduced to the model. The model then calculated the proportion of each of these stocks based on the personality traits and risk tolerance established in the previous stage.

Finally, the dashboard displayed the historical performance of this portfolio based on an initial investment of $100.

Figure 12.
Robo-Advisor Investment Dashboard



(Source: Researcher's Findings)

Discussion and Conclusion

This research demonstrated that machine learning models can analyze the behavior of various investors in changing markets and examine the impact of these changes on the determinants of risk appetite. The results revealed complex and nonlinear relationships between individual variables and risk tolerance, with the most significant variables being income, net worth, age, and risk preference. These findings suggest that by utilizing machine learning models, more accurate patterns of investor behavior can be extracted and leveraged for optimizing financial decision-making.

Future Research Direction

Here are some suggestions for further research and future work:

1. *Utilization of Broader and More Realistic Data*: One of the limitations of this research was the restricted access to data from asset managers and brokerage firms. It is recommended that investment companies develop similar models using their operational data to analyze customer behavior and implement risk tolerance dashboards as decision-making tools.
2. *Expansion of Portfolio Optimization Approaches*: This study employed the mean-variance method for portfolio optimization. Future researchers and financial

analysts can utilize more complex approaches, such as Value at Risk (VaR) optimization or genetic algorithms, to enhance stock portfolio optimization and achieve more accurate results.

3. *Use of Nonlinear and Advanced Methods in Risk Models*: The research results indicated that the relationships between personal variables and risk tolerance are nonlinear. Therefore, employing more advanced methods, such as neural networks or deep learning-based models, could improve predictions and provide more precise analyses.
4. *Integration of These Models with Digital Financial Platforms*: Investment firms can leverage machine learning models to build smart financial platforms that offer investment suggestions based on customer risk profiles. Such platforms can play a crucial role in enhancing investment efficiency and customer satisfaction.

This research demonstrates that applying machine learning models in analyzing investor risk tolerance and optimizing portfolios can significantly improve the accuracy and efficiency of financial decision-making, thereby aiding investment firms in providing better services to their clients.

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The Role of Fintech in Shaping Modern Banking: A Bibliometric Analysis of Past, Present, and Future

Fatemeh Rasti[1*] | **Mohammad Hosein Soleimani Sarvestani**[2] | **Saeed Akhlaghpour**[3]

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Fatemeh Rasti
Corresponding Author, Department of Management, Faculty of Social and Economic Sciences, Al-Zahra University, Tehran, Iran.
E-mail: fatima.rasti@yahoo.com

Mohammad Hosein Soleimani Sarvestani
Ph.D. in production and operation management, Faculty of Management and Accounting, Farabi College, University of Tehran, Tehran, Iran.
E-mail: m.h.soleimani@ut.ac.ir

Saeed Akhlaghpour
Ph.D. in systems management, Faculty of Economics, Management and Social Sciences, Shiraz University, Shiraz, Iran
E-mail: s.akhlaghpoor@gmail.com

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ABSTRACT

This systematic mapping study provides a comprehensive review of the existing literature on Fintech and its role in banking, exploring the current state, development, and future prospects of Fintech research. By analyzing 687 Fintech-related articles from academic databases covering the years 2015 to 2024, this article examines the evolution of Fintech. After describing the process of this phenomenon we identified a significant increase in research activity within this field during the past 5 years. This study offers a unique viewpoint, enabling both researchers and practitioners to reconsider the future direction and scope of Fintech research. This paper reviews the literature on Fintech and its interaction with banking, encompassing innovations in payment systems, credit markets, and insurance, with Blockchain-powered smart contracts also playing a role. It defines Fintech, presents relevant statistics and key insights, and reviews both theoretical and empirical studies. This review is centered around research questions, summarizing current knowledge, and concluding with recommendations for future research avenues.

KEYWORDS

Banking, Bibliometric Analysis, Financial Innovation, Fintech.

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Introduction

Fintech, (financial technology) is a modern financial industry that involves using technology to enhance financial operations. Leong et al. (2018) further define Fintech as any innovation that enhances financial service processes by offering tech-based solutions tailored to specific business needs (Suryono et al., 2020). Fintech encompasses a broad spectrum of meanings. In the business context, it is expansive enough to describe an entire supply chain. Specifically, Fintech refers to the provision of technology to financial service providers. In business, Fintech encompasses a broad range of meanings. It can describe an entire supply chain and is defined as the application of technology to financial service providers (Dorfleitner et al., 2017). Additionally, Fintech includes the delivery of financial products or innovative services characterized by advanced technology (Knewtson et al., 2020). Furthermore, Fintech is used to describe new business models that significantly affect the financial market and the supply of financial services (Li & Xu., 2021). It can even help an industry focused on using technology to enhance financial activities (Schueffel., 2016). In academia, Fintech is viewed as a cross-disciplinary field that merges finance, technology, and innovation management (Leong et al., 2018). Financial services and banking institutions must adopt digital transformation and utilize internet-based technologies to meet the evolving expectations of stakeholders while maintaining a competitive advantage. Over the past two decades, Fintech has revolutionized the banking sector by leveraging existing technologies. This transformation is likened to a revolution that demands increased flexibility. Traditional institutions are required to innovate continuously to keep pace with the rapidly changing and increasingly digitalized environment (Durak et al., 2024). Thakor (2020) identified four key areas where Fintech is making an impact on banking:

1. *Credit, deposits, and capital -raising services*: Fintech enhancies the management of loans, deposits, and fundraising, offering more efficient and accessible options for both individuals and businesses.
2. *Payments, clearing, and settlement services*: Fintech has significantly improved payments processing, with providing faster and more secure systems that challenge traditional banks, particularly in the payments sector.
3. *Investment management services*: Fintech companies offer advanced tools and platforms for managing investments, making it easier for people to invest and manage portfolios.
4. *Insurance*: Fintech innovations are transforming the insurance industry by automating processes, improving risk assessment, and offering personalized policies.

Questions and Research Objects:

- How many articles have been published on the application of Fintech in Banking over different time periods (e.g., years, decades)?
- What are the most frequently used keywords and phrases in the titles and abstracts of these articles?

- Has the publication trend in this area increased or decreased over time?
- Which countries and institutions have published the highest number of articles in this field?

Researchers use both quantitative and qualitative methods to investigate approaches to understanding and organizing findings. They use primary data meanwhile, bibliometric has the potential to introduce a systematic, transparent review process, ensuring reproducibility through the statistical measurement of science, experts, and research activities.

Examine Research Trends: Analyze the trends in research on the use of Fintech in banking in finance, determining whether interest and the volume of publications in this area are on the rise or declining.

Identify Keywords: Identify the major themes and current hot topics being explored at the intersection of Fintech and the banking sector.

Future Research Directions: Offer insights into potential future research directions and emerging trends in applying recommender systems to finance.

Literature Review

Thakor (2020) viewed Fintech as a "disruptive innovation, meaning it fundamentally changes the way traditional banks operate, particularly in the payment sector, where Fintech solutions provide faster, cheaper, and more efficient services than traditional methods. Sangwan et al. (2020) conducted a thematic review of Fintech articles, organizing their findings into three primary themes:

1. *Industrial*: This theme examines Fintech's role in reshaping industries, particularly how financial technologies influence traditional financial sectors.
2. *Entrepreneurial*: This theme focuses on how Fintech fosters innovation and new business opportunities, enabling startups and entrepreneurs to create disruptive solutions in financial services.
3. *Legal*: This theme addresses the regulatory and legal challenges that arise as Fintech develops, highlighting he need for laws and policies to adapt to these new technologies. Their study found that Fintech has significantly impacted the financial market, particularly capital and information asymmetry Fintech solutions bridge the gaps in access to capital and information among different market participants. Offering more transparency and efficiency. Additionally, Sangwan et al. (2020) highlighted the potential for further research on Fintech by various stakeholders, indicating that this field is still growing and evolving. Fintech is transforming the financial industry in several ways. One of contribution is "*Data Collection and Analysis*", Fintech makes it easier to gather and analyze data in financial markets. Reducing information asymmetry, when one party has more or better information than the other. By improving access to data, Fintech helps create a more transparent market. Another: *AI and Big Data in Trading*: With the help of "artificial intelligence (AI)" and "big data", new trading and investment strategies are emerging. These technologies enhance the price

discovery mechanism the process by which the market determines the fair price of a financial asset. They also improve transaction speed, increase market liquidity (the ease of buying and selling assets), and boost the overall efficiency and stability of financial markets. *Regulatory improvements* are another area where Fintech plays an important role. Fintech tools help regulators monitor the financial system more effectively. By analyzing vast amounts of data, they can detect, warn against, and prevent systemic risks, thus promoting a safer financial environment. *Cost efficiency* is another benefit of Fintech**.** Using AI and big data, Fintech can automate many tasks, reducing labor costs and staff duplication. This allows companies to run more efficiently with fewer workers handling repetitive tasks. Financial in collusion is also one of Fintech's most important contributions. By reducing costs and offering convenient services, Fintech helps more people, especially the poor, access banking, loans, and other financial tools. Finally, Fintech has a *Global Impact via the Belt and Road Initiative*: The development of Fintech is shared globally, particularly through initiatives like the "*Belt and Road*" countries along this route benefit from innovations like mobile payments, which drive economic growth and financial development (Li & Xu, 2021).

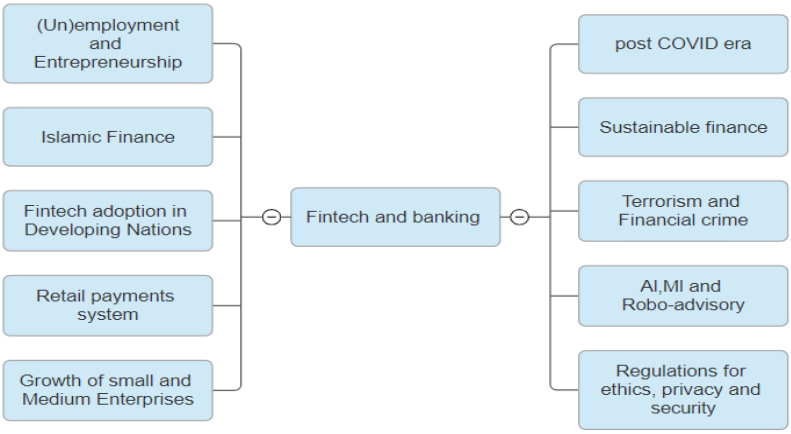
We can describe the evolution of Fintech in three distinct phases, each characterized by significant technological advancements and their impacts on the financial industry:

1. *First phase (1866 to 1967)*: innovations during this time allowed for the rapid transmission of financial information, improving the speed and reliability of international financial transactions and payments. Communication over long distances was revolutionized, laying the groundwork for global financial systems (Mohammadi et al., 2019).
2. *Second phase (1967 – 2008)*: The development of electronic payments and clearing systems. ATMs and online banking were introduced and traditional financial institutions started using information technology to enhance their products and services. This phase marked the digitization of financial services, making banking more accessible through electronic means, thereby improving customer convenience and operational efficiency.
3. *Third phase (2008 up to now)*: The rise of new technology-driven companies offering non-intermediated financial services defines this phase. These companies use technology to provide financial services directly to consumers, bypassing traditional banks and financial institutions. The increasing complexity of activities and the environment has led to new innovations in the world (Safari et al., 2013).

Figure 1.
The Phases of Fintech

(Source: Takor, 2020)

Figure 2.
Framework for Future Research Agendas for Fintech in Banking and Finance



(Source: Researcher's Findings)

This paper focuses on understanding Fintech and the applications in the banking sector. To achieve this research objective, the authors analyze Fintech development trends, especially the Fintech application in the banking sector. To improve the quality of Fintech services at banks, the authors examined factors affecting customers' intention to use Fintech services.

Methodology

The quantitative method "bibliometric" is one of the most quantitative measures used in evaluating literature. (Fairthorne., 1969) In this study, we utilize the bibliometric method to investigate the research background on the application of Fintech in banking. The steps involved in the bibliometric method are clearly outlined.

To conduct the bibliometric analysis, the authors chose the Scopus and Web of Science databases for their robust reputation as leading multidisciplinary abstract and citation databases. This research is practical in terms of objective.

Figure 3.
Map of Keywords Used in Articles

(Source: Researcher's Findings)

Table 1 shows the descriptive statistics of research conducted in the field of Fintech and banking.

Table 1.
Descriptive Statistics of Research Conducted on Fintech and Babking

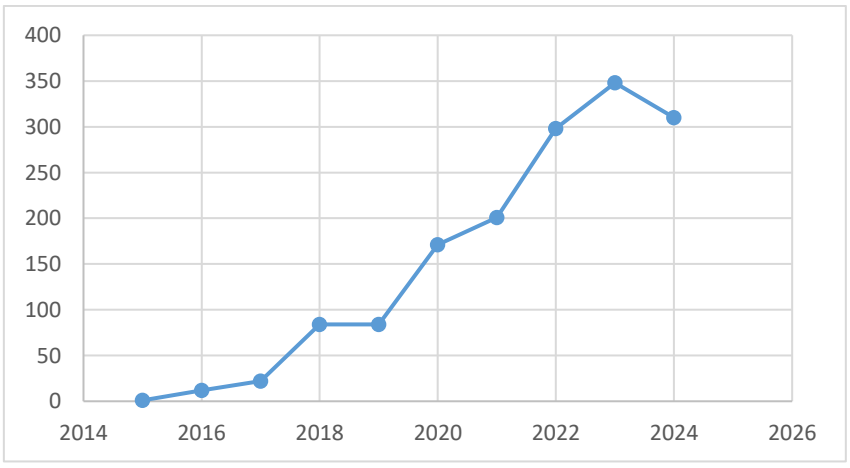
Descriptive	Results
Main Information About Data	
Timespan	2015:2024
Sources (Journals, Books, etc)	687
Documents	1531
Annual Growth Rate %	89.16
Document Average Age	2.23
Average citations per doc	12.44
Document Contents	
Keywords Plus (ID)	3006
Author's Keywords (DE)	3548
AUTHORS	
Authors	3499
Authors of single-authored docs	227
Authors Collaboration	
Single-authored docs	251
Co-Authors per Doc	2.94
International co-authorships %	19.66
Document Types	
Article	955
Article conference paper	2
Book	30
Book chapter	92
Conference paper	227
Review	56

(Source: Researcher's Findings)

According to Table (1) above, 687 studies have been conducted by 3499 authors on Fintech and banking.

Findings

Figure 4.
Annual Scientific Production

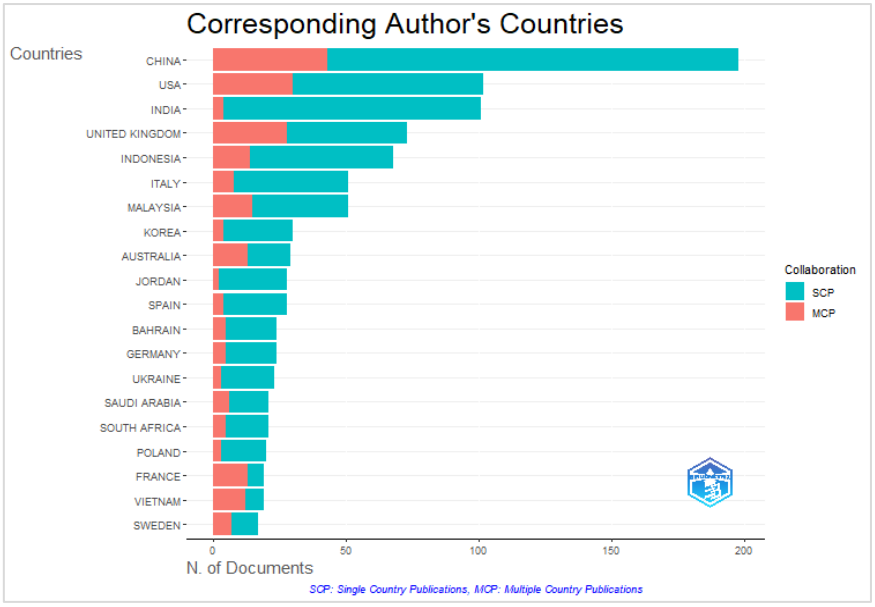


(Source: Researcher's Findings)

This graph shows a line chart with data points plotted between 2014 and 2024 on the x-axis and values ranging from 0 to 400 on the y-axis. The general trend indicates a consistent increase over time, with a noticeable acceleration in growth after 2018, peaking in 2022 at a value just above 350. After this peak, there is a slight decline between 2022 and 2024, where the value decreases but remains above 300.

- In 2014, the number of publications was close to zero.
- From 2015 to 2017, there was a very slow increase in publications.
- A significant rise in the number of publications started around 2018, with a noticeable jump from 2019 onward.
- The growth continues steadily, peaking in 2023 with over 350 publications.
- In 2024, there is a slight decline, but the publication volume remains above 300.

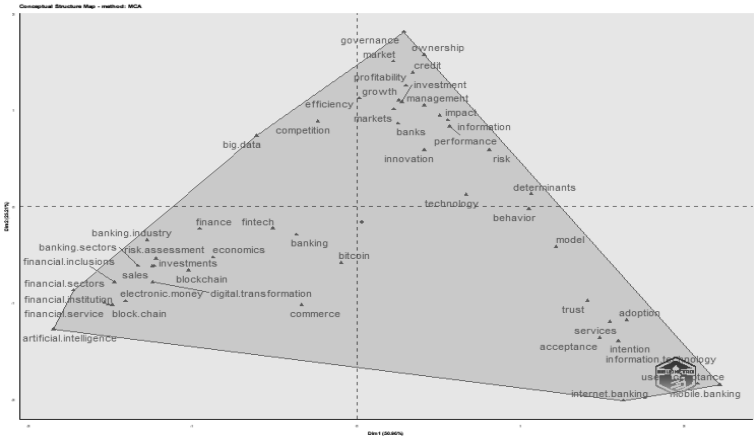
Figure 5.
Corresponding Author's Countries



(Source: Researcher's Findings)

The chart you provided illustrates the distribution of corresponding authors by country, broken down into two types of collaborations: Single Country Publications (SCP) and Multiple Country Publications (MCP). The x-axis represents the number of documents, while the y-axis lists the countries. SCP is shown in turquoise, representing publications from authors based in a single country, and MCP is shown in red, representing collaborative publications involving authors from multiple countries. China leads significantly in terms of total publications, with a vast majority being SCPs. The USA ranks second, with a more balanced mix of SCPs and MCPs. India, the United Kingdom, and Indonesia follow, with SCPs being more prominent than MCPs for each of these countries. Countries like Spain, Germany, and Sweden show a higher proportion of MCPs relative to their total number of publications.

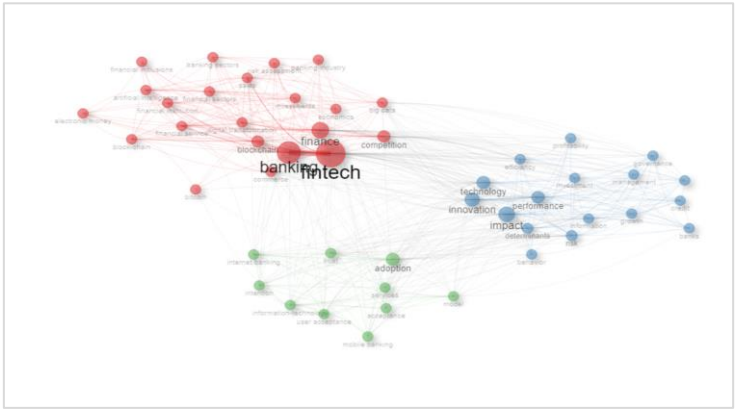
Figure 6.
Conceptual Map and Keyword Clusters



(Source: Researcher's Findings)

The triangular plot visualizes clusters of keywords related to a specific topic, likely within the realm of finance and technology. This type of plot, known as a co-occurrence or thematic map, helps identify the relationships between various terms based on their proximity and positioning within the triangle. The axes are labeled with different concepts that guide the interpretation of the terms' placements. For instance, terms like "mobile banking", "trust", "technology", and "acceptance" are grouped together, indicating a focus on user behavior and technological adoption. Terms like "governance", "ownership", "profitability", and "investment" form another cluster, pointing towards themes related to market structure, financial management, and economic performance. Closer to the bottom left, words like "Blockchain", "artificial intelligence", "financial inclusion", and "Fintech" highlight innovation and emerging technologies within the financial sector. The spread of terms suggests thematic areas related to financial services, banking, digital transformation, and related technologies like "big data" and "bitcoin". The shading of the triangle emphasizes the interconnectedness of these themes, with the overall shape suggesting how various topics like governance, technology adoption, and financial innovation interact within the broader ecosystem of finance and technology.

Figure 7.
Network of Keyword Clusters



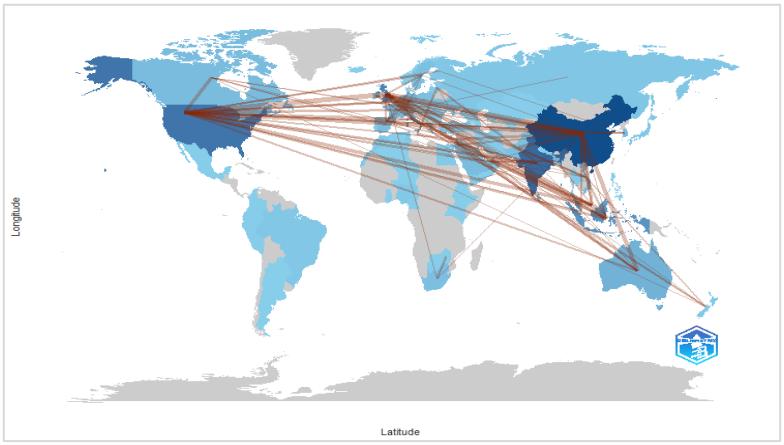
(Source: Researcher's Findings)

The image presents a network map showing the co-occurrence and relationships between keywords, likely from a research or topic analysis related to finance, banking, and technology. Nodes represent key terms, and the size of each node corresponds to its centrality or importance within the network. Lines (edges) between nodes indicate relationships or co-occurrence between the terms. The network visualization depicts the relationship between key terms in research related to Fintech, finance, and banking, organized into three primary clusters, each represented by different colors:

1. *Red Cluster (Finance and Banking Focus)*: This cluster is centered around the terms *Fintech, banking, and finance*, which are the largest nodes in the network, indicating their central role in the literature. Surrounding terms include *Blockchain, competition, banking sectors, risk assessment, financial inclusion, digital transformation, and big data*. These terms indicate that this cluster primarily focuses on the interplay between financial technologies, financial institutions, and competitive dynamics within the banking sector.
2. *Blue Cluster (Technology and Performance)*: This cluster revolves around terms like *technology, innovation, impact, performance*, and *efficiency*. Additional terms like *profitability, governance, management, credit*, and *investment* suggest that this area of research focuses on how technology drives innovation and affects performance and governance within financial services.
3. *Green Cluster (Adoption and User Behavior)*: The green cluster focuses on terms like *adoption, trust, acceptance, services, internet banking*, and *mobile banking*. This part of the network likely emphasizes studies related to the adoption of Fintech services, user behavior, and factors affecting consumer's acceptance of technological innovations in banking.

Overall, the visualization highlights the interconnectedness of research themes, with strong links between core topics like *Fintech, finance*, and *banking*, and subtopics ranging from *technological innovation* and *competition to user adoption* and *performance outcomes*.

Figure 8.
Global Collaboration Network



(Source: Researcher's Findings)

This map illustrates the global collaboration network in Fintech research based on co-authorship connections between countries. The darker shades of blue represent countries with a higher volume of research output, while lighter shades indicate less involvement.

Fintech and Financial services

This table summarizes key studies exploring various aspects of Fintech and its impact on different sectors, with each study focusing on a unique area of Fintech-related analysis.

Table 2.
Review of Research

Authors	Description
(Jun and Yeo, 2016)	This study shows the impact of Fintech firms' entry on competition in the retail payments market using a two-sided market model with vertical restraints. The key findings are: Entry of Vertically Integrated Providers, the entry of Downstream-Only Providers and the Regulatory Role. This suggests that regulation plays a critical role in fostering competition and achieving desirable outcomes in the retail payments sector following Fintech entry.
(Buchak et al., 2018)	This study examines the rapid growth of shadow banks, particularly online "Fintech" lenders, in residential mortgage origination between 2007 and 2015. The research highlights two main factors contributing to this growth: regulatory differences and technological advantages.
(Dranev et al., 2019)	This paper analyzes the impact of Fintech acquisitions on the post-acquisition performance of acquiring firms, focusing on abnormal returns from an investor's perspective.
(Palmi´e et al., 2020)	This study examines the growing importance of ecosystems in driving disruptive innovations, opposed to standalone firms, with examples like Apple and Uber. The paper highlights that academic research has largely overlooked the role of ecosystems in the context of disruptive innovations. To address this gap, the study: defines disruptive innovative ecosystems, impact on the Financial Services Industry, and outlines a future Research Agenda.
(Barbu et al., 2021)	This paper analyzes customer experience (CX) in the Fintech sector, focusing on its determinants and outcomes. Using the stimulus-organism-response (S-O-R) framework, the study proposes a model where customer experience is shaped by the customer's evaluation of the stimuli offered by Fintech firms.

(Source: Researcher's Findings)

This table reviews some studies related to Fintech and crowdfunding, offering insights into different aspects of Fintech's growth and its relationship with investment strategies, technology, and portfolio diversification.

Table 3.
Fintech and Crowdfunding

Authors	Description
(Lee & Shin, 2018)	This article explores the transformative impact of Fintech on the financial industry, presenting it as a disruptive innovation reshaping traditional markets. It discusses the ecosystem of the Fintech sector, highlighting the various components and players. Different Fintech business models and investment types are explored, show casing the diversity in the sector. The article introduces the concept of using real options for Fintech investment decision-making, providing a strategic framework for investors. Finally, addresses both technical and managerial challenges faced by Fintech startups and traditional financial institutions.
(Haddad & Hornuf, 2019)	This study examines the economic and technological factors that drive entrepreneurs to create Fintech ventures. It shows that Countries with more developed economies and greater availability of venture capital experience higher rates of Fintech startup formation. A strong technological infrastructure, including the number of secure internet servers, mobile phone subscriptions, and a well-developed labor force, positively influences the growth of Fintech startups. In countries where companies face greater difficulty accessing loans, there is a higher likelihood of Fintech startup formation. The study concludes that Fintech startup growth can be strategically encouraged through active policies rather than relying on random market forces.

Authors	Description
(Huynh et al., 2020)	This study explores the role of AI, robotics stocks, and green bonds in portfolio diversification amid the 4th industrial revolution, AI advancements, and environmental challenges. Using daily data from 2017 to 2020, the study focuses on tail dependence and volatility connectedness. Key findings include: the study highlights the need for cautious diversification when including AI, robotics stocks, and green bonds in a portfolio due to high volatility and interconnected risks.
(Le et al., 2021)	This study showes the connectedness and volatility spill-over among Fintech, green bonds, and cryptocurrencies during the 4th industrial revolution using data from November 2018 to June 2020. It highlights the importance of cautious portfolio construction, particularly when combining Fintech with other assets, due to the high levels of connectedness and volatility.

(Source: Researcher's Findings)

The table provides a comprehensive overview of studies that explore the intersection of Fintech and the financial industry, with a focus on how new technologies like Blockchain and decentralized finance are reshaping the landscape.

Table 4.
Fintech and Financial Industry

Authors	Description
(Leong et al., 2017)	This case study examines the development of a Chinese Fintech company offering micro-loans to college students, highlighting key lessons for organizations navigating financial sector disruptions. Overall, the study presents five lessons for managing challenges and leveraging opportunities in the evolving financial landscape. It underscores how digital technologies are reshaping traditional financial systems, offering both opportunities and challenges.
(Gomber et al., 2018)	This study examines the significant impact of new technology innovations and disruptions in the financial services industry, driven by the "Fintech Revolution and highlights the need for traditional financial firms to adapt to Fintech innovations or risk losing dominance.
(Du et al., 2019)	This study explores how organizations can effectively implement Blockchain technology, addressing the following gap in existing research studies have mainly focused on Blockchain's potential impacts. Using the affordance-actualization (A-A) theory as a framework, the study presents a case of successful Blockchain implementation.
(Chen & Bellavitis., 2020)	This article assesses the impact of Blockchain technology on decentralized financial services (DeFi) and their potential to reshape the financial industry. Some important points of this article are: Blockchain can lower transaction costs, build distributed trust, and support decentralized platforms, forming a new foundation for business models. (DeFi) has the potential of transforming modern finance and creating new opportunities for innovation and entrepreneurship, while also addressing the associated challenges.
(Garg et al., 2021)	This study evaluates the perceived business benefits of implementing Blockchain technology in the banking sector and develops a measurement instrument for these benefits. The study highlights both the scientific and societal importance of its practical and theoretical contributions.
(Tao et al., 2022)	This study examines whether Fintech development contributes to a reduction in carbon and greenhouse gas emissions, addressing environmental concerns associated with high electricity consumption in cryptocurrency mining.

(Source: Researcher's Findings)

This table provides an overview of key research studies on Fintech and credit sourcing, focusing on Fintech's role in transforming credit access, especially for small businesses and unbanked populations. The table highlights how Fintech innovations such as crowdlending, Blockchain, mobile payments, and mobile money transform credit sourcing and financial inclusion across different sectors and regions. This table

emphasizes the need for strategic approaches to promoting Fintech adoption, considering both the technological infrastructure and behavioral factors of potential users.

Table 5.
Fintech and Credit Sourcing

Authors	Description
(Maier., 2016)	This article examines the growing phenomenon of consumer crowdlending in small and medium enterprises (SMEs), facilitated by platforms acting as intermediaries.
(Larios-Hernandez., 2017)	This article explores the role of Blockchain technology in promoting financial inclusion, particularly for the two billion people in developing economies with limited or no access to formal financial services. The article provides insights for Blockchain entrepreneurs to better understand and address the financial habits of the unbanked population, promoting innovative, semi-formal financial solutions.
(Stewart & Jürjens., 2018)	The purpose of this study is to empirically analyze the key factors that influence the adoption of financial technology innovation in the country Germany. He authors demonstrated that the number of mobile users in Germany is rapidly increasing; yet the adoption of Fintech is extremely sluggish. It is intriguing to reckon that 99 per cent of respondents had mobile devices, but only 10 per cent recognized Fintech
(Lee et al., 2019)	This study investigates the factors influencing the adoption of platform-based mobile payment services from both consumer and retailer perspectives, filling a gap in existing research that primarily focuses on consumers. Some key points include: Two-sided Market: The study presents an integrated model that explores how consumer and retailer adoption of financial technology mutually influence each other within a two-sided market framework. Consumer vs. Retailer Perspectives: The analysis separately examines the factors affecting financial technology adoption from each perspective, providing a comprehensive view of both sides of the market.The study also highlights the interdependent nature of financial technology adoption by consumers and retailers, providing valuable insights for understanding and promoting the widespread use of mobile payment platforms.
(Senyo & Osabutey., 2020)	This study examines the factors influencing the adoption of mobile money, a Fintech innovation aimed at deepening financial inclusion, using the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) and Prospect Theory.The study sheds light on the technological and behavioral antecedents to Fintech adoption and offers guidance for promoting broader usage.

(Source: Researcher's Findings)

Studies presented in this table collectively highlight the growing influence of Fintech in the lending sector. They illustrate how Fintech innovations, such as alternative data usage and Blockchain technology, broaden access to credit, improve lending efficiency, and enable financial institutions to serve traditionally underserved or high-risk populations. Fintech is crucial in enhancing credit access in underserved regions and for small and medium-sized enterprises (SMEs), often facilitated through larger banks leveraging technological advancements.

Table 6.
Fintech and Lending

Authors	Description
(Jagtiani & Lemieux., 2018)	This paper examines the impact of Fintech on expanding credit access, using account-level data from Lending Club and Y-14M data from U.S. banks. It highlights Fintech's potential to reach consumers who may not have access to traditional banking services, especially in underserved regions and struggling economies.
(Jagtiani & Lemieux., 2019)	This study examines the use of alternative data by Fintech lenders, specifically comparing loans made by Lending Club with similar bank-originated loans. This .study highlights Fintech lenders' growing reliance on alternative data to assess creditworthiness, which enhances credit access for certain borrowers.

Authors	Description
(Thakor., 2020)	This paper reviews the literature on Fintech and its interaction with banking, focusing on innovations in payment systems (e.g., cryptocurrencies), credit markets (e.g., peer-to-peer lending), and insurance particularly Blockchain-assisted smart contracts.
(Sheng,, 2021)	This study investigates the effect of Fintech on banks' ability to provide credit to small and medium enterprises (SMEs) in Chinese provinces from 2011 to 2018. The findings indicate that Fintech significantly enhances banks' credit supply to SMEs, with a more pronounced impact on large banks compared to smaller ones. The study suggests that leveraging Fintech may be more crucial for increasing SME credit access than merely expanding the number of small banks. This highlights the potential of Fintech to improve credit availability for SMEs, particularly through larger financial institutions.

(Source: Researcher's Findings)

Classification of articles by Fintech business model

This table categorizes various research topics within the broader field of Fintech. It highlights key areas of study, including Fintech adoption, problems, trends, challenges, and innovations, along with the associated academic research.

Table 7.
Research on Fintech (in general)

Topic	Research
Adoption	(Mathur et al., 2018), (Fernando et al., 2018), (Nomakuchi, 2018),(Ryu, 2018), (Iman, 2018), (Stewart et al., 2018), (Huei et al., 2018), (Hu et al., 2019)
Problems	(Wang., 2018)
Trends	(Gimpel., 2018), (Gai et al., 2018), (Hatammimi & Krisnawati, 2018), (Jin et al., 2019), (Pantielieiev,a et al., 2018), (Mehrotra, 2019), (Shim, 2019), (Eickhoff et al., 2016), (Basole et al., 2018), (Riyanto et al., 2018), (Haddad et al., 2019)
Challenges	(Lee et al., 2018), (Gomber et al., 2017), (Anagnostopoulos, 2018), (Hung et al., 2016), (Kim & Hong, 2016), (Dimbean-Creta, 2017), (Muthukannan et al., 2017), (Ivashchenko et al., 2018), (Abubakar & Handayani, 2018), (Xiang et al., 2018), (Milian et al., 2019)
Innovation	(Gomber et al., 2018), (Puschmann, 2017), (Coeckelbergh, 2016), (Soloviev, 2018), (Drasch et al., 2018), (Tsai et al., 2017), (Wonglimpiyarat, 2017), (Azarenkova, 2018)

(Source: Researcher's Findings)

This table offers a comprehensive look at the research landscape surrounding payment, clearing, and settlement systems. The studies address the growing adoption of digital payment technologies, the problems associated with current systems, emerging trends, challenges in implementation and security, and the innovations driving the future of financial transactions.

Table 8.
Research on Payment, Clearing, and Settlement

Topic	Research
Adoption	(Chang et al., 2018), (Bello et al., 2019), (Nabila et al., 2018) , (Chandra et al., 2018), (Wiradinata, 2018), (Ting et al., 2016), (Riskinanto et al., 2017), (De Luna, 2019), (Kalinic et al., 2019), (Kelana et al., 2017)
Problems	(Armey et al., 2014)
Trends	(Dahlberg et al., 2015), (Lin et al., 2018), (Omarini, 2018)
Challenges	(Moon et al., 2016), (Ogbanufe et al., 2018), (Kang., 2018)
Innovation	(Lai, 2018), (Liu et al., 2015), (Heredia Salazar., 2017), (Iman, 2018), (Chiu, 2017), (Ashta et al., 2018)

(Source: Researcher's Findings)

Research on Risk Management and Investment

This table provides an overview of the current research on the adoption, problems, trends, and innovations in the Fintech ecosystem, showcasing how new technologies are being integrated into financial systems while addressing their challenges. The studies emphasize the importance of innovation and regulatory frameworks in shaping the future of Fintech.

Table 9.
Research on Risk Management and Investment

Topic	Research
Adoption	(Abdullah et al., 2018), (Belanche et al., 2019)
Problems	(Alexeev, 2019)
Trends	(Liu et al., 2018), (Kumari et al., 2017), (Lee, 2019), (Faloon et al., 2017)
Innovation	(Day et al., 2018), (Serrano, 2018), (Jung et al., 2018) , (Stoeckli et al., 2018), (Marafie et al., 2018)

(Source: Researcher's Findings)

Discussion and Conclusion

This paper conducts a bibliometric analysis to explore the topic of Fintech as a disruptor in the financial sector. Bibliometric analysis is a relatively recent research method that has gained increasing popularity across various academic disciplines, including finance. It falls under the broader field of scientometrics, which focuses on studying the quantitative aspects of science and research. This methodology involves analyzing bibliometric data, such as publication sources or documents, using quantitative approaches. As a result, researchers can efficiently organize information by visually mapping the existing literature. This method also facilitates the identification of key research trends and the most frequently cited authors and papers within a vast collection of academic publications on a specific topic. Therefore, bibliometric analysis helps in finding and categorizing relevant data. The findings of this analysis provide a broad perspective on Fintech as a financial disruptor. Through this paper, the authors aim to generate greater interest and encourage more in depth research on the topic. The social and economic effects of the disruption caused by Fintech are especially promising areas for future investigation. Social capital, defined broadly as the resources and benefits derived from interpersonal relationships and networks, plays a significant role in Fintech's success and its ability to foster inclusion, trust, and innovation (Mostafazadeh et al., 2014)

Here are some examples of future research suggestions:

1. Impact of Emerging Technologies on Privacy and Security in Fintech: One area that requires further investigation is the impact of emerging technologies, such as AI and Blockchain, on the privacy and security of user data in the Fintech industry. Future research could explore the challenges of protecting sensitive customer data from cyber-attacks and breaches. This issue is particularly critical in countries with stricter data security regulations.
2. Role of Fintech in Reducing Financial Inequality in Developing Countries:

Research can examine how Fintech helps increase access to financial services in underserved communities and developing countries. Specifically, the impact of mobile payment systems and digital banking services on reducing economic and social inequalities could be an attractive topic for future researchers.

3. Social and Environmental Impacts of Fintech Services: Given the growing trend of environmental sustainability and social responsibility, future research could investigate Fintech activities' social and environmental impacts. For example, studying how Fintech startups support sustainable businesses and facilitate investment in green projects is a novel and less-explored area.
4. *Effects of financial policies and government regulations on innovation in Fintech* Another important topic in Fintech that requires more research is the impact of government regulations and financial policies on innovation in this field. Researchers can examine how strict or facilitative policies affect the adoption speed of new technologies in Fintech. For instance, future research can examine the impact of anti-money laundering regulations on innovations related to digital currencies and international financial transactions.
5. *Relationship between user experience and adoption of Fintech technologies in different communities*: One area for future research could be studying the impact of user experience (UX) design and user interface (UI) design on the adoption of Fintech by users in different communities. Specifically, examining cultural and regional differences accepting Fintech technologies and their impact on the development of digital financial services globally could be an interesting research topic.

These suggestions, in addition to opening new doors for research, can spark readers' interest in emerging topics in Fintech and contribute to advancing the academic field.

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Smart Treasury: Leveraging Artificial Intelligence and Robotic Process Automation for Financial Excellence

Ali Shirzad[1*] | **Ali Rahmani**[2]

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Ali Shirzad
Corresponding Author, Postdoc Researcher, Department of Accounting, Faculty of Social and Economic Sciences, Alzahra University, Tehran, Iran.
E-mail: a.shirzad@alzahra.ac.ir

Ali Rahmani
Professor, Department of Accounting, Faculty of Social and Economic Sciences, Alzahra University, Tehran, Iran.
E-mail: rahmani@alzahra.ac.ir

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ABSTRACT

This research study aims to investigate the role of Artificial Intelligence (AI) in efficient management of public financial systems and treasury functions. AI involves a broad array of knowledge, including various concepts, methodologies, strategic tools, and diverse applications. It can be defined as the study of systems that gather inputs from the environment and respond through actions. Using AI in financial management and treasury presents distinct challenges and opportunities, as many treasury tasks have transitioned from physical to virtual processes, with automation advancing quickly. Financial and treasury teams are largely made up of knowledge workers who make decisions and perform analyses within dynamic frameworks. These frameworks must take into account both external and internal factors, as well as the effects of any actions on treasury outcomes. AI in finance and treasury functions closely mirrors the complexity of human nervous system, as it extends well beyond the basic automation. Like the nervous system, AI in these fields must process data rapidly and accurately, handling tasks such as data collection, classification, and integration into broader datasets. Today, neural networks within AI have advanced significantly and are widely applied across various treasury management areas, including early fraud detection, risk assessment, liquidity management, debt management, financial data quality control, extraction of hidden financial insights, accounting, and financial reporting. This review article aims to introduce readers to the various areas where AI can be applied in treasury operations, while also highlighting opportunities for enhancing accounting practices and driving digital transformation in treasury management. Additionally, it explores some potential research areas within these two fields.

KEYWORDS

Artificial Intelligence, Machine Learning, Public Financial Management, Robotic Process Automation, Treasury Management.

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Introduction

Given the environmental changes and the increasing advancements in the field of information and communication technology, using these technologies is essential for transforming the financial system of the country. Undoubtedly, strategic planning in various areas of public financial management, including government and public debt management, liquidity management, governmental financial reporting, risk management, financial oversight, and payment management, requires access to documented, reliable, and timely statistics and information. The Ministry of Economic Affairs and Finance has initiated the major project called "Transparency and Smartening of Government Financial Operations" to effectively utilize the capabilities of information technology in optimizing its missions and responsibilities. This project is pursued as one of the key and central projects of the ministry and holds unique importance and complexity.

One of the most important focal points in the project for the transparency and smartening of government financial operations is resource management. Given the existing budgetary constraints, optimal management of these resources, including avoiding the accumulation of liquidity in executive agencies, becomes crucial. Therefore, direct payments to final beneficiaries are a solution that the legislator has emphasized, obligating the Treasury to provide the necessary infrastructure for this purpose. Direct payments to the final beneficiaries, are an important and complex issue. The prominent and unique position of e-government and the widespread growth of information technology applications provide a valuable opportunity to create substantial effectiveness in resource management and achieve the goal of direct payments to the final beneficiaries. Given the government's serious need for electronic and informational systems, utilizing the emerging and advanced tools such as AI is very serious and essential.

AI technology is utilized to prevent the accumulation of government financial resources, enhance financial discipline, ensure transparency in public financial management and the Treasury, detect risks and fraud, manage accounting and financial reporting in the public sector, allocate budgetary resources efficiently and purposefully, strengthen the financial and accounting system, manage liquidity, manage debt, control the quality of financial information data, and extract hidden financial data.

AI considers the idea of replicating human talents such as creativity, self-correction, and language use. Additionally, AI is the only field that aims to create machines that can operate autonomously and automatically in complex, changing environments. AI is a broad branch that includes concepts, approaches, strategic techniques, and numerous applications, and it can be understood as the study of propositions that receive perceptions from the environment and take action accordingly (Polak et al., 2018).

AI is a central focus of global research; however, much of the research in this field remains fragmented and unstructured. This is particularly evident in the areas of financial management and treasury, where knowledge is often isolated and incomplete, terminology is inconsistent, and the number of studies on the topic is limited. One of the primary goals of this paper is to clarify the knowledge and terminology related to AI in

financial management and treasury, addressing the current lack of coherence in this field. Additionally, the paper will explore different forms of automation and AI, explaining their implementation, as well as discussing the advantages and challenges of applying these advanced technologies in public financial management and treasury (Polak et al. 2019).

Literature Review

Functions of Treasury

Many important components of the public expenditure management system are covered and supported by the Treasury. The vital functions of the Treasury include securing and transferring cash in line with annual budget, financial planning, controlling budget consumption processes, managing government cash flows, managing financial assets and debts, and accounting and internal auditing of budget execution. Public expenditure management will be effectively achieved when the government establishes powerful mechanisms and executive agencies (institutions) to support the desired functions (Pattanayak, 2016).

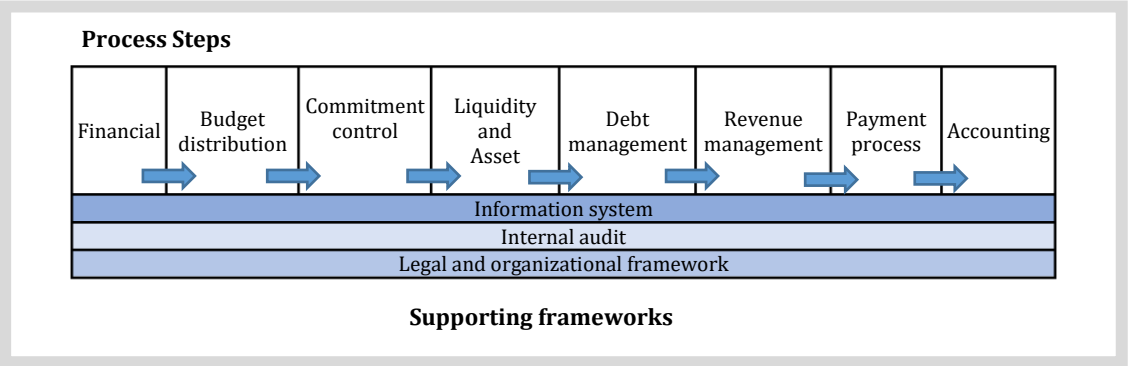
Patnaik (2016) states that the design of the treasury system is unique and varies according to the conditions of each country. In some countries, the Treasury is an independent organization with a wide network of departments that holds significant power and is largely accountable. In other countries, different treasury functions have been delegated to various sectors of the government to reduce centralization. Governments must ensure the efficient execution of the budget and good management of their financial resources, provide the necessary credits for the timely implementation of the budget to cost units, and minimize the cost of government borrowing. Additionally, proper management of financial assets and liabilities is essential. Government financial management involves a range of activities, including the formulatingfiscal policy, preparating and executing budget, controlling financial operations, enforcing accounting laws and controls, maintaining and recording historical and comparative data, and auditing the financial performance and outcomes of government policies and programs. Within this broad scope, the Treasury aims to achieve specific objectives, which may include some or all of the following:

- Cash Flow Management
- Supervision of Government Bank Accounts
- Financial Accounting and Reporting
- Budgeting and Cash Flow Forecasting
- Administrating Government Debt and Guarantees
- Monitoring Foreign Grants and International Aid Funds
- Managing Financial Investments and Assets Figure (1) describes a specific value chain as a comprehensive treasury system (Tendberg, World Bank, 2005). This figure presents a set of important functions that are defined as treasury functions in most countries. The value chain describes the process of producing (services) within the Treasury system. The value chain can serve as a framework for

analyzing the components or arrangement of the processes in a treasury system within a specific country.

The value chain and its processes highlight the importance of each component. It addresses how each of these functions and decision-making processes can be delegated to other government organizations or how needs can be met through a network of private sector resource providers by referring to these processes. The main criterion for decision-making regarding which components are included in the Treasury system is the value creation of that process and its position within the value chain.

Figure 1.
The Value Chain of Treasury



(Source: World Bank, 2005)

In Iran, the General Treasury, considering its importance and position in the public finance system from the perspective of the Constitution and conducting studies and the latest revision of the structure and responsibilities of the General Treasury, consists of three main subunits:

1. Center for the Management of Public Debt and Government Financial Relations;
2. Deputy for Treasury Affairs and Government Financial Reporting;
3. Deputy for Financial Supervision and State Assets.

In this context, the role of the functions of the General Treasury in Iran is crucial. Based on the conducted studies, the overall responsibilities of the Treasury of Iran can be summarized as follows:

- Management of government public expenditures
- Budget management and commitments control
- Management of bank accounts
- Management of public resources and risks
- Management of government accounting and financial reporting
- Management of auditing and financial supervision

It should be noted that the application of AI using information technology to generate hidden and effective information for predicting financial resources is not possible without reforming the structure of the financial system. Budget control and financial commitments, management of public resources, management of financial information,

alertness of liquidity shortages and commitments, risk management, and quality control of financial reports can only be achieved through smart automation and transparency of government financial operations. The impact of reforming the methods used in the General Treasury, particularly the organization of state-owned enterprises, will lead to increased financial controls, transparency, and fiscal discipline. The management of public funds can only be facilitated by centralizing accounts in the central bank, which will enable oversight and monitoring of government public resources and expenditures. The establishment and development of AI in the Treasury will be carried out by identifying and documenting current processes and formulating a desirable architectural document, as well as transitioning from traditional to modern systems. The publication of financial reports at government level to enhance accountability in financial and operational matters through AI and the creation of a comprehensive financial system database for forecasting and financial planning in macroeconomic policies will increase the added value of public services and ensure continuous oversight of the budget and financial performance of the government (Polak et al., 2019).

Artificial Intelligence, Robotic Process Automation (RPA), and Treasury Management

The government is required to take actions to reform the financial and accounting system and improve the operational methods used in the General Treasury in accordance with relevant laws. This will be done to achieve the objectives of the announced general policies of the resistance economy, which call for a fundamental transformation in structures and the reform and enhancement of the financial management and accounting system (Article 8 of the Sixth Development Plan Law). To achieve a smart treasury, one must pass through the path of a digital treasury, with the primary goal of the General Treasury being the full establishment of AI.

Treasuries can be categorized based on their level of adoption of AI and machine learning into high, medium, and low adoption levels. This trend often follows a predictable pattern within a country. Although the tools and infrastructure for AI in the Treasury are still in their early stages, it is anticipated that treasury management systems that have effectively integrated and utilized AI will enhance certain treasury functions and deliver genuine added value (Polak et al., 2019). AI, Machine Learning, and RPA have begun to make a significant impact on treasury management. While many of these technologies are still in the early phases (e.g., handling basic tasks such as monitoring liquidity, forecasting cash flow, and automating repetitive processes), they mark the start of a major transformation. Initially, AI enabled the treasuries to automate processes related to paper payments and remittance data. AI is often defined as the capability of machines to perform tasks that were once considered intelligent human activities. Machine learning, a subset of AI, focuses on utilizing data and statistical techniques to allow machines to learn and improve on their own, without the need for explicit programming (Polak et al., 2019).

In the near future, pattern recognition, machine learning, RPA, and advanced AI are expected to become integral parts of the standard treasury processes. In some cases, the terms data analysis" in general literature and "data analysis" in the context of machine

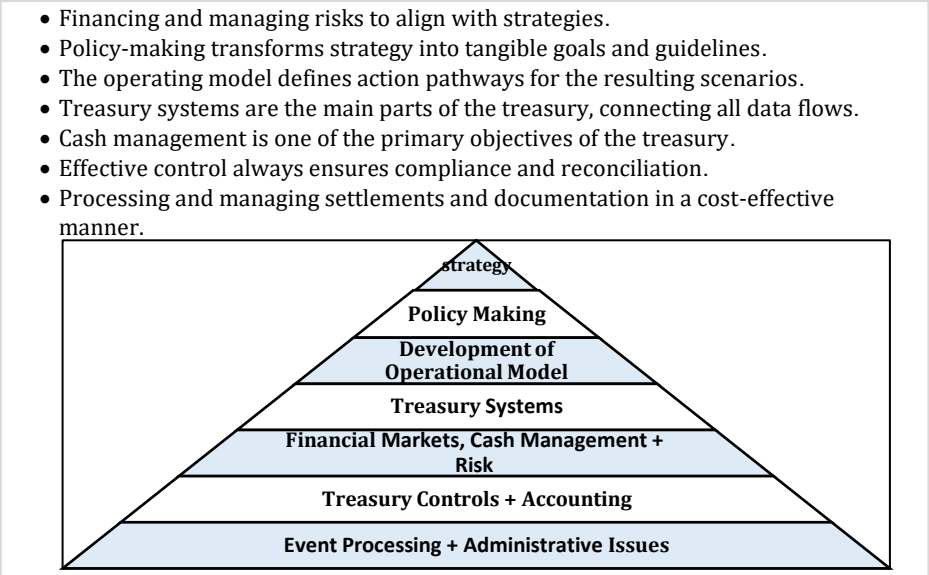
learning and AI may be used interchangeably. Although we are still in the early stages, it is clear that the application of AI in public financial management and treasury has great potential and deserves further research attention. It can be stated that AI, machine learning, and RPA have already begun to play a role in treasury management (Polak et al., 2018).

Today's computational resources and Internet-connected devices can rapidly process and store vast amounts of data in treasury management. AI techniques, especially machine learning, facilitate the collection, storage, exploration, and analysis of this data. AI can serve as a powerful tool in identifying and preventing cybercrime by detecting unusual transactions and flagging them. This capability also acts as a deterrent for cybercriminals, both within and outside the organization. Cybercrime prevention often involves a human element, offering an opportunity for treasurers to combine technology with effective people management. In data forecasting, AI enhances both accuracy and timeliness, utilizing more comprehensive and concise data that includes historical trends, budgeted, forecasted, and actual figures, all analyzed based on currency units. Additionally, this analysis is expected to be predictive. In treasury operations, AI should enable automated matching and processing to improve liquidity management, debt management, cost control, accounting and financial reporting, asset management, risk management, and internal controls. Algorithms can be created to match data, identify gaps, and fill them (Polak et al., 2019). Cash management, a key area of treasury activity, heavily depends on forecasting the cash flow, a process familiar to treasuries. Typically, past data is used to predict future cash flows, but this method fails to account for changes and developments. One of the primary objectives of the treasury is forecasting the cash flow. However, it should be noted that the level of detail, accuracy, and timing required for financial planning, in general, differs significantly from the treasury's needs. Another closely related area of treasury activity is risk management. Understanding, quantifying, and forecasting the risks with a certain degree of accuracy are crucial for effective treasury performance. When evaluating the benefits of AI and machine learning, it can be stated that simpler cash management operations are more likely to benefit from AI. AI should allow the treasury to delegate many cash flow forecasting tasks to automation, resulting in greater accuracy, reduced workload, and faster access to forecasts (Polak et al., 2019).

Technologies like RPA can significantly improve internal efficiency by reducing the time spent on administrative tasks. Some treasuries in various countries are already utilizing this technology to assist with tasks such as cash collection, financial reporting, auditing, and data consolidation. Looking ahead, as AI and RPA continue to advance, we can expect the emergence of digital assistants capable of supporting more complex and advanced tasks (Polak et al., 2019). Virtual advisors can assist treasurers in performing several essential tasks more efficiently. These tasks may include advising on the best strategies for optimizing liquidity, conducting complex risk assessments, managing immediate risks, and enhancing forecasting accuracy. By leveraging technology,

treasurers can save time, allowing them to focus on broader goals such as fostering innovation and planning for the future (Figure 2).

Figure 2.
The Value Pyramid of the Treasury

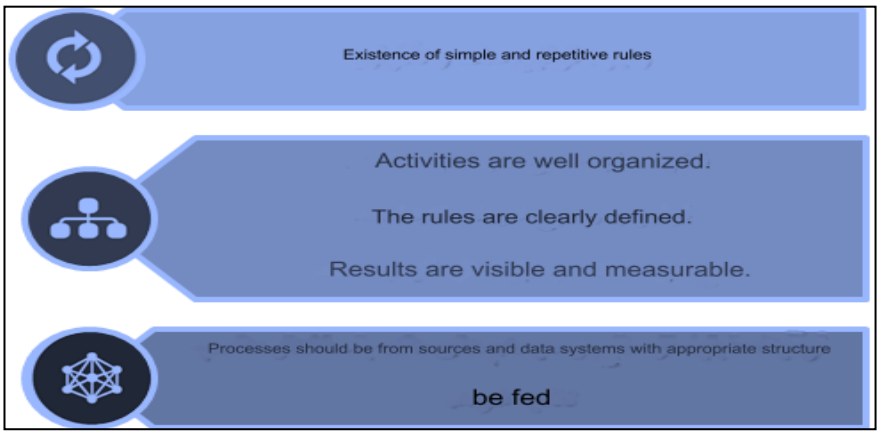


(Source: Polak et al., 2019)

AI should enable the treasury to make numerous cash flow forecasts with greater accuracy, reduced workload, and quicker access to such forecasts. RPA automates routine tasks, even knowledge-based tasks, such as cash position management and bank account opening. In treasury operations, especially in daily cash risk management, it is expected that AI will assist in skill development and further automation of classic primary activities such as cash position management. These tasks follow a well-defined logic and are performed within specific parameters. Like all change initiatives, demonstrating tangible benefits and progress is necessary and beneficial to garner and maintain organizational support and sustain project momentum. Quick success in implementing AI at a visual level, with observable tactical benefits, can significantly help in gaining support within the organization regarding the impact of using AI in the Treasury.

For instance, further automation can be introduced in cash position management by utilizing the existing data. In back-office operations, AI can help detect exceptions and identify unusual activities. Practical applications include monitoring reconciliations, verifying settlement accuracy in compliance with laws and regulations, and reporting on liquidity status. Although some of these tasks have already been partially automated, there is still room for improvement, and opportunities for quick gains remain. Moving forward, the Treasury should assess the current datasets, organize and make them accessible, and identify the resources and storage locations, as well as the data format. The next step is to leverage this data by establishing logical connections between them to support the identified workflows (Figure 3).

Figure 3.
Robotics and Automation in Treasury Management



(Source: Polak et al., 2019)

Automation Framework and Common Gateway Interface (CGI)

The challenge in treasury management and AI is that most treasury functions have shifted from physical processes to virtual ones, which are becoming increasingly automated and activated. These processes, including decision-making and analysis within frameworks that account for both environmental and internal factors, must be evaluated for their impact to guide decision-making (e.g., in areas such as risk management, resource management, and cash management) (Figure 4).

Figure 4.
Intelligent Automation Network and Framework

Primary Automation	Robotic Process Automation	Advanced Process Automation	Algorithmic Automation	Artificial Intelligence
Human-initiated Rule-based Unit system Macros, workflows	Initiated by humans or systems Rule-based processes, high volume (IT) Structured data Multiple systems Organizational level	Support for fundamental analytics / decision-making support Optical character recognition (OCR) Intelligent document processing Structured and unstructured data Simple chatbot (e.g., FAQs)	Complex processes and decisions Supported by predictive analytics Machine learning, limited intelligence, basic reasoning Unstructured and big data Language processing, chatbots	Cognitive technology capable of mimicking human capabilities, including empathy Full autonomy, hypothesis generation, reasoning Deep learning, deep neural networks Complete speech recognition and generation Fully capable virtual agents Virtual reality

(Polak et al., 2021)

Based on the information presented above, it can be said that the treasury management may currently be involved in all of these "types" of automation (Table 2).

Table 1.
Types of Automation in Financial and Treasury Management

Types of Automation	Example
Basic Automation	Instead of manually collecting bank data to integrate cash positions, this process is now automated through software and technology that collects the data and calculates the liquidity status.
Robotic Process Automation	When the treasury has surplus cash, an investment proposal is submitted within the framework of laws and regulations. This proposal can either be approved and executed manually, or, if it falls within set parameters, can be automatically executed through simple financial calculations.
Advanced Process Automation	Remittances sent in PDF format are automatically decoded using Optical Character Recognition (OCR). Fields are assigned based on predefined terms and their placement within the remittance document. This process eliminates the need for manual data entry or physical interaction with the image fields, replacing them with variable-based automation.
Algorithmic Automation	Automated predictive models evaluate the optimal coverage within legal structures, incorporating balance sheet cash, options, and future contracts, and recommend the most effective strategy. The Treasury staff can interact with the banking portal using natural language, addressing issues without needing to directly communicate with a banker, through a "virtual assistant."
Artificial Intelligence	Collection strategies leverage human analytics, incorporating messages for debt collection, inferring treasury behavior, managing liquidity, and facilitating smart payments.

(Source: Researcher's Findings)

It should be note, It can be said that all RPA solutions have been published by the four major auditing firms in the world.

Treasury Activities Prone to Automation

The concept of AI was first introduced in 1956 and refers to systems that enable intelligent actions through rule-based and automated processes. AI involves simulating human intelligence, including learning, reasoning, and self-correction. It can swiftly and accurately classify data, process it, and integrate it back into its original location. Over time, AI's neural networks have improved significantly and are now widely applied in treasury management, including areas like early detecting liquidity crises and risks, controlling financial data quality, and uncovering hidden financial information. Expert systems, a more advanced form of AI with specialized professional understanding, can address complex challenges faced by organizations. In the treasury field, AI systems can address various issues related to accounting and finance. AI in treasury management is not a centralized effort but a decentralized collaboration through technology initiatives such as RPA, treasury management systems, and the procurement of tools and services

that support managing liquidity and risk, accounting, analyzing, and forecasting. New technologies from financial service companies are continuously reshaping how treasuries interact with executive devices (Polak et al., 2019). RPA is starting to transform treasury functions by automating low-value, repetitive tasks, while AI facilitates the execution of cognitive tasks based on historical data and machine learning. Treasuries globally are identifying areas that are suitable for automation and AI implementation. The most important areas of focus for these technologies are outlined in Table 2 (Polak et al., 2019).

Table 2.
Treasury Activities Susceptible to Automation

Activities	Planning	Control	Execution
Financial Operations	Financial Procedures and Regulations	Authority and Delegation Limits Reconciliation Operations Monitoring Financial Policies	Payroll Accounting Expense Processing Accounting Deductions Fixed Assets Accounting Project Accounting Receivables Processing Payables Processing Procurement
Cash Management	Liquidity Planning Treasury Procedures and Regulations Investment Portfolio Planning Investment Procedures and Regulations	Reconciliation of Bank Statements Performance Monitoring	Cash Forecasting and Management Cash Management Operations Portfolio Management Investment Modeling Debt Management Buying and Selling Securities Settlement
Payment Management	Treasury Procedures and Regulations	Limitations on Expense Amounts Limiting the Time Horizon of Expenses Control at Various Stages of Payment	Expense Authorization Allocation of Authorization for Specific Periods and Cost Centers Cash Reserve Commitment Approval (or Certification) Payment Order Execution of Payment
Accounting	Accounting Policies and Procedures	Financial Reconciliation Review and Approval of Journal Entries	Periodic Performance Mergers
Financial Reporting	Financial Disclosure Requirements Management of Relationships with Executive Bodies	Monitoring Compliance of Reports Approval of Financial Statements	Preparation of Financial Statements Preparation of Management/Activity Reports Preparation of Compliance Reports Addressing Regulatory Inquiries
Performance Management	Management Reporting Framework Management Reporting	Performance Evaluation Integration	Management Report Performance Analysis Cost Accounting Management Creation of Dashboards and Balanced Scorecard

Activities	Planning	Control	Execution
Planning, Budgeting, and Forecasting	Procedures and Regulations Budgeting Procedures and Guidelines Strategic Planning and Goal Setting Operational Planning	Budgeting/Forecasting Model Design Monitoring Budget Policy Plan Approval	Budget Preparation Preparation of Forecasts
Risk Management and Compliance	Internal Control Framework Enterprise Risk Framework	Risk and Compliance Monitoring Control Monitoring Fraud Management	Risk Assessment and Scoring Risk Reporting Compliance and Control Reporting
Internal Audit	Internal Audit Objectives and Planning	Monitoring Audit Recommendations	Execution of Internal Audits Special Projects and Internal Consulting
Financial and Human Resources Systems	Financial Policies and Procedures Architecture of Financial Systems Workforce Planning Data Governance Strategy and Regulations Financial Service Delivery Model	Policy Monitoring Employee Performance Data Management Compliance with Financial Systems Architecture Monitoring Service Providers	Data Maintenance Management Employee Development and Retention Maintenance of Financial Systems Service Provider Management

(Source: Researcher's Findings)

Based on the information presented above, the most important applications of AI in treasury management can be outlined as follows:

A) AI and Payment Management

The Treasury manages organizational payments through a centralized payment system, which requires strategic transformation and innovation. By establishing a unified payment and settlement platform and integrating various payment channels, the treasury can achieve seamless processing across multiple access points. This platform can be applied broadly to fund transfers, payments, and settlements. An integrated enterprise payment and settlement platform consolidates scattered online transactions from different systems—such as online banking and instant payment systems—into a cohesive settlement framework, supporting a range of payment methods.

The platform can facilitate intelligent communication with payment gateways, such as banks and third-party providers, through a bot interface. Internally, it provides a single interface for all treasury systems, streamlining settlement processes and ensuring intelligent compliance with cost centers and the central bank. The system incorporates intelligent routing to select the most efficient payment path based on regulations, offering a wide variety of payment options for users through group payment methods.

Public expenditure control will be executed exclusively through direct payments to beneficiaries. The Treasury can manage costs in the public sector by delivering goods and services, fulfilling contracted agreements, issuing payment orders by authorized officials, and transferring funds to the beneficiaries. The objective of cost management is to ensure that public funds are used within set limits and in alignment with sound financial

practices. To achieve these goals, government spending generally goes through seven key stages, starting from legislative approval to the final payment to the beneficiary. These stages, which are well-suited for smart automation, include (Patnaik, 2016):

1. Authorization of Expenditures

A key principle of public finance is that both expenditure and revenue proposals must have legal authorization to ensure accountability. Expenditure authorization is usually provided through the budget law, which outlines the time frame, limits, objectives, and the responsible administrative unit for the government spending. In order to accommodate unforeseen costs, some flexibility may be allowed for reallocating funds between sectors, provided there are clear laws or criteria in place (e.g., through cash transfers or contingency reserves).

However, the budget is not the only legal mechanism for authorizing expenditures. Certain expenses can be made under permanent laws rather than annual budgets. For instance, established rules may allow for expenditures related to legal programs, debt payments, or membership fees to international organizations, which are authorized on a permanent basis but still subject to specific parameters or criteria. Nevertheless, in line with principles of transparency, comprehensiveness, and accountability, such expenditures must be documented in the budget and should be subjected to regular oversight and controls.

2. Authorization Allocation for Specific Periods and Cost Units

The allocation process aims to prevent cost units (executive bodies) from making commitments that would require additional fund approval for the current fiscal year. Once expenditure authorization is granted, funds are allocated for specific time periods and/or cost units. This process typically occurs in two phases: (1) the Ministry of Finance allocates credits on a quarterly or monthly basis to ministries, and (2) ministries or primary spending units distribute these credits to their subordinate units. Spending authority is transferred to these units through mechanisms such as guarantees or allocations. Centralized control at this stage is common across most countries and is generally overseen by the budget department of the Ministry of Finance's. This allocation process is vital for ensuring that overall expenditure limits are respected and to account for any claims or contingencies reflected in revised credit allocations. Any request for allocation or reallocation must include a financial or cash plan from the relevant ministry or spending organization, ensuring proper integration between allocation and cash management.

3. Reserve

In the public sector of some countries' financial management systems, there is a step where funds are set aside for a specific expense, even before a contract is in place. This process is referred to as "holding credit" in Spain and Portugal, and "budget commitment" in France, occurring prior to the "legal contract" or legal commitment stage. At this point, there is no formal obligation, but it is anticipated that the expense will be incurred within

the budget year, so the reserved funds cannot be used for other purposes. This reservation of funds for future expenses should not be mistaken for a legal commitment, as no official contract has been signed at this stage.

4. Commitment

The commitment stage is when a potential future payment obligation is established. It occurs when a formal action, like an order or contract, binds the government to make a payment at a later date when the other party fulfills the terms. A commitment only requires payment once the contract is executed by the third party. For ongoing expenses under a contract (such as wages, utility services, rent, and debt payments) or legal obligations (like transfers to local governments), these payments must be estimated and treated as certain liabilities. Since commitments generally become payable when the payment is due, monitoring them is crucial for managing costs and avoiding overruns. A commitment does not always mean payment will be made within the same fiscal year, especially for long-term expenses like multi-year capital projects.

5. Confirmation (or Acknowledgment)

At this stage, after the supplier has delivered goods or provided services, an authorized official in the cost unit assesses whether the delivery aligns with the contract or order, identifies the outstanding liability, and sets the payment due date. If accrual accounting is in use, the government's assets and liabilities are recorded in the books. When expenses involve an ongoing contract (such as wages, utility services, rent, or debt services) or a legal obligation (like transfers to local governments or household benefits), a confirmation is required to ensure that the commitment has matured. Expenses at this stage are often referred to as accrued expenses (as in the U.S.), payable accounts, or actual expenses. The key aspect of expenses at the confirmation stage is the creation of a liability. Additionally, there may be overdue expenses that have not been paid by the due date specified in contracts, laws, or general business terms.

6. Payment Order

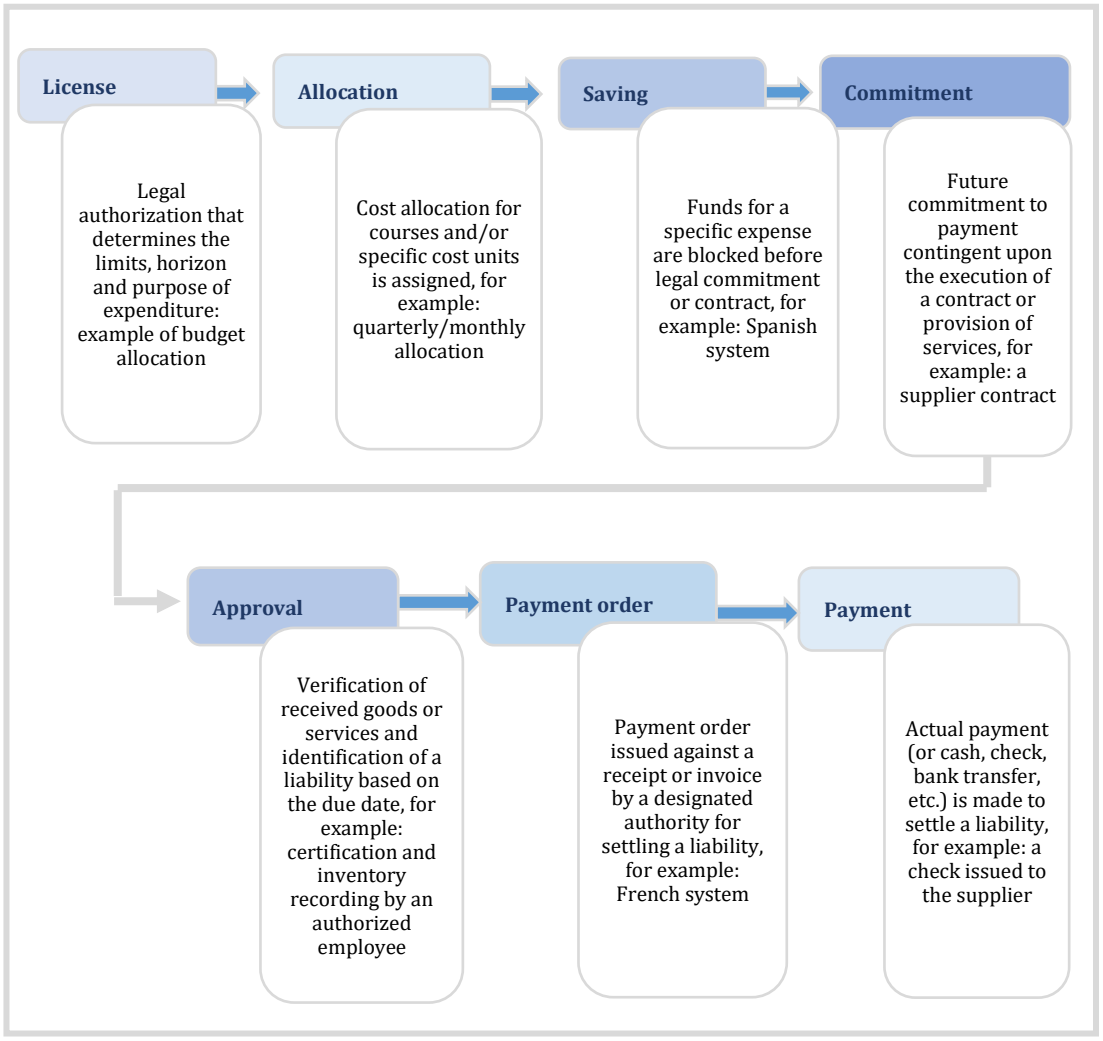
After the necessary reviews to ensure that all predetermined controls have been performed and documented, a payment order is issued. The payment order is an authorization for payment (usually against a document or invoice) issued by officials of ministries, other spending units, or the Ministry of Finance. Before issuing the payment order, the issuing authority (usually the treasury) checks whether sufficient funds are available for the payment. Once the liquidity is confirmed, a designated official approves the payment, and the payment order is issued. In cases where a centralized payment system has been established, spending units can prepare payment orders electronically and submit them through the Financial Management Information System (FMIS) for payment to the central unit/treasury.

7. Payment

Once the payment order is issued, payments are processed using different methods, such

as checks, Electronic Funds Transfers (EFT), or occasionally cash payments to the supplier or another recipient to fulfill the financial obligation. In line with internationally recognized best practices, payments should be conducted through the Treasury Single Account (TSA) system. Settling payments using revenues from the same unit is not advisable, as it undermines the transparency of reporting government revenues and expenditures at various stages.

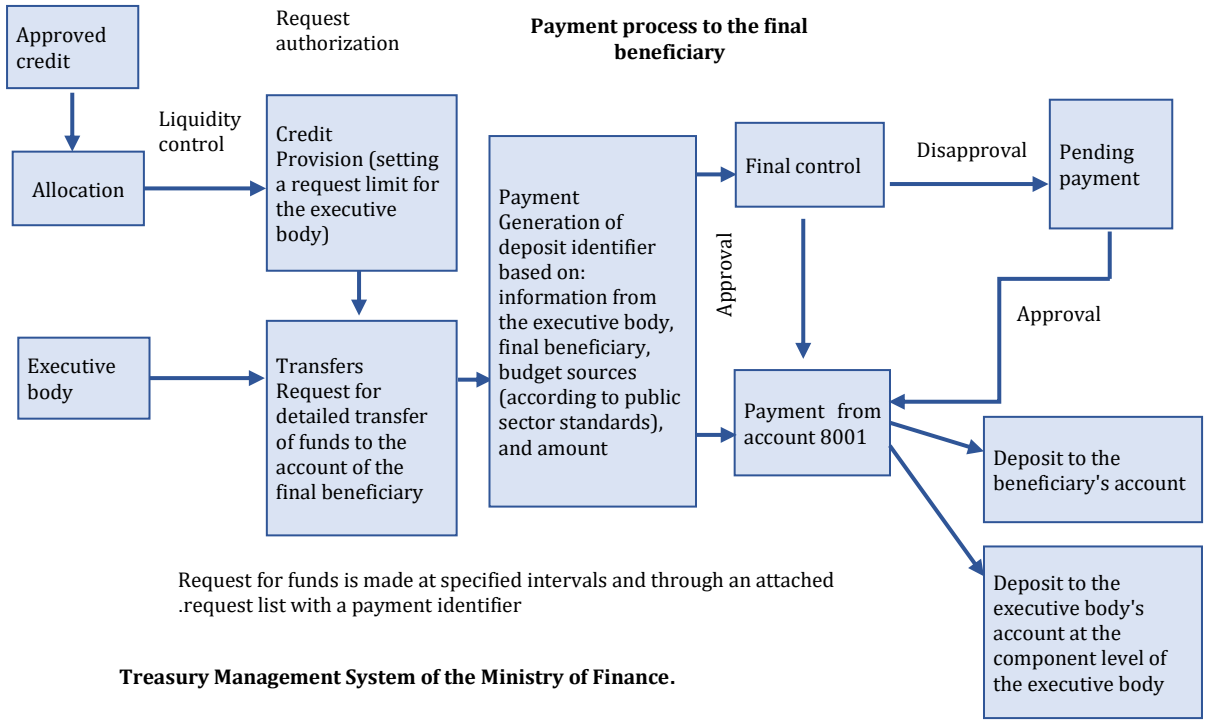
Figure 5.
The Main Stages of the Cost Chain (International Monetary Fund)



(Source: Researcher's Findings)

In the Treasury of Iran, the payment process to beneficiaries is designed as follows, and it can be automated at various stages of this process using the AI technology.

Figure 6.
The Payment Process to the Final Beneficiary in the Treasury of Iran



(Source: General Treasury, 2022)

Examining a Sample of Direct payments to the Final beneficiary and the Feasibility of Automating it

By examining the documented processes in the General Treasury, the payment process of the employee's salary was selected. The reason for choosing this process is to analyze a sample of direct payment processes to the final beneficiary. Payments based on this process are carried out in four stages, and in this section, the current status of each stage in terms of automation is reviewed, along with suggestions for automating each stage.

Stage One: Initially, the payroll list of employees from the executive agencies is uploaded to the payroll system. Based on control rules, the system generates two lists of warnings and errors. The agency must address the items on the error list and, if necessary, correct the warnings. After the payroll information of the executive agency is confirmed, it is resubmitted for alignment with the allocation. If the amount of salary exceeds the allocation, the system-generated feedback is sent to the executive agency to correct the salary information and upload it again from the beginning. If the amount of salary aligns with the allocation, a request for funds and a summary payroll list for official, contractual, and temporary employees are automatically generated and uploaded to the system after being signed by the authorized officials (The request for funds must be signed solely by the budget officer or financial manager, and the summary payroll list must be signed by the head of the agency and the budget officer or the financial manager of the agency).

Table 3.
Analysis of Stage One of the Payment Process of Employee's Salary in Iran

Current Status of Stage One	Use of Basic Automation
Automation of Stage One	**Suggestion: Use of Algorithmic Automation** After uploading payroll information, the system automatically detects certain errors, such as alignment with the allocation; however, resolving these issues is done manually by the user. In this section (alignment with the allocation and error resolution), algorithmic automation and/or artificial intelligence technology (machine learning) can be utilized to identify and rectify errors, which can enhance both speed and accuracy.

(Source: Researcher's Findings)

Stage Two: After the request for funds is submitted, warnings, the summary payroll list, the request for funds, and the relevant signatures are processed by the payroll payment expert and the head of the department. If any issues are identified, feedback on these matters will be sent to the agency, which must then make the necessary corrections and re-upload the payroll information from the beginning. If approved (this status is also visible to the agency in the system), the request for funds is confirmed by the verification department, and the relevant accounting documents, including net salary accounting documents, other deductions, and legal deductions, are generated in the accounting system.

Table 4.
Analysis of Stage Two of the Payment Process of the Employee's Salary in Iran

Current Status of Stage Two	Using Basic Automation
Automation of Stage Two	**Suggestion: Using Advanced Process Automation and Transition to AI** • Intelligent calculation and control of deductions • Intelligent detection and resolution of payroll and errors of funds' request • Intelligent creation of documents, accounting entries, and reporting • Optical Character Recognition (OCR) and intelligent document processing • Intelligent signatures of the expert and the head of the payment department

(Source: Researcher's Findings)

Stage Three: After the accounting documents are created, the head of the payroll department generates the net salary list and other deductions, along with the relevant Excel file, on the payroll system for submission to the central bank. Additionally, the agencies that need to have payments processed for them are selected.

Table 5.
Analysis of Stage Three of the Payment Process of the Employee's Salary in Iran

Current Status of Stage Three	Using Basic Automation
Automation of Stage Three	**Suggestion: Using Algorithmic Automation and Transition to AI** • In this stage, uploading the net salary list and deductions is performed by the head of the payroll department through using Excel, which can be automated using advanced automation. • Intelligent enhancement of the process for controlling the payroll list sent to the central bank.

(Source: Researcher's Findings)

***Stage Four*:** After reviewing the accounting documents issued by the Deputy and the Director General of the Treasury, the final approval is granted by them. In this case, the net salary is deposited into the relevant account at the central bank, other deductions are deposited into the agency's account, legal deductions are sent to the relevant authorities, and provincial salaries are deposited into the intermediary account of the province. Finally, the payroll department uploads the net salary list and other deductions, along with the relevant Excel file, to the PBN portal of the central bank (for payment to the main beneficiaries, namely government employees). Additionally, the list of the legal deductions paid is posted on the portal of the General Treasury. It is important to note that the payment information is recorded in the accounting system.

Table 6.
Analysis of Stage Four of the Payment Process of the Employee's Salary in Iran

Current Status of Stage Four	Using Basic Automation
Automation of Stage Four	**Suggestion: Using Algorithmic Automation and Transition to AI** As stated in Figure (4), AI is a technology capable of mimicking human capabilities. In this stage, since the documents must be finally approved by the Deputy and the Director General of the Treasury, using AI for automating this stage is recommended. Additionally, using AI is also suggested for intelligent payments and the automatic deployment of information on the central bank system. **Final Approval** • Intelligent Execution of Payments • Intelligent Deployment of Information on the Central Bank Portal

(Source: Researcher's Findings)

Automation of Controls -One of the very important aspects of the employee's salary payments is the control and oversight of this process, which includes the validation of the received information (ensuring it does not exceed the allocated amount, that employees are not duplicated, that the numbers and totals are reasonable), the accuracy of documents, and the correct payment to the final beneficiary. Therefore, automating controls and managing risks are essential. For this purpose, the use of algorithmic automation and the transition to AIare recommended.

B) Intelligent Liquidity Management

Another use of AI is to develop a smart environment for cash flow forecasting, which is particularly important for treasuries dealing with daily challenges in cash and liquidity approvals. Research by the international consulting firms highlights the liquidity management and risk management as two key elements of the treasury management. This has led many treasuries to focus on improving transparency and control over cash flows, enhancing cash flow forecasting, increasing management attention, and optimizing processes.

Effective liquidity management hinges on having access to real-time cash data, including the current liquidity level and the expected future inflows and outflows of the cash. To achieve this, the treasury must first be able to monitor its liquidity status

accurately and promptly. Next, intelligent cash flow forecasting mechanisms, powered by AI, are developed. These systems often rely on machine learning algorithms, predictive analytics, and knowledge mapping to predict future cash flows as precisely as possible and generate actionable insights. In environments where treasury functions, particularly cash risk management, are handled daily, AI is expected to support skill development and automate traditional tasks like managing cash positions (Zeidan & Shapir, 2017). AI can replace human judgment and experience, serving as a clear operational model that enhances the quality of treasury operations and facilitates greater automation. Moreover, establishing a diverse financing platform can significantly boost treasury liquidity. A range of banking financing products is employed to optimize the treasury's cash position, primarily through credit payments. Additionally, various management tools, including information systems and AI technologies, are used to enhance the treasury operations. These include "smart cash pools," "smart invoicing," "intelligent management of financial status," "smart financing," and other innovative solutions. Management systems such as "intelligent internal control systems," "intelligent cash flow forecasting systems," and "smart investment and financing platforms" are also integrated to improve the overall efficiency (Polak et al., 2019).

C) Intelligent Investment

A key function of treasuries is managing the investment of funds held in the treasury's single account. One application of AI in this area is intelligent investment, or robotic investing. This approach is based on the modern portfolio theory by Markowitz and integrates the treasury's risk tolerance with its capital status and financial objectives, utilizing intelligent algorithms and asset management strategies. Compared to traditional investment advisory methods, AI not only enhances investment accuracy but also significantly reduces the costs. Since the process can fully or mostly automate the operational management, it is often referred to as intelligent investment (Zidan & Shapir, 2017). The intelligent investment process at the treasury level typically encompasses market analysis, large-scale asset allocation, portfolio selection, transaction execution, portfolio rebalancing, and performance analysis. During the key stages of data analysis, asset allocation, and portfolio selection, the intelligent investment system tailors its services according to the risk profile and investment horizon. Following the investment, the system incorporates traditional investment theories (such as risk diversification and quantification), strategies, and other methods to create and track a portfolio in real-time, adjusting based on macroeconomic events, market fluctuations, and investor preferences. While this automation can enhance efficiency, it is essential to approach its implementation with caution.

D) Intelligent Risk Management

Intelligent risk management is expected to become a crucial technology in treasury operations in the near future. Treasury functions are typically divided into two groups of specialists who focus on Treasury Management Systems (TMS) and generalists who work with Enterprise Resource Planning (ERP) systems. AI also plays a key role in enhancing

risk management within the treasury. Financial sectors have employed various predictive algorithms to analyze different risk models, including liquidity risk, debt risk, payment processing risks, revenue collection risks, behavioral analysis, anti-money laundering, and more. The algorithms used in these analyses include Online Analytical Processing (OLAP), clustering, correlation analysis, decision trees, neural networks, predictive modeling, self-organizing maps, and network data mining, among others (Polak et al., 2018).

The rise of AI technology significantly improves the accuracy of the algorithms and models mentioned earlier, leading to more effective risk assessment. For instance, in fraud detection, AI can automatically extract text, data, and images to gain a deeper understanding, identify potential risks, and generate alerts. In the broader scope of risk management, AI optimizes risk models and enhances risk assessment by incorporating various events into the analysis using advanced learning algorithms like Q-learning algorithms (Polak et al., 2019). The first stage of intelligent risk control starts with data collection, which includes user-submitted data during data entry, information generated through usage, transaction data, and data from organizations. The second stage focuses on model development, with fraud detection being the primary task. The third stage involves optimizing and continuously improving the model through machine learning. For instance, IBM Cognos Analytics offers cognitive services based on natural language processing that provide risk monitoring services, such as monitoring, risk assessment, and compliance for bank and investment accounts (Polak et al., , 2019).

A Critical Review of AI

AI can be divided into two types of weak and strong. Weak AI refers to a mid-level system designed and trained for specific tasks, while strong AI can respond autonomously to data and information without human intervention (Polak et al., 2019).

Developing and maintaining AI is costly due to the complexity of these systems. AI involves sophisticated software applications that require regular updates to adapt to a changing environment. In the case of significant failures, restoring the system and recovering lost data may take considerable time and resources. AI as a service allows treasury departments to experiment with AI for various functions and explore different platforms before making a long-term commitment. Popular cloud-based AI services include Amazon AI, Watson, Microsoft Cognitive Services, and Google AI.

Although AI tools provide advanced practical capabilities, their use raises ethical and professional concerns, such as the risk of misuse. Hackers can exploit sophisticated machine learning tools to breach sensitive systems, increasing security challenges. This often stems from deep learning algorithms, which rely on knowledge gained during training and are effective primarily due to the data they process. As a result, the individuals involved in training AI systems must have the necessary expertise and ethical standards, as human bias can be introduced, and their work must be rigorously monitored (Moosa & Ramiah, 2017).

AI is essential for safeguarding personal data, particularly as cybercrime rates are

increasing. AI-driven fraud detection helps prevent such criminal activities. For large treasuries, AI plays a crucial role in the broader field of cybersecurity (Moosa & Ramiah, 2017).

One challenge with AI is the lack of regulation. Despite the risks it poses, there is minimal regulation overseeing the use of AI tools, and any existing laws typically address AI in an indirect manner. AI has the potential to empower a small group of individuals who are skilled in its use, creating a risk if these individuals have malicious intentions, as they could cause disruption with these powerful technologies. Furthermore, AI can replace human labor with machines that offer significant capabilities. As AI becomes more prevalent, there is a concern that people might become overly reliant on machines, potentially diminishing their creative abilities (Polak et al., 2019).

Although AI has the capacity to learn and improve, it still lacks the ability to make nuanced judgments. Humans are able to consider specific circumstances and exercise discretion when making decisions, a capacity that AI may never fully achieve. Relying on AI to replace human adaptability could lead to irrational behavior within the human-machine ecosystem (Moosa & Ramiah, 2017).

Discussion and Conclusion

AI focuses on replicating human abilities like creativity, self-correction, and language processing. It is the only field aimed at creating machines that can function independently and autonomously in complex, evolving environments. AI encompasses a wide range of concepts, methodologies, strategies, and applications, and can be viewed as the study of systems that gather information from their surroundings and take actions based on that data.

As advanced technologies like AI continue to evolve, it becomes crucial for public financial management and treasury operations to adopt intelligent solutions. The treasury leverages AI tools to optimize and streamline its processes.

AI should empower the treasury to delegate cash forecasting tasks, enhancing accuracy, reducing workload, and providing faster access to forecasts. RPA can handle routine tasks, including knowledge-based activities like monitoring cash status and managing bank account openings. In treasury operations, particularly in daily cash risk management, AI is anticipated to support skill development and further automate traditional activities, such as cash status management, which follow structured procedures within set parameters.

By integrating Blockchain technology with AI in the treasury operations, secure and efficient management of digital identity information can be achieved, improving user identification and reducing costs, while ensuring privacy, provided that there is trust among the involved stakeholders.

By systematically capturing, storing, transferring, verifying, and analyzing data, significant reductions in labor costs and intermediary fees can be achieved, while also enhancing accuracy and security. Recorded credit information becomes more comprehensive and difficult to falsify. Although Blockchain technology is still developing,

it holds the potential to eliminate fraud risks in financial transactions, remove settlement processing delays and errors, and facilitate real-time integrity between financial systems and treasury functions.

Simplicity in treasury operations offers distinct advantages. When evaluating the benefits of AI and machine learning, it can be argued that the more streamlined liquidity management processes are, the easier it becomes to leverage the full potential of AI.

Like any transformational initiative, it is crucial to demonstrate tangible benefits and progress to maintain organizational backing and keep the project momentum going. Achieving quick wins with visible, practical advantages of AI implementation can significantly help build support for its impact on the treasury management. For instance, further automation of cash status monitoring can be accomplished using the existing data. In back-office operations, AI can also play a key role in identifying anomalies and reporting unusual activities.

Treasury systems are deployed in the cloud, either as specific software-as-a-service (SaaS) solutions or through private cloud setups using dedicated databases. Despite shifts in technology trends, the Treasury Management System (TMS) remains central to treasury operations. A TMS utilizes reference data and incoming feeds to manage liquidity, process bank statements, and record transactions, settlements, and forecasts, along with assessments and accounting events. Regardless of where the TMS is hosted, liquidity status, settlements, and forecasts remain accessible.

Although AI offers robust support for treasury functions, it still faces the challenge that many treasuries are unaware of how AI can assist and continue to rely on outdated methods for data analysis and integration. The failure to fully automate the treasury activities is often tied to underutilizing AI to analyze relevant data and information.

In handling simpler financial tasks like identifying financial events, accounting, and liquidity management, treasuries often employ RPA. Intelligent financial robots can automate various financial processes, significantly boosting efficiency and service quality. RPA encompasses software applications that can gather and analyze information through configuration or interaction with other software, enabling tasks such as transaction processing, data transfer, and comparison. This technology is widely adopted across sectors, including finance, HR, and auditing. By leveraging RPA to enhance financial operations, the treasury departments, particularly in shared financial services centers, have achieved substantial reductions in labor costs and improvements in work quality. This opens up new research opportunities in the areas of accounting, AI, banking, and payment technologies, allowing for both independent and interdisciplinary studies.

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Evaluating Factors Influencing Knowledge Management Effectiveness: A Conceptual Framework for Knowledge-Based Service Organizations

Fatemeh Abbasi[1*] | **Mohammad Musakhani**[2]

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Fatemeh Abbasi
Corresponding Author, Associate Professor of Information Technology Management, Faculty of Management, University of Tehran, Tehran, Iran.
E-mail: f_abbasi@sbu.ac.ir

Mohammad Musakhani
Assistant Professor, Faculty of Management and Accounting, Shahid Beheshti University, Tehran, Iran.
E-mail: mosakhani@ut.ac.ir

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ABSTRACT

Culture, infrastructure, organizational structure, and leadership are critical factors influencing the implementation of knowledge management processes in knowledge-based service organizations, thereby impacting the overall effectiveness of knowledge management. This research aims to introduce a comprehensive model that elucidates the interrelated factors affecting knowledge management processes in these organizations. Through an extensive review of existing literature, the authors developed a conceptual model that highlights these dynamics and their implications for practice. The model was rigorously tested and validated using a questionnaire distributed among various knowledge-based service companies in knowledge-based service companies, with 10 companies selected as the sample. A sample of 10 companies was selected for data collection, with data analyzed through Structural Equation Modeling using LISREL software. The research was conducted during a six-month period. The findings reveal that organizational culture, infrastructure, structure, and leadership enhance knowledge management capabilities significantly and influence knowledge management processes positively. Furthermore, these processes are shown to significantly improve the effectiveness of knowledge management, leading to enhanced communication, collaboration, and overall performance within service organizations, which ultimately fostered a more innovative and responsive organizational environment.

KEYWORDS

Culture, Effectiveness of Knowledge Management, Infrastructure, Knowledge Economy, Knowledge Management Processes, Leadership, Organizational Structure.

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Introduction

Knowledge management is a crucial intangible asset for organizations and institutions, involving processes such as creation, acquisition, storage, transfer, sharing, and applying knowledge. However, despite its importance, there are significant gaps in understanding the specific dynamics of these processes. This research focuses specifically on the methods of knowledge creation, storage, transfer, and application.

Effective use of knowledge through knowledge management enhances an organization's competitive advantage (Welch, & Smith, 2023). The necessity of this research arises from the fact that nearly 84% of knowledge management programs have failed, highlighting the complexities involved in their implementation (Conallin et.al, 2018). This challenge is particularly severe in knowledge-based service organizations, which inherently rely on the creation and transfer of knowledge but often struggle with limited resources for service delivery.

Given these challenges, it is essential to ensure that operational processes in knowledge-based service organizations deliver maximum value despite the existence of resource constraints. Therefore, this research aims to develop a core framework of knowledge management tailored to these organizations while evaluating a conceptual model for assessing the factors influencing the effectiveness of knowledge management.

This study examines the impact of knowledge management capabilities—namely culture, infrastructure, leadership, and organizational structure—on knowledge management processes. Additionally, it investigates how these processes affect the knowledge management effectiveness. Moreover, it evaluates the indirect impact of knowledge management capabilities on overall effectiveness, a topic which remains underexplored in existing literature.

In terms of culture, the evaluation focuses on aspects such as cultural alignment with goals, sharing and learning, trust and collaboration, and innovation. For infrastructure, factors like the history of knowledge management implementation, encouragement of human resources, and technology appropriateness are assessed. The effectiveness of knowledge management, particularly regarding improved collaboration, communication, and performance, is also critically analyzed.

Literature Review

Knowledge Management

A recent definition of knowledge management is provided by Alavi and Leidner (2022,1), who describe it as "a systematic approach to managing an organization’s knowledge assets, involving the processes of creating, sharing, and utilizing knowledge to enhance organizational effectiveness and competitiveness". The American Productivity and Quality Center defines knowledge management as a set of emerging strategies and approaches for creating, maintaining, and utilizing knowledge assets (including people

and information) that allow knowledge to flow from individuals at the right time, enabling them to leverage these assets to create greater value for the institution and organization. Generally, the factors contributing to knowledge management can be categorized into four layers of leadership, culture, structure, and information technology infrastructure (Munro et.al, 2017).

Researchers have proposed various frameworks related to knowledge management processes. Hisig's model consists of four processes: Create, Store, Share, and Apply which are explained below:

- Create: This refers to the ability to learn and communicate. Developing this capability is crucial for sharing the existing knowledge and experiences, establishing connections between ideas, and building cross-disciplinary relationships.
- Store: This is the second essential element of knowledge management which provides an organized capability for quick retrieval of information, access to information for other employees, and effective knowledge sharing. In this system, necessary knowledge should be easily stored for everyone's use.
- Share: This process fosters a collective spirit where individuals feel connected as collaborators pursuing common goals and are interdependent in their activities
- Apply: The fourth process begins with the idea that creating more knowledge is possible through the practical application of new knowledge. This element completes the central process of unified knowledge management (Edward, 2011). This model comprises four key processes (Create, Store, Share, and Apply) that facilitate effective knowledge management. However, this model does not adequately consider the cultural and environmental factors that may influence the effectiveness of these processes. Additionally, the model may be insufficient for complex and dynamic organizations, as it does not address the specific needs of different organizations.

Becman proposed an eight-stage model for knowledge management processes:

1. Identification: Determining internal competencies, strategic sources, and the scope of knowledge.
2. Capture: Formalizing existing knowledge.
3. Selection: Determining the relevance, value, and accuracy of knowledge, and resolving incompatible knowledge.
4. Storage: Introducing a unified memory in the knowledge repository with various knowledge patterns.
5. Distribution: Automatically distributing knowledge to users based on interest and work, and facilitating knowledge sharing among real groups.
6. Application: Retrieving and using knowledge in decision-making, problem-solving, automating, and supporting work, job assistance, and training.

7. Creation: Discovering new knowledge through research, experimentation, and creative thinking.
8. Commercialization: Selling and trading, developing, and marketing new knowledge of products and services (Kwon, 2004). The eight-stage model by Becman comprehensively covers the stages of knowledge management and emphasizes the identification and storage of knowledge. Nevertheless, this model could place greater emphasis on the distribution and application of knowledge. There is also less focus on inter-organizational interactions and addressing customer needs.

The effectiveness of knowledge management in an organization leads to improved collaboration, enhanced communication, and better performance.

In this research study, the framework proposed by Downs (2013) serves as the basis for performance assessment, and the proposed model is evaluated in knowledge-based service organizations (Li, & Xiong, 2021). Our research aims to address these weaknesses by designing a new model that includes the following elements:

- *Attention to Cultural Factors:* By examining the organizational culture and its specific needs, we aim to design processes that are more aligned with the real conditions of organizations.
- *Integration of New Technologies:* Utilizing new technologies such as artificial intelligence and machine learning can enhance the processes of knowledge storage and sharing.
- *Facilitating Collaborative Environments:* By creating shared workspaces and effective communication tools, we can promote collaboration among employees and different departments.

Providing Knowledge-Based Services

A recent definition of knowledge-based services can be found in the work of Ghasemi and Zare (2023,2), who describe them as "services that leverage specialized knowledge to create value for clients, emphasizing collaboration and innovation in fields such as consulting, legal services, and IT solutions".

Knowledge-based services are those that heavily rely on specialized knowledge and are provided for the processes of other businesses. Therefore, companies operating in the service sector can be divided into two categories:

1. Companies that provide services using scientific and technological knowledge (such as research and development services, engineering services, computer services, etc.).
2. Companies that offer traditional professional services (such as legal services, accounting, and management consulting)

Knowledge-based companies and institutions are private or cooperative entities established to synergize the development of a knowledge-based economy, achieve

scientific and economic goals (including the expansion and application of inventions and innovations), and commercialize knowledge and wealth. They focus on research and development (including the design and production of goods and services) in high-tech areas with significant added value, especially in software production (Regulation of the Law on Support for Knowledge-Based Companies, 1391).

According to the OECD definition, those educated human groups in scientific, research, and investigative centers who have been able to learn theoretical sciences and scientific theories and convert the acquired knowledge into income-generating and value-producing activities are recognized as knowledge-based companies (González-Illescas & Zaragoza-Sáez 2023). Harvard Business Review points out that a common feature of knowledge-based business services is the provision of services that are a joint product of collaboration between the customer and the service provider. This has a profound impact on the quality of services provided and increases the customer satisfaction.

With proper management of this feature, knowledge-based service providers can improve their operational efficiency and create a sustainable competitive advantage (Lin et al., 2023).

Types of economic activities defined as knowledge-based services include:

- High-tech knowledge-based services: programming, consulting, and doing computer-related activities, scientific research, information services, etc.
- Knowledge-driven market services: advertising and market research, legal and consulting activities, etc.
- Knowledge-driven financial services: financial services, insurance, etc.
- Other services: publishing, education, etc. (Eurostat, 2014).

Knowledge Management Capabilities

Knowledge management capability is the ability to create and apply knowledge through the combination and integration of various activities and resources in knowledge management, aimed at impacting competitive advantage, knowledge management effectiveness, and organizational effectiveness (Chuang, 2004). In this research study, organizational culture, infrastructure, leadership, and organizational structure are considered as influential factors in knowledge management capability.

- Organizational Culture: Refers to the organizational climate and working conditions of employees that affect the knowledge management. If the culture is not ready for changes in knowledge management, the implementation of knowledge management programs will fail. An appropriate and effective organizational culture for knowledge management includes criteria such as a shared vision, expertise, and attitudes (Rai, 2011).
- Organizational Infrastructure: A systematic framework that provides a strategic basis for guiding and forecasting the organization (Dixon & Lucas, 2013).
- Organizational Structure: Refers to the formal and informal operational and

directive structure within organizations. Additionally, it includes methods, processes, incentive policies, and job design (Naseri Najafabadi et al., 2013).

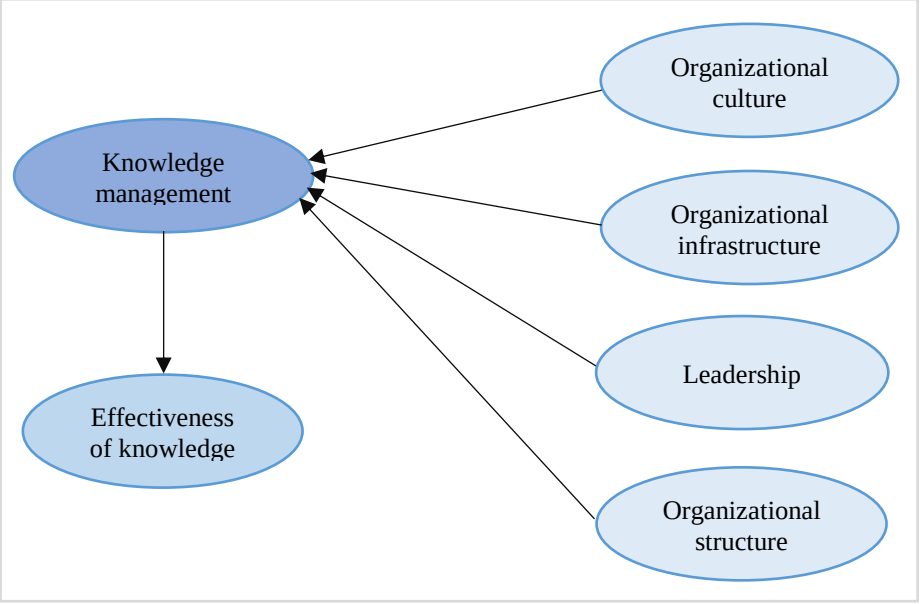
- Organizational Leadership: The leadership style is defined by a set of attitudes, traits, and skills of managers that are shaped based on a value system, trust in employees, leadership tendencies, and a sense of security in ambiguous situations (Rowold, 2009).

Conceptual Model

The theoretical framework of a conceptual model is based on the theoretical relationships among a number of factors that have been identified as significant concerning the research issues. This theoretical framework logically flows from the examination of research backgrounds to the domain of the problem.

Considering the provided definitions and theoretical backgrounds, the researchers have proposed the following conceptual models regarding how knowledge management capabilities influence knowledge management processes and their outcomes:

Figure 1.
The Theoretical Framework of the Research



(Source: Researcher's Findings)

Main and Sub-Hypotheses of the Research Study

H1: Organizational culture has a direct, positive, and significant effect on knowledge management processes.

H2: Organizational infrastructure has a direct, positive, and significant effect on knowledge management processes.

H3: Leadership has a direct, positive, and significant effect on knowledge management processes.

H4: Organizational structure has a direct, positive, and significant effect on knowledge management processes.

H5: Knowledge management processes have a direct and significant effect on the effectiveness of knowledge management.

Methodology

This research aims to determine the causal relationships among organizational culture, organizational infrastructure, leadership, organizational structure, knowledge management processes, and the outcomes of knowledge management, namely the effectiveness of knowledge management, within the framework of the conceptual model. The research is applied-quantitative in terms of purpose and descriptive and correlational in terms of data collection method, specifically based on Structural Equation Modeling. The study is conducted within the context of education industry, which provides knowledge-based services.

In the analytical model of the study, organizational culture, organizational infrastructure, leadership, and organizational structure, which are referred to as knowledge management capabilities, are considered as independent variables. Knowledge management processes are the mediating variables, and the effectiveness of knowledge management is the dependent variable.

The main tool for data collection is a questionnaire. Accordingly, for the variables under study, 34, 20, 6, 4, 19, and 8 questions have been designed for organizational culture, organizational infrastructure, organizational leadership, organizational structure, knowledge management processes, and the effectiveness of knowledge management, respectively, using a 5-point Likert scale. In this study, to assess the knowledge management practices in knowledge-based service organizations, particularly within the education industry, we used a questionnaire designed and implemented by Downes (2014)

To assess the validity of the research instrument, feedback was obtained from three experts in the field of digital and social innovation. These experts, with both academic and practical experience in the field, reviewed the questions and research instruments thoroughly and provided their feedback. Based on their suggestions and input, necessary adjustments were made to improve the quality and accuracy of the instrument, ensuring that the questionnaire has acceptable content validity.

To measure the reliability of the instrument, a pilot sample consisting of 30 questionnaires was pre-tested, and then the reliability coefficient was calculated using Cronbach's alpha test based on the data obtained from the questionnaire, which is presented in Table 1 for organizational culture, organizational infrastructure, organizational leadership, organizational structure, knowledge management processes, and the effectiveness of knowledge management.

Table 1.
Reliability of the Questionnaire

Variable name	Number of questions	Reliable number
Organizational culture	34	90 percent
Organizational infrastructure	20	80.6 percent
Organizational leadership	6	76.3 percent
Organizational structure	4	81 percent
Knowledge management processes	19	86.2 percent
Effectiveness of knowledge management	8	78.5 percent

(Source: Researcher's Findings)

Since the result of Cronbach's alpha test for all variables and the entire questionnaire is greater than 0.7, it can be said that the questionnaire has an appropriate level of reliability.

Before testing the hypotheses and the conceptual models of the study, it is necessary to ensure the validity of the measurement models for the exogenous variables (culture, infrastructure, leadership, and organizational structure) and the endogenous variables (knowledge management processes and the effectiveness of knowledge management). To do so, first-order and second-order confirmatory factor analysis methods have been used.

This method is one of the oldest statistical methods used to examine the relationships between latent variables and observed variables, and it represents the measurement model (Salehi et al., 2012).

The results of the second-order confirmatory factor analysis for the exogenous and endogenous variables (Table 2) indicated that appropriate measurement models have been selected and all numbers and parameters of the model are significant. The fit indices of the measurement models, as described in Table 2, indicate the appropriateness of these models.

Table 2.
The Results of the Measurement Model of the Research Variables

Measurement model	The scumbags (independent, intermediary. dependent)	Chi-square value	degree of freedom(df)	Chi-square ratio to degrees of freedom	Amount RMSEA
Independent variable measurement model	culture	930	517	1/8	0.07
	Infrastructure	192	155	1/23	0/04
	leadership	15	9	1/66	0.06
	Organizational structure	4/3	2	2/15	0/08
Mediating variable measurement model	Knowledge management processes	240	146	1.64	0.065
Dependent variable measurement model	Effectiveness of knowledge management	335	171	1.95	0.07

(Source: Researcher's Findings)

Findings

As can be inferred from Table 3, most variables have an appropriate distribution and pattern.

Table3.
Descriptive and Inferential Statistics

Variables and their components	average	Observed t-value	degree of freedom	status
Organizational culture	28/3	2	149	suitable
Culture assessment	2.87	1.87	149	inappropriate
Communication to achieve goals	20/3	3.5	149	suitable
Share and learn	98/2	92/1	147	inappropriate
Trust, cooperation and respect	2/3	1.98	147	suitable
Innovation and initiatives	2.88	1.68	149	inappropriate
Organizational infrastructure	98/2	1.88	149	inappropriate
Experience in knowledge management	96/2	1.78	148	inappropriate
Encouraging human resources and knowledge management	97/2	94/1	149	inappropriate
Performance evaluation	14/3	2.12	149	suitable
Suitability of technology	95/2	1.55	149	inappropriate
Learning and technology support	23/3	2.01	149	suitable
Knowledge sharing potential	13/3	3.5	149	suitable
Organizational leadership	3.4	2.03	149	suitable
Organizational structure	04/3	1.95	148	inappropriate
Knowledge management processes	97/2	1.04	147	inappropriate
Creation	98/2	1.88	149	inappropriate
Storage	96/2	1.55	149	inappropriate
transmission	14/3	3.3	149	suitable
Application	08/3	1.65	149	inappropriate
Effectiveness of knowledge management	97/2	1.55	146	inappropriate
Improve cooperation	3.19	2.9	149	suitable
Improve communication	14/3	1.99	149	suitable
Improve performance	3.11	1.98	148	suitable

(Source: Researcher's Findings)

As shown in Table 4, the relationship between knowledge management capabilities, namely culture, infrastructure, leadership, and organizational structure (exogenous variables), and the variables of knowledge management processes and the effectiveness of knowledge management (endogenous variables) is significant at the 0.01 level.

The highest significant correlation is observed between the effectiveness of knowledge management and infrastructure at 0.7, while the lowest significant correlation is between leadership and infrastructure at 0.41. From the correlation analysis among the endogenous variables, it can be concluded that any improvement in the critical success factors and knowledge management processes leads to an improvement in the effectiveness of knowledge management, and consequently enhances collaboration, communication, and performance.

Table 4.
Correlation Analysis between Research Variables

Correlation between exogenous and endogenous variables	culture	Infrastructure	leadership	Structure	Knowledge management processes	Effectiveness of knowledge management
Culture	1	0	0	0	0	0
Infrastructure	0.59	1	0	0	0	0
leadership	0.65	0.41	1	0	0	0
Structure	0.57	0.51	0.59	1	0	0
Knowledge management processes	0.68	0.48	0.61	0.48	1	0
Effectiveness of knowledge management	0.59	0.7	0.68	0.47	0.64	1

(Source: Researcher's Findings)

Standard Estimation Model

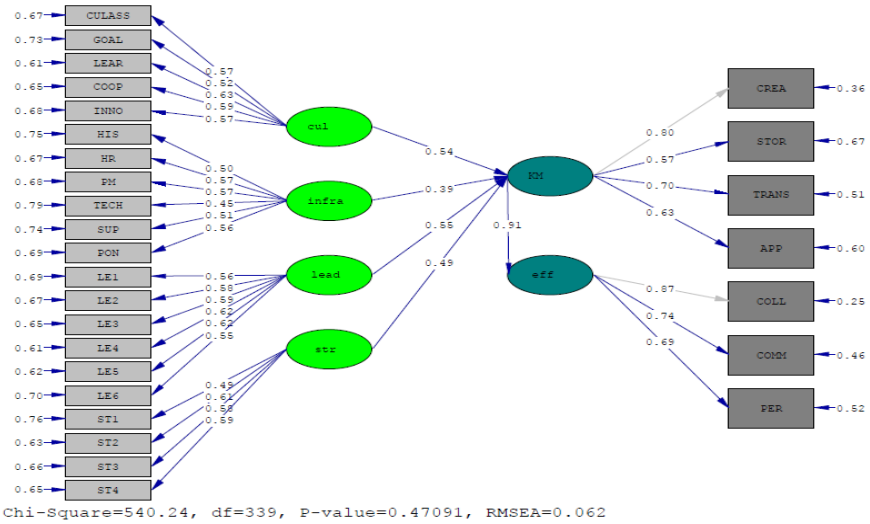
The fit indices indicate an appropriate fit for the model. The ratio of chi-square to degrees of freedom (1.59) is less than the permissible value of 3, and the RMSEA value (0.062) is less than 0.08.

Figure 2 shows the structural model of the research in the standard estimation state. In this model, culture has a positive and significant effect on knowledge management processes (0.54). Infrastructure also has a positive and significant effect on knowledge management processes (0.36) and effectiveness (0.25).

Organizational leadership has a positive and significant effect on knowledge management processes (0.39). The fourth factor, organizational structure, also has a positive and significant effect on knowledge management processes (0.55).

The knowledge management processes have a positive and significant effect on the effectiveness of knowledge management (0.91).

Figure 2.
The Structural Model of the Research in Standard Estimation Mode

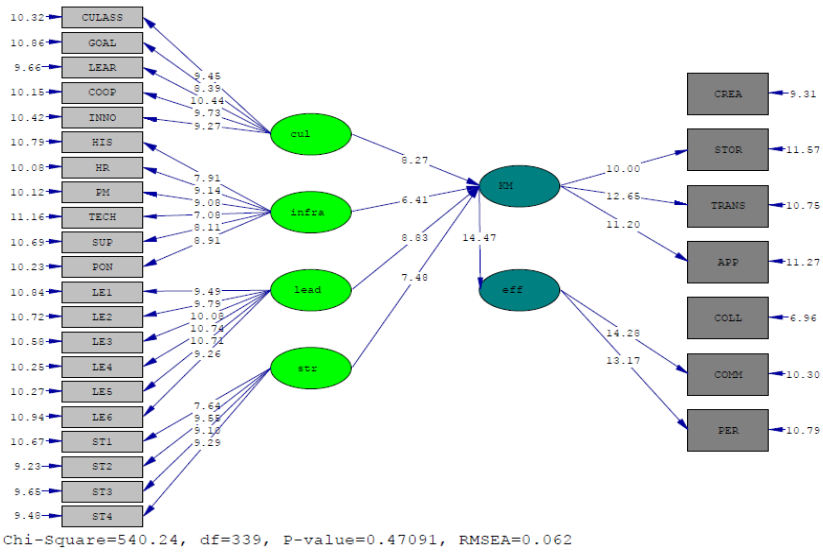


(Source: Researcher's Findings)

Model of Significant Values

As shown in Figure 3, organizational culture, organizational infrastructure, organizational leadership, and organizational structure have a positive and significant effect on knowledge management processes, and knowledge management processes also have a positive and significant effect on the effectiveness of knowledge management. Therefore, all research hypotheses are confirmed.

Figure 3.
Structural Model of the Research in terms of Significant Values



(Source: Researcher's Findings)

Table 5.
Summary of the Results of Structural Model of the Research

Relationships	Path coefficient	
	Direct impact on knowledge management processes	Indirect effect on the effectiveness of knowledge management
Culture	0.54	0.49
Infrastructure	0.39	0.35
Leadership	0.55	0.5
Structure	0.49	0.44

(Source: Researcher's Findings)

Table 5 presents the path coefficients that summarize the results of the structural model of this research, focusing on the relationships between knowledge management capabilities (culture, infrastructure, leadership, and structure) and their impacts on knowledge management processes and effectiveness.

Culture: The path coefficients for culture for the direct impact on knowledge management processes and for the indirect effect on the effectiveness of knowledge management are 0.54 and 0.49, respectively. This suggests that a strong organizational culture significantly enhances knowledge management processes' efficiency and

contributes to overall effectiveness. The high coefficients indicate that fostering a supportive culture is crucial for successful knowledge management.

Infrastructure: With a path coefficient of 0.39 for direct impact and 0.35 for indirect effect, infrastructure plays a significant role in facilitating knowledge management processes. While the values are slightly lower than those for culture, they still demonstrate the importance of having a robust infrastructure in place to support knowledge management initiatives. This includes technological resources and support systems that enable effective knowledge sharing and application.

Leadership: The leadership variable shows the highest path coefficients, with 0.55 for direct impact and 0.50 for the indirect effect on knowledge management effectiveness. This indicates that effective leadership is pivotal in both driving knowledge management processes and enhancing their overall effectiveness. Leaders play a critical role in creating an environment conducive to knowledge sharing and innovation, reinforcing their influence in organizational contexts.

Structure: The path coefficients for structure for direct impact and indirect effect are 0.49 and 0.44, respectively. This signifies that an appropriate organizational structure is essential for facilitating knowledge management processes. A well-defined structure allows for clearer communication and collaboration, which influences the effectiveness of knowledge management positively.

In summary, all four capabilities—culture, infrastructure, leadership, and structure—have significant direct impacts on knowledge management processes and also indirectly affect the overall effectiveness of knowledge management. The coefficients highlight the interconnectedness of these factors and underscore the importance of integrating them to optimize knowledge management practices within organizations.

Discussion and Conclusion

In recent decades, the increase in data volume within organizations and the necessity of making decisions based on the information extracted from this data have led to the emergence of a phenomenon known as knowledge management. Knowledge-based service organizations provide services to their customers based on the knowledge available within their organization. Therefore, knowledge management processes such as creation, storage, transfer, and application serve as vital arteries for gaining competitive advantage and ensuring the survival of such organizations. Knowledge management needs to be effective, and this effectiveness is created and accelerated through knowledge management capabilities. This research aimed at providing a conceptual framework for evaluating the factors influencing the effectiveness of knowledge management in knowledge-based service organizations. Accordingly, five hypotheses were tested, and the results of the hypothesis testing indicate that all hypotheses are confirmed, meaning that culture, infrastructure, structure, and organizational leadership have a positive and direct impact on knowledge management processes, and knowledge management

processes also have a positive and direct impact on the effectiveness of knowledge management in knowledge-based service organizations. Therefore, improving the status of knowledge management capabilities can also enhance its effectiveness.

As mentioned, the enabling factors of organizational structure and infrastructure are not in a suitable condition. Given that knowledge-based service organizations are moving towards knowledge structures, they need to be organic, flexible, and flat. Since the success of knowledge management depends on collaboration, teamwork, and interaction among individuals, these organizations must pay attention to this issue and focus on teamwork and collaboration while controlling dominance and authoritarianism. Regarding organizational infrastructure, it is essential to focus on human resource learning and using up-to-date and relevant technologies, to keep pace with rapid technological changes.

In terms of knowledge management capabilities, leadership and organizational culture in knowledge-based service organizations are in a suitable condition, while infrastructure and organizational structure are not. In an organizational culture, knowledge sharing and learning are not in a good state, even though they are the factors that have the most significant effect on organizational culture. Taking organizational culture into consideration, it is necessary to focus on learning, interaction, and knowledge sharing in knowledge-based service organizations, encouraging explicit and implicit knowledge sharing through seminars and workshops related to these topics.

In the area of knowledge management processes, the creation and storage of knowledge is not in a good state. To improve these processes, it is recommended to establish mechanisms and systems for documenting and recording individuals' knowledge and to encourage and support individuals through a reward and promotion system for generating and presenting new ideas.

One of the primary limitations of this study is its reliance on self-reported data, which may introduce biases and affect the accuracy of the findings. Additionally, the research focuses primarily on knowledge-based service organizations, which may limit the generalizability of the results to other sectors. Future research could explore comparative studies across various types of organizations to validate the framework developed in this study.

The final recommendation is to focus on the effectiveness of knowledge management and the improvement of collaboration, communication, and performance in organizational improvement programs. It is essential for organizational managers to support new and innovative ideas and to encourage the presentation of new opinions, collaboration, and teamwork. By creating internal communication networks, an organic structure, and interaction-based systems, communication and interaction among individuals within the organization can be enhanced. Future research should also examine the role of technology adoption in facilitating knowledge management processes and its impact on organizational effectiveness.

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Content Analysis of Blockchain and Cryptocurrency Applications in the Metaverse: A Study on Users' Financial Behaviors

Fatemeh Fathi[1*]

Article Type:
Research Article

Fatemeh Fathi
Corresponding Author, Assistant Professor, Faculty of Financial Sciences, Management and Entrepreneurship, University of Kashan, Kashan, Iran.
E-mail: fathi@kashanu.ac.ir

ABSTRACT

This study conducts a content analysis of Blockchain and cryptocurrency applications within the metaverse, focusing specifically on how these technologies shape users' financial behaviors. With Blockchain facilitating decentralized finance and secure asset ownership, and cryptocurrencies enabling fluid transactions in virtual environments, these technologies are integral to developing metaverse economies. By applying bibliometric and content analysis methods to articles from 2021 to 2024 in the Scopus database, the study identifies key themes and emerging trends in digital asset utilization, user engagement, and financial decision-making. The findings reveal that Blockchain and cryptocurrency applications foster new and varied financial behaviors among metaverse participants, shaping an ecosystem that is progressively diverging from traditional financial models.

KEYWORDS

Blockchain, Cryptocurrency, Financial Behavior, Metaverse, Transparency.

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Introduction

The rapid advancement of digital technologies has led to the emergence of the metaverse, a virtual ecosystem where users interact, transact, and collaborate in immersive digital spaces. Huynh-The et al. (2023) argue that Blockchain technology plays a critical role in creating a secure and transparent environment for the metaverse, addressing challenges related to scalability and privacy within this emerging digital ecosystem. Recent studies on Blockchain applications in the metaverse indicate that this technology can play a key role in the growth of virtual ecosystems by enhancing data security, improving scalability and interoperability, and supporting decentralized applications. In particular, Blockchain has the potential to enhance user privacy and facilitate secure transactions, features that can help create new frameworks and increase engagement in virtual environments, thereby expanding the metaverse's capacity as a safe and flexible platform for users and developers (Gadekallu et al., 2022).

Integrating Blockchain technology and artificial intelligence (AI) in the metaverse has can enhance security, improve data management, and enrich user experiences. This research explores various applications of this convergence and addresses the associated challenges, offering insights into how these technologies can reshape the metaverse (Yang et al., 2022). Blockchain integration in the industrial metaverse enhances data transparency, security, and interoperability in industrial applications. The study discusses its implications for supply chain management, manufacturing processes, and collaborative environments, while highlighting the challenges and opportunities that arise from implementing Blockchain within this context (Mourtzis et al., 2023). An exploration of the metaverse reveals its significant role in the cryptocurrency ecosystem, particularly in facilitating transactions and enhancing user engagement within virtual environments. This research analyzes the potential for developing innovative economic models and ecosystems in the metaverse while addressing the challenges and opportunities associated with the integration of cryptocurrencies in these digital spaces (Osivand, 2021).

Financial behavior refers to how individuals manage and make decisions about their financial resources, including saving, spending, investing, and debt handling. These behaviors are influenced by various factors such as financial knowledge, self-esteem, personal values, and past financial experiences, playing a crucial role in achieving financial stability and economic goals. In the study conducted by Stolper and Walter (2017), the relationship between financial literacy, financial advice, and individuals' financial behaviors is closely examined. The research highlights that higher financial literacy is directly associated with more informed and deliberate financial decision-making, helping individuals avoid common financial errors. Furthermore, the study emphasizes that financial advice can play a key role in promoting optimal financial behaviors, especially for those with lower levels of financial knowledge, by guiding them in areas such as planning and saving.

Despite the promising potential of Blockchain and cryptocurrencies in the metaverse,

several challenges hinder their effective integration and adoption. Key questions arise regarding how users evaluate the security and functionality of these technologies in digital environments and what factors influence their willingness to adopt Blockchain and cryptocurrency solutions. While existing research highlights the benefits of Blockchain in enhancing data security and facilitating transactions, there is limited empirical evidence showing how these factors influence users' financial behaviors. Additionally, it is essential to determine the roles that Blockchain and cryptocurrencies play in users' financial behaviors within the metaverse and the key challenges that prevent the widespread adoption of these technologies. This study employs bibliometric methods and content analysis to explore these issues, aiming to identify barriers and provide solutions for improving user experience and increasing trust in digital environments. The research questions are as follows:

1. What patterns and trends exist in the research literature related to Blockchain, cryptocurrencies, and financial behaviors?
2. What insights does the content analysis of related articles provide about the role of these technologies in shaping economic and social structures in the metaverse?

Theoretical literature

Metaverse

Recent research on the metaverse focuses on fundamental principles, security, and privacy, emphasizing their importance in creating safe virtual environments. It analyzes the challenges and opportunities related to security and privacy while proposing strategies to enhance user data protection and build trust in digital interactions (Wang et al., 2022). Recent research in the field of the metaverse examines the latest status, technologies, applications, and challenges within this domain. The authors analyze current trends while identifying key opportunities and barriers for metaverse development, emphasizing the need for innovative approaches to overcome these challenges (Wang et al., 2022). The content analysis of metaverse articles identifies key patterns and research topics within this field. The findings provide insights into current trends and future directions in metaverse research, emphasizing the importance of further investigation to advance scientific knowledge in this area. This article serves as a valuable resource for better understanding the developments and challenges within the metaverse in the research literature (Narin, 2021).

Blockchain and Cryptocurrency

Recent research shows that Blockchain technology and cryptocurrency applications significantly influence economic patterns and users' financial behaviors in the metaverse. These technologies enhance transparency, security, and decentralized ownership, particularly through digital assets, smart contracts, and NFTs, fostering independent virtual economies and facilitating economic participation. Overall, Blockchain plays a crucial role in building trust and promoting sustainable economic interactions within the digital economy of the future (Zhang, 2023). The analysis of Blockchain role in the

metaverse emphasizes its significance for secure digital asset management, ownership transparency, and interoperability among virtual worlds. The research highlights how Blockchain facilitates decentralized financial systems (DeFi) and examines its current applications and challenges, underscoring its transformative impact on the sustainability of digital assets within metaverse ecosystems (Truong & Niyato, 2023).

Cryptocurrencies and Blockchain have the potential to revolutionize virtual economies through offering secure transactions, enhancing asset ownership, and enabling decentralized governance. However, research also addresses the associated risks, such as financial volatility, regulatory challenges, and ethical concerns, underscoring the need for balanced policies to foster innovation and safety in metaverse environments (Radanliev, 2024). Blockchain technology is increasingly viewed as a foundational element for managing virtual assets in the metaverse, providing essential transparency and verifiability for digital economies. While it enhances tracking and ownership validation, it also raises regulatory challenges and requires standardized accounting practices, highlighting its potential to influence future metaverse economic policies (AL-Hawamleh et al., 2024).

Literature Review

With the emergence of the metaverse and rapid advancements in Blockchain and cryptocurrencies, numerous studies have explored integrating these technologies within financial markets, their effect on consumer behavior, and their security and social challenges. For example, in a notable study, Özkaynar (2022) investigates banks' marketing strategies in the metaverse, Blockchain, and cryptocurrencies through the lens of consumer behavior theories and illustrates that these technologies have significantly transformed consumer preferences and behaviors.

In addition, several review studies have examined the role of Blockchain in the metaverse, highlighting its opportunities and security and technical challenges (Gadekallu et al., 2022). Research has also focused on integrating Blockchain with digital asset management, exploring how data and assets are managed within the metaverse. These studies analyze the economic and social opportunities presented by Blockchain, alongside the security challenges inherent in the metaverse environment (Truong, et al., 2023; Radanliev, 2024). Furthermore, Blockchain-based asset storage mechanisms have been proposed as innovative solutions for managing digital assets and enhancing accessibility and security within the metaverse (Ersoy & Gürfidan, 2023).

Conversely, other studies have examined financial market behavior about Blockchain and the metaverse, discussing topics such as digital payment innovations and consumer behavior in this new era (Kara, 2023; Shaikh, Mutanov, & Karjaluoto, 2024). Additionally, Polas et al. (2022) focused on risk behavior among small and medium-sized enterprises in Bangladesh and examined the influence of artificial intelligence and Blockchain technology within the context of the Fourth Industrial Revolution .

Further investigations have concentrated on the role of Blockchain in the industrial

metaverse and the challenges associated with financial security and financial crimes in this domain. These studies categorize and propose solutions for addressing financial crimes within the metaverse (Mourtzis et al., 2023). Moreover, some research has explored the use of digital assets, such as NFTs and cryptocurrencies, within the metaverse, examining their financial and social implications (Belk et al., 2022).

Overall, this body of research indicates that studies on integrating Blockchain, the metaverse, and cryptocurrencies encompass a diverse range of topics from marketing strategies to security challenges and economic opportunities. This field of study continues to expand, underscoring the need for further investigations to gain a deeper understanding of how these technologies influence various economic and social sectors.

Methodology

This study aims to systematically examine how Blockchain and cryptocurrency technologies relate to financial behaviors in the metaverse through a bibliometric analysis. Bibliometric analysis, as a quantitative approach, evaluates scientific publications by measuring various aspects of scientific production, including collaboration networks, citations, and publication patterns across diverse fields (Amin et al., 2019; Caya & Neto, 2018). The research uses reliable scientific tools and databases to collect and analyze relevant data.

In this research, a bibliometric analysis of the application of cryptocurrencies and Blockchain in the metaverse is conducted to address the research questions. Accordingly, an initial search was performed in the Scopus database using the keywords in Table 1. The output of these searches was imported into VOSviewer for analysis. Subsequently, content analysis was conducted by accessing the Web of Science and Scopus databases, again using the keywords from Table 1. The resulting outputs were examined, and after excluding books and conference papers, only research articles were analyzed, resulting in a total of 24 articles. Keywords related to the research topic, such as *Blockchain*, *Cryptocurrency*, *Metaverse*, *Financial Behavior*, *Decentralized Finance (DeFi)*, and *Virtual Economies*, were used individually and in combination to retrieve relevant articles. To refine the search results to recent, relevant studies, filters were applied for publication date (focusing on the last five years) and article type (including research and review articles). Only English-language articles with full-text access were selected for the in-depth analysis.

For the bibliometric analysis, the study utilized VOSviewer, a powerful and widely-used tool for creating and analyzing networks of citations, co-authorship, and keyword co-occurrence. VOSviewer enables creating science maps that help identify various research clusters and emerging trends within the field. Through this tool, the study could effectively visualize patterns in collaboration and key thematic areas, contributing to a better understanding of current research directions and knowledge gaps in Blockchain and financial behaviors in the metaverse.

Bibliometric analysis is particularly valuable in rapidly evolving and innovative fields

like Blockchain, cryptocurrency, and the metaverse,. This approach allows researchers to explore financial behaviors comprehensively, identify emerging research avenues, and offer valuable recommendations for future studies.

Table 1 presents key data such as keywords, website addresses, and the publication year of each article. The selected keywords reflect the primary research topics—Blockchain technology, cryptocurrencies, and the metaverse—used to search scientific databases, specifically Scopus. Due to the recent emergence of these research variables, no restrictions were placed on the publication year of articles, allowing for an inclusive analysis of available literature. This foundational data aids in locating and analyzing scientific articles related to the influence of novel technologies on financial behaviors within the metaverse.

Table 1.
Data Collection Protocol

	First Search	Second Search	Third Search
Data Source	**Scopus**		
Key Words	(Virtual Economies AND Blockchain AND Decentralized Finance)	(Metaverse AND Cryptocurrency AND Digital Assets)	(Blockchain AND Metaverse AND Financial Behavior)
Search Fields	Titles, Keywords, Abstracts		
Publication Year	2021-2024		
Number of Results	27		

(Source: Researcher's Findings)

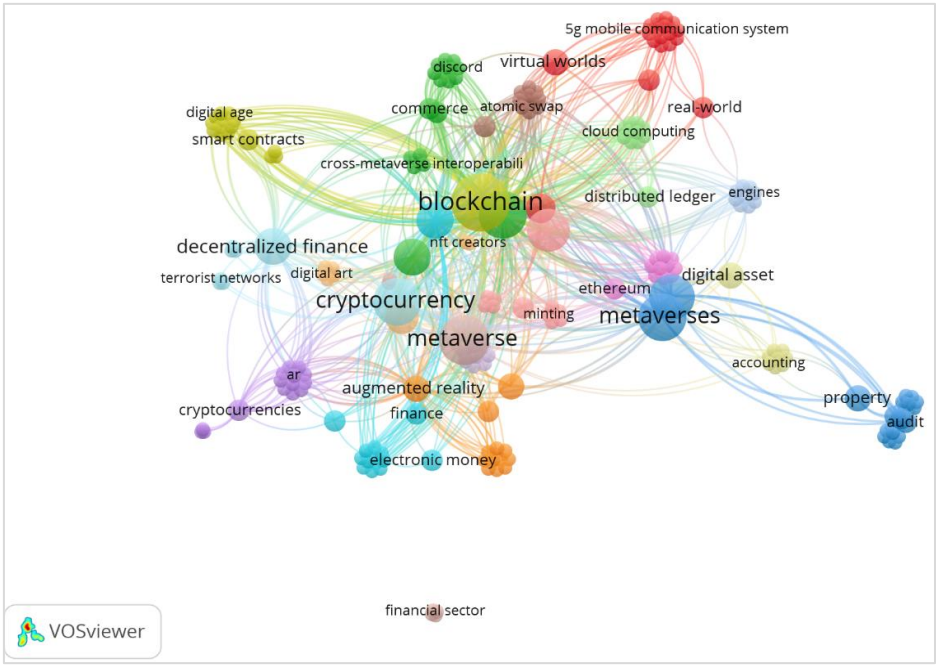
The method of content analysis was subsequently employed. This approach is a research method widely used for systematically analyzing and interpreting textual or visual data to identify patterns, themes, or biases within it. Content analysis is a systematic research method used to interpret and quantify patterns within textual, visual, or multimedia data. It involves categorizing and coding data into meaningful themes, which can reveal underlying ideas, trends, and relationships within the material. This approach allows researchers to analyze communication, attitudes, or representations in various contexts, whether written documents, speeches, media, or visual content. By breaking down the content into manageable units, content analysis helps make qualitative data more accessible for interpretation and often allows for a blend of qualitative and quantitative insights. This method is especially valuable in exploratory research, where themes, concepts, or patterns need to be extracted from large datasets to support broader analytical goals (Harwood & Garry, 2003).

Findings

In this study, we first examine the primary themes of interest through bibliometric software and document analysis. To analyze the extracted studies, we focus on keyword analysis. When entering the data into VOSviewer, given the limited total number of articles, it was determined that each keyword should appear at least once. A total of 206 top keywords from the Scopus database were selected for software analysis. Based on the

"strength and correlation", the software output among all 206 keywords, resulted in Fig 1 (Scopus database). Criteria used to assess keyword strength and correlation include the frequency of keyword occurrences, interdependency among keywords within a study or referenced studies, recurrence over time, and similar factors.

Figure 1.
Bibliometric Map Based on Keyword Strength and Correlation

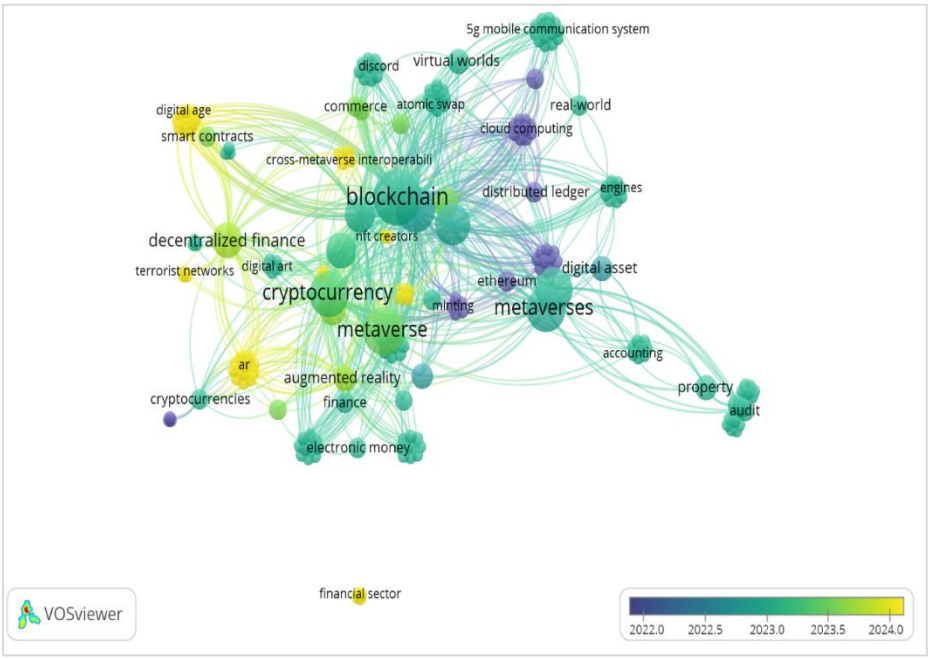


(Source: Researcher's Findings)

In the bibliometric map shown in Figure 1, terms like “Blockchain,” “cryptocurrency,” “metaverse,” and “metaverses” are positioned at the network's center, indicating the high importance and frequency of these concepts in recent research. These three areas are closely interlinked, underscoring the value of examining their shared applications. Terms like “decentralized finance (DeFi),” “NFT creators,” “virtual worlds,” “augmented reality,” and “distributed ledger” are connected to the central keywords, highlighting the focus on key topics related to decentralized finance, non-fungible tokens, virtual worlds, and distributed ledgers within the metaverse. These concepts play an essential role in shaping financial and economic interactions, particularly in the metaverse,. On the other hand, terms such as “atomic swap,” “cloud computing,” “digital asset,” and “finance” represent emerging trends studied in recent research on financial technology and the metaverse. These topics explore novel aspects of finance in the metaverse and the development of new financial structures based on Blockchain technology.

Figure 2 also reflects the chronological trend of keywords: darker terms indicate attention in earlier periods, while lighter ones represent topics that have gained prominence in more recent research. This demonstrates how specific topics have evolved over time, with research gradually shifting focus from initial concepts to more advanced topics in this field.

Figure 2.
Visualization of the Overlapping Terms and Associated Keywords Based on Time



(Source: Researcher's Findings)

In Figure 2, the emphasis on specific keywords is observed more distinctly, allowing a temporal analysis by comparing these trends over time. The color variations in the figure represent different periods in which these keywords garnered researcher attention: darker hues denote terms frequently studied in earlier years (like 2022), while brighter hues (yellow) highlight concepts that have gained prominence recently (up to 2024). Terms such as "decentralized finance (DeFi)," "smart contracts," and "cross-metaverse interoperability" appear in yellow, underscoring a growing interest in these emerging topics in 2023 and 2024. These keywords point to recent trends that currently attract significant research interest.

In contrast, foundational terms like "Blockchain," "cryptocurrency," and "metaverse," displayed in green and blue, were especially prominent in 2022. Although these terms continue to be relevant, they have become less of a central focus compared to newer terms. Their interconnectedness reflects that studies in one area frequently overlap with other core concepts in this domain. The strong links among terms like "distributed ledger," "finance," and "NFT" highlight the interplay and overlap between these ideas. Terms such as "financial sector" and "audit," observed on the right side of the visualization, suggest that applications of Blockchain and cryptocurrencies have progressively expanded into financial and accounting sectors, which have gained more research interest in recent studies.

This diagram indicates a trend in recent research towards emerging concepts such as Decentralized Finance (DeFi), smart contracts, and cross-metaverse interoperability, highlighting a shift in focus towards new and diverse applications of Blockchain and cryptocurrency in the metaverse. This focus signifies an evolving interest in exploring

novel applications, with Blockchain and financial interconnectivity underscoring the rising importance of these technologies in financial decision-making and digital asset management within the metaverse.

The second research question was answered using content analysis. A search of the Scopus and Web of Science databases and excluding duplicate and conference articles yielded a set of 24 research papers. These papers, analyzed using content analysis and summarized in Table 2, provide a detailed examination of current research topics and approaches within this evolving field.

Table 2.
Research Findings

NO.	Dimensions	Factors	Source
1	Trust and Transparency in Digital and Blockchain Transactions	Enhancing financial trust through arbitration in dispute resolution	(Chen, 2022)
		Reducing instability through Blockchain transparency	(Liu et al., 2022)
		Building trust through decentralized credit systems	(Ying et al., 2023)
		Building Financial trust through smart contracts	(Imperius & Alahmar, 2022)
		Impact of governance and decentralized organizations on financial behavior	(Goldberg & Schär, 2023)
		Effect of legal regulations on financial trust	(Блихар et al., 2023)
2	Financial Risks and Social Impacts in Cryptocurrency and NFT Transactions	Risks from illegal cryptocurrency activities	(Burgess et al., 2024)
		Market volatility and NFTs' stability in financial strategies	(Bourron, 2023)
		Motivations of financial participation by NFT creators	(Lee & Shen, 2024)
		Blockchain adaptation to cultural and economic needs	(Zhao et al., 2023)
		Fraud risks in the metaverse	(Smaili & de Rancourt-Raymond, 2022)
3	Innovations and Economic Opportunities in the Metaverse and Decentralized Technologies	Economic models of the metaverse and their impact on financial markets	(Sahiner, 2023)
		New financial opportunities in the NFT market	(Balaji et al., 2023)
		Financial behavior shifts through Web 3.0 and decentralized technologies	(Xu et al., 2023)
		Economic systems in the metaverse and investment patterns	(Huawei et al., 2023)
		Role of virtual worlds in digital financial transactions	(Kumar et al., 2023)
		Financial innovations in the metaverse	(D'Ulizia et al., 2024)
		Digital asset management in Blockchain	(Ersoy & Gürfidan, 2023)
		Decentralized asset management in the metaverse	(Alston, 2024)
4	Financial Motivations and Adoption in Digital and Metaverse Communities	Excessive expectations from the metaverse economy	(Vidal-Tomás, 2023)
		Gender influence on cryptocurrency adoption and participation	(Henshaw, 2023)
		Perception and acceptance of cryptocurrencies by younger generations	(Maciejasz et al., 2023)
		Acceptance of metaverse auditing and financial transparency	(Handoko et al., 2023)
		Motivation and appeal of digital real estate investment	(Ante et al., 2023)

(Source: Researcher's Findings)

Based on the classifications, it can be concluded that Blockchain and cryptocurrency technologies shape financial behaviors within the metaverse and digital economy by influencing various variables. These effects can be examined as follows:

1. *Increased Transparency and Financial Trust*: Blockchain technology enhances transparency in transactions and credit systems, strengthening users' trust in the digital economy. Decentralized tools like smart contracts and cryptocurrency dispute resolution systems help mitigate risk and bolster financial security within digital environments. Consequently, users are more inclined to engage with these platforms and participate in financial transactions within the metaverse, leading to increased financial engagement and trading activity.
2. *Diversification of economic and investment opportunities*: Blockchain and cryptocurrencies have created novel economic opportunities, including NFT markets and decentralized economic models within the metaverse. These opportunities allow users to gain profits and returns through digital assets, virtual investments, and even digital real estate. This introduces new forms of financial behavior and investment practices and broadens the diversity within financial markets.
3. *Asset management and decentralized economy*: Applying Blockchain and cryptocurrency technologies in the metaverse has expanded the concept of decentralized asset management. Users can manage and transfer their assets independently, without intermediaries, fostering a shift in financial behaviors toward financial autonomy and reduced reliance on traditional institutions. Additionally, digital assets can be exchanged across different metaverses, giving users direct control over asset management.
4. *Diverse financial motivations and acceptance based on demographic and cultural characteristics*: Research indicates that acceptance of Blockchain and cryptocurrency technologies in the metaverse is influenced by users' cultural and gender-specific traits. For instance, gender, age, and cultural background directly affect users' motivations for entering this field and their financial participation patterns. Therefore, Blockchain technologies and the metaverse pave the way for broader financial inclusion and foster new financial behaviors across diverse groups.

Discussion and Conclusion

The evolution of Blockchain and cryptocurrency technologies within the metaverse presents significant changes in user financial behaviors and interactions with digital economies. This study indicates that these technologies not only enhance transparency and trust in financial transactions but also create new economic opportunities, fundamentally transforming user engagement in financial activities.

The findings reveal that Blockchain's inherent transparency can mitigate the risks associated with traditional financial systems, increasing user confidence in digital asset

transactions. The integration of smart contracts and decentralized dispute resolution mechanisms further bolsters this trust, encouraging users to participate in the financial landscape of the metaverse actively. As users become more adept at navigating these digital environments, the frequency and volume of transactions will likely rise, contributing to the growth of a vibrant virtual economy.

Moreover, this research, in line with Yadav et al. (2022), highlights that diversifying economic opportunities through Blockchain and cryptocurrency enables the emergence of innovative investment practices. Users are engaged with established financial instruments and can explore new avenues such as non-fungible tokens (NFTs) and decentralized finance (DeFi) platforms. This diversification reflects a broader trend toward financial innovation, empowering users to take control of their financial futures through direct engagement with digital assets. The implications of this trend are substantial, suggesting a move towards a more participatory financial ecosystem that prioritizes user agency over traditional financial intermediaries.

In exploring the social and cultural dimensions of Blockchain and cryptocurrency adoption in the metaverse, this research underscores the importance of demographic factors in shaping financial behaviors. Variations in acceptance and participation rates based on gender, age, and cultural backgrounds indicate that financial technologies must be inclusive and adaptable to meet the diverse needs of users. As the metaverse evolves, stakeholders need to address these differences to promote widespread financial inclusion and equitable access to digital financial opportunities.

The research also identifies emerging trends that might influence future inquiries in this rapidly evolving field. Continuous examination of the effects of Blockchain and cryptocurrency technologies on economic frameworks and user behaviors is crucial, as emphasized by Afzal and Asif (2019). Future studies should focus on how these technologies can enhance financial literacy and inclusion, particularly for marginalized communities. Additionally, understanding the long-term effects of decentralized financial systems on traditional economic models will be vital for policymakers and financial institutions as they adapt to this changing landscape.

In conclusion, the intersection of Blockchain, cryptocurrency, and the metaverse represents a promising frontier for understanding financial behaviors, offering enhanced transparency, new economic opportunities, and greater financial autonomy. The insights gained from this study lay a foundational understanding of these technologies within the digital economy, paving the way for future inquiries into their broader societal implications. As researchers continue to explore this rapidly evolving domain, the potential for Blockchain and cryptocurrency to drive innovation in financial behaviors remains vast and largely untapped.

Limitations of the Research

Some of the limitations of the research include:

- Limited data: This study relies on data from specific databases such as Scopus and Web of Science. This may restrict the scope of the research and overlook

some relevant articles or findings in other databases.

- Timeframe: The research examines publications from a specific period (2021 to 2024). This choice may lead to a lack of attention to previous trends or relevant historical data, which could result in an incomplete picture of the impact of Blockchain and cryptocurrencies on financial behaviors.
- Language diversity: Only articles in English have been considered. This may lead to losinng important perspectives and research from non-English-speaking countries, which could contribute to a better understanding of the social and economic impacts of Blockchain and cryptocurrencies.
- Focus on research articles: This study has focused solely on research and review articles, excluding conference papers and books from the analysis. This may lead to overlooking some significant insights provided in these formats.
- Not considering other variables: The research focuses on the impacts of Blockchain and cryptocurrencies on financial behaviors, but other influencing variables in this field, such as psychological or cultural factors are disregarded in the analysis.

Suggestions for Future Research

The following practical suggestions can assist authors and researchers interested in further exploring the applications of Blockchain and cryptocurrencies in the metaverse and their implications for financial behavior:

- Expand Data Sources: Researchers should consider utilizing a more comprehensive range of databases beyond Scopus and Web of Science, such as Google Scholar or industry-specific repositories. This approach helps uncover additional relevant articles and findings that enhance the overall understanding of Blockchain and cryptocurrency applications in the metaverse.
- Broaden Timeframe: Future studies should examine publications from a longer historical period to identify trends and patterns over time. By including literature before 2021, researchers can gain valuable insights into the evolution of Blockchain and cryptocurrency technologies and their effects on financial behaviors.
- Incorporate Multilingual Research: To capture diverse perspectives, researchers should include articles published in multiple languages. Collaborating with international scholars or using translation tools can help integrate important findings from non-English-speaking countries, enriching the understanding of the global social and economic impacts of these technologies.
- Include Diverse Publication Formats: Future research should not only focus on research and review articles but also consider conference papers, white papers, and books. These formats may contain significant insights and innovative ideas that can contribute to a more comprehensive understanding of the applications of Blockchain and cryptocurrencies.

- Investigate Additional Variables: Future studies should explore psychological and cultural factors that influence user engagement with Blockchain and cryptocurrency technologies to create a holistic view of financial behaviors. Understanding these variables can provide deeper insights into how individuals interact with financial systems in the metaverse.
- Engage with Stakeholders: Researchers should actively collaborate with industry stakeholders, including technology developers, financial institutions, and policymakers, to gather practical insights and real-world data. This engagement can facilitate a better understanding of the practical applications and challenges associated with Blockchain and cryptocurrency adoption in the metaverse.

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The Impact of Customer Knowledge Management on Service Quality with the Mediating Role of Open Innovation

Sepideh Khodabakhsh[1] | **Mona Jami Pour**[2*] | **Rasoul Abbasi**[3] | **Mohammad Asarian**[4]

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Sepideh Khodabakhsh
M.A. of e-Business, Department of Business, Hazrat-e Masoumeh University, Qom, Iran.
E-mail: 3pid.khodabakhsh@gmail.com

Mona Jami Pour
Corresponding Author, Associate Professor, Hazrat-e Masoumeh University, Qom, Iran.
E-mail: m.jami@hmu.ac.ir

Rasoul Abbasi
Associate Professor, Hazrat-e Masoumeh University, Qom, Iran.
E-mail: r.abbasi@hmu.ac.ir

Mohammad Asarian
Ph.D. student of strategic management, Faculty of management, University of Tehran, Tehran, Iran.
E-mail: asarian@ut.ac.ir

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ABSTRACT

Service quality (SQ) is crucial for customer retention, making it essential for managers to understand the factors influencing it. In today's competitive landscape, organizations are increasingly investing in customer knowledge management (CKM) to enhance their service delivery. Although substantial research has been conducted on SQ, significant gaps persist, highlighting the need for further investigation. This study addresses these gaps by exploring the impact of CKM on SQ, with a particular focus on the mediating role of open innovation (OI). Adopting a quantitative approach, the research employs a descriptive correlational design and utilizes structural equation modeling for data analysis. The study sample comprises 200 companies in the information technology (IT) sector in Tehran, of which 139 completed the questionnaires. The obtained data were analyzed using AMOS and SPSS software. The findings indicate a positive and significant relationship between CKM and SQ, confirming that OI serves as a mediator in this relationship. Organizations that effectively integrate CKM with OI are more likely to achieve higher service quality, underscoring the importance of these strategies for enhancing customer satisfaction.

KEYWORDS

Customer Knowledge Management, Knowledge Economy, Knowledge Management, Open Innovation, Service Quality.

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Introduction

Recently, as the market has become consumer-oriented, improving SQ has been recognized as a strategic issue for businesses and a high-priority demand for customers (Yum & Yoo, 2023; Silvestri et al., 2017). Businesses that achieve a higher level of SQ have greater customer loyalty and brand attachment (Sharif et al., 2024; Rather & Camilleri, 2019; Budianto, 2019). To achieve such benefits, organizations must be aware of customer expectations and demands. One effective way to adapt to the changing needs of customers is through using CKM and treating it as an important source of tacit knowledge (Riggs, 2019).

Customer knowledge plays a significant role in the management of large organizations; therefore, organizations must acquire, develop, and enhance this knowledge to improve their performance (Tseng & Fang, 2015). Customer knowledge can support the development of new products, facilitate the understanding of emerging market opportunities, and improve long-term relationships with customers (Duarte et al., 2016). It is highly significant for a company's competitiveness, as customer engagement positively impacts outcomes such as customer loyalty and satisfaction, and value addition, which in turn affect business results like sales and market share (Fidel et al., 2015). Thus, organizations that focus on collecting, managing, and disseminating customer knowledge across their units are more likely to achieve a sustainable competitive advantage (Jaziri, 2019). In fact, 89% of the surveyed organizations considered customer-related information to be very significant and essential for their business success (Boateng, 2016).

Extensive research shows that the implementation of CKM leads to improved innovative activities, and increasingly emphasizes the role of customer collaboration in service delivery and innovation (Fidel et al., 2015). Also, understanding customer demands and managing the flow of knowledge between a company and its customers are vital for business model innovation (Wu et al., 2013). Rapid technological changes, short technology life cycles, high internal research and development costs, intense global competition, and advancements in IT have driven businesses towards creativity and innovation, a process which is referred to as open innovation (OI) (Secundo et al., 2019). Sharing knowledge through OI has become increasingly important since companies can use technological innovations to provide high-quality and personalized services at reasonable costs (Bican et al., 2017, Fisher & Qualls, 2018). A company’s capacity for innovation and competition depends on knowledge, highlighting that knowledge and innovation inseparable (Fidel et al., 2015).

The importance of customer knowledge (Gibbert et al., 2002; Wang & Xu, 2018), SQ (Solimun & Fernandes, 2018), and OI (Donate & de Pablo, 2015) in driving organizational success is well-established in the literature. Despite this extensive body of work, a comprehensive investigation of the interconnections among these three critical variables—CKM, SQ, and OI—remains considerably absent. While existing studies have partially addressed the relationships between these elements, they have mostly examined

them in isolation, focusing on the effects of knowledge management or customer relationship management (CRM) on individual outcomes such as SQ or innovation.

Accordingly, the current study seeks to bridge this gap by investigating the interplay between CKM and SQ, with a particular focus on the mediating role of OI within this dynamic. In doing so, this research not only aims to enhance our understanding of the relationships among CKM, SQ, and OI, but also underscores the crucial need for an integrated approach that acknowledges the synergies among these variables for improving organizational performance.

Literature review

Service Quality (SQ)

In today's business landscape, quality is essential for an organization's survival and success. Optimal quality and customer satisfaction guarantee the survival of an industrial unit, allowing for greater profitability and achieving competitive advantage (Solimun and Fernandes, 2018). To survive in today's markets, businesses must offer products and services that meet customer needs and address their expectations of product and service quality (Saglik et al., 2014). SQ is recognized as a vital factor affecting an organization's success in creating a competitive advantage (Rod et al., 2009). Quality refers to the development, design, production, and delivery of economic and usable services and products that satisfy consumer needs. SQ is "the measurement of how well the level of service delivery meets customer expectations" (Rod et al., 2009). In this research, the SQ model has been chosen as the foundational framework, and through a review of the theoretical foundations of SQ, the data points and dimensions have been identified, as outlined in Table 1.

Table 1.
The Dimensions and Indicators of SQ

Dimensions	Indicators	Sources
Responsiveness	Speed of responding to complaints	Fernandes and Coutinho, 2017; Lau et al., 2013
	Willingness to support customers	Duarte et al., 2016
	Service delivery speed	Tseng and Fang, 2015
Reliability	Maintaining customer records	Lau et al., 2013
	Assurance in dealing with problems	Duarte et al., 2016
	Assurance of financial communications	Duarte et al., 2016; Fernandes and Coutinho, 2017
	Fulfilling organizational promises	Lau et al., 2013; Tseng and Fang, 2015
	Providing accurate and high-quality services	Lau et al., 2013
	Providing timely service delivery	Tseng and Fang, 2015
Guarantee	Providing consultation and support to ensure the correct performance of tasks	Duarte et al., 2016
	Building customer trust in employees	Fernandes and Coutinho, 2017; Lau et al., 2013
	Creating a sense of security for customers	Fernandes and Coutinho, 2017
	Guaranteeing employees' politeness from the customers' perspective	Fernandes and Coutinho, 2017

Dimensions	Indicators	Sources
Empathy	Availability during hours suitable for customers	Lau et al., 2013
	Ease of communication with customers	Duarte et al., 2016
	Attention and patience of sales staff	Lau et al., 2013; Tseng and Fang, 2015
	Organizational attention to all customers	Fernandes and Coutinho, 2017
	Awareness of customer needs	Lau et al., 2013
Physical evidences	Using modern equipment in the organization	Duarte et al., 2016
	Suitability of the physical space for customers	Lau et al., 2013
	Personnel order and cleanliness	Fernandes and Coutinho, 2017; Lau et al., 2013
	Appropriateness of the physical space for the organization's services	Duarte et al., 2016; Lau et al., 2013

(Source: Researcher's Findings)

Customer Knowledge Management (CKM)

The development of technology has enabled organizations to collect, store, and manage information about their customers. To address the challenges posed by increasing competition and to remain in the competitive market, businesses must utilize customer information (Davenport & Völpel, 2001). Customer knowledge is defined as information regarding customers that has a direct or indirect impact on organizational performance (Zanjani et al., 2008). Customer knowledge is an essential intangible asset for organizations, as it helps them to align themselves with value creation (Tseng, 2009). According to Taherparvaret al. (2014), customer knowledge has become an important resource for improving company performance and achieving success. Therefore, given that customer knowledge plays a significant role in the management of companies, organizations must acquire and utilize it to enhance their performance (Boateng, 2016). Consequently, organizations that focus on collecting, managing, and disseminating customer knowledge across their units are more likely to achieve a competitive advantage (Jaziri, 2019). Customer knowledge can be categorized into three types, which are discussed below:

1) Knowledge for the Customer: It refers to the insights, data, or information that can be analyzed, interpreted, and ultimately transformed into knowledge to reach the target customer. In the literature, sources that provide knowledge for the customer are often overlooked. This knowledge can be obtained from various sources, including other customers, consulting institutions, competitors, and the company itself, to meet customer information needs.

2) Knowledge from the Customer: It refers to the insights, data, or information that can be analyzed, interpreted, and ultimately transformed into knowledge that an organization acquires to enhance its products and services.

3) *Knowledge about the Customer:* It refers to the insights, data, or information that a company uses to understand its target customer. Companies not only gather information about customers but also acquire information and knowledge related to them (Zanjani et al., 2008).

Integrating CRM with knowledge management systems in a business environment and establishing knowledge-based CRM processes guarantee the success of CRM. Therefore, organizations have integrated CRM with knowledge management, leading to the emergence of CKM (Dous et al., 2005). CKM results from the integration of knowledge management and CRM, offering organizations insights into their customers' profiles, latent needs, and desires. This, in turn, creates a competitive advantage for organizations and enhances their value and service capabilities for customers (Boateng, 2016) .

An effective way to adapt to customers' changing needs is to leverage customer knowledge and treat it as an important source of tacit knowledge (Taherparvar et al., 2014). Furthermore, by gaining a better understanding of customers, companies can increase their consumer engagement and market penetration (Singh and Kaur, 2011). Therefore, companies must effectively manage their interactions with customers to acquire knowledge that helps them to recognize costumer needs, characteristics, and purchasing behaviors (Jaziri, 2019). CKM has been established with the aim of creating value in organizations by transforming intellectual capital into an organizational asset (Allee, 2012). Table 2 outlines the dimensions and indicators used in this research, based on the established theoretical foundations.

Table 2.
Dimensions and Indicators of CKM

Dimensions	Indicators	Sources
Knowledge from the Customer	Customer experience with the product or service	Taherparvar et al., 2014; Wu et al., 2013
	Customers' creative ideas about the product or service	Solimun and Fernandes, 2018
	Customer feedback regarding SQ	Belkahla and Triki, 2011; Rollins and Halinen, 2005; Peng et al., 2009
	Customer feedback regarding competitors' SQ	Rollins and Halinen, 2005; Wu et al., 2013
	Customer feedback regarding their service needs	Taherparvar et al., 2014; Peng et al., 2009
Knowledge for Customer	Providing knowledge about future products and services	Belkahla and Triki, 2011, Sulaiman et al., 2011
	Providing knowledge about current products and services	Belkahla and Triki, 2011, Rollins and Halinen, 2005
	Providing information on the benefits of innovative services or products	Taherparvar et al., 2014
	Helping customers make better decisions regarding the organization	Wu et al., 2013
Knowledge about Customer	Gathering information about customer history	Peng et al., 2009, Taherparvar et al., 2014
	Gathering information about the number of customer referrals	Rollins and Halinen, 2005, Sulaiman et al., 2011
	Gathering information about costumer needs and expectations	Sulaiman et al., 2011, Taherparvar et al., 2014
	Gathering information about costumer demands	Peng et al., 2009, Rollins and Halinen, 2005
	Gathering information about customer problems and concerns	Wu et al., 2013
	Gathering information about customers' jobs and income levels	Peng et al., 2009, Rollins and Halinen, 2005
	Gathering information about customers' preferences and tastes	Taherparvar et al., 2014

(Source: Researcher's Findings)

Open Innovation (OI)

Henry Chesbrough, a professor at the University of California, Berkeley, introduced the concept of OI. He regarded OI as a new necessity for creating and profiting from technology and explained how companies in the twentieth century made significant investments in research and development, hired the talented individuals to foster innovative ideas, supported them with intellectual property strategies, and reinvested the profits back into research and development (Singh & Kaur, 2011). Fundamentally, OI suggests that valuable ideas can originate from both inside and outside the company, and can be commercialized from within or outside the company. Based on IO, companies need to embrace both the benefits and risks of lifting the barriers between organizational knowledge and the outside world. In fact, instead of keeping their technologies and innovations confined, one the one hand, companies share their ideas and organizational knowledge and utilize external sources of knowledge and technology, . On the other hand, they create opportunities for others, including their competitors, to benefit from the results of their organizational knowledge (Hafkesbrink & Schroll, 2010).

In OI, a company collaborates with technology suppliers and customers to enhance its internal innovation capabilities and simultaneously expand the market by externalizing its internal innovations (Jacobides & Billinger, 2006). As seen, in OI, the boundaries of a firm are highly permeable, and innovative activities do not occur solely within the company but extend beyond its borders (Fetterhoff & Voelkel, 2006). OI is divided into four different types: external innovation disclosure, external innovation sales, internal innovation sourcing, and internal innovation acquisition (Dahlander & Gann, 2010). The theoretical foundations of the indicators and dimensions of OI are provided in Table 3.

Table 3.
Dimensions and Indicators of OI

Dimensions	Indicators	Sources
Acquisition of Internal Technology/Knowledge	Participating in exhibitions to stay updated with current knowledge	Donate and de Pablo, 2015
	Acquiring technical knowledge from outside the organization	Hitchen et al., 2017, Mount and Martinez, 2014
	Systematic search for ideas outside the organization	Donate and de Pablo, 2015
	Active collaboration with external partners	Hitchen et al., 2017
	Collaboration with external partners based on their innovations	Gassmann et al., 2010
	Efficient system for searching external intellectual property and knowledge	Gassmann et al., 2010, Hitchen et al., 2017
	Membership in business and research clubs	Mount and Martinez, 2014
	Collaboration with external partners for innovation and product development	Donate and de Pablo, 2015
Extraction/External Knowledge	Mastering formal processes for selling technical knowledge and intellectual property	Donate and de Pablo, 2015, Gassmann et al., 2010
	Dedicating units to knowledge commercialization	Mount and Martinez, 2014
	Welcoming the sale of intellectual property	Donate and de Pablo, 2015, Gassmann et al., 2010
	Extracting technical knowledge and sharing it with external partners	Hitchen et al., 2017, Mount and Martinez, 2014
	Using advanced products and new knowledge within the organization	Hitchen et al., 2017

(Source: Researcher's Findings)

As seen, the systematic review of the related literature highlights the importance of customer knowledge (Gibbert et al., 2002; Wang and Xu, 2018), SQ (Solimun & Fernandes, 2018), OI (Donate & de Pablo, 2015), and their impact on the success and performance of organizations. However, the simultaneous effect of these three variables has not been investigated in previous studies. Tseng and Fang (2015) have explored the relationship between CKM and SQ (). Wu et al. (2013), Wang and Xu (2018), and Su et al. (2006) have investigated the impact of CKM on OI (), while Bican et al. (2017) and Fisher and Qualls (2018) have examined the relationship between OI and SQ. Therefore, a study needs to be carried out to investigate the relationship among these three variables simultaneously, and take the mediating role of OI into account.

Conceptual Model and Hypotheses Development

Relationship between CKM and SQ

Customers are essential for the survival of organizations. To retain customers, it is essential to identify their needs. Organizations cannot engage with customers unless they understand which services are valuable to them, how and when they need these services, and what value these services hold for their different customers (Madhoushi et al., 2011). This information must then be applied in companies' products and services to enhance their SQ level in areas that matter to their customers. Achieving this requires the implementation of CKM concepts and systems. Knowledge management serves as a key enabler allowing businesses to leverage their knowledge assets and provide better services to their customers. By utilizing CKM, organizations become more competitive and offer more cost-effective, and high-quality services that foster customer intimacy (Zaharova & Zelmene, 2004). Accordingly:

Hypothesis 1: *CKM has a positive and significant impact on SQ.*

Relationship between CKM and OI

In a knowledge-based economy, customer knowledge is an important resource for the innovation process, directly influencing the discovery of innovative ideas and indirectly affecting the efficiency of innovation. Therefore, companies are increasingly integrating their resources with those of external actors, especially customers, to acquire new ideas for improving their innovation capabilities. Customer ideas and knowledge can lead to the creation of new products/services, or improve existing products/services that have been overlooked by the company. Thus, if customer knowledge is effectively managed, it can improve the innovation process, research and development activities, and the future of organizational innovation (Huizingh, 2011) .

CKM actively collects knowledge through various techniques, such as market studies, online discussion forums, social networks, and running focus groups with customers. By providing knowledge about and from customers, CKM helps companies acquire valuable information and ideas that can benefit the innovation process (Taherparvar et al., 2014). CKM is a strategic tool for organizations to enhance innovation (Abou-Zeid & Cheng, 2004), identify new market opportunities, and maintain long-term relationships with

their customers (Darroch, 2005). Attention to knowledge flows, which affects the speed and quality of innovation, is important for companies (Wang & Wang, 2012). Companies should implement special systems to create collaboration and reintegration, enabling them to identify and meet customer needs, create an environment appropriate for engaging customers in innovation processes, and achieve valuable knowledge and innovative ideas (Hoyer et al., 2010) .

By providing an environment dedicated to obtaining appropriate feedback and information sharing among customers and between companies and customers, CKM enables companies to increase thier customer knowledge. Therefore, through CKM, companies gain access to a valuable source of new ideas that are suitable for innovation (Taherparvar et al., 2014). Accordingly:

Hypothesis 2: *CKM has a positive and significant impact on OI.*

Relationship between OI and SQ and mediating role of OI

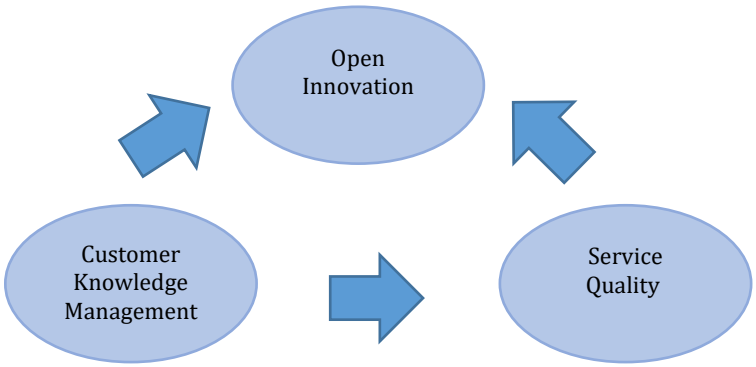
In OI, companies leverage the knowledge and skills of their partners during the innovation process, and accordingly, enhance the quality of their products, reduce costs, and manage risks (Fisher & Qualls, 2018). Factors such as increasing environmental ambiguities and uncertainties, changes in customer tastes and preferences, heightened competition, and technological developments have led companies to consider product quality more than ever as a critical factor for survival and success in competitive markets. Companies that implement OI processes based on external resources tend to be more profitable than those that rely solely on internal organizational resources. This can stimulate and encourage innovation by combining a wide variety of external resources. Additionally, the adoption of OI can manage the increasing diversity of products and lead to the better alignment of products with customer needs (Caputo et al., 2016).

Hypothesis 3: *OI has a positive and significant impact on SQ.*

Hypothesis 4: *OI plays a mediating role between CKM and SQ.*

Figure 1 illustrates the conceptual model of the research, designed to show the impact of CKM on SQ, while considering the mediating role of OI based on the identified variables.

Figure 1.
Conceptual Model of the Research



(Source: Researcher's Findings)

Methodology

The present research is quantitative in its purpose, and descriptive-correlational in nature. The statistical population consists of companies operating in the IT industry in Tehran. These companies were identified from a list provided in the database of active companies in the field of IT on the organization's website, . Then, questionnaires were distributed electronically and in person to managers and experts in the fields of customer relations, knowledge management, IT, and quality assessment, requesting their cooperation.

In this research, structural equation modeling was adopted to analyze the hypotheses, using Amos and SPSS. After persistent follow-ups and reminders over a period of one and a half months, from 200 distributed questionnaires, a total of 139 questionnaires were completed and used in the final analysis.

The main questionnaire of the present research was closed-ended and utilized a 5-point Likert scale. The questionnaire consisted of four sections: demographic information (6 questions), CKM (16 questions), SQ (22 questions), and OI (14 questions) .

To ensure the face and content validity of the questionnaire, it was sent to 5 professors in the field of management, particularly those specializing in knowledge management. After receiving their feedback, necessary revisions were made, and the content validity of the questionnaire was confirmed. For structural validity, indicators such as AVE and VIF were used. Additionally, composite reliability (CR) was employed to assess reliability.

Findings

The first section of the questionnaire includes demographic questions such as employees' gender, age, education, and number, and organization's age, and area activity. The results are presented in Table 4.

Table 4.
Demographic Statistics of the Participants

Feature	Dimension	Frequency
Gender	Female	44
	Male	95
Age	Under 25 years	6
	25-35 years	84
	35-45 years	32
	Over 45 years	17
Field of Activity	IT	50
	Communication Technology	19
	Information Society	29
	Producers and Contractors	13
	Consulting, Research, and Development	23
	Commercial Services	5

(Source: Researcher's Findings)

The results of validity and reliability, along with the mean and standard deviation of the dimensions are presented in Table 5. As shown, the reliability of all dimensions is

greater than 0.7, and the AVE of all dimensions exceeds 0.5. Additionally, the VIF for all dimensions is less than 2. Therefore, the validity and reliability of the questionnaire are confirmed.

Table 5.
Validity and Reliability of the Questionnaire

	Question Number	Dimensions	Mean	Standard Deviation	CR	AVE	VIF
1	1-3	Responsibility	3.364	0.914	0.764	0.698	1.338
2	4-9	Reliability	3.570	0.671	0.725	0.734	1.182
3	10-13	Assurance	3.658	0.704	0.856	0.699	1.148
4	14-18	Empathy	2.895	0.875	0.835	0.635	1.283
5	19-22	Physical evidences	3.492	0.798	0.921	0.711	1.519
6	23-31	Technology/External Knowledge Acquisition	3.962	0.955	0.879	0.806	1.108
7	32-36	External Knowledge	4.02	0.764	0.954	0.722	1.362
8	37-41	Customer Knowledge	3.325	0.925	0.722	0.665	1.329
9	42-45	Knowledge for Customer	3.681	0.939	0.822	0.693	1.639
10	46-52	Knowledge about Customer	3.775	0.922	0.935	0.709	1.113

(Source: Researcher's Findings)

The relationship between the variables is shown in Table 6 using the Fornell-Larcker criterion. The diagonal of this table represents the square root of the AVE of the variables, which should be greater than the correlation between that variable and other variables. Additionally, the CMIN/DF index is 1.670, which is less than 3. The GFI is 0.915, the CFI is 0.97, and the RFI is 0.929, all of which are greater than 0.9. The RMSEA index at 0.076 is also less than 0.08, confirming the model fit of the research.

Table 6.
Fornell-Larcker Criterion Results

Dimensions	1	2	3	4	5	6	7	8	9	10
1. Responsibility	0.83									
2. Reliability	0.28	0.85								
3.Assurance	0.31	0.29	0.84							
4. Empathy	0.35	0.11	0.46	0.80						
5. Physical evidences	0.41	0.16	0.39	0.27	0.84					
6. Acquisition/External Knowledge	0.18	0.30	0.17	0.17	0.23	0.90				
7. Extraction/External Knowledge	0.27	0.43	0.34	0.16	0.22	0.43	0.85			
8. Customer Knowledge	0.36	0.42	0.25	0.34	0.27	0.32	0.38	0.82		
9. Knowledge for Customer	0.45	0.21	0.27	0.28	0.26	0.16	0.36	0.39	0.83	
10. Knowledge about Customer	0.37	0.34	0.14	0.26	0.22	0.17	0.46	0.29	0.33	0.84

(Source: Researcher's Findings)

After examining the validity and reliability of the questionnaire and confirming the model fit, the model was implemented. The results of the hypotheses are presented in Table 7.

Table 7.
Results of the Examination of the Hypotheses

Hypothesis	Path	Path Coefficient	p-value	Result
1	Customer knowledge management → Service quality	0.32	0	Hypothesis Confirmed
2	Customer knowledge management → Open innovation	0.64	0	Hypothesis Confirmed
3	Open innovation → Service quality	0.45	0.01	Hypothesis Confirmed

(Source: Researcher's Findings)

In the next step, the mediating role of OI in the relationship between CKM and SQ was examined. In statistical tests, two questions need to be addressed about mediating variables: a) What is the indirect effect of X through M on Y? and b) Is the indirect effect of X through M on Y significant? For this purpose, the Sobel test was used to assess the significance of the mediating role of the two variables mentioned above. In this method, the amount of the indirect effect is calculated using the following formula, where 'a' represents the effect of the independent variable on the mediator, and 'b' represents the effect of the mediator on the dependent variable.

$$B_{indirect} = a * b$$

In addition to calculating the amount of the indirect effect, its significance can be assessed using tests such as Sobel, Baron and Kenny, and Goodman. In this research, the Sobel method was used for assessing the indirect effect. The test statistic is as follows:

$$z = \frac{a * b}{\sqrt{b^2 * sa^2 + a^2 + sxb^2}}$$

The assumptions are as follows:

a: The effect of the independent variable on the mediator

Sa: The standard error of the effect of the independent variable on the mediator

b: The effect of the mediator on the dependent variable

Sb: The standard error of the effect of the mediator on the dependent variable

As shown, the path coefficient for the relationship between CKM and OI is 0.64 (standard error = 0.079), and for the relationship between OI and SQ, itis 0.45 (standard error = 0.053). Therefore, as calculated below, the indirect effect of CKM on SQ is 0.288.

$$\mathrm{B_{indirect}} = \mathrm{a} * \mathrm{b} \rightarrow 0.64 * 0.45 = 0.288$$

Then, the significance of the indirect effect was examined using the obtained results:

$$\mathrm{z} = \frac{\mathrm{a} * \mathrm{b}}{\sqrt{\mathrm{b}^2 * \mathrm{sa}^2 + \mathrm{a}^2 * \mathrm{sb}^2}} = \frac{0.64 * 0.45}{0.45^2 * 0.079^2 + 0.64^2 * 0.053^2} \rightarrow \mathrm{t-value} = 5.538$$

Given that the calculated t-value is greater than 1.96, the indirect effect of CKM on SQ

through the mediating variable of OI is significant, and accordingly, the fourth hypothesis is confirmed. It is worth noting that since the direct effect of CKM on SQ is confirmed, the mediation of OI in the relationship between these two variables is partial, meaning that the CKM variable influences SQ both directly and indirectly (through OI).

Discussions and Conclusions

Today, competition to improve SQ is a strategic issue for organizations operating in the service sector. For many organizations, focusing on SQ is a necessary prerequisite for gaining customer satisfaction, building trust, and establishing long-term relationships with customers. As a result, SQ has become a vital factor guaranteeing organizations' success and competitive advantage in today's competitive market. Research has revealed that knowledge is the most important strategic resource for creating sustainable competitive advantage. Customer knowledge is an intangible and essential asset for any organization, helping them to create value. Customer knowledge can support the development of new products, facilitate the understanding of emerging market opportunities, and improve long-term relationships with customers. Therefore, organizations that focus on collecting, managing, and disseminating customer knowledge across their units are more likely to achieve sustainable competitive advantage. Innovation enables organizations to adapt to changing environments and enhance their efficiency.

Companies that invest in knowledge management and innovation can improve their performance and maintain their competitive advantage. Thus, being interested in the effect of customer knowledge on the goods and services provided to customers, we examined the effect of CKM on SQ with the mediating role of OI in this study. The analysis of the hypotheses showed that all hypotheses were confirmed.

According to *Hypothesis 1*, CKM has a positive and significant impact on SQ. The research findings regarding the first sub-hypothesis indicate that CKM has a positive and significant impact on SQ, with a coefficient of 0.35 and a significance level (critical ratio) of 2.589. One of the most important advantages of utilizing customer knowledge in an organization is the enhancement of products and services. For this reason, organizations must manage customer knowledge to enhance their efficiency and effectiveness, ensure the optimal delivery of high-quality products and services to customers, and achieve their satisfaction (Singh and Kaur, 2011). Studies conducted on this issue show that although implementing the CKM process is complex and challenging, organizations that successfully implement it improve their SQ and customer satisfaction (Denizci Guillet and Shi, 2019).

According to *Hypothesis 2*, CKM has a positive and significant impact on OI. The findings of the research regarding the second sub-hypothesis indicate that CKM has a positive and significant impact on OI, with an impact coefficient of 0.65 and a significance level (critical ratio) of 5.413. Many studies have demonstrated the effect of customer knowledge on fostering innovation (Gibbert et al., 2002; Donate and de Pablo, 2015). This hypothesis highlights the importance of customer knowledge flow in the IT industry. Through

utilizing the knowledge flow customers, companies active in the field of IT become aware of external ideas more quickly, and as a result, are more innovate and faster in their service offerings. Additionally, by leveraging customer knowledge, companies assure their customers that their opinions are important to the company. This assurance, in turn, paves the way for achieving better operational outcomes, such as high-quality products and customer satisfaction.

According to *Hypothesis 3*, OI has a positive and significant impact on SQ. The findings of the research regarding this sub-hypothesis indicate that OI has a positive and significant impact on SQ, with an impact coefficient of 0.43 and a significance level (critical ratio) of 3.162. Rapid changes in the competitive environment of the new world have created a new form of competition. Today's economy is driven more quickly by innovative organizations (those that create, generate, or transform knowledge into new products, services, and methods) than by other competitors. Nowadays, companies no longer need to create the best knowledge themselves to succeed; it is sufficient to leverage both internal and external knowledge and combine them to create innovative products and services. Moreover, the IT industry is one of the most dynamic sectors in the world, characterized by a high rate of change. Hence, the more innovative companies in this field are, the better products and services they provide to their customers.

According to *Hypothesis 4*, OI acts as a mediator in the relationship between CKM and SQ. To examine the role of this mediating variable, the Sobel test was used. The Sobel test calculations obtained a t-value of 5. 538.Since this value is greater than 1.96, the indirect effect of CKM on SQ through the mediating variable of OI is significant, thereby confirming the fourth hypothesis.

A review of the research background shows that numerous studies have highlighted the importance of SQ and customer knowledge in delivering services and products (Duarte et al., 2016; Tseng and Fang, 2015). In examining the first sub-hypothesis, the research findings indicated that there is a positive and significant relationship between CKM and SQ. This finding is in line with previous studies in that Torbati et al. (2014) and Tseng and Fang (2015) have also demonstrated that there is a significant relationship between CKM and SQ. The examination of the second sub-hypothesis, in keeping with previous research (Taherparvar et al., 2014; Wu et al., 2013), showed that there is a positive and significant relationship between CKM and OI. The examination of the third sub-hypothesis, consistent with the results of Duarte et al. (2016), indicated that there is a positive and significant relationship between OI and SQ.

Theoretical and practical implications

In today's highly competitive market, understanding the factors that influence service quality is essential for improving customer experience. Despite extensive research on service quality, the relationship among CKM, OI, and SQ has not received the attention it deserves. This research aims to address this gap to enhance the theoretical understanding of these concepts and providing managers looking to improve their service delivery with valuable insights.

Based on the results of the hypotheses of the present research, the following recommendations are provided:

Based on the findings of hypothesis 1, regarding the impact of CKM on SQ, it is recommended that managers and experts in customer relations within organizations in the IT industry allocate specific times for consulting and guiding employees. This will help them become more familiar with customer needs, and adopt and disseminate customer knowledge in various ways. It is suggested that companies in the IT sector conduct periodic surveys to gather customers' attitude towards service deficiencies and improve their services through customer feedback. When customers encounter problems, organizations should provide them with systematic solutions through their websites. Organizations are advised to provide their customers with information regarding the services and products they offer in the form of brochures, booklets, or electronic files.

Based on the results obtained from hypothesis 2, regarding the impact of CKM on OI, organizations can classify customers and offer products and services based on their needs and expectations. It is recommended that companies in the IT sector establish a dedicated CKM unit within their organizations. Organizations can improve customer information storage by utilizing databases, newsletters, workshops, and article libraries. They can also gather innovative feedback from customers through various mechanisms, such as wish lists, customer surveys, customer ratings, and having meetings with customers.

Based on the findings of hypothesis 3, regarding the impact of OI on SQ, it is recommended that companies in the IT sector participate in exhibitions and conferences to stay informed about the latest global knowledge and utilize it. Companies in the IT sector are encouraged to enhance their research and development units and establish a unit dedicated to commercializing the knowledge of this field. They are also encouraged to join domestic and international research and business clubs.

In this research, in addition to confirming the direct impact of CKM on SQ, the indirect impact of CKM on SQ through the mediating variable of OI was confirmed. Accordingly, organizations and companies active in the IT sector are advised to strengthen the relationship between CKM and SQ by enhancing OI mechanisms, thereby providing improved services to customers.

Research Limitation and suggestion for future studies

Like other research, this research is not without its limitations, which also highlight opportunities for future quantitative and qualitative studies. Firstly, this study focused solely on companies within the IT sector. It would be beneficial to conduct similar research across different industries and compare the findings to see how they align or diverge. Second, future research could examine moderating variables such as organizational culture, company size, and organizational structure to better understand their influence on the relationships identified in this research. Exploring these aspects could provide a more comprehensive understanding of the phenomena under investigation.

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The Impact of Digital Marketing Competencies on Performance of Sales Force

Zohreh Mohammadyari[1*]

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Zohreh Mohammadyari
Corresponding Author, Assistant Professor, Department of Management, Lorestan University, Khorramabad, Iran.
E-mail: mohammadyari.z@lu.ac.ir

ABSTRACT

In the 21st century, the sales landscape has grown increasingly complex due to the shifts in behavioral, technological, and managerial practices. The performance of sales teams has been a long-standing topic of interest for both academics and marketing professionals. Understanding the factors that boost the performance of sales force is a key aspect of sales management and can greatly influence a company's success and survival. This study aims to explore the effect of digital marketing competencies on the sales performance of small and medium-sized enterprises (SMEs) in Ilam city. The research is applied in nature and utilizes a descriptive-correlational approach, with data gathered through surveys. The study's population consists of the sales forces of active SMEs in Ilam city. Given the small size of the population, a census sampling method was employed. After data collection, 132 valid questionnaires were used to be analyzed. The research instrument was a standardized questionnaire, with content validity confirmed by subject matter experts and reliability established through Cronbach's alpha test. Data analysis was conducted using LISREL software. The findings indicated that digital marketing competencies have a significant and positive influence on the sales performance of SMEs in Ilam city. Moreover, technical-specialized, human-behavioral, and analytical competencies were also found to positively impact the performance of sales force. The results of this study suggest that digital marketing skills are critical for improving the performance of sales force. By providing sales teams with the necessary digital marketing tools and strategies, companies can enhance customer engagement and drive sales. Integrating digital marketing into sales operations can lead to better customer interaction, increased lead generation, and improved conversion rates. Sales professionals with digital marketing expertise are better equipped to navigate the evolving digital marketing landscape and meet the changing demands of modern consumers.

KEYWORDS

Digital Marketing, Performance of Sales Force, Sales.

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Introduction

In the modern era, the sales landscape has evolved significantly, driven by changes in consumer behavior, technology advancements, and shifts in management approaches (Han et al., 2018). Sales effectiveness has been a focal point for researchers and professionals in marketing field. Understanding the key elements that contribute to improved sales performance is fundamental in sales management and can play a critical role in a company's competitiveness and prosperity (Asgari, 2018). Undoubtedly, profit growth in the market is one of the main objectives of institutions and economic enterprises. That is, one of the important factors in evaluating the growth and profitability of these institutions is their sales volume (Kim et al., 2017). To achieve a higher level of sales and market share, continuous alignment with customer expectations and needs is the key to success for companies, and success in this endeavor is possible when marketing principles and techniques are employed (Dehdashti Shahrokh & Pour Hosseini, 2013).

One of the newest marketing tactics is digital marketing. In the last decade of the current century, digital transformations have enabled many marketers to produce and distribute more goods and services while reducing costs, requiring them to place the customer at the center of the company's organizational culture and align all sections and functions accordingly, replacing the transactional view with a customer relationship perspective (Kanan, 2017). The emergence and development of the Internet have created new opportunities for marketers to better carry out their current marketing activities (Kardaras et al., 2019). Digital marketing refers to marketing products and services using online tools. These tools are utilized by many multinational and international companies, and their scope has expanded worldwide. The Internet has fundamentally changed the concept and perspective of marketing, significantly impacting the global economy. Additionally, online marketing has altered marketing methods and consumer behavior (Mohammadian et al., 2019).

The emergence of this type of marketing has shifted the marketers' responsibilities from billboard and print advertising to online marketing environments. Today, companies focus on designing web pages instead of advertising their products through television commercials, billboards, magazines, newspapers, and so forth. Digital marketing is the future of marketing management because it is fast, cost-effective, and it provides accurate information to customers in a timely manner (Ronaqi & Maniyan, 2015). Research has shown that many people are attracted to digital advertisements today. Social networks and web environment are not specific to a particular age group, and everyone can view these advertisements on web pages. Nowadays, consumers are not loyal to a specific brand; therefore, with the help of digital marketing, companies can update their products and services to maintain consumer loyalty (Patrick et al., 2018).

To survive in today's business world, companies must adopt online marketing tools for buying and selling, and it can be said that these tools are the golden key to the success of companies (Soleimani & Dadras, 2017). Despite the numerous advantages and applications of the Internet and digital marketing which are widely used, they have not

found their true place in Iran and in many manufacturing and service companies yet due to various reasons such as lack of infrastructure, trust issues, and so forth.

This issue has increased customer purchasing inclination, with customers showing little attention to this type of purchase and being minimally influenced by it. Although numerous studies have been conducted abroad on digital marketing, very few studies have been carried out in an Iranian context. Thus, it is necessary to investigate the impact of digital marketing on the performance of sales force, which is the ultimate goal of this paper, as it can somewhat fill the scientific gap in this area. Therefore, the main question of this study is if digital marketing competencies have a significant impact on the performance of sales force in small and medium-sized enterprises in Ilam city.

Theoretical Framework

Digital Marketing

Digital marketing is essential in today's interconnected world, utilizing online tools and platforms to effectively reach and engage target audiences. Its importance stems from its ability to connect businesses with customers in a more personalized and interactive way than traditional marketing methods. By leveraging digital channels like social media, email marketing, search engine optimization (SEO), and content marketing, businesses can not only boost brand visibility but also drive conversions and foster customer loyalty (Deku et al., 2024).

Moreover, digital marketing provides businesses of all sizes with an opportunity to compete in global markets. Small enterprises can leverage cost-effective digital strategies to reach a wide audience and compete with larger corporations. The ability to track and analyze data in real-time also provides valuable insights for marketers to optimize their campaigns, target specific audiences, and measure the return on investment accurately. In essence, digital marketing has become a cornerstone of modern business practices, offering unparalleled reach, flexibility, and measurability for brands striving to remain relevant and competitive in digital age (Jadhav et al., 2023).

Digital marketing refers to a set of activities aimed at promoting products and services using digital tools. This is a very simple definition of digital marketing; in reality, digital marketing is much broader than other methods used by traditional companies (Apasrawirote et al., 2022). In another definition, digital marketing encompasses the activities for promoting or selling products, services, or offerings in the online space; it specifically refers to marketing conducted over the Internet (Jadavi et al., 2023).

Digital marketing utilizes the Internet, mobile devices, social media, search engines, and other channels to engage consumers. Many marketing experts consider it a novel approach for reaching customers, offering new insights into consumer behavior that differ from traditional marketing methods. Digital marketing focuses on targeting specific audience and building a dynamic, two-way relationship with customers. This includes strategies such as online advertising, email campaigns, job-related tweets, and initiatives that encourage customer feedback.

Digital marketing represents a two-way interaction between companies and consumers (Amiri et al., 2023). In today's world, television advertising, billboards, street advertising, telemarketing, or in-person marketing are no longer the only ways to attract customers. People are spending more time than ever on the Internet and in virtual spaces, making this environment a very suitable place for marketing (Ranjan, 2023). Digital marketing affects the behavior of users and audiences through implementing tools such as websites, emails, and social networks. In fact, the main goal of digital marketing is to sell, especially to increase sales by reaching a wider target audience. In traditional marketing, it may never be possible to reach a wide range of audiences (Zaki et al., 2023).

Performance of Sales Force

The performance of Sales and its management are key strategies for any business (Høgevoldet al., 2024). A sales manager's ability to train and retain sales representatives is vital for both the company's performance and its long-term success. Employee retention in sales remains a major challenge. When sales reps are equipped with the necessary skills for their roles, they are more likely to feel satisfied with their jobs and recognize that their efforts are valued by their employer. This, in turn, decreases the chances of their resignation (Saha & Kar, 2021). The performance of sales involves ensuring that every team member meets the organization’s objectives and delivers the desired outcomes.

An effective performance management process for sales teams typically includes training, tracking progress, and fostering the development of new skills (Shin et al., 2023). The performance of sales is the result of customer interactions and the influence a salesperson exerts, achieved through the sales process (Yazdanshenas & Khorsandi, 2020). Historically, sales success relied heavily on verbal communication, with salespeople playing a key role in persuading customers to make purchases. However, in today’s unpredictable purchasing landscape, product packaging has become a critical factor in the performance of sales, using visual communication to capture consumer attention and drive buying decisions (Kuo et al., 2023). Implementing a robust management process of the performance of sales is essential for team success. There is often a direct link between the efforts of sales representatives and the measurable outcomes seen by sales managers and the company as a whole (Rodriguez et al., 2022).

Digital Marketing and Performance of Sales

The modern world is experiencing rapid and extraordinary changes, with the pace and scope of these transformations being unprecedented. While change has always been a part of life, the current rate of evolution is remarkable. Organizations, as key elements of contemporary societies, are also swiftly adapting, and improving the performance of sales has become a primary goal for many (Poursalimi et al., 2014). As a result, understanding the factors that influence the performance of sales is crucial, as it provides valuable insights for managers looking to enhance both organizational and employee performance (Marjani & Mosafer, 2017).

One of the key factors influencing the performance of sales is the application of marketing principles (Yazdanshenas & Khorsandi, 2020). In today's business landscape, digital marketing has become an essential element of a brand's overall marketing strategy. Digital marketing capabilities involve an organization's ability to leverage the Internet and various information technologies to enhance communication with customers. These interactions not only provide customers with access to the organization's information and resources but also offer valuable insights into customer behavior (Soleimani & Dadras, 2017). Digital marketing goes beyond just online advertising and includes activities such as management of customer relationship, sales operations, post-sales support, and marketing research.

Digital marketing adds value in two primary ways: by closely aligning with the company's business processes and by granting customers direct access to the company's resources (Kanan, 2017). It offers numerous benefits, including access to a global market, greater efficiency compared to traditional marketing channels, the ability to provide new services through the Internet technology, and saving both time and costs. Digital marketing also enables continuous, interactive relationships with customers, simplifies choices, supports using text, audio, and video content, delivers a wealth of useful information, uncovers new opportunities, and keeps companies updated on the latest trends (Chkoniya & Matthews, 2019).

Literature review

Several studies have been conducted regarding the variables of the present research, which are summarized below. Babashahi et al. (2020) conducted a qualitative study which involved a total of 17 interviews. After collecting the data, the codes related to the written interviews were analyzed using thematic analysis. The findings of the research, following the three stages of open, axial, and selective coding, revealed that the model of digital marketing competencies for managers was formed with 114 codes and 26 concepts across three categories of technical-specialized competencies, human-behavioral competencies, and analytical competencies.

Mohammadian et al. (2019) conducted a study using a meta-synthesis approach based on 2,150 articles. They found that the Internet of Things (IoT) technologies can be applied across seven areas of the marketing mix including product, place, price, promotion, processes, physical evidence, and human resources. Their quantitative analysis showed that research in this field is on the rise, with the majority of applications focusing on promotion, followed by product and process areas. Rahimi et al. (2018) conducted a research study with 74 employees from Alborz Insurance Agency in Ahvaz with results indicating that listening skills within the sales force have a positive and significant effect on adaptive selling behavior and performance of sales. Moreover, adaptive selling behavior positively impacts the performance of sales and partially mediates the relationship between sales force listening and performance.

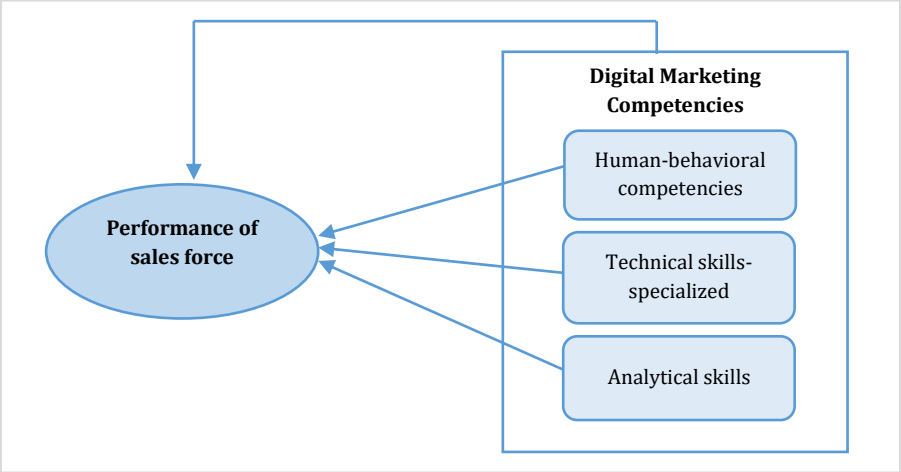
Saberi (2018 who conducted a study among 384 customers of chain stores in Tehran, emphasized that the intelligent use of tools and facilities to enhance production quality and effective promotion is referred to as a knowledge-based process. Utilizing knowledge from the virtual space to achieve this goal is termed the Internet or electronic marketing, which is considered as a modern and successful process. To keep pace with global transformations and achieve success in various aspects of trade and interaction, it is essential to consider this option as an impactful indicator aligned with global standards. Using expertise and creativity in providing successful solutions will play a fundamental role.

Ghotbifar et al. (2016) identified and analyzed the factors contributing to skill gaps in digital marketing among 226 employees of communication companies. Their findings revealed that operational strategic factors and environmental factors had a direct and positive influence on the creation of skill gaps in digital marketing within the studied companies. Among these, the environmental factors such as social and cultural conditions, religion, technology, and economy had the most significant impact. Additionally, it was found that the largest skill gap among the companies was in communication principles, while the smallest gap was in future forecasting.

In a 2024 study, Deku et al. explored how digital marketing influences the business performance of small and medium-sized enterprises (SMEs) in emerging markets with results indicating that digital marketing positively impacts the business performance of these companies. Similarly, in another study, Jadhav et al. (2023) focused on the role of digital marketing in transforming small and medium-sized companies with results showing that it leads to positive changes in their performance. Raj and Vee (2021) studied factors that improve the relative performance of sales forces in an Indian insurance industry, identifying marketing strategies, brand positioning, and digital advertising as key elements influencing the performance of sales. Kardaras et al. (2019) conducted another research study to emphasize on the role of social networks in digital marketing. The participants were 400 customers of service companies in Albania. Their study showed that digital marketing positively impacts the innovation and overall organizational quality. Patrick et al. (2018) examined the effect of online marketing strategies on hotel performance in France. The findings showed that these strategies enhance the performance of seven-star hotels significantly. Kaku (2017) explored the impact of digital marketing in mobile industry, revealing that digital marketing tools significantly boost electronic advertising and trust, contributing to improved strategic sales for companies.

Based on the theoretical foundations and empirical background presented, the conceptual model of the current research is illustrated in Figure 1.

Figure 1
Conceptual Model of the Research Study



(Source: Researcher's Findings)

Based on the conceptual model of the research, a total of four hypotheses (one main hypothesis and three sub-hypotheses) were formulated to be examined in this study. The research hypotheses are formulated as follows:

- Digital marketing competencies significantly affect the performance of sales force (Main Hypothesis).
- Technical and specialized competencies in digital marketing significantly impact the performance of sales force (Sub-Hypothesis 1).
- Human-behavioral competencies in digital marketing significantly influence the performance of sales force (Sub-Hypothesis 2).
- Analytical competencies in digital marketing significantly contribute to the performance of sales force (Sub-Hypothesis 3).

Methodology

This research study is categorized as an applied study based on its objectives and is classified as descriptive-correlational in terms of its methodology. The data collection method employed is survey-based. The study's statistical population consists of 150 sales representatives from small and medium-sized enterprises (SMEs) in Ilam city. Given the relatively small size of the population, a census method was utilized for sample selection. As a result, 150 questionnaires were distributed, and 132 were deemed valid for analysis.

In this study, a field method was employed to collect the information relevant to answering the research questions. Additionally, library methods such as studying books, articles, journals, research proposals, and online databases were utilized for compiling and writing the literature review and theoretical foundations. The primary data collection tool in this study is a questionnaire. The overall framework of the questionnaire and the questions related to each variable are presented in Table 1.

Table 1.
Questionnaire Questions

Variable	Dimensions	Many questions	Cronbach's alpha coefficient
Performance of sales force	----------	6	0.79
Digital Marketing Competencies	Technical-Specialized Competencies	4	0.82
	Human-Behavioral Competencies	4	0.76
	Analytical Competencies	4	0.85
The whole questionnaire	----------	18	0.88

(Source: Researcher's Findings)

To assess the validity of the questionnaire, expert opinions and professors' evaluations were sought, emphasizing its content validity. The questionnaire was approved by 10 faculty members from the management department of Tehran University. To assess the reliability, Cronbach's alpha coefficient was calculated, with results presented in Table 1. Since the Cronbach's alpha values for all variables and dimensions exceeded 0.70, the reliability of the questionnaire was confirmed. Furthermore, the data analysis in this study was conducted using LISREL software.

Findings

In this section, we will first examine the normality of the data using the Kolmogorov-Smirnov test, along with the sample adequacy test (KMO) and Bartlett's test of sphericity. The results of these tests are reported in Table 2.

Table 2.
Results of Normality and Sample Adequacy Tests

index (KMO)	Bartlett's Test sig	Variables	Number of items	"Significance Level of K-S"	the result
0.85	0.001	Performance of Sales Force	6	0.88	The data distribution is normal
0.93	0.000	Technical-Specialized Competencies	4	0.94	The data distribution is normal
0.76	0.000	Human-Behavioral Competencies	4	0.90	The data distribution is normal
0.79	0.000	Analytical Competencies	4	0.67	The data distribution is normal

(Source: Researcher's Findings)

As shown in the above table, the significance level for all variables is greater than 0.05; therefore, with 95% confidence, the hypothesis of normality of the data is confirmed for all variables. Additionally, the acceptable value for the KMO index is greater than 0.50, and the significance level in Bartlett's test should also be less than 0.05.

Based on the results obtained in Table 2, it can be concluded that the sample adequacy for the present research is in a favorable condition. The results of the correlation test between the research variables are reported in Table 3.

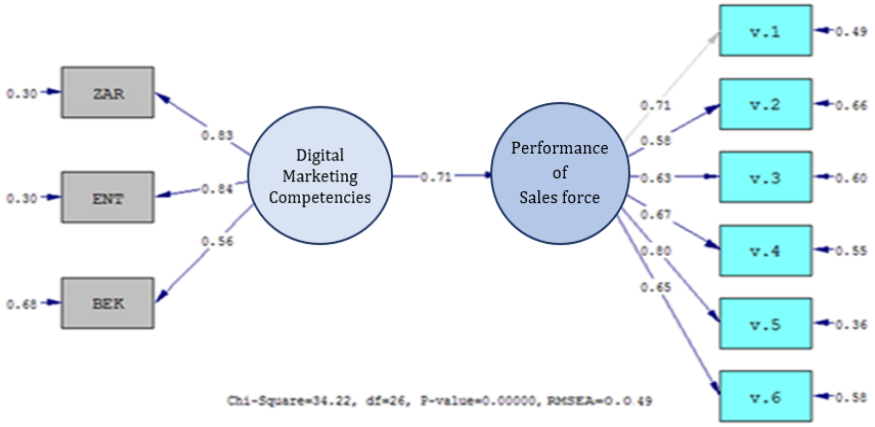
Table 3.
Correlation Matrix between Independent and Dependent Variables

Variables	1	2	3	4
Sales Force Performance	*	0.77	0.87	0.84
Technical-Specialized Competencies	*	*	0.86	0.80
Human-Behavioral Competencies	*	*	*	0.81
Analytical Competencies	*	*	*	*

(Source: Researcher's Findings)

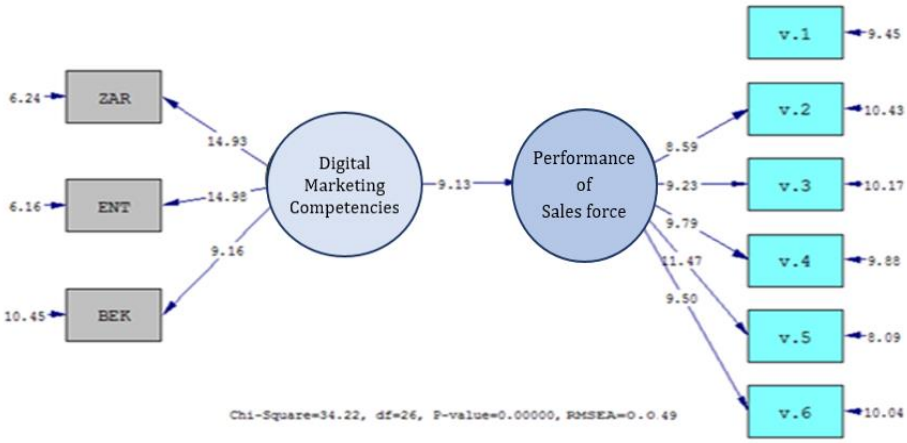
As shown in Table 3, the correlation coefficients between the research variables are positive and significant. To test the research hypotheses, Structural Equation Modeling (SEM) was employed. In this study, two different models were used to test the main hypothesis and the sub-hypotheses.

Figure 2.
The Structural Model of the Main Research Hypothesis in Standard Estimation Mode



(Source: Researcher's Findings)

Figure 3.
The Structural Model of the Main Research Hypothesis in the Significance Coefficients Mode



(Source: Researcher's Findings)

To evaluate the model's goodness of fit, some specific indices were utilized, as shown in Table 4. The calculated values of these indices were compared with the acceptable thresholds, and the findings demonstrate that the model fits satisfactorily.

Table 4.
Comparison of the Goodness-of-fit Indices of the Main Research Hypothesis

Indicators	Permissible value:	Calculated coefficients of the main research model	The result
GFI	Greater than 0.9	0.90	good fit
AGFI	Greater than 0.9	0.91	good fit
RMR	The closer to zero, the better	0.09	good fit
NFI	Greater than 0.9	0.94	good fit
IFI	Greater than 0.9	0.96	good fit

(Source: Researcher's Findings)

Table 4 displays the status of the indices for the structural model related to the main research hypothesis. A comparison between the calculated coefficients and the acceptable range shows that the model's goodness-of-fit indices are suitable. The findings concerning the main research hypothesis are presented in Table 5.

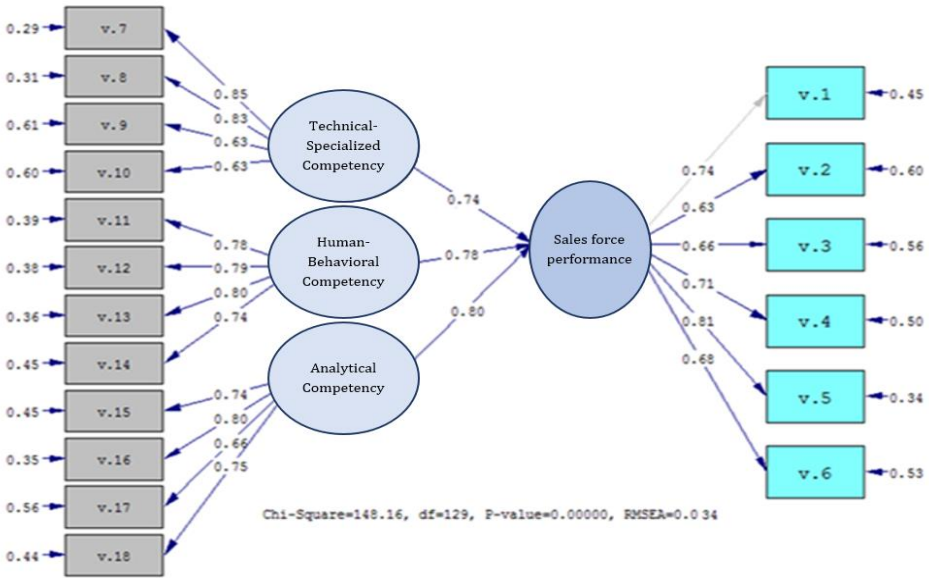
Table 5.
Results of the Examining the Main Research Hypothesis

Standard coefficient	T-value	Independent variable	Dependent variable	Test result
0.71	13/9	Digital Marketing Competencies	Performance of Sales force	Rejection H0

(Source: Researcher's Findings)

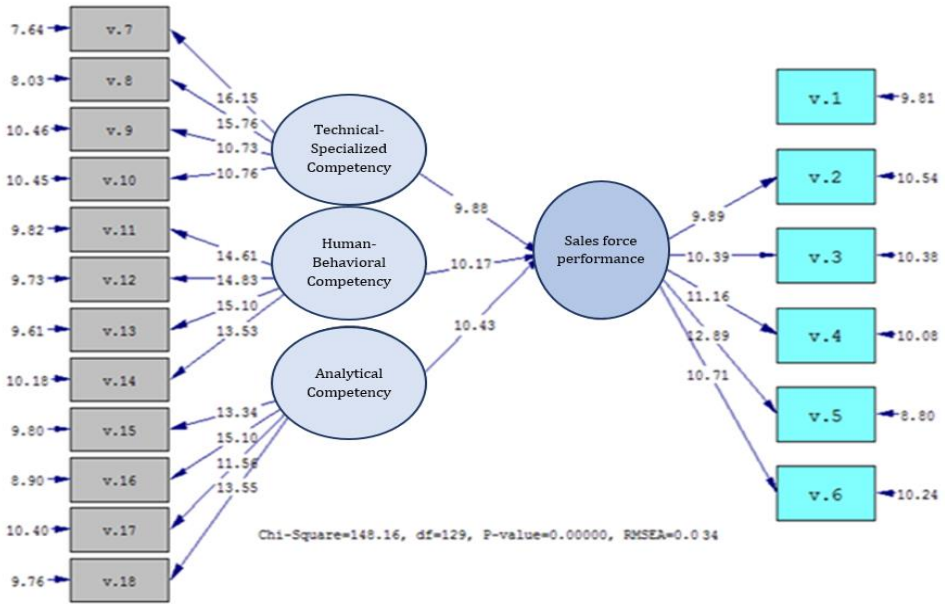
According to Table 5, the standard coefficient between digital marketing competencies and the performance of sales force is 0.71. With a t-value of 9.13, which exceeds the threshold of 1.96, the main research hypothesis is supported. This indicates that digital marketing competencies have a direct, positive, and significant influence on the performance of sales force of small and medium-sized enterprises in Ilam city.

Figure 4.
Structural Model of Research Sub-Hypotheses in Standard Estimation Mode



(Source: Researcher's Findings)

Figure 5.
The Structural Model of the Sub-Hypotheses in the Significance Coefficients Mode



(Source: Researcher's Findings)

The goodness-of-fit indices of the structural model of the sub-hypotheses are reported in Table 6. The results indicate a satisfactory fit of the model.

Table 6.
Comparison of the Goodness-of-fit Indices of the Structural Model of the Sub-hypotheses

Indicators	Permissible Value	Calculated Coefficients of the Sub-Hypotheses Model	The result
GFI	Greater than 0.9	0.96	good fit
AGFI	Greater than 0.9	0.99	good fit
RMR	The closer to zero, the better	0.07	good fit
NFI	Greater than 0.9	0.92	good fit
IFI	Greater than 0.9	97/	good fit

(Source: Researcher's Findings)

Based on the structural model of the sub-hypotheses of the research in standard estimation mode and significance coefficients, the results of examining the sub-hypotheses of the research are reported in Table 7.

Table 7.
The Results of Examining the Sub-hypotheses

Independent variable	Dependent variable	Standard coefficient	T-value	Test result
Technical skills – specialized	Performance of Sales force	0.74	88/9	confirmation
Human-behavioral competencies	Performance of Sales force	0.78	17/10	confirmation
Analytical skills	Performance of Sales force	0.80	43/10	confirmation

(Source: Researcher's Findings)

Based on Table 7, the standard coefficients between the independent and dependent variables have all been found to be positive. Additionally, considering the t-values obtained for all three sub-hypotheses, which are greater than 1.96, it can be concluded that technical-specialized competencies, human-behavioral competencies, and analytical competencies in digital marketing have a direct, positive, and significant impact on the performance of sales force of small and medium-sized enterprises in the city of Ilam.

Discussion and Conclusion

The reliability of any research study is largely determined by the results it produces and their relevance in practical terms. This study sought to explore the effect of digital marketing competencies on the performance of the sales force in small and medium-sized enterprises in Ilam. Following the introduction and clarification of the topic, four hypotheses were developed—one main hypothesis and three sub-hypotheses—based on the theoretical framework and conceptual model of the study. After gathering the data using a standardized questionnaire and analyzing it through LISREL software, the findings confirmed all four hypotheses.

The main hypothesis of this study revealed that digital marketing competencies significantly and positively influence the performance of the sales force in small and medium-sized enterprises. These competencies allow sales teams to access global markets more effectively through digital platforms and modern techniques. According to Kordaras et al. (2019), utilizing digital marketing enables sales forces to better promote their brand and enhance the brand recognition, which in turn boosts the products' sales. Babaei and colleagues (2020) also highlighted that digital marketing competencies can equip sales teams with more effective methods for negotiating and closing deals with customers.

The sub-hypotheses of the research further confirmed that technical-specialized competencies, human-behavioral competencies, and analytical competencies in digital marketing all have a direct, positive, and significant impact on the performance of sales force in small and medium-sized enterprises in Ilam. In this regard, digital marketing not only helps sales teams utilize technology efficiently but also improves their interactions with customers. Kannan (2017) emphasized that digital marketing competencies enhance the speed and efficiency of the sales process, directly contributing to increased sales and revenue. Moreover, Chakania and Matthews (2019) pointed out that with digital marketing competencies, the sales force can respond more quickly and effectively to competitors, thereby enhancing business competitiveness.

Based on the results obtained, the following recommendations are suggested:

- One of the main challenges of digital commerce is the issue of ethics and adherence to ethical standards. Therefore, it is recommended that managers create appropriate legal conditions to provide a suitable environment for ethical behavior among sales staff.
- Self-development and improvement of individual capabilities of the sales force in

establishing constructive communication with customers and having the necessary knowledge to respond to questions, requests, and guidance for customers are recommended.

- Senior managers of small and medium-sized enterprises are advised to enhance their skills in analyzing and understanding markets, as well as in identifying environmental opportunities and threats.

To guide and assist future research conducted by other researchers in this field, it is suggested that this research be examined in other industries and different geographical areas.

In conducting this study, the researcher faced limitations, some of which are unavoidable due to the nature of this type of scientific research in human domain. Since this research was conducted in a small segment of a large statistical population, generalizing its results to similar sectors and organizations should be done with caution. Another limitation of the current study is the small sample size and the possibility of bias in the results and how to generalize the results to other companies.

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Examining Technological Trends in Iran's Manufacturing Sector through Science and Technology Indicators

Sahar Bashiri[1*] | **Hassan Heydari**[2]

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Sahar Bashiri
Corresponding Author, Assistant Professor of Economics, Hazrat-e Masoumeh University, Qom, Iran.
E-mail: sahar.bashiri01@yahoo.com

Hassan Heydari
Assistant Professor, Department of Economics, Faculty Member of Tarbiat Modares University, Tehran, Iran.
E-mail: hassan.heydari@modares.ac

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ABSTRACT

This paper examines the technological trends in Iran's manufacturing sector over time, using the following science and technology indicators: human capital per capita from the Federal Reserve Bank of St. Louis, the ratio of research and development expenditures to gross domestic product calculated by the World Bank, the World Bank human capital index , the economic complexity index from Harvard University's Atlas of Economic Complexity, the Global Innovation Index published by the World Intellectual Property Organization, and the manufacturing competitiveness performance as calculated by UNIDO. By analyzing the developments in various science and technology indicators within Iran's manufacturing sector, it can be concluded that these indicators showed an upward trend until the late 1380s (2000s in the Gregorian calendar). Overall, both the Iranian economy and the manufacturing sector were moving towards greater complexity and increased technology use. However, since the early 1390s (2010s in the Gregorian calendar) and the onset of economic sanctions, technological advancement in the manufacturing sector has stalled, leaving the Iranian economy in a relatively stagnant state, with some indicators even showing a backward movement. Despite this, given the potential of Iran's economy, appropriate policymaking could partially reverse this trend. Considering the overall findings of this article, which indicate a decline in technological activities of the manufacturing sector over the past decade, we can argue that the lack of economic stability in the manufacturing sector, and macroeconomic developments in the country, have created an unfavorable environment for Iranian industries. This situation has led entrepreneurs and industrialists to focus more on maintaining existing performance rather than pursuing innovation and increasing competitive capacity, which has hindered efforts to expand activities and capture a larger share of the global market.

KEYWORDS

Economic Complexity Index, Iran, Manufacturing Sector, Science and Technology Indicators.

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Introduction

In recent decades, serious competition in the global economy has rendered traditional economic advantages-such as cheaper energy, lower labor costs, access to natural resources, economies of scale, and mass production- insufficient for the success of a company or industry. Therefore, additional advantages are necessary to remain competitive in the global market. For example, skilled human resources, mastery of technical skills and up-to-date technologies, effective communication both at corporate and individual levels, organizational structures that foster problem-solving capabilities, and flexibility to address interdisciplinary challenges provide a stronger chance of survival in today's competitive landscape, compared to an industrial economy solely reliant on factories and physical production.

For this reason, both industrialized and emerging economies are rapidly shifting from their traditional models to knowledge-based economies. In a knowledge-based economy, knowledge and technology serve as the main engines of economic growth and development and are the key and dominant factors of production. Thus, a knowledge-based economy can be defined as one where the creation, dissemination, and utilization of knowledge are the primary sources of economic growth (Abramovitz, 1986; Nelson, 1998).

Consequently, in the current context, physical and natural resources are less important than knowledge, which has become a more significant input, alongside labor and capital, for production. Without knowledge, the creation of economic value is no longer feasible (Arundel, 2005). In other words, what distinguishes a knowledge-based economy from a resource-based economy is its greater focus on human capital, industrial property rights, and research and development as the main sources of innovative ideas, information, and new methods. In such an economy, there is a strong emphasis on an advanced service sector, driven by information technology and the digital economy (Kwon, 2009).

Thus, in a knowledge-based economy, physical capital is relegated to a secondary position, with knowledge-based assets and resources becoming the primary advantages of industries and companies. Knowledge-based capital refers to a range of non-physical assets, including in-company research, data, software, design skills, and human skills, which are now regarded as the main competitive advantages for companies. These assets enable countries and companies to dominate other industries with higher added value and greater complexity, thereby increasing their competitiveness in the global market and ultimately achieving material prosperity.

In this context, previous definitions of economic growth and development, proposed by scholars in the early decades after World War II, which defined economic development as a shift from low-productivity structures to higher productivity structures, are no longer sufficient. Today, a new body of literature, termed "economic complexity", has been introduced by scholars such as Hidalgo and Hausmann (2009). It considers a country's economic development path as being dependent on its capacity to aggregate and equip technological capabilities to produce more diverse and complex products. In other words,

economies that move towards greater economic complexity are more likely to sustain economic growth. Thus, it can be argued that improving economic complexity, whether at the level of companies, economic sectors, or countries, is closely tied to mastering knowledge, fostering a knowledge-based economy, and accumulating knowledge-based capital. In fact, there is a direct relationship between economic complexity and the economic competitiveness of countries (Erkan and Yıldırım, 2015).

This indicates that the more complex an economy is, the more its sectors will rely on knowledge and technology, resulting in greater competitiveness for companies. Specifically, a firm can achieve greater success in global competition if two essential prerequisites are met: first, the overall environment in which it operates is more complex (a complex economy), and second, the firm itself has made sufficient efforts in innovation (investment in empowerment) (Besanko, et al., 2016).

Extending this concept to the manufacturing sector, it can be said that Iranian economy's manufacturing sector can also become more competitive if, first, the overall Iranian economy moves towards greater complexity, and second, sufficient investments and efforts are made within the manufacturing sector to foster innovation and knowledge enhancement. Given this framework, the present research addresses two fundamental questions: What is Iranian economy' current position on the economic complexity path? And to what extent have efforts and investments been made within manufacturing sector to promote innovation and knowledge? To answer these questions, this article examines the position and potential of the Iranian economy through the lens of knowledge and technology indicators, to clarify the environment in which Iranian manufacturing firms operate. The following section evaluates the overall status of the manufacturing sector in terms of trends in knowledge and technology indicators and provides a summary of key concepts.

Literature Review

Many studies have examined the status of countries in terms of science and technology indicators. For example, Lima et.al. (2022) demonstrated how production (manufacturing), disaggregated into sub-sectors based on research and development (R&D) intensity, affects the level of economic complexity (ECI). Wo methods were used: 1) the parametric by Panel Dynamic Ordinary Least Squares (PDOLS) and 2) the non-parametric: a) Data Envelopment Analysis (DEA) and b) Malmquist Decomposition. The econometric results suggest that the allocation of workers in the manufacture of high R&D level has a positive impact on the ECI level of all the countries in the sample analyzed, whereas in the sectors of lower R&D there is a greater impact in emerging countries, but lower effects (or negative) on advanced countries. In general, the non-parametric results present the relationship between efficiency in manufacturing subsectors and economic complexity as an inverted U shape. Special attention is given to Brazil, which manufacturing catching up was underperformed in explaining total factor productivity in the analyzed period.

Koch (2021) stated that economic complexity is typically calculated based on a country's gross export structure. However, when global value chains become more integrated, gross exports may present a misleading picture of a country's economic performance. According to the findings of Sokolo-Maldanovic et al.'s (2016) research, which is based on a new empirical approach, economic complexity is approximated using a country's value-added export structure. They also confirmed the positive impact of innovation and the production of technical knowledge on economic or productivity growth.

Javadi (2023) examined the development trends of medium and advanced technologies and Iran's global standing from 1990 (1369) to 2020 (1399), using data from the United Nations Industrial Development Organization (UNIDO) and the 2022 Industrial Competitiveness Performance Index report. Overall, Iran ranks 73rd out of 154 countries in terms of the share of medium and advanced technology exports in total industrial exports, with countries like Turkey (55) and India (61) holding better positions.

An analysis of the industrial competitiveness index indicates that although one of its sub-indices, titled "Deepening and Upgrading Technology" (the share of value added from medium and advanced technology products in Iran's industrial value added), improved between 1990 and 2010, reaching 45%, it remained stable from 2011 to 2020. Additionally, in 2020, over 54% of Iran's industrial exports consisted of raw and semi-raw products, with only about 0.5% being advanced technology products, and approximately 32.5% being medium technology products. Thus, it can be concluded that Iran is heavily reliant on raw and semi-raw material export, and advanced technologies have a minimal contribution to its exports.

Yaghoubi Manzari et al. (2022) examined the impact of product complexity on participation in global value chains among the member countries of the Organization of Islamic Cooperation (OIC), using a generalized method of moments model. The estimation was conducted using panel and time series data of 56 Islamic countries from 2008 to 2018, and employed the generalized method of moments and ordinary least squares techniques.

The results indicated that increasing product complexity in Islamic countries enhances their participation in global value chains. Additionally, "technology absorption index" and "share of R&D expenditures" were confirmed to significantly impact participation in global value chains. Therefore, based on the existing capacities and research findings, Yaghoubi Manzari et al. (2022) recommend that the investigated countries prioritize their programs to increase participation in global value chains by focusing on complexity and product development (through diversification and quality enhancement), technology absorption and competitiveness, enhancing horizontal and vertical collaborations for technology development, creating technology exchange networks, improving R&D activities through the alignment of industrial and trade policies, and providing the necessary conditions for improving human capital development policies and investment development.

Samandar Ali Eshtahardi et al. (2020) investigated the causal relationship between the components of a knowledge-based economy and the economic complexity index. For this purpose, the panel data of 113 countries from 2006 to 2016 were examined. The fourteen variables introduced by the World Bank were used to represent the axes of knowledge-based economy. Through principal component analysis, these axes were condescended into four components. Then, the Granger causality relationship between these components and the economic complexity index, as well as the reverse, was examined.

The findings suggest a bidirectional causal relationship between education, information and communication technology, and economic institution with economic complexity, as well as a unidirectional causal relationship from innovation to economic complexity. Additionally, the results show different outcomes in these causal relationships for OECD-member and non-member countries.

Afshin and Azadari (2019) conducted a study for the Research Center of the Parliament to analyze Iran's industrial competitiveness performance in comparison to regional and selected global countries. The research employed a statistical analysis methodology based on UNIDO time series data. The statistical population included the industrial sector or manufacturing industries, and the statistical base covered the long-term period from 1990 to 2017. The findings indicated that Iran's industrial competitiveness performance (CIP) in 2017 (1396) ranked 49th among 150 countries worldwide, with a score of 0.062, showing an improvement from its 53rd rank in 2016. According to the UNIDO report, over 65% of Iran's industrial products in 1396 were resource-based (RB). Medium technology products (MT) accounted for approximately 25.5%, while high technology products (HT) accounted for about 0.9%, indicating a significant challenge for Iran's industrial products in terms of enhancing competitiveness in global markets .

In the long-term analysis of industrial competitiveness performance indicators from 1990 to 2017, the findings suggest that Iran's industrial development is relatively good, but, compared to various countries worldwide, it has regressed. Although the role of Iran's industrial sector in the international arena has generally increased, due to sanctions and external conditions such as the post-JC POA environment, some fluctuations are observed. The analysis of industrialization intensity indicators shows that the third development plan, starting in 1379 and continuing with ups and downs in subsequent years, was a turning point for industrial development in Iran. However, over the past decade, due to various reasons, including consecutive negative growth rates and negative capital formation, the industrial sector's share of Iran's GDP has declined to about 12.5%. This situation is a wake-up call for industrial policymakers, emphasizing the need to gain the private sector's trust, strengthen capital formation, and remove production barriers to enhance the role of this sector in Iran's economy.

Shahmoradi et al. (2018) examined Iran's technological competitiveness in comparison to the countries outlined in the Vision Document over a ten-year period. They sought to assess Iran's competitiveness in technological products compared to regional countries and to identify its main competitors using the economic complexity approach.

The findings, based on the four-digit codes of the Harmonized System, indicate that two products—profile bars and wires made from artificial wax and ready-made wax—exhibit the highest complexity, in which Iran has competitive power with no regional rivals. In classifying countries based on economic complexity, Iran falls into the lowest class, while in classifying products based on economic complexity, most of Iran's competitive products fall into the second-lowest class.

The findings also suggest that although the occupied Palestinian territories have the highest economic complexity and the greatest diversity of complex products in the region, they are not considered Iran's main competitors in competitive technological products. Meanwhile, Iran shares the most technological overlap with Egypt and Turkey, which are considered its main competitors in the region.

Methodology

Knowledge and technology are the most important factors of production in today's world, essential for achieving success in competition and gaining a share of the global market. Given that Iran's manufacturing sector is a subset of the broader economy, the structure of knowledge creation and dissemination, and its role in Iran's economy directly influences the manufacturing sector and its success in technological competition. Therefore, this issue will be examined by analyzing the status of the Iranian economy through key science and technology indicators.

One of the fundamental components of science and technology indicators is the status of human resources and human capital in each country. As emphasized in the literature on economic growth and supported by empirical studies, one of the main drivers of economic growth is human capital. Although human capital is often defined as the average years of education within a country's population, this definition overlooks some important theoretical and empirical dimensions. In economic growth theories, both the investments individuals make in accumulating human capital and the returns of these investments are significant. Therefore, it is necessary to adopt a comprehensive approach when examining and calculating the indicators of this topic (Acemoglu, 2009)

One of the most comprehensive indicators of human capital is the human capital index per individual (Feenstra et al., 2015). This index consists of two main components: the average years of education, as measured using Bro and Lee's (2013) methodology, and the returns to education, as determined by Psacharopoulos's (1994) methodology. The returns to education refer to the extent to which education has influenced productivity within the economy. This brings into focus the quality of education and its alignment with the economy's needs. In other words, if education has led to an increase in economic productivity, it signifies an enhancement in the country's human resources.

Another indicator used to assess human capital across countries is the Human Capital Index (HCI), calculated by the World Bank[1]. This index measures the development and

1. For more details, please refer to the link below on the World Bank website.
http://databank.worldbank.org/data/source/human-capital-index

nurturing of human capital and the extent to which individuals' potential is utilized in different countries.

In fact, this index addresses the extent to which newborns have access to health and educational facilities, and how much they can contribute to the organization they work for in the future[1].

One of the indicators that reflects a country's investment in knowledge enhancement is the ratio of research and development expenditures to its gross domestic product (GDP). To assess Iran's status in terms of science and technology, the Economic Complexity Index (ECI) can be used (Samandral & Eshtahardi, 2020). The core idea of this index is that economic development depends on the accumulation of knowledge and its increased utilization in producing more complex goods and services[2].

In fact, the more diverse a country's produced goods are (increased diversity) and the more complex its exported goods become, the higher its economic complexity will be. In other words, the greater the diversity of a country's export products and the more unique goods it can produce—goods that fewer countries can produce—the more complex its economy becomes.

One of the indicators of countries' science and technology is the Global Innovation Index. This index consists of 81 sub-variables that are classified into two main sub-indices, namely innovation input and innovation output. The Global Innovation Index is the average of these two main indices (Javadi, 2022). The innovation input sub-index includes the following five main pillars: Quality of institutions, Human and research capital, Quality of infrastructure, Market sophistication, and Business sophistication, each receiving a score between zero and 100.

Furthermore, to examine the role and position of medium and high-tech industries in the manufacturing sector, the manufacturing competitiveness performance is analyzed. This index, used by UNIDO (United Nations Industrial Development Organization), evaluates the competitiveness and industrial performance of various economies. It includes a set of related sub-indices, utilized to assess the production and export capacity of manufactures in an economy and compare it with other countries. This index reflects countries' capacity to participate in domestic and international markets and engage in high value-added activities with superior technology. A country's competitiveness in industrial production is measured on a scale from zero to one. The closer this number is to one, the greater the country is in industrial competitiveness (Afshin and Azadari, 2019)

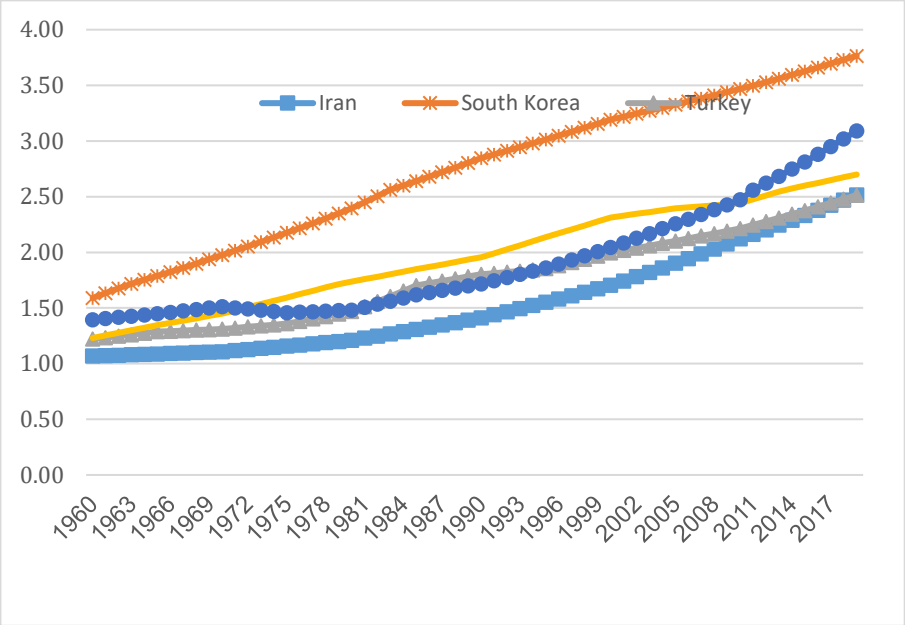
Findings

The trend of human capital for Iran and selected countries shows that in Iran human capital has been gradually increasing over time. However, its level significantly lags

1. https://www.bishtarazyek.com/the-human-capital-index/
2. More information regarding this indicator, its definitions, calculation methods, and the status of countries and industries is available on the Harvard University Atlas of Economic Complexity website at the following address. https://atlas.cid.harvard.edu/glossary

behind that of prominent developing countries, such as South Korea, China, and Brazil, that are successful in achieving economic growth. Nevertheless, in recent years, Iran's human capital trend has become closer to that of Turkey, and Iran has even shown a better status than Turkey (see Figure 1).

Figure 1.
The Human Capital Index per Person Comparison Between Iran and Selected Countries



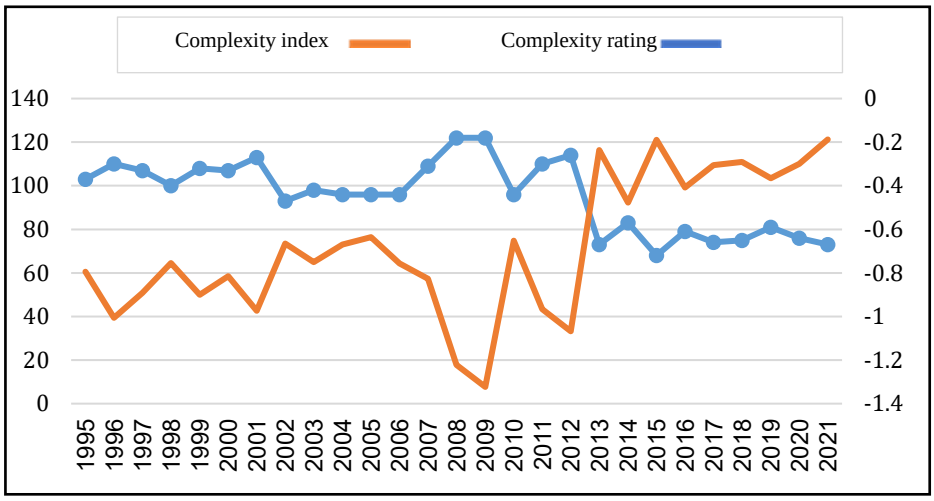
(Source: https://fred.stlouisfed.org/series)

According to the latest the Human Capital Index calculation in 2020, Iran's index value is 0.59, which is approximately equal to the global average of 0.60. In this regard, Iran's status is better than countries like India (0.49), Iraq (0.41), Kuwait (0.56), Indonesia (0.54), and Egypt (0.49). However, compared to countries like Oman (0.61), China (0.65), Russia (0.68), Vietnam (0.69), and the UAE (0.67), a significant gap exists between Iran and these countries. The top country in this ranking is Singapore, with an index value of 0.88, followed by Hong Kong, Japan, and South Korea. Overall, Iran's human capital status is at a global average level, but it seems that appropriate policies could improve its status. Given the significant investment made in public education and the expansion of universities over the past decades, an important question arises: why has Iran not yet reached the level of human capital seen in countries like China, South Korea, Singapore, and Brazil? It appears that factors such as the return on education, the quality of education, and the structure of educational system need to be analyzed to answer this question.

In the above Figure, the ratio of research and development expenditure to the gross domestic product (GDP) of countries is presented as an average over a 20-year period. Accordingly, Iran's investment in research and development, averaging 0.5%, lags far behind the global average (2.1%) and many developing countries such as the UAE, Turkey,

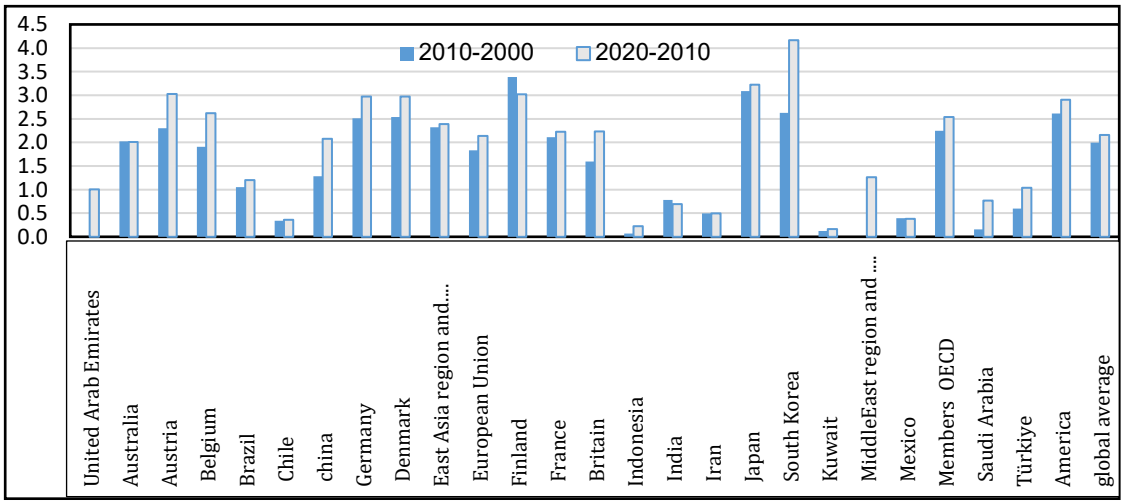
China, Brazil, and Singapore. Although Iran's situation is better than that of countries like Indonesia, Mexico, Chile, and Kuwait, it is not comparable to countries like India, South Korea, or even the average of countries in the Middle East and North Africa. Among Iran's neighboring countries, Saudi Arabia, the UAE, and Turkey have improved their status by increasing their research and development expenditures significantly from 2010 to 2020, which is expected to lead to economic success and increased competitiveness in the region in the coming years. Overall, it can be said that, there is a significant gap between Iran's investment in the production of knowledge and new technologies and the global average.

Figure 2.
The Ratio of Research and Development Expenditures to Gross Domestic Product (Average for the Years 2000-2010 (Bold) and 2010 to 2020 (Light))



(Source: World Bank)

Figure 3.
The Trend of the Economic Complexity Index (Right Vertical Axis) and Iran's Ranking (Left Vertical Axis) Over Time



(Source: Harvard University Economic Complexity Atlas)

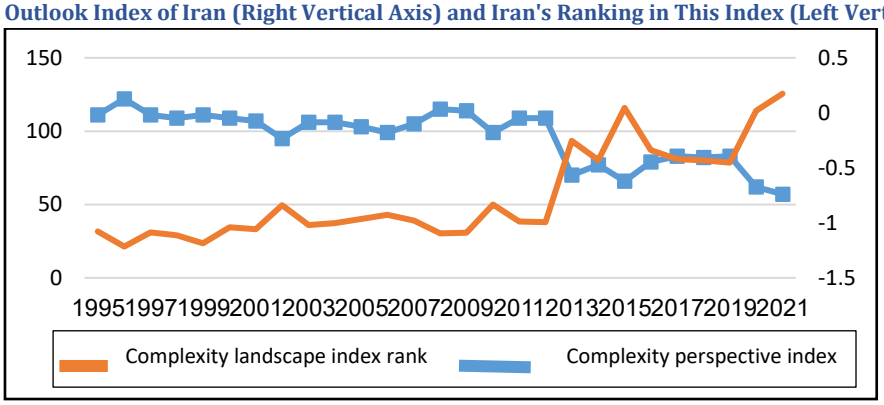
As shown in Figure 3, the value of Iran's Economic Complexity Index (orange) has increased over the past decade. In 2021, Iran's economic complexity ranking (blue) was

73 out of 133 countries, which is a relatively acceptable rank. Additionally, this index has shown an upward trend in recent years, leading to a six-place improvement in Iran's ranking from 2016 to 2021. Overall, Iran's status in terms of the Economic Complexity Index, like its the Human Capital Index, is around the global average, positioning Iran at a medium-level in this regard.

Despite this, it seems that the Iranian economy has greater potentials than what is currently observed, which could be utilized better. This is also reflected in the Complexity Outlook Index (COI), a measure indicating how many complex goods are accessible in the current economic complexity of a country. In other words, COI shows how many complex goods are available based on the level of complexity that an economy can potentially achieve. In fact, a higher value of this index indicates abundance greater number of complex products that can be produced with a country's existing capabilities under current conditions.

As shown in Figure 4, the value of this index for Iran has increased over time and Iran's ranking in this index has also improved. This indicates that Iran, especially in recent years, has had the potential to produce and export more complex goods using its existing economic and technical capabilities. However, it should be noted that this progress cannot be sustained in the long term without making appropriate investments in science and technology and making Iran's economic environment more conducive.

Figure 4.
The Complexity Outlook Index of Iran (Right Vertical Axis) and Iran's Ranking in This Index (Left Vertical Axis)



(Source: Harvard University Economic Complexity Atlas)

Table 1 shows Iran's score and ranking in the Global Innovation Index and its sub-indices[1]. According to the 2023 Global Innovation Index, Iran has a score of 30.1 and ranks 62nd among 132 countries, which is not favorable considering Iran's potential and capabilities[2]. As indicated in Table 1, Iran's status in institutional quality (rank 131) and infrastructure quality (rank 97) is very low, suggesting that its institutions and infrastructure are not adequately aligned to support innovation. Additionally, Iran ranks very low in business complexity (rank 117), indicating that its businesses do not have much complexity, and

1. The green row indicates the score, while the white row represents the rank.
2. World Intellectual Property Organization (WIPO), "Global Innovation Index 2023: Innovation in the face of uncertainty," Geneva: WIPO. DOI:10/34667/tind.48220.

therefore, innovation does not play a significant or suitable role within them. Overall, the inputs for innovation in Iran are in a poor state, which could lead to high costs for the Iranian economy in terms of long-term competitiveness.

Table 1.
Iran's score and ranking in the Global Innovation Index and its sub-indices

Global Innovation Index						
30.1 62						
Innovation Output	**Innovation Input**					
48	87					
Creative Outputs	**Outputs of Knowledge and Technology**	**Business Complexity**	**Market Complexity**	**Infrastructure**	**Human Capital and Research**	**Institutions**
33.1	25.9	17.7	52.9	29.3	32.6	20.6
43	55	117	19	97	60	131
Intangible Assets	**Creation of Knowledge**	**Knowledge Workers**	**Credibility**	**Information and Communication Technology**	**Education**	**Political Environment**
55.7	32.0	18.8	27.7	51.2	41.5	15.2
13	29	102	70	97	96	127
Creative Goods and Services	**Effects of Knowledge**	**Innovation Links**	**Investment**	**Public Infrastructures**	**Higher Education**	**Legal Environment**
4.3	35.2	11.4	83.3	25.0	41.8	38.0
90	40	113	3[1]	74	31	121
Online Creativity	**Dissemination of Knowledge**	**Knowledge Acquisition**	**Business, Diversification, and Market Scale**	**Environmental Sustainability**	**Research and Development**	**Business Environment**
16.8	10.5	22.9	47.8	11.8	14.5	8.7
86	107	116	90	120	49	128

(Source: Researcher's Findings)

Examining some of the sub-pillars under the main pillars of the Global Innovation Index reveals Iran's position regarding innovation and knowledge metrics on a global scale. This section analyzes the sub-pillar of research and development under the main pillar of human capital and research, as well as the sub-pillars of knowledge workers, innovation links, knowledge absorption, knowledge creation, knowledge impact, and knowledge dissemination under the main pillar of business complexity. Additionally, the sub-pillar of intangible assets under the main pillar of creative outputs is analyzed. The aim is to select the sub-pillars that are most closely connected to the technology and innovation environment.

1. The minimum coverage reported in the World Intellectual Property Organization (WIPO) (2023) Global Innovation Index has not been met.

Table 2.
Iran's Ranking in Terms of Subcomponents of the Global Innovation Index and Sub-indices

Title	2015	2020	2021	2022	2023
Subsection of Research and Development	59	48	48	47	49
Ratio of full-time researchers to the population (per one million people)	54	44	44	47	45
Ratio of gross research and development expenditures to gross domestic product	46	44	45	45	46
Average expenditure of the top three global companies in research and development		42	41	38	40
Average score of the top three universities based on global university rankings	56	44	44	43	44
Subsection of Knowledge Workers	109	103	104	97	102
Knowledge-based employment	90	77	80	78	76
Ratio of companies with formal training programs for employees	n/a	n/a	n/a	n/a	n/a
Ratio of research and development expenditures conducted by businesses to gross domestic product	64	50	53	53	53
Research and development expenditures funded by business enterprises to total research and development expenditures	48	n/a	n/a	n/a	n/a
Ratio of employed women with higher education	n/a	n/a	80	83	85
Subsection of Innovation Links	107	100	102	107	113
Collaborative research between universities and industry	99	117	120	121	124
Cluster development	94	88	87	81	87
Research and development expenditures funded from abroad	n/a	n/a	n/a	n/a	n/a
Joint investment contracts	89	122	127	129	126
Ratio of registered patents to GDP	107	64	74	86	85
Subsection of Knowledge Absorption	137	99	117	119	116
Payment of intellectual property rights (royalties)	90	94	97	95	89
Import of advanced technology	111	92	119	117	114
Import of ICT services	86	101	107	113	96
Foreign direct investment (net inflow)	116	119	110	109	112
Research talents in businesses		56	55	54	54
Subsection of Knowledge Creation	24	25	14	20	29
Resident patent applications	8	14	7	10	13
Global patent applications	n/a	53	44	40	41
Utility model applications	n/a	n/a	n/a	n/a	n/a
Publication of scientific and technical articles	40	21	11	15	27
"H" index of citable publications	44	40	40	39	40
Subsection of Knowledge Impact	114	86	85	65	40
Labor productivity growth rate	114	115	119	67	82
Rate of new business density	n/a	101	101	90	48
Total expenditure on computer software	55	58	38	30	16
Products with advanced technology	28	26	28	29	44
Subsection of Knowledge Dissemination	135	117	119	103	107
Revenues from intellectual property	92	86	95	90	88
Complexity of production and exports	n/a	n/a	100	78	84
Exports of advanced technology as a percentage of total trade	75	90	117	111	109
Exports of ICT services	114	92	125	127	122
ISO 9001 quality certifications	93	96	87	94	108
Subsection of Intangible Assets	113	13	13	10	13
Intangible asset intensity	n/a	n/a	n/a	n/a	n/a
Trademark registration applications	65	1	1	1	1
Global brand value	n/a	78	78	76	73
Industrial designs	n/a	14	4	6	11
Adaptation of organizational and ICT models	108	92	92	n/a	n/a

(Source: Global Innovation Index, WIPO, 2015, 2020, 2021, 2022 & 2023)

In 2023, Iran ranked 49th in the Research and Development subsection. The rankings of the indicators, including the ratio of full-time researchers to the population (per one million people), the ratio of gross research and development expenditures to gross domestic product, the average expenditure of the top three global companies in research and development, and the average score of the top three universities based on global university rankings, fall within the range of 40 to 46. These rankings indicate a moderate position for Iran compared to other countries worldwide.

In 2023, Iran's rank in the Knowledge Workers subsection has worsened compared to the previous year. Since the ranks reflect comparisons between countries, this decline indicates that other countries have outperformed Iran and obtained higher scores. The decrease in Iran's score in this subsection is partly due to a reduction in knowledge-based employment and partly due to a lack of data on the amount of research and development expenditures funded by business enterprises during the studied years. The indicator for knowledge-based employment, which reflects the percentage of employment in knowledge-intensive services relative to the labor force, along with the indicator for the ratio of employed women with higher education, shows Iran's poor ranking in 2023 (76 and 85, respectively).

In 2023, Iran ranked 113th in the Innovation Links subsection which is not favorable compared to other subsections. The indicator for collaborative research between universities and industry, which examines collaboration between businesses and universities in research and development, has decreased in 2023. The trend of this indicator shows that Iran performs poorly in joint research and development between universities and industries, with a decline observed each year. The cluster development indicator is derived from the average response to the following survey question: "In your country, how extensive are developed and deep clusters (geographical concentration of companies, suppliers, producers of related products and services, and specialized institutions in a specific field)?" While this indicator has improved during the studied period compared to 2015, Iran's rank has worsened compared to 2022.

The indicator for joint investment contracts, which reflects the average number of joint investment/strategic alliance contracts per billion dollars of gross domestic product over three years, highlights Iran's significant weaknesses in joint innovation investment. Additionally, Iran's poor ranking in the indicator for registered patents to GDP reflects weaknesses in international patent registration, reducing international innovation links and negatively impacting the innovation index.

Iran's ranking in the Knowledge Absorption subsection, the under business complexity main section, has improved compared to 2022. The indicator for advanced technology imports as a percentage of total trade, as well as the indicator for ICT services imports- including telecommunications, computer, and information services- as a percentage of total foreign trade has improved in 2023 compared to the previous year. However, the indicator of foreign direct investment has worsened, and Iran's ranking compared to other countries is unfavorable.

In the Knowledge Creation subsection, part of the knowledge and technology outputs main section, Iran's performance is relatively well compared to its rival countries, ranking 29th in 2023. Additionally, in the Knowledge Impact subsection, under the broader knowledge and technology outputs section, Iran holds a relatively good position with a rank of 40 in 2023. However, Iran's ranking in the indicator for labor productivity growth, which measures the average growth rate of real gross domestic product per employed person over the last three years, has been significantly inadequate during the studied years. It is important to note that factors such as international sanctions and the contributions of the oil sector have significantly affected this variable. In this context, sanctions have been a major limiting factor, halting technological advancement of Iran's industrial sector. On one hand, sanctions have reduced national revenues. On the other hand, they have increased the political and economic risks, which in turn reduce the opportunities for investing in technology within the country.

Furthermore, the indicators for Knowledge Dissemination subsection, within the knowledge and technology outputs main section, is unfavorable for Iran. In 2023, Iran ranked 109th in advanced technology exports and 122nd in ICT services exports, which include telecommunications, computer, and information services as a percentage of total trade, reflecting its poor position compared to other countries. Additionally, the indicator for production and export complexity- measured by the Economic Complexity Index, which ranks countries based on the diversity and complexity of their export baskets- shows that economies with high complexity possess a wide range of complex and specialized capabilities, enabling them to produce a wide array of complex products. Iran's rank in this indicator is 84th in 2023.

Iran's ranking in the Intangible Assets subsection, part of creative outputs section, is favorable, placing13th in 2023. Specifically, Iran ranks very well in the indicator for trademark registration applications, which reflects the number of resident trademark applications filed in national or specific regional offices per billion dollars of real gross domestic product. However, Iran's position in the global brand value indicator, measuring the total value of global brands (among the top 5000 brands) as a percentage of gross domestic product, is not favorable, ranking 73rd in 2023. In contrast, in the indicator for industrial designs, reflecting the number of designs registered in a national or specific regional office per billion dollars of GDP (PPP), Iran performs very well, ranking 11th in 2023.

Overall, the assessment of global innovation indicators places Iran's economy at an average level on the global scale. However, Iran requires more attention and effort to ensure it keeps pace with the trends set by countries in the Middle East, North Africa, and successful developing countries. Given that the present research focuses on the quality of the operational environment of industrial enterprises from the perspective of knowledge and technology, it can be concluded that the current state of Iran's economy in this regard is at an average level. Therefore, to enhance the competitiveness of industrial enterprises, more efforts are needed to improve and elevate the quality of the knowledge-based economy.

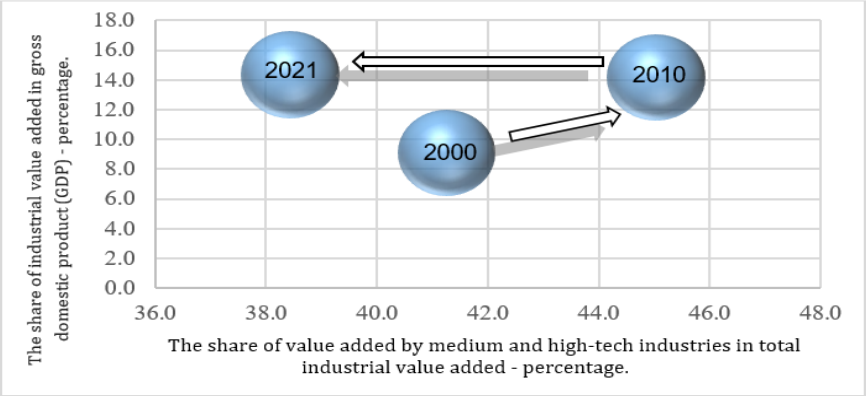
Analysis of the Structure and Developments of the Manufacturing Sector from the Perspective of Science and Technology

One of the most important questions is "to what extent the production structure of Iran's manufacturing sector is intertwined with science and technology?" This issue can be examined by analyzing the production structure of Iran's manufacturing products in the selected years of 2000, 2010, and 2021 from a technological perspective. In Figure 5, the vertical axis represents the manufacturing sector's value-added share in the gross domestic product (GDP) (manufacturing sector's share in economy), while the horizontal axis indicates the value-added share of medium and advanced technology industries within the manufacturing sector. Therefore, to move rightward over time in this Figure, Iran's manufacturing production structure requires to incorporate more technology and knowledge.

However, examining this Figure in the selected years reveals two completely opposite trends. Between 2000 and 2010, a rightward and upward movement is observed, suggesting that manufacturing sector's share in Iran's economy has increased (vertical movement) and medium and advanced technology industries' share in the total manufacturing sector has grown (horizontal movement). Specifically, the value-added share of Iran's manufacturing products relative to GDP has increased from 9.1% in 2000 to 14.2% in 2010, and the value-added share of medium and advanced technology products in the total value added of the manufacturing sector (horizontal axis) also rose from about 41% in 2000 to 45% in 2010. This trend is indicative of an increase in the importance of the manufacturing sector in Iran's economy, with a growing focus on medium- and higher- technology industries.

However, from 2010 to 2021, this trend has been completely reversed from science and technology perspective, indicating the second trend. Specifically, during these years, the share of medium- and higher-technology industries in the total value added of the industry decreased from 45% to about 38%. This not only erases the achievements of the previous decade, but also exacerbates the situation. Meanwhile, the manufacturing sector's share in Iran's total economy has remained almost constant at around 14% (vertical axis). In other words, it can be concluded that lower-technology industries have replaced medium-and higher-technology industries in the structure of Iran's manufacturing sector. Based on the points made in the previous section about the importance of science and technology in competitiveness in today's world, we can argue that since Iran's economy is following a reverse trend, it leads to a loss of share in the global economy and a decrease in long-term growth in the coming years.

Figure 5.
Changes in the Structure of Industrial Product Production in Iran

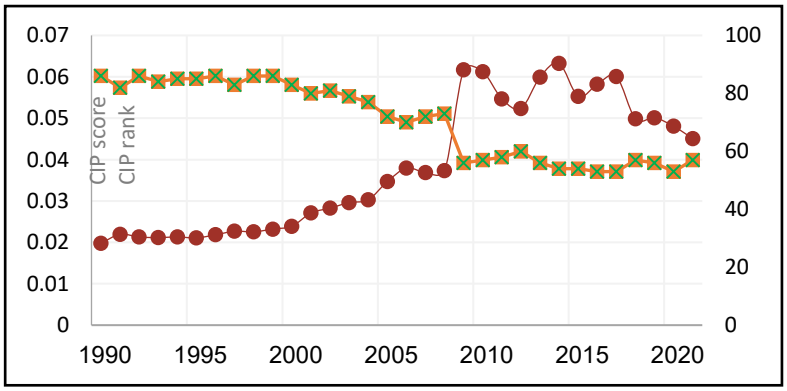


(Source: Calculations based on data from the UNIDO Database: CIP - Competitive Industrial Performance Index)

Figure 6 presents the trends of various Competitive Industrial Performance (CIP) indicators for the Iranian economy from 1990 to 2021, highlighting the developments of this index and its related sub-indices. As shown, Iran's Competitive Industrial Performance index sharply increased with the onset of the Western financial crisis in 2009, rising from rank 73 in 2008 to rank 56 in 2009. However, due to the intensification of Western sanctions from 2009 to 2012 the index declined. It observed some improvements during the following years due to the better post-JCPOA environment and the easing of sanctions. However, after 2018, with the re-escalation of economic sanctions, Iran's industrial competitiveness index again experienced a significant decline.

Although Iran’s industrial competitiveness index improved in some years over the past decades, its rank shows an overall downward trend over these three decades. This indicates that, despite improvements in this index in certain years, Iran's economy is losing its position in terms of industrial competitiveness due to the better performance of other countries. In addition to the adverse effects of economic sanctions, inappropriate industrial policies have also exacerbated this situation, as the decline in industrial competitiveness rank is not limited to the years of economic sanctions and has persisted during years without significant sanctions.

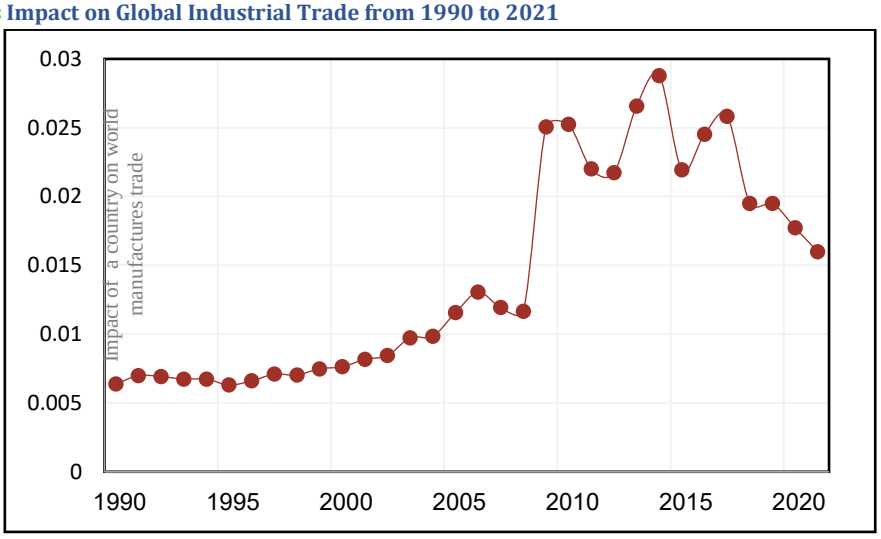
Figure 6.
Trends and Rankings of Iran's Industrial Competitiveness Index from 1990 to 2021



(Source: UNIDO Database: CIP- Competitive Industrial Performance Index

One of the indicators that reflects the level of industrial competitiveness is the Iran's impact on global industrial trade index, which is shown in Figure (7). This index reflects Iran's influence on global industrial trade and its relative competitiveness compared to other countries in international markets. According to this index, Iran's role in global industrial trade has been minimal during all the examined years, as this index peaked just over 0.28% in 2014. Since 2017, this index has shown a continuous downward trend, indicating that the role of Iran's industrial sector in global industrial trade has been declining in recent years.

Figure 7.
Trends of Iran's Impact on Global Industrial Trade from 1990 to 2021

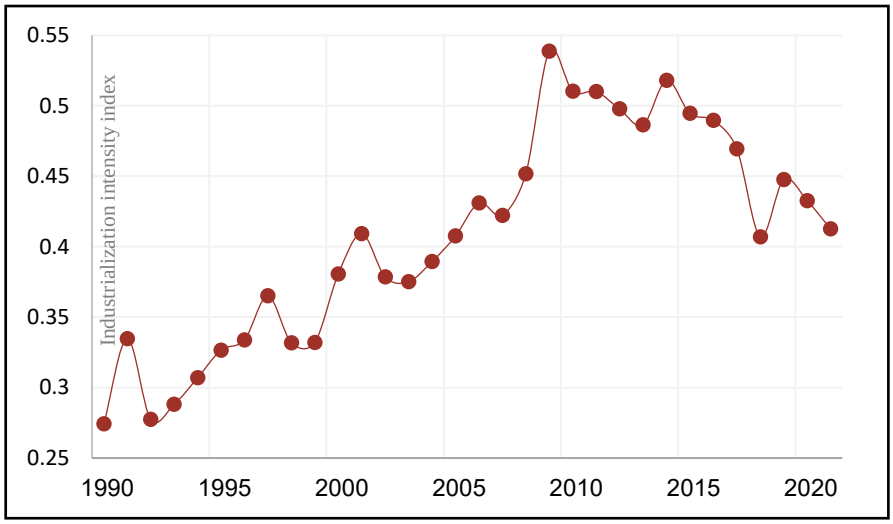


(Source: UNIDO Database: CIP - Competitive Industrial Performance Index)

Another important indicator for analyzing Iran's industrial sector is the Industrialization Intensity Index, which reflects the level of industrialization in a country (Figure 8). This index is measured based on the simple average of the share of industrial value added in gross domestic product (GDP) and the share of medium-and advanced-technology (MHT) activities within industrial value added, calculated on a scale from 0 to 100.

An examination of this index reveals two distinct trends over the past three decades. From 1990 to 2009, this index shows an upward trend, indicating that Iran's industrial sector has gained a larger share of its economy and the share of advanced-technology activities has also been increasing. This period can be interpreted as the industrialization phase of Iran's economy. In contrast, from 2009 onwards, this index has been on a downward trajectory, with a significant decline occurring after 2014, reaching its lowest point in 2018 with the onset of international sanctions.

Figure 8.
Industrialization Intensity Index of Iran from 1990 to 2021

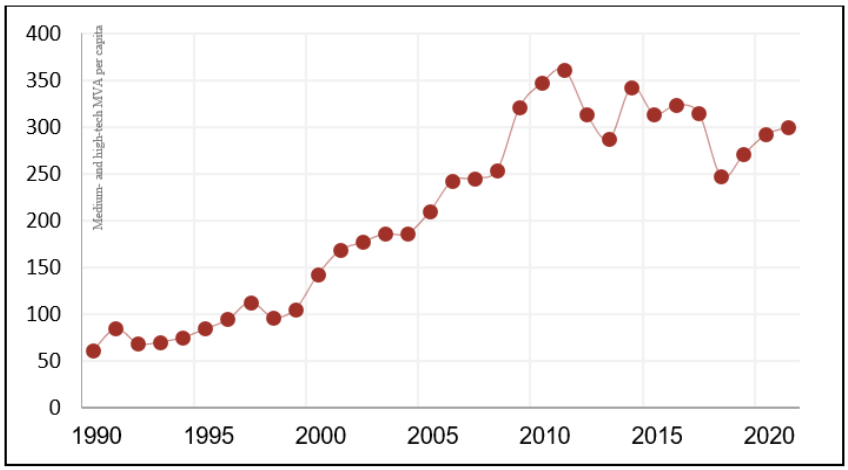


(Source: UNIDO Database: CIP - Competitive Industrial Performance Index)

Figure 9 shows the per capita value added of medium- and advanced-technology industries in Iran, which measures of the level of technological complexity in the country's industrial production compared to its potential human resources. As with the previous Figures, two trends can be observed. From 1990 to 2011, the index exhibits an upward trend, indicating that the technological complexity of Iran's industrial sector productions has been increasing in line with its human resource capacities. During this period, the per capita value added of medium- and advanced-technology industries rose from $62 in 1990 to approximately $361 in 2011, representing a significant and favorable increase.

However, after 2011, the upward movement of this index stalled, with fluctuations until 2018, when the per capita value added of medium- and advanced-technology industries decreased to $247. Although a mild upward trend can be observed after 2018 until 2021, raising the index to $300, it has not reached its 2011 level after a decade.

Figure 9.
Per Capita Value Added of Medium and Advanced Technology Industries in Iran from 1990 to 2021

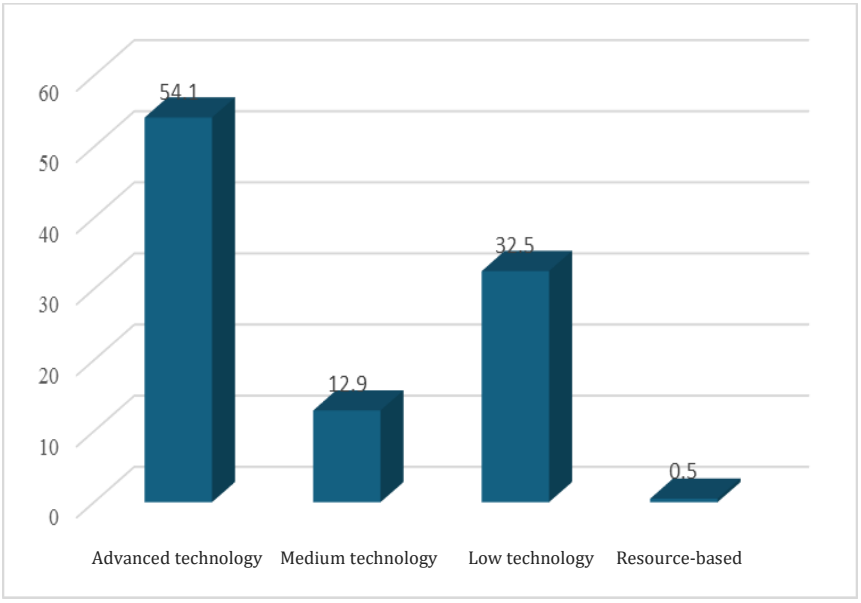


(Source: Calculations based on data from the UNIDO Database: CIP - Competitive Industrial Performance Index)

An examination of Iran's industrial exports reveals that the majority are currently resource-based, with a very small share coming from advanced-technology industries. Although the exports of medium technology industry accounts for a significant share and ranks second (Figure 10), over 54% of Iran's industrial exports are resource-based products, and only about 0.5% are from advanced technology products. Approximately 33% of Iran's industrial exports are from medium-technology products, and around 13% come from low-technology industries.

A suitable strategy for Iran would be to increase the share of exports from advanced industries. Given the significant share of medium-technology industry exports, appropriate investments in these industries could lead to advancements in their technology and quality. Additionally, as indicated by the Complexity Outlook Index in the previous section (Figure 4), the Iranian economy has considerable potential to enhance the complexity of its products, which is essential for the competitiveness of its industries in the medium and long term. By increasing the share of medium-technology industry exports, it is feasible to move towards upgrading these products to advanced technology products and reduce the share of resource-based exports.

Figure 10.
Structure of Iran's Manufacturing Exports (Share of Iran's Exports in Total Manufacturing Exports) in 2021



(Source: UNDP, the Competitive Manufacturing Performance (CIP), 2021)

In summary, an examination of various science and technology indicators in Iran's manufacturing sector showed that the upward trend of these indicators continued until the late 1380s (2000s in the Gregorian calendar). During this period, the Iranian economy and the manufacturing sector were moving towards greater complexity and increased technology use. However, since the early 1390s (2010s in the Gregorian calendar), with the onset of economic sanctions, the technological advancement trend in the manufacturing sector has halted. Accordingly, the Iranian economy has remained relatively stagnant, even showing backward movement in some indicators.

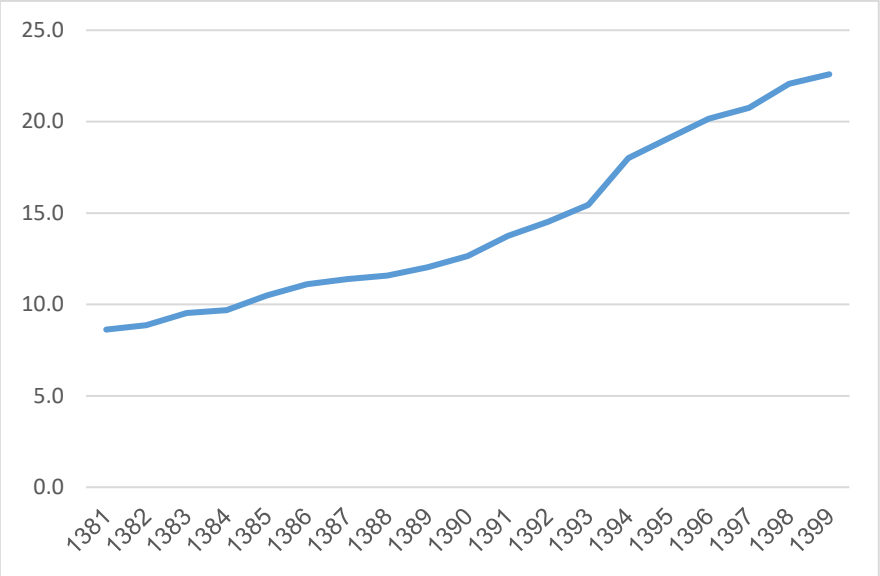
Nevertheless, given the potential of the Iranian economy, appropriate policymaking could partially rectify this trend. Specifically, focusing more on high-tech industries and implementing policies to increase competition, with the aim of enhancing innovation incentives, could improve this situation. It is important to note that if the current trajectory continues, Iran risks losing its position in global markets and, in the medium term, results in a decrease in its economic power.

One of the pathways for technology transfer to the industrial sector is through the recruitment of educated and skilled human resources. According to the literature on economic growth, knowledge enhancement and the accumulation of human capital are the key sources of growth in the industrial sector. Two major indicators—the share of employees in the industrial sector with a bachelor's degree or higher, and the ratio of training expenses to the value added of industrial workshops with ten or more employees—reflect the changes and developments within the industrial sector in terms of science and technology.

The share of employees in the industrial sector with a bachelor's degree or higher indicates the average level of education among the workforce in this sector. An analysis of this trend (Figure 11) shows that the share of employees with a bachelor's degree or higher has increased over time, demonstrating a consistent upward trend. In other words, the structure of employment in the industrial sector is shifting in favor of university education. However, this shift alone is not sufficient for economic growth; it is crucial to consider how employees with higher education are utilized in the industrial sector and what conditions are necessary for their effective integration. Otherwise, the industrial sector may merely absorb changes occurring in the labor market without gaining substantial benefits from the more educated workers.

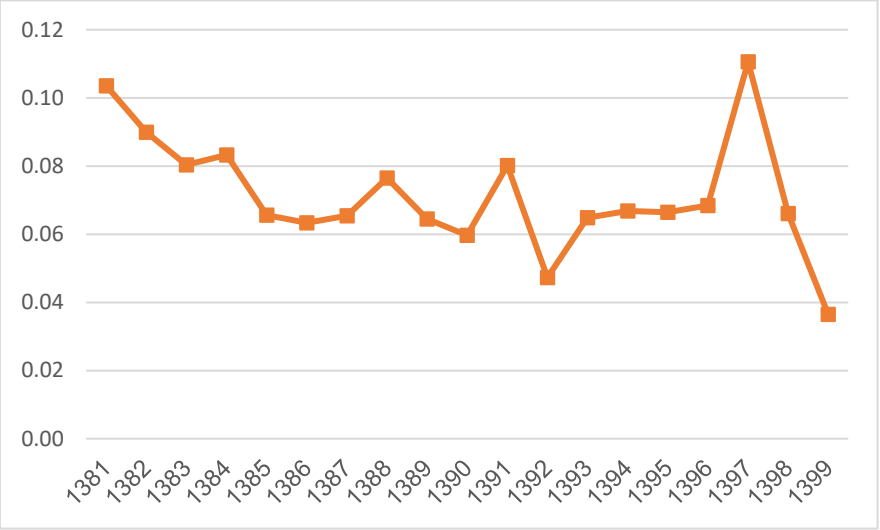
The ratio of training expenses to the value added of industrial workshops with ten or more employees can also serve as a measure of the efforts made by enterprises to empower their human resources (Figure 12). This indicator shows how much businesses invest in enhancing their workforce. Contrary to the smooth upward trend in the share of more educated workers in the industrial sector, the ratio of training expenses to the value added of industrial workshops with ten or more employees is not only negligible (even at its peak, it does not exceed 0.11% of the value added), but also downward. This indicates that the industrial sector is making little effort to enhance human resources through training. Accordingly, this sector, failing to make adequate investments in this area, relies on the knowledge human resources gain through formal education and the experience they accumulate over time.

Figure 11.
Share of Employees with a Bachelor's Degree and Higher among Total Employees in Industrial workshops with Ten or More Employees (Percentage)



(Source: Calculations Based on the Statistics of Industrial Workshops with ten or more Employees from the Statistical Center of Iran)

Figure 12.
Ratio of Training Expenses to the Value Added of Workshops with Ten or More Employees (Percentage)

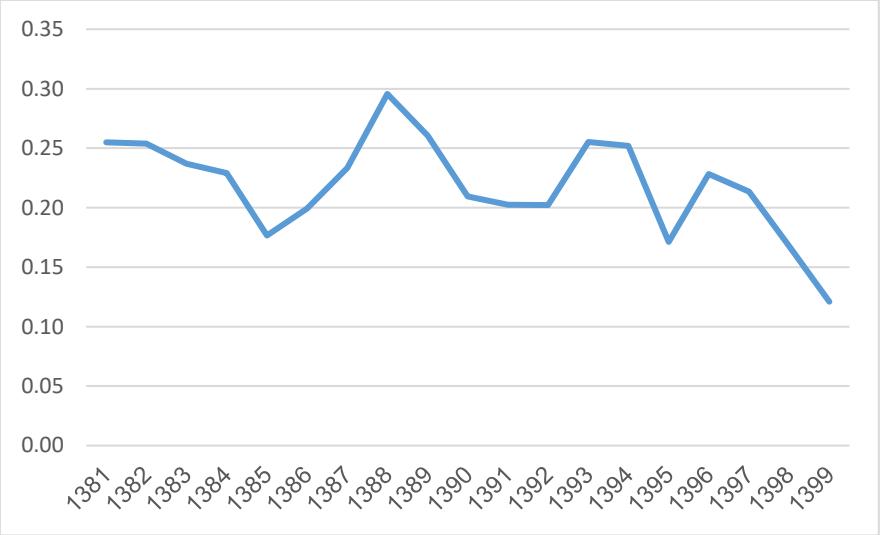


(Source: Calculations Based on the Statistics of Industrial Workshops with Ten or More Employees from the Statistical Center of Iran)

On the other hand, research and development activities are key to enhancing the technological capabilities of enterprises and industries. Indicators show that Iran is not performing well in this area compared to the global average. This issue is examined at the industrial sector level by analyzing the ratio of research and laboratory expenses to the value added of enterprises, as a measure of research and development activity level (Figure 13). Contrary to the smooth upward trend of the share of more educated workers in the industrial sector, the ratio of research and laboratory expenses to the value added

of industrial workshops with ten or more employees is not only negligible (even at its peak, it does not exceed 0.3% of the value added, which is significantly lower than the national average of 0.5%), but also downward.

Figure 13.
Ratio of Research and Laboratory Expenses to the Value Added of Workshops with Ten or More Employees (Percentage)

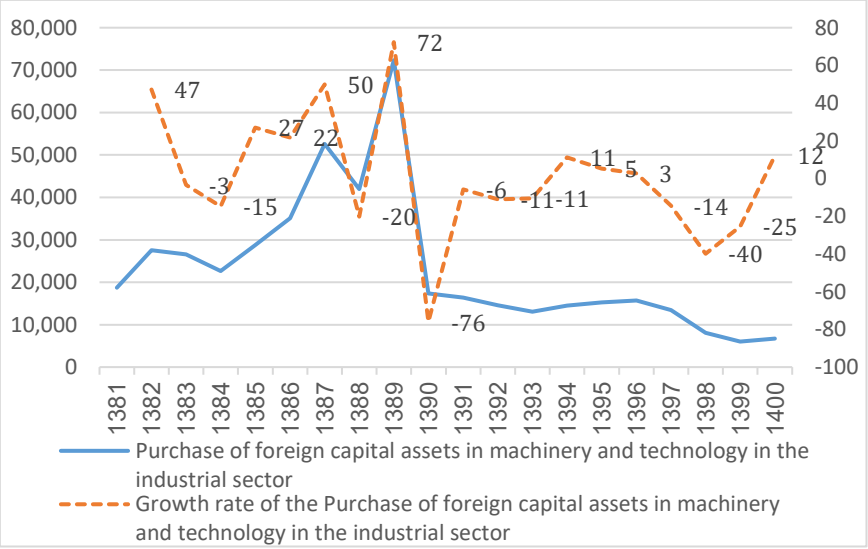


(Source: Calculations Based on the Statistics of Industrial Workshops with Ten or More Employees from the Statistical Center of Iran)

It is important to note that one of the pillars of the Global Innovation Index is knowledge absorption, indicating that one of the ways of absorbing knowledge is importing advanced technologies. Historically, technology transfer through machinery and equipment has always been one of the most important ways of technology transfer and enhancement in the Iranian economy. A significant portion of Iran's imports has consistently consisted of capital goods, indicating Iran's considerable demand for technology. This trend is also evident in the industrial sector. Given the importance of this issue, this section aims to examine the structure of investments in machinery and technology in the industrial sector from various aspects, considering both temporal trends and distribution across different industrial activity categories. Each of these aspects depicts only one part of the industrial sector's structure. Hence, when they are combined, they provide overall comprehensive picture.

Initially, the trend of purchasing or acquiring machinery and technology from abroad at constant prices (right vertical axis) can be examined alongside its growth (left vertical axis) (Figure 14). This indicator effectively shows how much the industrial sector has spent (at constant prices) on purchasing foreign machinery and technology. Notably, since 1390 (2011), the trend of purchasing foreign capital assets in Iran's industrial sector has been declining. Although there was a slight increase in this variable during the 1390s (2010s), the overall reduction in foreign capital purchases in the industrial sector is clearly less than in the previous decade.

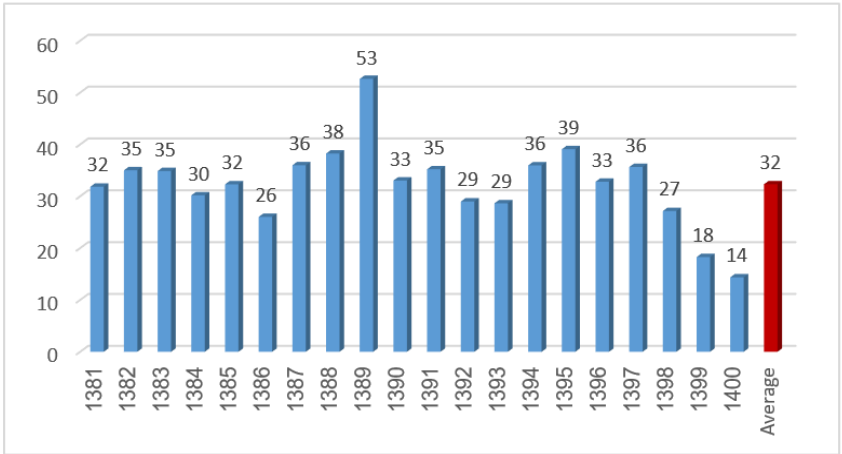
Figure 14.
Purchase or Acquisition of Foreign Capital Assets in Machinery and Technology in the Industrial Sector (Fixed Billion Rials)



(Source: Calculations Based on the Statistics of Industrial Workshops with Ten or More Employees from the Statistical Center of Iran)

The decline in the value of foreign equipment purchases in the 1390s (2010s) can be observed in relation to the total capital assets acquired in the industrial sector. In other words, when the share of foreign capital assets relative to the total capital assets acquired in this sector has decreased, it suggests that the pathway for technology transfer through foreign machinery has weakened. This trend is illustrated in Figure 15. Specifically, from 1381 to 1399 (2002 to 2020), this ratio averaged 33%, indicating a substantial reliance on foreign purchases for supplying capital assets in industrial workshops with ten or more employees. However, in the 1390s, a relative decline can be observed in this ratio, especially in 1398 and 1399 (2019 and 2020).

Figure 15.
Share of Purchases or Acquisitions of Capital Assets in Machinery and Technology from Abroad Relative to Total Capital Assets in the Industrial Sector (Percentage)



(Source: Calculations Based on the Statistics of Industrial Workshops with Ten or More Employees From the Statistical Center of Iran)

Discussion and Conclusion

The aim of this article is to examine technological trends in Iran's manufacturing sector over time. The importance of studying these trends lies in the fact that maintaining the competitiveness of the Iranian economy, particularly in the manufacturing sector, requires medium- and long-term investment in knowledge and technology. In recent decades, serious competition in the global economy has made traditional economic advantages, such as cheaper energy, low-cost labor, access to natural resources, economies of scale, and mass production, insufficient for an industry's success. Therefore, additional advantages are necessary to remain competitive in the global market. Under these conditions, neglecting investment in science and technology could weaken cpuntries' manufacturing sector in the long run.

The findings of this article indicate that Iran's human capital is at an average global level, but with right policies, this situation could be improved. Given the significant investments made in public education and the expansion of universities over the past decades, issues such as the return on education, the quality of education, and the educational structure of the country play an important role in shaping the outcome.

An examination of the Iranian economy in terms of science and technology indicators shows that Iran ranks as an average country globally in this respect. However, in terms of research and development expenditure, which reflects investment in science and technology, greater attention and effort are needed to prevent Iran from lagging behind the trends adopted by countries in the Middle East, North Africa, and other successful developing countries.

By analyzing various science and technology indicators within Iran's manufacturing sector, we can argue that these indicators exhibited an upward trend until the late 1380s (2000s in the Gregorian calendar). Overall, the Iranian economy and the manufacturing sector were moving towards greater complexity and increased technology use. However, since the early 1390s (2010s in the Gregorian calendar), with the onset of economic sanctions, technological advancement in the manufacturing sector has halted, leaving the Iranian economy relatively stagnant and even showing backward movement in some indicators. Nevertheless, given the potential of the Iranian economy, appropriate policymaking could help reverse this trend. Specifically, greater attention to high-tech industries and policies aimed at increasing competition to enhance innovation incentives could improve the situation. It is important to note that if the current state continues, Iran risks losing its position in global markets and, in the medium term, results in a decrease in Iran's economic power.

Considering the overall findings of this research, indicating a decline in the technological activities of Iran's manufacturing sector over the past decade, the following hypothesis is confirmed: economic instability in the manufacturing sector, on the one hand, and macroeconomic developments in the country, on the other hand, have created an unfavorable environment for Iran's industries. This has led entrepreneurs and manufacturing owners to focus more on maintaining existing performance rather than

increasing competitive capacity and innovation, thus hindering activities and efforts for gaining a larger share of the global market.

Based on the findings, the following strategies can be proposed to enhance Iran's industrial sector in terms of science and technology, and consequently, increase its competitiveness in the medium term:

- *Serious attention to competitive policies that increase demand for science and technology*. As shown in the article, the industrial sector had fewer technological activities in the 1390s (2010s). One reason for this decline can be attributed to the tightening of Iran's economy (due to economic sanctions and shifting towards protectionist policies), which has led to reduced competition. Therefore, one of the fundamental strategies could be to increase Iranian industries' exposure to competition- particularly foreign competition- in a measured and reasonable way.
- *Attention to stabilizing policies in the industrial sector and seriously addressing barriers to production and investment*. As mentioned, Iran's industrial sector has experienced greater volatility compared to the overall Iranian economy, leading to decreased technological activities. Thus, focusing on stabilizing policies and removing production barriers could reverse this trend. Frequent changes in policies, unfavorable macroeconomic conditions, and policies such as price controls have reduced the productivity of this sector and increased its risks. Addressing these issues could enhance the demand for science and technology in the industrial sector, which is necessary for maintaining competitiveness in the medium term.

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The Impact of Digital Transformation on Human Resource Productivity: The Mediating Role of Strategic Renewal

Vahid Sharafi[1*] | **Hassan Hoseini**[2]

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Vahid Sharafi
Corresponding Author, Assistant Professor, Department of Management, Faculty of Humanities, Hazrat Masoumeh University, Qom, Iran.
E-mail: v.sharafi@hmu.ac.ir

Hassan Hoseini
Ph.D. student in Media Management, Faculty of Islamic Governance, Islamic Azad University, Khorasgan Branch, Isfahan, Iran.
E-mail: Hassan.hosseini63@gmail.com

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ABSTRACT

Digital transformation is essential for various businesses. Organizations seek to create a competitive advantage and improve productivity through digital transformation. The main objective of this research is to examine the impact of digital transformation on human resource productivity, considering the mediating role of strategic renewal. This research is applied in purpose and descriptive-correlational in nature. The statistical population of this study consists of 103 employees from the post office in Ilam, Iran. Due to the small size of the statistical population and the risk of non-response bias, a census method was used for sampling. The data collection method was survey-based, as the data were primarily collected using questionnaires. The standardized questionnaire by Gavarila et al. (2022) was used to measure the digital transformation variable, the standardized questionnaire by Elyasi et al. (2018) was used to measure the productivity variable, and the standardized questionnaire by Fatehmi et al. (2017) was used to measure the strategic renewal variable. The data was analyzed using LISREL software. The results indicated that digital transformation has a positive and significant impact on human resource productivity (0.89) and strategic renewal (0.72) of Ilam Post Office. Strategic renewal also has a positive and significant impact (0.84) on human resource productivity in Ilam Post Office.

KEYWORDS

Digital Transformation, Human Resource Productivity, Post Office, Strategic Renewal.

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Introduction

Digital transformation is essential for various businesses. It involves the integration of digital technology across all areas of a business and fundamentally focuses on changing the way operations are conducted and value is delivered to customers (Amali & Mohammadi, 2022). The digitization of an organization's processes means creating new data sources. In fact, every digitized process is a data source, consisting of both human and machine data (Li et al., 2023). Digitized processes generate data, which are monitored and measured through key performance indicators, leading to a more realistic understanding of organizational performance (Zhao et al., 2024). With the digitization of processes, the ability to control and monitor activities and individuals within the organization increases, as digitization transforms processes into rich data sources. This allows for measuring processes, assessing how closely the organization is aligned with its goals and strategic priorities, and identifying the future objectives and goals it should pursue (Nasiri et al., 2022).

Organizations aim to create a competitive advantage through digital transformation. Businesses might adopt transformation for many reasons, but the most significant reason seems to be that they are compelled to do so. For many, this issue is a matter of survival, and organizations must embrace digital transformation to ensure their long-term continuity (Hauer et al., 2021). The digitization of processes leads to improved productivity, which is recognized as one of the most important indicators of economic, social, and cultural development within organizations. In fact, success in productivity is a key requirement for achieving a strong position in the global competitive arena (Soma & Insprack, 2016).

Hence, one of the main objectives of any organization is to achieve higher productivity. One of the primary criteria for evaluating an organization's performance is its human resource productivity (Tabibi et al., 2018). Implementing productivity and examining the factors that influence productivity enhancement in any organization create a wave of change and transformation within that organization, as productivity is inherently dynamic, transformative, and evolutionary. Therefore, if organizations wish to benefit from productivity gains, they must adopt it as one of their primary strategies, embody it in all of their organizational activities, maintain a systems-thinking approach, and foster a culture of innovation and creativity within the organization (Azimian et al., 2023).

Human resource productivity is recognized as a precursor to organizational productivity. It refers to the scientific maximization of resources, human capital, and arrangements to reduce costs and enhance the satisfaction of employees, managers, and consumers (Sepahvand et al., 2023). Human resource productivity involves making the most appropriate use of human resources to achieve organizational goals with minimal time and cost (Balaz et al., 2024). Strategic management plays a key role in developing and enhancing human resource productivity. Strategic renewal is a suitable approach for fostering innovative performance in today's business environment. This approach

provides an alternative advantage in highly competitive and unpredictable market (Charles et al., 2023).

The Post office, as one of the service providers of the country, is a communication agency that interacts with other agencies, organizations, institutions, and the public. Human resource productivity is a key focus in the strategic plans of the post office. Therefore, the main research question of this study is as follows: Does digital transformation significantly impact human resource productivity, considering strategic renewal, in the Post Office of Ilam?

Literature Review

Digital Transformation and Human Resource Productivity

With the emergence of digital transformation, businesses are evolving, leading to increased efficiency and profitability (Al-Oqaily et al., 2022). The adoption of new technologies has driven innovations that are reshaping the way we live and work. Information has become a digital asset, and modern tools and processes have provided a clearer reflection of workforce's status. , businesses are empowered through shared platforms, and a culture of continuous advancement is fostered (Sabk Araa and Pourghaderpoob, 2022). Digital transformation can help businesses automate manual tasks, free up their employees' time, and allow them to focus their time and energy on more valuable projects (Wang et al., 2020).

Given that digital transformation affects all dimensions of individual and social relationships in local, national, regional, and even global economies, it can be generally stated that it has led to an increase in competitive capability, productivity, and overall performance of organizations (Zhao et al., 2024).

Digital transformation requires new skills, such as artificial intelligence, data analysis, programming, and cybersecurity. To achieve greater productivity, the workforce must be trained and updated on these new skills (Du and Kang, 2022). As digital transformation reshapes organizations and work methods, it necessitates a shift in behavior and attitude. Thus, employees must familiarize themselves with advanced developments and new technologies and learn to to leverage new methods. This change in attitude can contribute to improving human resource productivity (Bertani et al., 2020).

The advancement of technology and the growing digitization of processes and tools reduce errors and mistakes, and by minimizing the time spent on correcting minor errors and mistakes, allow the workforce to focus more on important and critical tasks, (Gaglio et al., 2022). Based on the above points, the following hypothesis is formulated:

H1: *Digital transformation has a significant impact on human resource productivity.*

Digital Transformation and Strategic Renewal

Digital transformation plays a crucial role in innovation and affects different aspects of an organization. It influences methods and processes of innovation significantly, enabling companies to achieve substantial improvements in innovation (Trevisan et al., 2024). By

enhancing existing workflows and offering new opportunities, digital transformation supports the creation of innovative work processes (Vaska et al., 2021). It provides companies with new tools that enable them to deliver innovative products and services. By leading to improvements in research and development processes, product design and manufacturing, and data use, it helps companies bring newer and better products and services to market. It allows companies to refine their approaches and processes, align with new technologies, and experience greater innovation (Zhao et al., 2024). Digital transformation equips companies with new tools and opportunities for innovation, enables them to perform existing functions, and strive more powerfully and creatively in designing new strategies (Li et al., 2023). Based on the above points, the following hypothesis is formulated:

H2: *Digital transformation has a significant impact on strategic renewal.*

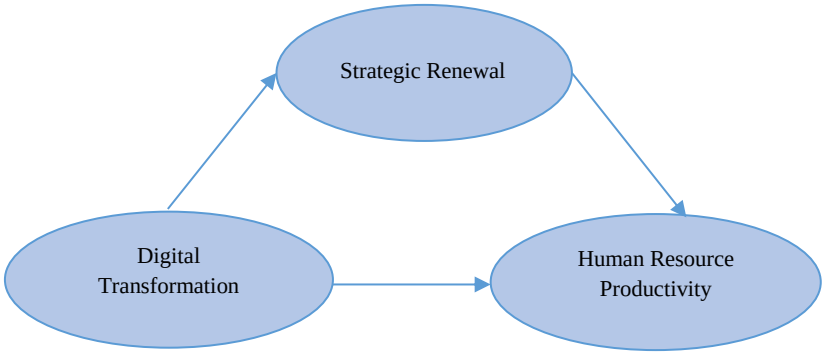
Strategic Renewal and Human Resource Productivity

Strategic renewal helps organizations align and adapt their human resources with organizational strategies and goals. This means attracting individuals and training them with the skills and capabilities essential for achieving the organization's strategic objectives. Additionally, this approach assists organizations in preparing their personnel for new tasks that require new expertise and skills (Albis et al., 2023). Strategic renewal enables organizations to identify and develop the necessary expertise, skills, and motivations to enhance the capabilities of their human resources. By improving human resource management and aligning strategies with the workforce, it enhances human resource productivity and improves organizational performance (Sanchis et al., 2024). Strategic renewal can also improve internal communication and collaboration across different departments of an organization. This leads to more information sharing, and better adjustments to organizational processes and structures (N'Diko et al., 2023). Organizations that adopt a strategic perspective often demonstrate stronger competitive capabilities, better efficiency, and improved effectiveness. In such organizations, strategic renewal is prioritized, leading to an innovative atmosphere, improved productivity, and superior performance (Kalabi et al., 2016). Based on the above points, the following hypothesis is formulated:

H3: *Strategic renewal has a significant impact on human resource productivity.*

Based on the above theoretical foundations and formulated hypotheses, the conceptual model for the current research is illustrated in Figure 1.

Figure1.
Conceptual Model of Research



(Source: Researcher's Findings)

Methodology

The present research is applied in terms of its objective and descriptive-correlational in terms of its methodology. Additionally, it is classified as field research (survey) regarding data collection. The statistical population of this study consists of 103 employees of the post office in Ilam Province. Given the small size of the statistical population, a census method was employed. The data of this study were collected through a standardized questionnaire package that includes the following three questionnaires: Gavrila et al (2022) 12- item questionnaire which was utilized to measure digital transformation, Elyasi et al.'s (2018) 10-item questionnaire which was used to measure productivity, and Fatehmi et al.'s (2019) 6-item questionnaire which was employed to measure strategic renewal.

The overall structure of the questionnaire package and the questions of each variable are presented in Table 1.

Table 1.
Research Questionnaire

Variable	Number of Questions	Source
Digital Transformation	12	Gawriela et al. (2022)
Human Resource Productivity	10	Elyasi et al. (2018)
Strategic Renewal	6	Fatehmi et al. (2019)
Total Questionnaire	28	--------

(Source: Researcher's Findings)

To establish the validity of the research questionnaire, both content and construct validity were utilized. Given that the questionnaires deployed in this research were standard, content validity was assessed based on the opinions of 12 faculty members from the management department. For construct validity, confirmatory factor analysis was employed. As shown in Table 2, all factor loadings exceed 0.50 and the Average Variance Extracted (AVE) for all research variables is also greater than 0.50, confirming the construct validity of the questionnaire.

To assess reliability, both Cronbach's alpha coefficient and composite reliability were used. As the results reported in Table 2 show, the Cronbach's alpha coefficients and composite reliability (C.R) for all variables are greater than 0.70, confirming the reliability of the research questionnaire.

Table 2.
The Results of Validity and Reliability of the Research

Variable	Factor Loading	Ave	C.R	Cronbach's Alpha
Digital Transformation	0.87	0.74	0.91	0.87
	0.89			
	0.82			
	0.82			
	0.88			
	0.91			
	0.89			
	0.86			
	0.90			
	0.85			
	0.80			
	0.84			
Human Resource Productivity	0.83	0.78	0.93	0.89
	0.89			
	0.84			
	0.88			
	0.85			
	0.87			
	0.80			
	0.83			
	0.81			
	0.85			
Strategic Renewal	0.82	0.70	0.90	0.84
	0.86			
	0.90			
	0.81			
	0.77			
	0.80			

(Source: Researcher's Findings)

After examining the validity and reliability of the variables, the next step is to examine the absence of cross-loadings of the variables, which is referred to as discriminant validity. It determines the extent to which a construct is distinct from other constructs. Alack of discriminatory validity suggests that an indicator is associated with more than one construct, a phenomenon known as cross-loading.

Table 3.
Cross Factor Loadings

Questions	Digital Transformation	Human Resource Productivity	Strategic Renewal
Question 1	0.8954	-0.0022	0.2745
Question 2	0.9428	0.0853	0.1563
Question 3	0.9081	0.0157	0.0756
Question 4	0.8994	0.0063	0.1985
Question 5	0.7859	0.2318	0.0858
Question 6	0.8149	0.0843	0.0037
Question 7	0.8365	0.2640	0.0005
Question 8	0.9055	0.2731	0.0017
Question 9	0.9471	-0.1067	0.0802
Question 10	0.8760	0.0070	0.0207
Question 11	0.8529	0.0321	0.1238
Question 12	0.8945	0.2640	-0.1234
Question 13	0.0921	0.9066	0.0023
Question 14	0.0834	0.7952	0.1093
Question 15	0.0040	0.8129	0.1256
Question 16	0.2539	0.8859	-0.0302
Question 17	-0.2341	0.9642	-0.1005
Question 18	0.0981	0.8865	0.0916
Question 19	0.0321	0.9216	0.0045
Question 20	-0.1164	0.8497	0.1146
Question 21	0.1705	0.8318	0.1039
Question 22	0.0181	0.9055	0.0058
Question 23	0.1202	0.0562	0.8847
Question 24	0.1047	0.1108	0.8642
Question 25	0.2091	0.0104	0.8522
Question 26	0.1193	0.1053	0.8945
Question 27	0.1218	0.1342	0.9143
Question 28	0.1066	-0.2301	0.8681

(Source: Researcher's Findings)

Discriminant validity is established when the manifest variables (questions) of each variable have the highest factor loading for their respective variable and the lowest factor loading for latent variables. As seen in the above table, the factor loadings for each variable are highest for their respective variable and lowest for other variables, confirming the discriminatory validity of research variables.

Findings

Before discussing inferential statistics, the results of descriptive statistics are presented. As for the demographic information of the respondents, 70.3% were male and 29.7% were female in terms of education, 5.5% had post-graduate education and below, 41.3% held a bachelor's degree, 51.2% had a master's degree and 2% had a PhD. Regarding

service experience14% had less than 10 years of experience, 64% had between 10 and 20 years of experience, and 22% had more than 20 years of experience. In terms of age, 6%were younger than 35 years, 61.9%were between 35 and 45 years old, 29.8%were between 45 and 55 years old, and 2.3%were over 55 years old.

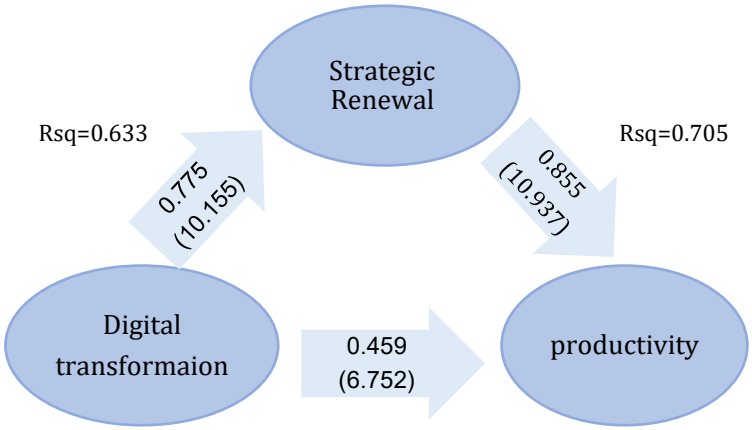
Table 4.
Descriptive Statistics of Respondents

Variable	Frequenc	Percent ge	Variable	Frequency	Percentage
Age	Less than 35 years	6%	Education	Associate Degree and below	5.5%
	35 to 45 years	61.9%		Bachelor's Degree	41.3%
	45 to 55 years	29.8%		Master's Degree	51.2%
	55 years and older	2.3%		Doctorate	2%
Gender	Male	70.3%	Work Experiene	Less than 10 years	14%
	Female Frequency	29.7%		10 to 20 years	64%
				Morethan20 years	22%

(Source: Researcher's Findings)

To test the research hypotheses, the Partial Least Squares (PLS) method was employed using the Visual PLS software. The results are presented in Figure 2. Visual PLS software, designed to solve Partial Least Squares problems, allows for examining the relationship between latent variables and observable measures. This technique is particularly useful when the sample size is small or the distribution of variables is not normal. The most important fit index in the Visual PLS software is the Goodness of Fit (GOF) index, which has also been examined in this research.

Figure 2.
Structural Model of Research



(Source: Researcher's Findings)

To assess the structural model of the research hypotheses, two criteria, $R^2$and Q^2, were used. The value of R^2 is 0.633 for the strategic modernization variable and 0.705 for

human resource productivity variable. These values indicate a good fit for the model. The value of Q^2 is 0.382 for strategic renewal and 0.552 for human resource productivity. Given that the obtained Q^2 values exceed 0.35, they show a strong predictive power for the structural model. The GOF index was used to evaluate the structural model. The value of GOF for the structural model of the research hypotheses is 0.83, indicating a strong overall fit.

The overall results of the research hypotheses, based on the path coefficient and the significance value obtained from the structural model, are summarized in Table 5.

Table 5.
Examining Research Hypotheses

Research Hypotheses	Path Coefficient	t-Statistics	Hypothesis Results
Digital Transformation → Human Resource Productivity	0.459	752/ 6	Confirmed
Digital Transformation → Strategic Renewal	0.775	155/ 10	Confirmed
Strategic Renewal → Human Resource Productivity	0.885	937/ 10	Confirmed

(Source: Researcher's Findings)

As shown, the significant value between digital transformation and human resource productivity is 6.752, which is greater than 1.96. Additionally, the path coefficient between them is 0.459. Therefore, we can conclude that digital transformation has a direct, positive, and significant impact on human resource productivity.

The significant value between digital transformation and strategic renewal is 10.155, which is also greater than 1.96. Given that the path coefficient between these two variables is 0.775, we can state that digital transformation has a direct, positive, and significant impact on strategic renewal. The significant value between strategic renewal and human resource productivity is 10.937, which is greater than 1.96. Additionally, the path coefficient between these two variables is 0.885. Thus, we can argue that strategic renewal has a direct, positive, and significant impact on human resource productivity.

Given that digital transformation has a significant impact (0.775) on strategic renewal, and strategic renewal also has a significant impact (0.885) on human resource productivity, we can conclude that digital transformation has an indirect impact (0.685 = 0.885 * 0.775) on human resource productivity.

To examine the mediating role of strategic renewal in the effect of digital transformation on human resource productivity, the Sobel test and VAF (Variance Accounted For) were used. In the Sobel test, a Z-value is obtained using Equation (1). If this Z-value exceeds 1.96, it confirms the significance of the mediating effect of a variable at a 95% confidence level.

Equation (1):

$$\text{Z-value}= \frac{a \times b}{\sqrt{(b^2 \times S_a^2)+(a^2 \times S_b^2)+(S_a^2 \times S_b^2)}}$$

In this Equation, a is the path coefficient between the independent variable and the mediator, b is the path coefficient between the mediator and the dependent variable, SEa is the standard error associated with the path between the independent variable and the mediator, and SEb is the standard error associated with the path between the mediator and the dependent variable. The values are as follows: a = 0.775, b = 0.885, SEa = 0.136, and SEb = 0.145. By substituting the obtained values into the above formula, the Z-value is calculated to be 4.92. Given that the Z-value is greater than 1.96, we can be conclude that the mediating effect of strategic renewal on the relationship between digital transformation and human resource productivity is significant at the 95% confidence level.

To determine the strength of the indirect effect on the mediator variable, the VAF statistic was used. It takes a value between 0 and 1, with values closer to 1 indicating a stronger the effect of the mediator variable. In fact, this value measures the ratio of the indirect effect to the total effect. VAF is calculated using Equation (2).

Equation (2):

$$VAF = \frac{a \times b}{(a \times b) + c}$$

In this equation, a is the path coefficient between the independent variable and the mediator, b is the path coefficient between the mediator and the dependent variable, and c is the path coefficient between the independent variable and the dependent variable. The values of a, b, and c are 0.775, 0.885, and 0.459, respectively. By substituting these values into equation (3), the VAF is calculated to be 0.599, indicating that more than half of the effect of digital transformation on human resource productivity is explained by the indirect effect and the mediating variable, strategic renewal.

Discussion and Conclusion

Human resource productivity is regarded as one of the key factors for organizational success and growth. It can add more value to the organization by increasing services and production level. A highly productive workforce can help improve performance, reduce unnecessary costs, and optimize work processes within the organization.

With recent advancements in technology, particularly digital transformation, the discussion of improving human resource productivity through this technology has gained momentum. Digital technologies can improve processes, reduce costs, increase human resource productivity, reduce human errors, enhance individual performance, facilitate communication among organizational members, and simplify the sharing of information, ideas, and knowledge.

The main objective of this research is to examine the impact of digital transformation on human resource productivity, considering the mediating role of strategic renewal. Based on the literature and the proposed conceptual model, one main hypothesis and three sub-hypotheses were formulated. The data was collected using standardized questionnaires, and analyzed using Visual PLS software. Based on the data analysis results, all research hypotheses were confirmed.

One of the hypotheses examined the impact of digital transformation on human resource productivity. The coefficient between digital transformation and human resource productivity was found to be 9.07, which is greater than 1.96, and the impact coefficient of digital transformation on human resource productivity was 0.72. Therefore, we can argue that digital transformation has a direct, positive, and significant impact on human resource productivity in the Post Office of Ilam. This finding aligns with the findings of Aditya et al. (2022), who demonstrated that digital transformation leads to learning and increases employee productivity. Bartch et al. (2021) also showed that digital transformation has a significant impact on employee productivity and performance.

To improve human resource productivity through digital transformation in Post Office, the following recommendations are suggested:

Implementing Digital Human Resource Management Systems: it can help automate processes, improve internal communication, speed up decision-making process, and enhance transparency.

Implementing Online Training and Professional Development Systems: offering online training can help human resources become familiar with new skills and pursue their professional development.

Implementing Business Intelligence Tools: analyzing various data and information about human resources can assist post offices in making better decisions and increasing their productivity.

Developing Internal Communication Systems: establishing strong internal communication systems using intranet tools can enhance workforce excellence, productivity, and coordination.

The second hypothesis states that digital transformation has a significant impact on strategic renewal in Ilam Post Office. The coefficient between digital transformation and strategic renewal was found to be 10.89, which is greater than 1.96, and the impact coefficient of digital transformation on strategic renewal was 0.89. This finding is consistent with the findings of Gaglio et al. (2022), who stated that digital transformation enhances the innovative climate and organizational agility, ultimately leading to strategic innovation. Golestaneh et al. (2021) also demonstrated that digital transformation is one of the drivers of innovation in organizations.

Practical suggestions

To enhance the impact of digital transformation on strategic renewal in post offices, the following recommendations are suggested:

- Training and Development of Digital Awareness: implementing training programs for employees to improve their digital knowledge and skills, thereby improving their ability to execute digital strategies.
- Development of Digital Work Processes: improving and optimizing the post office's work processes through digital processes to increase productivity and reduce costs.
- Advancement of Modern Technologies: utilizing modern technologies such as artificial intelligence, the Internet of Things, and automation to enhance performance and productivity within post offices.

The third hypothesis states that strategic renewal significantly impacts human resource productivity in the Ilam Post Office. The coefficient between strategic renewal and human resource productivity was found to be 10.50, which is greater than 1.96, and the impact coefficient of strategic renewal on human resource productivity was 0.84. Therefore, we can argue that strategic renewal has a direct, positive, and significant impact on human resource productivity in Ilam post Office. This finding is in line with the findings of Kalabi et al. (2016), who demonstrated that strategic renewal enhances competitive capability and ultimately improves productivity in organizations. N'dicu, et al (2023) also argued that organizations that value innovation have higher levels of productivity.

To improve human resource productivity through strategic renewal in post offices, the following recommendations are suggested:

- Setting Goals and Commitment: establishing a clear strategy and setting specific goals based on the needs and conditions of the postal company ensure commitment from all team members.
- Identifying Strengths and Weaknesses: conducting a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis to understand the strengths better and address weaknesses.
- Utilizing Appropriate Technology: employing modern technologies that are compatible with post office activities to enhance human resource productivity.
- Encouraging Collaboration and Teamwork: creating an environment where colleagues can propose innovative solutions collaboratively and are encouraged to engage in teamwork.

The main hypothesis of this research posits that digital transformation significantly impacts human resource productivity in Ilam Post Office, and strategic renewal plays a mediating role. Given that the z-value in the Sobel test was 4.92, which is greater than 1.96, the mediating role of strategic renewal in the impact of digital transformation on human resource productivity is confirmed. To the best of researchers' knowledge, previous studies have not examined this issue.

Regarding the variables of this research and the direct paths between them, studies have been conducted that examine the dyadic impact of the variables. The distinction of this research, however, lies in investigating both direct and indirect (mediating) paths, with strategic renewal confirmed as a mediating variable in the relationship between

digital transformation and human resource productivity. Thus, it can be stated that digital transformation has a significant impact on human resource productivity, and this impact is strengthened by strategic renewal. Moreover, the use of digital transformation and digital technologies improves communication, encourages individuals to present new ideas and innovations, improves individual performance, and enhances human resource productivity. Also, this study examined Ilam Post Office, whereas previous studies have mostly been conducted in governmental organizations.

Based on the results obtained, it is recommended that managers and policymakers in post offices develop policies and operational standards for the digitalization of work processes and digital security. It is suggested that post office managers strive to cultivate a culture of adhocracy, which supports creativity, entrepreneurship, openness, and risk-taking. Managers must ensure that all employees are aligned with the changes, as one of the key factors in a successful transformation is the adaptability of the organizational culture. In other words, overcoming cultural resistance is a challenge organizations must address. To achieve this, managers must ensure that all employees understand the reasons for these changes and are open to them. An organization with a culture that embraces these changes and encourages digital transformation is more likely to succeed.

Limitations and Suggestions for Future Researchers

Despite the theoretical value and innovation of the present research, like other studies, it has certain limitations that could inform future research on digital transformation and productivity. First, the data were collected from employees of Ilam post office. Therefore, to enhance the generalizability of the model, it is recommended that similar studies be conducted across various organizations with different social and cultural contexts. Second, while our results provide valuable insights into how strategic renewal acts as a mediating variable in the relationship between digital transformation and human resource productivity, it is suggested that future research analyze these relationships considering moderating variables such as gender. Third, this study employed a quantitative approach using structural equation modeling (SEM). For a deeper understanding of how of digital transformation affects human resource productivity, conducting qualitative research is recommended.

Conflict of Interest

The authors declare that there are no conflicts of interest in this research.

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Industry 4.0 Technology Communication Models for Achieving Sustainable Supply Chain: A Roadmap and Impact Dimensions

Fatemeh Zarei[1*] | **Jalal Naderi**[2]

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Fatemeh Zarei
Corresponding Author, Assistant Professor, Financial Management Department, Humanities Faculty, Meybod University, Meybod, Iran.
E-mail: zareifatemeh@meybod.ac.ir

Jalal Naderi
Assistant Professor, Department of Economics, Management and Accounting, Faculty of Humanities. Yasouj University, Yasouj, Iran.
E-mail: J.naderi@yu.ac.ir

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ABSTRACT

Industry 4.0 technologies are rapidly transforming production processes and value creation in the global economy. In recent years, significant attention has been directed toward linking these technologies with sustainable development goals, particularly sustainable production. This study addresses the existing gaps in understanding the role of digital processes in achieving sustainable production, and presents a roadmap for leveraging Industry 4.0 technologies to support sustainable supply chains. Through a systematic literature review, we identified 15 sustainability functions that can benefit from Industry 4.0 technologies. This study outlines pathways for implementing these technologies to enhance the economic, social, and environmental dimensions of sustainable supply chains and highlights their importance in achieving sustainability goals.

KEYWORDS

Economic Sustainability, Environmental Sustainability, Industry 4.0, Social Sustainability, Supply Chain, Sustainable Production.

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Introduction

Compliance with energy and material costs, along with exceeding stakeholder sustainability expectations, is a growing challenge that manufacturers worldwide are increasingly facing (Jena, 2020). Sustainable production and operating in a more responsible and sustainable manner are becoming essential business imperatives for maintaining competitiveness in manufacturing (Margherita & Braccini, 2020). Globally, manufacturers are already taking the necessary steps to better contribute to economic, social, and environmental development. Industry reports indicate that leaders in sustainable manufacturing benefit from more profitable opportunities and improved competitiveness. On the other hand, smaller-scale manufacturers are often unable to seize sustainable production opportunities, as they typically struggle with market turmoil and a lack of knowledge, strategy, and resources necessary for sustainable development.

It is difficult to provide a unified definition of sustainable production, but various definitions can be offered depending on its dimensions and applications (Moldavska & welo, 2020). The economic, environmental, and social dimensions, often referred to as the triple bottom line (TBL), are the most widely accepted dimensions of sustainable production among both industrial and academic communities (Junior et al., 2018). Sustainable production encompasses the entire product life cycle, from concept development and the production process to the end-of-life phase (Kamble et al., 2020). This requires a specific degree of integration and collaboration, scenario planning, and process innovation across the value chain (Bhatt et al., 2020). In such circumstances, Industry 4.0 technologies may offer promising opportunities to address the TBL challenges of sustainable production at both the factory and value chain levels.

From economic development perspective, Industry 4.0 and underlying digital technologies, such as cyber-physical systems and the Internet of Things (IoT), are expected to reduce operational costs associated with manufacturing activities (Gouda & Saranga, 2020; Ngu et al., 2020). Additionally, Industry 4.0 is expected to contribute to the environmental dimension of sustainable production by reducing waste during production activities, creating value, and promoting clean energy (Machado, 2020). Regarding the social sustainability dimension, it is believed that implementing Industry 4.0 will improve working conditions, enhance customer experience, and create new job opportunities (Sartal et al., 2020).

This research seeks to answer the question: "How can Industry 4.0 and its underlying industrial and digital transformation contribute to sustainable production?" For example, Ghabakhloo and Fathi (2020) demonstrated that Industry 4.0 technologies, such as industrial automation and IoT, by improving product quality and reducing errors, contribute to economic sustainability. Strandhagen et al. (2020) empirically demonstrated how certain Industry 4.0 technologies can overcome design barriers for sustainable production. A review of the literature reveals that only a few studies have empirically explained the applications of Industry 4.0 for sustainable production. However, the scope of Industry 4.0 extends far beyond the industrial application of isolated standalone digital technologies, such as value-added production (Beier, 2020).

This research aims to address the existing knowledge gaps regarding the applications of Industry 4.0 in sustainable production by providing a strategic roadmap that synthesizes and analyzes previous findings to clarify the pathway toward sustainable production within the framework of industrial digital transformation.

Literature Review

Sustainable Production

Sustainable production refers to the process of creating products through economically viable practices that minimize negative impacts on the environment. This approach represents the intersection of production management, sustainability, and sustainable development. Thus, the three key objectives—economic, social, and environmental—are central to sustainable production activities. In this context, manufacturing companies strive to reduce energy consumption, environmental pollutions, and industrial waste while utilizing processes that also maintain profitability and economic viability. Ultimately, society reaps the rewards of this production method (Le Bourhis, 2013).

The adoption of sustainable production is not merely an attractive slogan; it is a practical approach being implemented by various manufacturing firms. Given the significant importance of corporate social responsibility for these companies, the emphasis on sustainability in production has become a critical issue. Sustainable production has emerged as a focal point for both academic researchers and industry managers. By applying appropriate strategies in this field, organizations can achieve profitability alongside their social and environmental objectives (Le Bourhis, 2013).

Recognizing the substantial scientific and practical relevance of this concept, the literature reveals that sustainable production is increasingly being conceptualized through the lens of Industry 4.0 transformations (Beier, 2020)

Environmental Sustainability in Production

The environmental sustainability pillar of production focuses primarily on reducing the overall negative impact of manufacturing operations on the environment, which is evident chiefly in the reduction of carbon footprints, harmful gas emissions, energy consumption, and waste (Le Bourhis, 2013). In contrast, the social sustainability pillar is often considered the most underdeveloped aspect of sustainable production, as it is less clearly defined. The most recognized dimensions of social sustainability include improving customer shopping experiences, creating better working environments, and establishing fair job opportunities. However, this aspect of sustainability can also address a wide range of social concerns, such as child labor practicies or issues related to fair wages for workers (Sutherland et al., 2016; Mani et al., 2018). Furthermore, the social dimension of production sustainability deals with the welfare of stakeholders and the communities where production takes place (Ghobakhloo & Fathi, 2020).

Generally, implementing sustainability initiatives incur higher short-term costs for companies. However, when sustainability is strategically planned and successfully

executed, sustainable production initiatives can yield numerous dvantages for manufacturers (Sartal et al., 2020). Cost savings due to improved material, energy, and resource efficiency are the most apparent advantages of sustainability. Additionally, brand reputation, public trust, and greater competitiveness are among the other benefits associated with sustainability (Ngu, 2020).

Social Sustainability in Production

The Social Life Cycle Assessment (S-LCA) guidelines, developed under the United Nations Environment Programme, provide a valuable methodology to address the ambiguities in the concept of social sustainability. S-LCA offers a detailed framework for both internal and external stakeholders to effectively evaluate and map the social and socio-economic impacts throughout the product life cycle. Experts believe that sustainable production represents the next evolutionary step following green production, drawing from the philosophy of lean manufacturing (Kishawy, 2018). Unlike lean production, which aims to eliminate any non-value-adding activities solely for economic efficiency, green production advocates for environmental preservation even if it means reduced productivity (Inman & Green, 2018).

Sustainable production advances green production by considering the long-term perspective and prioritizing the sustainability of current production activities for future generations (Moldavska & Welo, 2017). Today, sustainable production is seen as a dynamic transition process, as the underlying elements, values, tools, and methods are continually evolving (Yong et al., 2020). Recent studies consistently strive to develop roadmaps that facilitate the implementation of innovative sustainable production practices, with a growing understanding of how production value addition or blockchain technology can contribute to sustainable thinking (Longo et al., 2017).

Sustainable production is defined as a set of techniques, strategies, and activities aimed at producing manufactured goods through processes that generate appropriate economic value, minimize adverse environmental impacts, conserve energy and natural resources, and enhance the well-being of stakeholder (employees, consumers, and communities). This approach to sustainable production encompasses both construction and manufacturing processes (Olfat et al., 2014).

Economic Sustainability in Production

Sustainable processes and the development of more sustainable products aim to deliver essential economic, environmental, and social benefits (Yong et al., 2020). Sustainable production adopts a holistic view of the entire product life cycle, supporting value creation and delivery channels that contribute to the Triple Bottom Line (TBL) of sustainability (Kamble et al., 2020). The economic sustainability aspect of production emphasizes that manufacturers must seek profitability to effectively pursue other sustainability objectives. However, the economic dimension of Industry 4.0 is marked by ambiguities (Ardito et al., 2019; Dev et al., 2020). Given the uncertainties surrounding Industry 4.0, researchers tend to define it in terms of digital transformation, focusing on

two main areas: design principles and technology trends (Garetti & Taisch, 2012; Sharma, 2020; Machado et al., 2020).

The design principles of Industry 4.0 establish the necessary conditions for industrial digital transformation and its unique advantages. While perspectives on these principles vary, real-time capability, virtualization, interoperability, decentralization, and extensive virtual/horizontal integration are among the most widely recognized (Zheng et al., 2021).

The Fourth Industrial Revolution or Industry 4.0

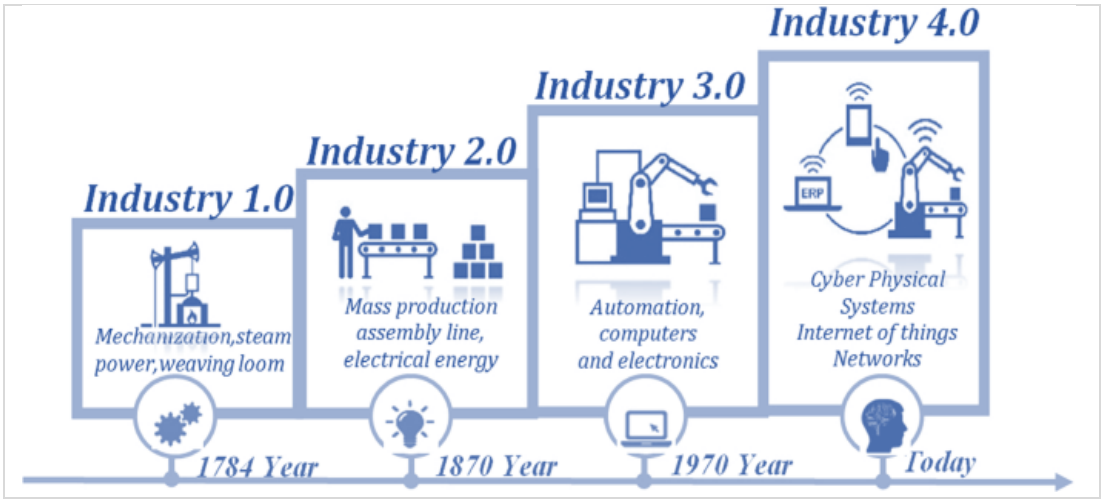
The Fourth Industrial Revolution, commonly referred to as Industry 4.0, has emerged over recent decades, emphasizing the application of digital technologies to elevate various industries. Industry 4.0 leverages the Internet of Things (IoT), real-time access, and cyber-physical systems to create a more integrated and comprehensive approach to production. By bridging the physical and digital worlds, it enables improved collaboration and access among sectors, partners, suppliers, products, and individuals.

Industry 4.0

Industry 4.0 empowers business owners to better control and understand various aspects of their operations, allowing them to leverage their data to enhance productivity, improve processes, and drive growth. From the 18th century to the present, four industrial revolutions have brought significant transformative changes, particularly in manufacturing (Mozafari, 2014).

This fourth industrial revolution integrates advanced technologies, such as artificial intelligence (AI), big data analytics, and automation, reshaping how businesses operate and compete in the global market. Real-time data collection and analysis enable organizations to make informed decisions, optimize resource allocation, and quickly respond to market changes. As a result, Industry 4.0 not only enhances operational efficiency but also fosters innovation and sustainability in production practices.

Figure 1.
Evolution of the Industrial Revolution 4.0



(Source: Khorasanchi, 2021)

What is the Fourth Industrial Revolution (Industry 4.0)?

The Fourth Industrial Revolution can be seen as an extension of the Third Industrial Revolution. While Industry 3.0 introduced computers into the manufacturing process, Industry 4.0 focuses on interconnecting these systems. However, it extends far beyond systems that can communicate within a single factory; when fully implemented, it enables the creation of smart factories and digital manufacturing. The Fourth Industrial Revolution facilitates connectivity across various production components through diverse technologies (Khorasanchi, 2021).

The notion of Industry 4.0 was first presented in 2011 and was defined by GTAI (Germany Trade & Invest) in a paper titled "Industry 4.0: Smart Manufacturing for the Future" It stated:

> "Smart industry, or 'INDUSTRIE 4.0,' refers to the evolution of technology and the shift towards intelligent systems. INDUSTRIE 4.0 represents the fourth industrial revolution and the accessibility of the Internet of Things, data, and services. Decentralized intelligence contributes to the creation of smart object networks and independent process management, showcasing a new aspect of the manufacturing process through the interaction between the real and virtual worlds."

It is clear that definitions of Industry 4.0 vary widely. In practice, Industry 4.0 holds different meaning to different stakeholders, each interpreting it differently. Generally, Industry 4.0 is defined as "a term for the current trend of automation and data exchange in manufacturing technologies, including smart systems, the Internet of Things, cloud computing, cognitive computing, and the establishment of smart factories" (Neshathi, 2017).

Technologies of the Fourth Industrial Revolution

Industry 4.0 is founded on nine key technology pillars, which create a bridge between the physical and digital worlds, enabling the establishment of intelligent and autonomous systems. While businesses and supply chains are currently utilizing some of these advanced technologies, the full potential of Industry 4.0 will be realized only when all these technologies work in synergy. By facilitating communication between the physical and digital realms, the technologies of the Fourth Industrial Revolution drive the development of smart processes and businesses (Almalki et al, 2022).

Figure 2.
Technologies of the Fourth Industrial Revolution

(Source: Almalki et al., 2022)

Big Data and Artificial Intelligence Analytics

In Industry 4.0, big data is collected from a wide range of sources, including factory equipment, Internet of Things (IoT) devices, Enterprise Resource Planning (ERP) systems, Customer Relationship Management (CRM) systems, as well as weather and traffic applications. Furthermore, AI and machine learning analytics are applied to this data in real-time, providing insights that can be utilized to enhance decision-making and automation across various areas of supply chain management, such as supply chain planning, logistics management, production, research and development, engineering, enterprise asset management (EAM), and procurement (Neshathi, 2017).

Horizontal and Vertical Integration

The backbone of Industry 4.0 is its horizontal and vertical integration. Horizontal integration involves the complete unification of processes at the "domain level," including manufacturing, production facilities, and the entire supply chain. Vertical integration, in contrast, connects all organizational layers, enabling free data flow across different levels. In other words, production is closely integrated with business processes such as research and development, quality assurance, sales and marketing, and other departments (Shafiei Nikabadi et al., 2023).

Cloud Computing

Cloud computing is a major "enabler" for Industry 4.0 and digital transformation. Recently, its impact on businesses extends far beyond speed, scalability, storage, and cost efficiency. In fact, cloud computing serves as the foundation for many advanced

technologies like AI, machine learning, and the Internet of Things, equipping businesses with tools for innovation. Moreover, much of the data supporting Industry 4.0 technologies resides in the cloud, where physical systems leverage cloud infrastructure to communicate and coordination (Shafiei Nikabadi et al., 2023).

Augmented Reality (AR)

Augmented reality, which overlays digital content onto real-world environments, is a key concept in Industry 4.0. With augmented reality systems, employees can use smart glasses or mobile devices to visualize IoT data, digital components, repair or assembly instructions, training content, and more. While AR technology is still evolving, it has already made significant strides in areas such as maintenance, service, quality assurance, and technician training and safety (Sarasht & Afsar, 2009).

Industrial Internet of Things (IIoT)

The Internet of Things (IoT) and, specifically, the Industrial Internet of Things (IIoT) are so crucial to Industry 4.0 that the terms are often used interchangeably. In Industry 4.0, most physical objects, such as devices, robots, machinery, equipment, and products, utilize sensors and RFID tags to provide real-time data about their status, performance, or location. This technology allows organizations to execute their supply chains more effectively, design and refine products rapidly, prevent equipment failures, maintain consumer preferences, and track products and inventory erffectively (Neshathi, 2017).

Additive Manufacturing / 3D Printing

Additive manufacturing, or 3D printing, is another technology driving Industry 4.0. originally developed as a tool for rapid prototyping, 3D printing now offers a broader range of applications, including mass customization and distributed manufacturing (Almalki et al, 2022).

Autonomous Robots

Alongside Industry 4.0, a new generation of autonomous robots is emerging. These self-driving robots, designed to perform tasks with minimal human intervention, vary significantly in size and function, ranging from inventory scanning drones to autonomous mobile robots for operations. Equipped with advanced AI software, sensors, and machine vision, these robots can perform complex and delicate tasks, analyzing and acting on the information they gather from their surrounding environment (Shafiei Nikabadi et al., 2023).

Simulation /Digital Twins

A digital twin refers to the virtual simulation of a real machine, product, process, or system based on data from IoT sensors. This core component of Industry 4.0 enables businesses to better understand, analyze, and improve the performance and maintenance of industrial systems and products. For example, an operator can use a digital twin to identify a specific faulty part, predict potential issues, and enhance uptime (Shafiei Nikabadi et al., 2023).

Cybersecurity

With the increasing connections and utilization of big data in Industry 4.0, cybersecurity has become critically important. By implementing a Zero Trust architecture and technologies such as machine learning and blockchain, organizations can automate the processes of threat detection, prevention, and response, minimizing the risk of data breaches and production delays within their networks (Almalki et al., 2022).

Impact of the Fourth Industrial Revolution on Business and its Applications

Industry 4.0 can be applied at all levels of the production process, from product development to end-of-life management. Additionally, some manufacturers utilize Industry 4.0 for concepts such as supply chain management. This way, these businesses can better predict supply disruptions and facilitate product manufacturing through optimal resource utilization.

Another application of Industry 4.0 is the acquisition of real-time data during the production process. Analyzing this data leads to optimizing operations, ultimately resulting in improved efficiency, reduced time to market, and increased organizational productivity. One of the best ways to better understand the concept of intelligent manufacturing is to think about its efficiency and how it can be applied within a business. Here are three examples of Industry 4.0 applications in business that can help illustrate the value of Industry 4.0 in a manufacturing environment (Shafiei Nikabadi et al., 2023).

Supply Chain Management and Optimization

The components of the Fourth Industrial Revolution provide businesses with more significant insights, control, and visibility over data throughout the supply chain. By leveraging supply chain management capabilities, companies can bring their products and services to market faster, at a lower cost, and with better quality, thereby gaining an advantage over traditional competitors (Sarasht & Afsar, 2009).

Maintenance, Repair, and Predictive Analytics

Fourth Industrial Revolution solutions empower manufacturers to anticipate potential problems before they occur. Without IoT systems in a factory, preventive maintenance is performed based on routines or scheduled timelines; in other words, it is manual. With IoT systems, preventive maintenance becomes much more automated and simplified. These systems can detect when issues arise or machinery needs repairs, thus enabling businesses to address potential problems before they escalate into more significant issues (Almalki et al., 2022).

Additionally, predictive analytics allows companies to not only ask reactive questions such as “What happened?” or “Why did this happen?” but also answer proactive questions like “What will happen?” and “What can we do to prevent it from happening?” This type of analysis enables manufacturers to shift from preventive to predictive maintenance.

Asset Tracking and Optimization

The components of the Fourth Industrial Revolution assist manufacturers in operating

more efficiently at every stage of the supply chain, providing better control over inventory, quality, and optimization opportunities related to logistics. By utilizing IoT in a factory, employees gain better visibility into business assets anywhere worldwide. Standard asset management tasks, such as transferring assets, reclassification, and adjustments, can also be managed in a centralized and real-time manner (Culot et al., 2020).

Technology Trends of Industry 4.0

The technology trends of Industry 4.0 refer to a wide range of information, digital, operational, and advanced manufacturing technologies that collectively create the digital industrial revolution. Based on their functionality, these trends can be classified into two categories: facilitating technologies and core technologies. Facilitating technologies include mature and accessible technologies that enable core technologies' implementation, integration, and proper functioning. Examples of facilitating technologies are legacy networking infrastructures, software, computer-aided design and manufacturing tools, and sensors (Muscio & Ciffolilli, 2020).

On the other hand, core technologies are digital technologies that have recently been commercialized, allowing for maximum flexibility, integration, and automation. Core technology trends in Industry 4.0 include cyber-physical systems, IoT, big data, 3D printers, AI (automation robots), and cloud computing. Although this concept is new and emerging, the literature on Industry 4.0 is rich, and the number of academic contributions to this field is growing exponentially (Oztemel and Gursev, 2020). Previous studies have made valuable contributions to understanding the fundamental concept of Industry 4.0, its scope, constituent components, implications, and trends.

The concept of sustainability in the digital industrial transformation is becoming one of the most popular research streams in the Industry 4.0 community. The contribution of Industry 4.0 to new economies and sustainable supply chains and logistics has been, respectively, the most popular research streams in Industry 4.0 and sustainability (Ding, 2018). Surprisingly, empirical assessments of Industry 4.0's sustainability implications for manufacturing still need to be improved in the literature to understand how manufacturers implement the digital technologies of Industry 4.0 and navigate the underlying digital transformation (Sharma et al., 2020). This means that there more studies need to examine how the implementation of Industry 4.0 relates to the scalability of various technologies and, subsequently, sustainability development (Machado et al., 2020). Industry 4.0 represents the current industrial revolution encompassing the digital transformation of value-creation processes across various industries, including manufacturing.

The integration of Industry 4.0 (I4.0) Technologies into Supply Chain

Integrating Industry 4.0 (I4.0) technologies into supply chain communication models significantly enhances the achievement of sustainable supply chains. These technologies, including IoT, big data, and cloud computing, facilitate improved operational efficiency

and transparency, which are crucial for sustainability goals. The following sections elaborate on the key aspects of this relationship.

Role of I4.0 Technologies:

- *Efficiency Improvement*: I4.0 technologies streamline logistics and manufacturing processes, reducing waste and resource consumption (Qureshi et al., 2024).
- *Enhanced Visibility*: Technologies like IoT enable real-time tracking of materials, fostering supply chain visibility (SCV) and supporting circular economy practices (Junaid et al., 2024).
- *Data-Driven Decision Making*: Big data analytics allows firms to make informed decisions that align with sustainability objectives (Stroumpoulis et al., 2024).

Impact on Sustainability:

- *Transparency and Trust*: Blockchain technology ensures the traceability of sustainable materials, promoting ethical practices and consumer trust (Laturkar & Laturkar, 2024).
- *Holistic Approach*: Integrating digital transformation with sustainability practices enhances overall business performance and societal impact (Stroumpoulis et al., 2024).

While the benefits of I4.0 technologies in promoting sustainability are evident, challenges such as the initial investment costs and the need for skilled personnel may hinder widespread adoption. Addressing these barriers is essential for maximizing the potential of I4.0 in sustainable supply chain management.

Introduction to Sustainable Production Function Patterns

To date, numerous models for sustainable production have been proposed. Below, we identify 15 unique sustainable production functions for Industry 4.0. It is essential to note that the functions of Industry 4.0 for sustainable production, as explained below, provide pathways to a more sustainable production ecosystem with varying qualities. While the literature offers the necessary support to link Industry 4.0 functions to different aspects of sustainable production, the sustainability benefits of these functions should be taken seriously, as they depend on the context and conditions under which producers operate. More importantly, these functions may be common to production systems utilizing Industry 4.0 technologies. Industry 4.0 primarily provides these functionalities by promoting and facilitating other tools, methods, and techniques for improving production and processes, including lean production or concurrent design and manufacturing. Below is a brief description of each of sustainable production functions, including: (Li et al., 2020).

- *Business Model Innovation (BUMI)*: Industry 4.0 and its components, such as real-time capabilities, decentralization, or modularity, complemented by modern technologies like value-added manufacturing and IoT, enable producers to transform their operational models and value creation capabilities (García-Muina et al., 2020; Li et al., 2020). Business model innovation enhances the value proposition of producers to customers by offering safer, cleaner, and more functional products and services (Leng et al., 2020).

- *Customer-Centric Production (CUOM)*: Under Industry 4.0, technologies such as value-

added manufacturing, service-oriented Internet, and the Internet of People, combined with the principle of modularity, empower producers to develop a more agile and flexible production system that facilitates the customization of products based on customer demands economically, thereby creating higher value for all stakeholders (Wang et al., 2017).

- *Employee Productivity (EMPP)*: Industry 4.0, through real-time information sharing, improved communication clarity, task automation, interdepartmental connectivity, enhanced human-machine interaction, and simplified production operations, can increase the relative performance of employees (Strandhagen et al., 2020; Beier, 2017). Higher employee productivity typically leads to healthier profit margins, improved working conditions, and a healthier business network (Jacobs et al., 2016).

- *Reduction of Harmful Emissions (HAER)*: Industry 4.0 technologies and principles, such as the Industrial IoT, cyber-physical systems, intelligent robots, real-time capabilities, interoperability, and horizontal and vertical integration, along with emerging concepts like smart factories and digital supply networks, offer significant opportunities for industrial productivity and subsequently for controlling and reducing emissions while preserving the environment (Bag, 2020).

- *Improvement of Production Profit Margins (IMPM)*: Smart factories under Industry 4.0 are more agile, flexible, and responsive (Yli-Ojanpera, 2019). In a smart production environment, efficient and automatic decision-making, higher product quality, satisfied customers, and reduced business risks, among many other benefits, provide higher profit margins for producers. Economically productive manufacturers are better equipped to enhance social and environmental sustainability (Vrchota et al., 2020).

- *Intelligent Production Planning and Control (IPPC)*: Digital technologies in Industry 4.0, such as the Industrial IoT, AI, big data analytics, and features like data transparency, real-time information sharing, context awareness, and resulting process clarity, facilitate the development of intelligent capabilities for production planning and control. This includes automated data collection and adaptive scheduling at the shop floor level. Optimized and intelligent production is widely accepted as a facilitator for sustainable production (Tsai et al., 2020).

- *Manufacturing Agility (MANA)*: The integrated, decentralized, and interactive production ecosystem under Industry 4.0 provides the necessary agility for manufacturers to effectively address environmental uncertainties (Braccini & Margherita, 2019; Müller et al., 2018). Industry 4.0 also enables supply chain partners to quickly and cost-effectively adjust the product processes and necessary adjustments while optimizing social and environmental impacts.

- *Productivity and Efficiency of Manufacturing (MAPE)*: Industry 4.0 enhances the productivity and efficiency of manufacturing systems through technological development and improved connectivity (Jena et al., 2020). Automation of production, process monitoring, and supply chain oversight lead to higher equipment reliability, reduced machine downtime, optimized inventory, and improved employee engagement (Ivascu,

2020). These conditions promote manufacturing profitability and environmental sustainability (Kiel et al., 2017; Jacobs, 2020).

- *Serious Employment Opportunities (NEEP)*: Digital transformation under Industry 4.0 significantly increases the complexity of manufacturing systems (Bag et al., 2020). Despite the undeniable job losses due to automation, Industry 4.0 creates new types of jobs that previously did not exist. Manufacturers investing in digital transformation have no choice but to add new professional job positions, such as software engineers, IT specialists, and operators of new machinery, to their workforce (Gualtieri et al., 2020). If adequately managed, new job opportunities under Industry 4.0, can reduce employment and income inequality (Sung, 2018).

- *Resource and Energy Efficiency (REEE)*: Resource and energy efficiency are at the core of Industry 4.0, as innovative technologies underpin real-time monitoring of energy and resource consumption across the supply chain (Bonilla et al., 2018). At the smart factory level, machines equipped with sensors, machine controllers, smart production execution systems, and cloud-based energy management systems enable continuous and real-time resource and energy consumption monitoring, reinforcing long-term sustainability (Nascimento et al., 2019; Ren et al., 2019).

- *Reduction of Manufacturing Costs in Industry 4.0 (REMC)*: Opportunities for savings in manufacturing costs include 24/7 automated production, increased production volume, improved product quality, greater precision in manufacturing, reduced production errors, and enhanced equipment effectiveness (Braccini & Margherita, 2019). Reducing manufacturing costs and increasing economic performance allows producers to prioritize and commit better to social and environmental development (Kamble et al., 2020).

- *Safe and Smart Work Environment (SSWE)*: Technologies of Industry 4.0 lead to more intelligent and connected employees (Dalenogare et al., 2018). Smart covers enable employees to acquire the necessary skills to maintain safety and productivity in the industrial environment (van Lopik et al., 2020). Automation and collaborative robots also free workers from non-ergonomic and hazardous tasks (Taylor et al., 2020).

- *Integration of Supply Chain Processes (SCPI)*: Horizontal integration and transforming traditional supply networks into a digital and integrated entity are among the fundamental principles of Industry 4.0 design (Ismailian et al., 2020). Integrated technologies such as the Industrial IoT, service internet, data internet, blockchain, and cloud analytics facilitate the integration of activities, real-time information sharing, integration of physical flows, and financial flow capabilities among resource members (Strandhagen et al., 2020). The integrated supply chain process and its features, such as collaborative knowledge management, product development, product planning, demand planning, and decision-making initiatives, provide significant economic and environmental development opportunities (Ding, 2018).

- *Sustainable Product Development (SUPD)*: Sustainable product development (SUPD) heavily relies on resources, information, and technologies from Industry 4.0. SUPD supports facilitating life cycle assessment approaches for new product development

(Leng et al., 2020). Digital twin technology and simulation of the entire life cycle of a product transform the ideation phase of SUPD (Tao et al., 2018). Furthermore, computer-aided design and high-efficiency computational methodologies enhance the effectiveness of SUPD (Dev, 2020). The development phase, which is crucial, is further promoted by smart manufacturing features, as Industry 4.0 enhances the commercialization phase of SUPD due to its efficiency and productivity capabilities (Lin, 2018).

- *Sustainable Value-Creation Networking (SVCN)*: Creating shared sustainability across value chains requires all value chain members, from the lowest-level suppliers to end consumers, to embrace the concept of sustainability to generate shared value (Kiel et al., 2017). Fortunately, Industry 4.0 and its underlying technologies enable the integration of value chains, allowing all value chain members to collaborate in the joint creation of more sustainable products and services (Ardito et al., 2019). Additionally, Industry 4.0 facilitates the incorporation of environmentally friendly technologies, raw materials, and renewable energy sources into production chains, ensuring that sustainable features are identified throughout the value chains. This way, sustainability benefits are distributed fairly among all value chain members (Ivascu, 2020; Sartal et al., 2020).

Methodology

In this research, we employed a bibliometric approach to review existing studies on the impact of Industry 4.0 technologies on sustainable supply chains. Bibliometric analysis is a quantitative method that helps researchers identify key concepts and trends within a specific field by mapping the intellectual structure and development of the domain. For this purpose, we searched the Scopus database using the following keywords:

- "Industry 4.0"
- "Industry 4.0 technologies"
- "Sustainable supply chain Industry 4.0"
- "Industry 4.0 revolution"

After data extraction, we conducted output analysis similar to previous studies, such as those by Zarei et al. (2023) and Nourahmadi et al. (2021), to uncover trends, patterns, and influential areas. This research follows a three-stage data analysis protocol: (1) dataset setup, including identification, screening, eligibility, and inclusion of relevant studies; (2) dataset refinement; and (3) data analysis from functional perspectives, scientific mapping, and network analysis.

The search was conducted in the Scopus database on October 19, 2024. In the subsequent step, the results of the articles were analyzed using the Bibliometrix package in R. The analysis revealed 3,684 documents related to this topic, of which only 1,746 were articles authored by 8,713 authors.

Table 1.
Descriptive Statistics of the Studies Conducted from 2013 to 2024

Results	Description
	Main Information About Data
2013:2024	Timespan
1141	Sources (Journals, Books, etc)
3684	Documents
51.83	Annual Growth Rate %
2.72	Document Average Age
28.87	Average citations per doc
0	References
	DOCUMENT CONTENTS
8151	Keywords Plus (ID)
6804	Author's Keywords (DE)
	Authors
8713	Authors
391	Authors of single-authored docs
	AUTHORS COLLABORATION
442	Single-authored docs
3.31	Co-Authors per Doc
29.13	International co-authorships %
	Document Types
1746	article
8	article article
3	article book chapter
6	article conference paper
1	article review
61	book
559	book chapter
3	book chapter article
2	book chapter book chapter
2	book chapter conference paper
1	book chapter review
1049	conference paper
6	conference paper article
1	conference paper book
1	conference paper book chapter
3	conference paper conference paper
39	editorial
5	erratum
23	note
4	retracted
156	review
5	short survey

(Source: Researcher's Findings)

The data spans from 2013 to 2024, encompassing 3,684 documents sourced from 1,141 publications, including journals and books. The annual growth rate of publications in this field is notably high at 51.83%, indicating increasing interest in the intersection of Industry 4.0 technologies and sustainable supply chains. The average age of the documents is approximately 2.72 years, with an impressive average citation count of 28.87 citations per document.

Regarding keyword usage, there are 8,151 Keywords Plus and 6,804 Author's

Keywords, reflecting a diverse range of topics within the research area. The research involved 8,713 authors, with 391 of them contributing to single-authored documents. Collaboration among authors is also significant, as evidenced by the 3.31 co-authors per document and an international co-authorship rate of 29.13%.

Regarding document types, the majority of the publications are articles (1,746), supplemented by various formats, including conference papers (1,049), book chapters (559), and reviews (156). The results indicate a robust and collaborative research environment in exploring the implications of Industry 4.0 technologies on sustainable supply chains.

Figure 3.
Important Keywords Used in the Studies

(Source: Researcher's Findings)

Table 3 highlights the most significant keywords frequently used in studies related to Industry 4.0. The term "Industry 4.0" dominates the list with 1,479 occurrences, reflecting its central role in the discourse around modern industrial advancements. Other prominent terms such as "Internet of Things" (250 occurrences) and "Sustainable Development" (210 occurrences) emphasize the importance of integrating emerging technologies with sustainability efforts.

Interestingly, terms like "Supply Chain" and "Supply Chain Management" appear frequently (171 and 91 occurrences, respectively), signifying the increasing focus on how Industry 4.0 technologies are transforming supply chain operations. The keyword "Cloud Computing" (178 occurrences) also indicates the growing reliance on cloud-based solutions to support digitalization.

Additionally, "Decision-Making" (168 occurrences) and "Electronic Transfer" (146 occurrences) suggest a strong interest in how these technologies are enhancing decision processes and data handling in modern industries. This table provides valuable insight into the key focus areas within Industry 4.0 research, highlighting the intersection of technology, management, and sustainability.

Table 2.
The Most Important Keywords Used in the Studies

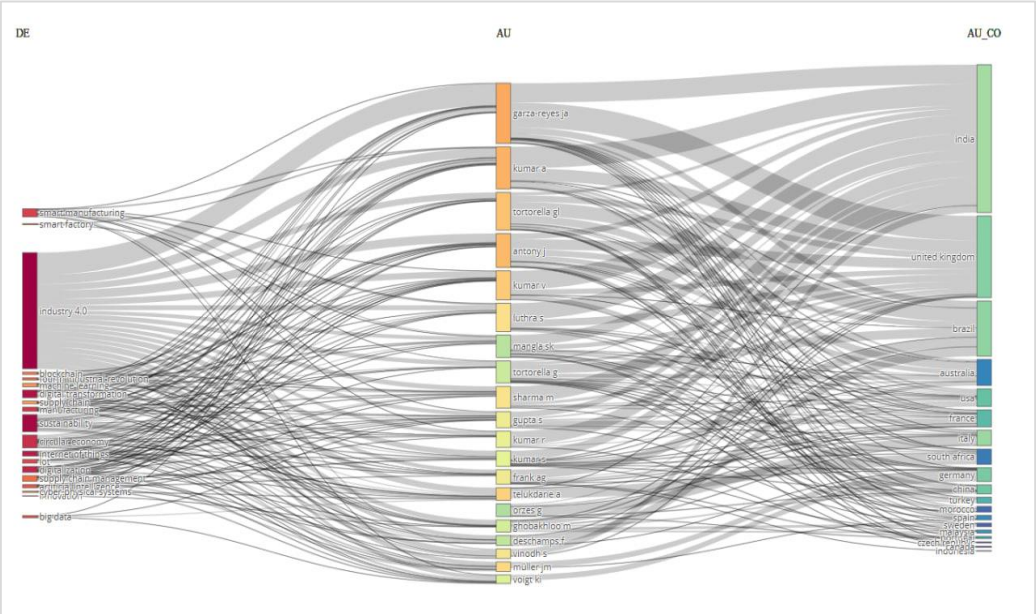
Keywords	Frequency
Industry 4.0	1479
Industrial Revolution 4.0	234
Internet of Things	250
Supply Chain	171
Sustainable Development	210
Cloud Computing	178
Decision-Making	168
Electronic Transfer	146
Supply Chain Management	91

(Source: Researcher's Findings)

Findings

Figure 4 illustrates the relationships between keywords, countries, and authors of the articles. This visualization highlights the interconnection of various keywords, the geographical distribution of research output, and the collaborative efforts among authors from different regions. Such insights can help identify trends and patterns in the research landscape concerning Industry 4.0 technologies and their impact on sustainable supply chains.

Figure 4.
Network of Communication between Authors, Keywords and Countries Producing Research

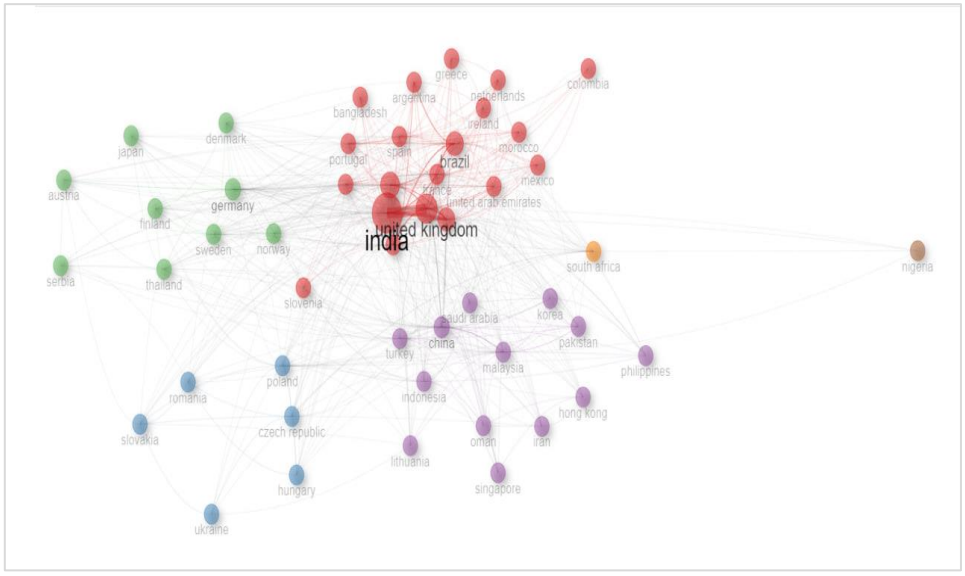


(Source: Researcher's Findings)

Figure 5 depicts the network of connections between countries with the highest number of published articles. This network visualization reveals the collaborative relationships and research outputs among these countries, illustrating how they contribute to the body of knowledge on Industry 4.0 technologies and sustainable supply

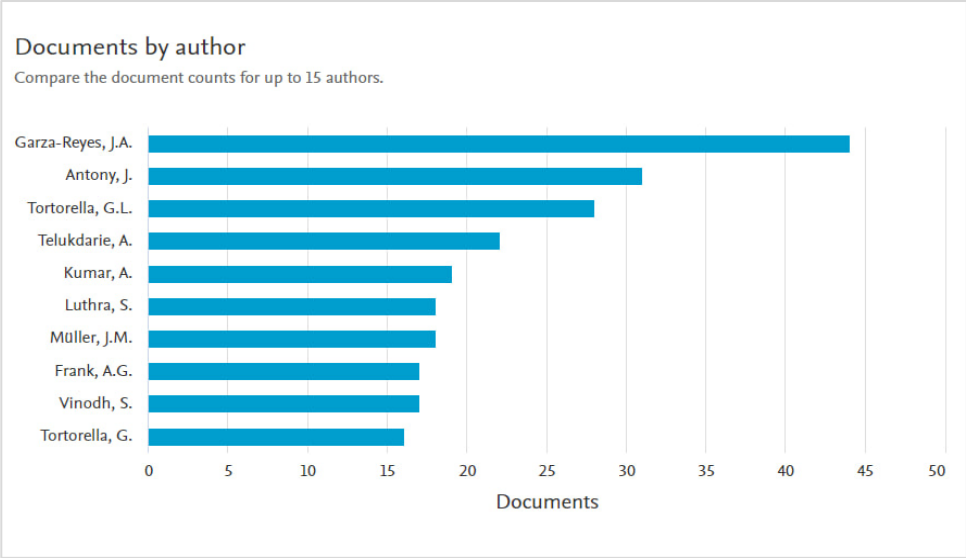
chains. It provides insights into global research trends and the extent of international cooperation in this field.

Figure 5.
The Network of Connections between Countries with the Most Studies



(Source: Researcher's Findings)

Figure 6.
Authors with the Most Research

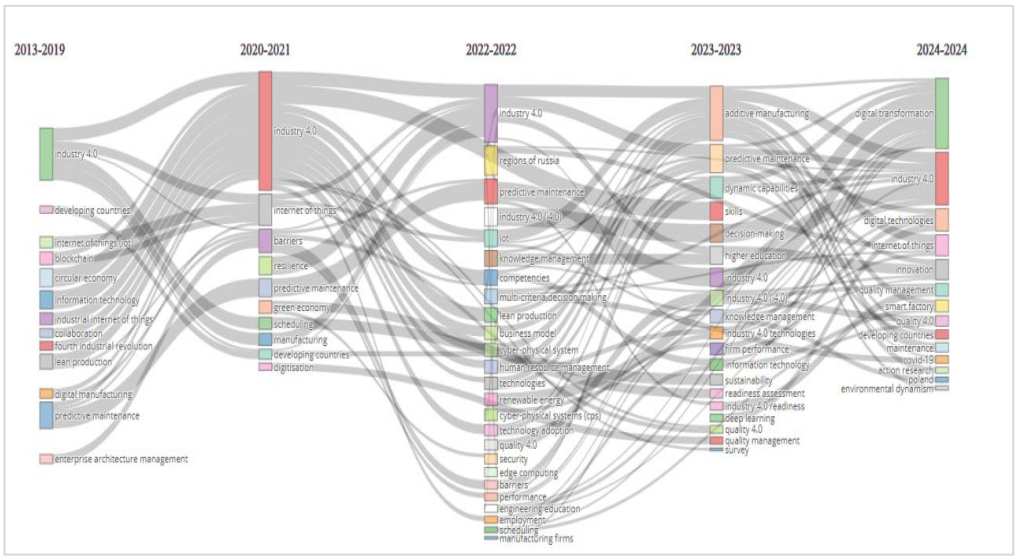


(Source: Researcher's Findings)

As shown in Figure 6, the authors Garza-Reyes, J.A., Antony, J., and Tortorella, G.L. are identified as the leading researchers in the field of Industry 4.0 technologies.

Figure 7 illustrates the evolution of the topic and research over five distinct periods, highlighting the significance of relevant keywords during each period. Notably, in 2022, there is an increased emphasis on Industry 4.0 technologies in conjunction with sustainable supply chains.

Figure 7.
Subject Evolution Over Time



(Source: Researcher's Findings)

Figure 7 illustrates the evolution of keywords in Industry 4.0, leading to several key conclusions:

1. Shifts in Focus over Time:

- *Phase One*: At the beginning of the timeline, keywords such as "knowledge development" and "innovation" were predominant. This indicates that initial attention was directed towards foundational concepts and establishing necessary infrastructures for transitioning into the Industry 4.0 era.
- *Phase Two*: Over time, keywords like "Industry 4.0," "artificial intelligence," and "Internet of Things" have gained prominence. This shift demonstrates a transition in research focus towards key technologies that underpin Industry 4.0.
- *Phase Three*: In later stages, keywords such as "smart manufacturing," "smart supply chain," and "data analytics" emerged as critical concepts. This indicates an increased emphasis on the practical application of Industry 4.0 technologies within production processes and supply chain management.

2. Interconnections between Concepts: The diagram reveals a strong correlation between many keywords. For instance, "artificial intelligence" is closely associated with terms like "machine learning," "neural networks," and "data analytics." This suggests that these technologies are utilized as primary tools to achieve the objectives of Industry 4.0.

3. Emergence of New Concepts: With technological advancements and shifting industry needs, new concepts have also entered the discourse of Industry 4.0. Keywords such as "digital twin," "collaborative robotics," and "cybersecurity" have gained increased importance in recent years.

Table 3.
The Background of the Research Done on Integrating Industry 4.0 (I4.0) Technologies into Supply Chain

Papers	Insights	Conclusions
Investigating industry 4.0 technologies in logistics 4.0 usage towards sustainable manufacturing supply chain (Karishma et al., 2024)	This study shows that I4.0 technologies enhance communication models in Logistics 4.0, influencing subjective norms and attitudes, which drive sustainable practices in the manufacturing supply chain.	I4.0 tech in L4.0 influences subjective norms, attitudes, and behavior control. It also enhances word-of-mouth and purchase intention for sustainability in SC.
Enhancing Sustainable Supply Chain Management through Digital Transformation: A Comparative Case Study (Stroumpoulis et al., 2024)	The study emphasizes that Industry 4.0 technologies enhance communication models, facilitating the integration of digital transformation and sustainability practices, thereby improving supply chain performance and operational excellence.	Digital transformation enhances sustainable supply chain management effectiveness. A holistic sustainability approach improves business performance and market share.
Creating a sustainable future through Industry 4.0 technologies: Untying the role of circular economy practices and supply chain visibility (Junaid et al., 2024)	The study emphasizes that I4.0-Tech enhances sustainable supply chains by improving supply chain visibility, enabling circular economy practices, facilitating real-time tracking, and optimizing resource utilization for sustainability goals.	I4.0-Tech impacts sustainability through SCV and CEP. SCV, CEP, and SUS have a positive relationship.
Harmonizing Innovation - Bridging Industry 4.0 with Supply Chain Sustainability. (Laturkar & Laturkar, 2024)	The study emphasizes that Industry 4.0 technologies enhance supply chain sustainability by improving transparency and traceability. This enables organizations to ensure sustainable materials and fair labor practices, thus fostering consumer trust and loyalty.	Integrating Industry 4.0 and supply chain sustainability benefits businesses. Industry 4.0 enhances transparency, traceability, and brand trust.
Investigating the Role of I4.0 Technology Using Extended Theory of Planned Behavior (ETPB) (Qureshi et al., 2024)	The study highlights that I4.0 technologies enhance communication models in Logistics 4.0, facilitate improved subjective norms and attitudes, and ultimately contribute to sustainable supply chain achievements.	I4.0 technology influences subjective norms and attitudes. It also promotes sustainability in manufacturing supply chain through L4.0 adoption.
Industry 4.0 Technologies: Opportunities in the Sustainable Supply Chain Management (nimal& reddy, 2023)	The study emphasizes that Industry 4.0 technologies enhance communication models, facilitate real-time data sharing and collaboration, which are crucial for optimizing sustainable supply chain management, and improve overall sustainability performance	Industry 4.0 tech aids sustainable supply chain management. SWOT analysis, limitations, and potential are discussed for technologies
The impact of emerging technologies of industry 4.0 on sustainability dimensions (Alnahhal et al., 2024)	The study highlights that I4.0 technologies enhance communication and collaboration in supply chains, contribute to sustainability by reducing waste, and improve efficiency through advanced systems like IoT and NFC.	It demonstrates that emerging technologies enhance sustainability and customer satisfaction. It also argues that challenges might be encountered during sustainability goals' Implementation.
Industry 4.0 Technology-Supported Framework for Sustainable Supply Chain Management in the Textile Industry (Chen et al., 2023)	The study emphasizes that Industry 4.0 technologies enhance communication models in supply chains, enable data-driven decision-making, and facilitate sustainability through improved tracking, traceability, and efficient information transmission in the textile industry.	This study proposes a sustainable closed-loop supply chain for textiles. It also recommends using Industry 4.0 technologies for sustainability.
Challenges for the Adoption of Industry 4.0 in the Sustainable Manufacturing Supply Chain (Hakeem et al., 2023)	The chapter emphasizes the need for effective communication models in Industry 4.0 to address data management complexities, ensuring sustainable supply chain practices through collaboration and technology integration.	It addresses challenges for successful Industry 4.0 adoption. It also prioritizes sustainability, energy efficiency, data ethics, and collaboration.
Nexus of Industry 4.0 and circular economy in solid waste management supply chains: a literature review (Afshari & Gurtu, 2024)	The study emphasizes that Digital technologies enhance communication models in supply chains, improve waste management efficiency and sustainability by enabling better segregation, and reduce environmental impacts of municipal solid waste.	It addresses efficient waste management through digital technologies It also focuses on the reduction of environmental impact and operational costs of waste management

(Source: Researcher's Findings)

The findings of this study further reveal that the successful integration of Industry 4.0 into sustainable manufacturing requires a clear strategy for overcoming technological and organizational challenges. Moreover, the study indicates that while larger manufacturers with greater resources are more capable of implementing Industry 4.0 technologies comprehensively, smaller manufacturers often face obstacles due to limited resources, insufficient expertise, and market instability. Therefore, customized approaches that support smaller firms in adopting key Industry 4.0 technologies, like energy-efficient systems or resource optimization tools, can help bridge this gap. Additionally, the study underscores the importance of cross-industry collaboration, policy support, and knowledge sharing to maximize the potential of Industry 4.0 in fostering sustainable production practices across the manufacturing sector.

Discussion and Conclusion

This study aims to address the knowledge gap regarding the opportunities that Industry 4.0 and the digital industrial revolution may offer for sustainable manufacturing. The findings indicate that Industry 4.0 supports sustainable manufacturing through 15 highly relevant functions, including business model innovation, customer-oriented production, employee productivity, reduction of harmful emissions (air pollution reduction), improvement of production profit margins, smart production planning and control, manufacturing agility, increased productivity, job creation, resource consumption reduction, energy efficiency enhancement, lower production costs, safe and smart working environments, integration of supply chain processes, sustainable product development, and sustainable value-creation networks. The role of each sustainability function is thoroughly explained in the roadmap for the sustainable manufacturing developed in this study. Overall, the results suggest that Industry 4.0 can play a significant role in sustainable manufacturing.

The implications of this research can be summarized as follows: Industry 4.0 and sustainable manufacturing share many common grounds that emphasize efficiency, productivity, continuous improvement, and enhanced customer experience. The results show that Industry 4.0 promotes sustainable manufacturing through a complex, gradual, knowledge-based, and costly mechanism, requiring manufacturers to possess a certain level of technology and knowledge management. Not all manufacturers have the capacity for the digital transformation inherent in Industry 4.0. However, independent technologies within Industry 4.0, such as 3D printers or value-added manufacturing, can still contribute to specific aspects of sustainable manufacturing. Industry 4.0 is a complex and multifaceted phenomenon encompassing various technologies and their applications in an overly interconnected manufacturing ecosystem. Each technological trend in Industry 4.0 offers unique sustainability concepts. For example, 3D printing promotes sustainable manufacturing by providing customized products and facilitating environmentally friendly goods. Conversely, cyber-physical and smart manufacturing execution systems enhance sustainability through increased productivity, resource efficiency, and waste reduction across various industrial operations. Therefore, the outcomes of sustainable manufacturing from Industry 4.0 depend on how manufacturers

understand this phenomenon, its underlying technologies, design principles, and sustainability functions. The significant synergy among Industry 4.0 technologies, design principles, and fundamental sustainability functions determines how chain-level digitalization contributes to sustainable development.

Industry 4.0 transforms the digitalization of industrial value creation processes, involving the implementation of modern digital technologies and the development of complex design principles. It is important to note that the digital transformation of Industry 4.0 is a gradual process that offers value partners new ways of value creation and transformation concerning the entire product and service life cycle. For this reason, Industry 4.0 presents significant opportunities for sustainable manufacturing, given that both are related to optimizing the entire product life cycle, value creation, and delivery channels. Sustainable manufacturing is multidimensional, encompassing sustainable development for the economy, environment, and society. It requires the participation of all stakeholders in the joint creation of sustainable value, and the integrated nature of Industry 4.0 enables value chain partners and even customers to converge towards sustainability. The findings suggest that integrating supply chain processes is a step towards sustainable manufacturing within the framework of Industry 4.0, emphasizing value chain thinking for sustainable development.

The social and environmental implications of Industry 4.0 should be viewed through the lens of productive-economic opportunities. Digital transformation suggests that without economic sustainability, manufacturers will lack the freedom to prioritize environmental conservation and social development since the survival of the company remains the only strategic priority. Not all the functions identified in this study are inherently sustainable. Each of the 15 functions has specific potential to empower or support particular aspects of sustainable manufacturing. For example, business model innovation is not inherently environmentally or socially compatible. Business model innovation can enhance environmental sustainability by enabling innovation in green products and processes, or it may contribute to social sustainability by facilitating product personalization and customer-centric strategies. A one-dimensional business model strategy may overemphasize production-economic efficiency and may also worsen the social and environmental sustainability impacts if poorly designed and managed. Therefore, the 15 functions of Industry 4.0 in sustainable manufacturing must be effectively managed based on the specific business environment of each manufacturer, thereby providing a balanced ecosystem of sustainable manufacturing among the triad (economic, social, and environmental).

The theoretical contributions to Industry 4.0 and sustainable manufacturing have been insignificant. Nevertheless, this field is in its embryonic stage, encouraging future research to address the impact of Industry 4.0 on sustainable development empirically. Furthermore, considering the complexity of Industry 4.0, future studies are invited to explore how the technologies of Industry 4.0, their integration quality, and synergy among them may impact sustainability outcomes.

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Identification of Information Technology Tools in Strategy Implementation: A QFD Approach

Samira Loghman[1*] | Hamidreza Yazdani[2] | Amin Hakim[3] | Asadollah Kordnaeij[4]

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Samira Loghman
Corresponding Author, Ph.D. in management (system), faculty of management and accounting, Tehran University, Qom, Iran.
E-mail: s.loghmanestarki@gmail.com

Hamidreza Yazdani
Associate professor, faculty of management and accounting, Tehran University, Qom, Iran.
E-mail: hryazdani@ut.ac.ir

Amin Hakim
Assistant professor, accounting and management, Farhangian University, Tehran, Iran.
E-mail: hakim@ut.ac.ir

Asadollah Kordnaeij
Professor, accounting and management, Tarbiat Modarres University, Tehran, Iran.
E-mail: naeij@modaress.ut.ac.ir

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ABSTRACT

One of the important challenges for organizations is that many strategic plans are not successfully implemented. Information technology (IT) tools can enable organizations to effectively implement their strategies by providing the necessary information infrastructure at various levels of the organization and among top and strategic managers. The main objective of this research is to identify the IT tools required to implement the strategies of Mellat Bank using the quality function deployment (QFD) approach. The research method in terms of outcome is categorized as developmental research, in terms of objective as applied research, and in terms of method as descriptive qualitative research. The statistical community in this study consists of experts and specialists from Mellat Bank Tehran. This research was conducted over one year, from 2019 to 2020. This research uses the method of extending the quality performance to translate strategies from high to low levels. In this study, the QFD method was used to translate strategies from high-level to low-level. To this end, QFD matrices were designed for each design subject, and the necessary IT tools for the expected functions were identified and scored using expert opinions. The findings show that for each strategy in an organization, we require specific information technology tools to execute the strategy within the organization properly. This study introduced the necessary tools for five strategic subjects, including integration and acceleration of design, production, and delivery of banking products and services, design and implementation of market penetration strategies, asset generation, improvement of credit processes, and financial and managerial independence of branches. Utilizing the identified IT tools will remove and reduce the barriers to implementing strategies and the strategic superiority of top-level and executive managers of organizations.

KEYWORDS

Information Technology Tools, Quality Function Deployment, Strategy Implementation.

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Introduction

Implementing strategy as a part of strategic management plays a significant role in achieving competitive advantage in organizations (Misankova & Kocisovaka, 2014). In the past two decades, strategy formulation was considered the main component of strategic management; however, recent research has shown that strategy implementation is more important than strategy formulation, and the key to the performance of top companies is the better implementation of strategy (Jooste & Fourie, 2009). Despite the significant importance of strategy implementation, more research research and investigation are needed on this subject (Vahidi et al., 2023). It is believed that formulating a business strategy is difficult while implementing the strategy throughout the organization is significantly more challenging than its formulation. Without effective implementation, no business strategy can succeed (Hrebiniak, 2013). In addition, implementing a strategy involves engaging more individuals than its formulation (Salami & Rahmanseresht, 2023). To implement strategies (mission and objectives) in the organization, these strategies must be transformed into processes (manifestation of strategies in processes). Then, the processes must be implemented through operational systems and executive activities (realization of objectives in process execution). Mechanized or manual systems can be utilized to execute processes, highlighting the necessity of utilizing information technology capabilities in strategy execution (Loghman Estarki et al., 2022). Information technology (IT) is considered a vital tool for implementing business strategies and a driver of strategy execution (Jorfi et al., 2017). The use of IT tools in implementing strategy can form the basis for creating a competitive advantage for organizations that have the skills and capabilities to use IT tools in managing the process of implementing strategy. The use of IT tools allows strategies to be properly implemented within the organization and for the obstacles in implementing the strategy to be removed or reduced (Laghman Estarki, 2020).

The research indicates that if an organization lacks sufficient organizational capability or IT capability, its strategy implementation will be subject to many external factors (Galbreath, 2003) .In other words, IT and its tools facilitate and organize data and information, disseminate and share information within the organization, increase the accuracy, speed, and accessibility of strategic information, accelerate the identification of issues, assist in strategic decision-making, enhance planning standards, reduce planning risks, and increase the speed and accuracy of planning, leading to facilitating and improving the implementation of strategy within the organization (Hakim, 2019).

The growth of IT and its penetration into the banking industry has led to significant changes. Thus, the survival of organizations is impossible without utilizing this technology. The emergence of concepts such as electronic banking and digital banking illustrates this fact. Statistical surveys indicate that various banks worldwide have embarked on the path of digitization and are formulating strategies in line with this goal, striving to integrate IT tools into all processes related to their programs. Mellat Bank, as one of the pioneers in Iran's banking industry, has recognized the impact of IT and its

capabilities as a facilitator and supporter of the banking industry. With a strategic outlook and significant investment in this area, Mellat Bank has created a suitable opportunity to move innovatively forward. In fact, in the strategic perspective of IT, Iran Mellat Bank has referred to this issue under the title of "Empowering Information Technology towards Achieving a Leading and Innovative Position to Ensure Stakeholder Satisfaction by Playing the Role of a Strategic Partner in Business".

Establishing the necessary information infrastructure in various organizational domains is considered as one of the most important concerns of the policymakers at Mellat Bank. We need effective and efficient use of IT tools to succeed in achieving our strategic goals. As a result, one of the challenges that this bank faces is the need for information in some cases, which will hinder the proper and economical management of the bank's strategic plans. IT tools provide the opportunity to facilitate the provision of appropriate services through information systems and the necessary technology infrastructure to implement strategies with proper data and information organization. Therefore, by providing the necessary information infrastructure through IT tools in various banking areas, strategy formulation will be carried out with greater accuracy, and the effectiveness of implementing and executing banking programs will be increased with greater precision.

Based on the above, the present research's subject is identifying IT Tools in Strategy Implementation, which will be addressed in the context of Mellat Bank of Iran. It should be noted that the reason for choosing Mellat Bank is that the bank under study is currently one of the largest banks in the country with a capital of over 500,000 billion rials, operating within the framework of the Islamic Republic of Iran. Furthermore, the bank's technology sector has made it the leading bank in IT and modern banking services. Accordingly, the present research aims to identify IT tools for implementing Mellat Bank's strategies using the QFD approach.

Literature Review

Meymandpour et al. (2008) in an article titled "The Impact and Applications of Information Technology in Strategic Management" have examined the comprehensive role of IT in strategic decision-making and information flow creation in all organizational processes, and its applications in strategic management. This article focuses on the profound influence of IT on improving the formulation and implementation of strategy.
Khedari (2017) conducted research entitled "The Impact of Information and Communication Technology on Improving Strategic Management in Executive Institutions of the Country". The results of his research showed that senior management support systems, management information systems, decision support systems, administrative activity automation systems, process workflow systems, and network systems improve the strategic management of executive institutions of Iran. Using IT and its capabilities in strategic management helps organizations to choose more reasonable ways or strategic options, formulate better strategies, and ultimately implement them

more efficiently. Using information and communication technology strategies for strategic management processes improves this process significantly. Razaei et al. (2018) in a study titled "The Role of Information Systems in the Effective Implementation of Strategies (Case Study: Bank Maskan Branches in Tehran)" investigated the role of information systems in the effective implementation of strategies. The research findings indicated that variables related to information systems and organizational factors are correlated and mutually influence each other. Furthermore, implementing information systems in organizations improves strategy execution. Maqdesi and Nahid (2021) demonstrated that internal environmental factors, including leadership, structure, human resources, financial information, and communication, as well as external environmental factors, including financial, informational, organizational culture, political/legal, and social/cultural factors, influence the successful implementation of strategy in Mellat Bank. Galbreath (2003) in a study entitled "A Review of the Role of Information Technology in Strategic Management," examined the significant role of IT in strategic management processes, including formulation and implementation processes, and the control of payments. Yeh et al. (2012) also investigated the impact of information system capabilities on i8mplementing IT strategies in e-businesses. This study categorized IT capabilities into the following three levels: individual, group, and organizational. At the individual level, this study examines the impact of information system leadership or IT leadership and the allocation of IT resources by senior IT managers on the quality of IT strategy implementation processes. At the group level, it examines the impact of collaboration capability and knowledge sharing in the organization on the quality of IT strategy implementation. At the organizational capability level, it investigates the influence of system development and project management capabilities on the quality of strategy execution processes. Gebczynska (2016), in a study titled "Investigating the Effectiveness of Strategy Implementation at the Process Level," examined the effectiveness of strategy implementation at the process level, which requires a process-oriented approach and process management system. In this study, the implementation of strategies and the tools used for executing strategies were compared, and the results revealed that organizations that use a process-oriented approach instead of a task-oriented approach and utilize process management systems in their strategy execution have performed more successfully than other companies. Jorfi et al. (2017), in a study titled "An Empirical Study of the Role of Information Technology Capabilities on Strategic Alignment of Information Technology Businesses," examined the role of IT capabilities in the strategic alignment of technology-based businesses. The results showed that IT capabilities have a positive and significant impact on the strategic alignment of technology-based businesses.

Strydom and Fourie (2018), in research titled "The Perceived Impact of Diversity Factors on Strategy Implementation in Higher Education Institutions," investigated the various reasons for diversity in strategy implementation in higher education institutions. Their research findings indicated that five factors influence strategy implementation and the diversity of strategy models in these institutions, one is human resource systems,

which includes the capabilities of IT. Loghman Estarki et al. (2022) conducted a study titled "Ranking Information Technology Capabilities in Strategy Implementation Using AHP Approach." The results showed that designing IT capability-based strategies is of utmost importance, followed by developing required IT capabilities ranking second. The analysis of the necessary financial model ranked third, and the definition of IT capabilities ranked fourth.

Methodology

The research method is categorized as developmental in terms of outcome, applied in terms of objective, and descriptive qualitative in terms of method. The statistical population in this study consists of experts and employees of Mellat Bank Tehran, especially the Organization and Planning Department, the Information Technology Department, and the Behsazan Mellat Holding (including Behsazan, Behpardakht, Yas Arghavani, Yas Industrial Engineering, and Shaghayegh companies). The experts involved in this research include 15 managers, deputies, and specialists from the Information Technology Department and the Organization and Institutions Department of Mellat Bank, and other knowledgeable experts in this field. In the present study, selected individuals possess advanced theoretical knowledge and expertise in strategic planning, including strategy formulation and implementation, as well as IT. They have been chosen from specific parts of the organization that are familiar with strategy execution and have participated in this process. Furthermore, most of the selected individuals in this study (12 out of 15 people) have more than ten years of experience and relevant education in management or IT. This research was conducted over one year from 2019 to 2020.

In this study, the method Quality Function Deployment (QFD) method has been used for the comparison, interpretation, translation, and integration of different criteria. QFD is used for different purposes, such as developing quality functions, applying qualitative performance, and determining qualitative functions. The translation of the term "Kanji" is used by the Japanese to express the concept of the generalization and expansion of quality. The function of QFD can be summarized in two sentences: translating and transforming customer needs into product technical specifications and determining quality activities appropriate to the product technical specifications. QFD adapts the Total Quality Management (TQM) philosophy and emphasizes customer-centric service/product design, continuous improvement, and individual participation. Its foundation lies in understanding customer needs for production and relating them to design characteristics through the quality house. This method identifies all customer requirements and needs and effectively transfer them to different parts of the organization. In this regard, QFD forms were designed for each design subjects, and the technical requirements or IT tools required for the operation of each expected functions were identified and scored using expert opinions.

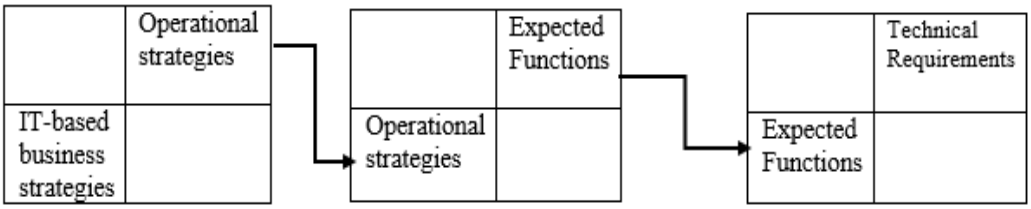
Generally, the role of QFD in strategic studies is to establish connections between strategic needs and operational decisions through the strategy house. In this study, an

attempt was made to utilize the QFD technique to align the implementation and execution of strategies. This approach enables the alignment of organizational macro strategies with operational and functional levels, facilitating the groundwork for implementing operational plans. The QFD tool can determine the technical requirements that need to be identified and implemented to achieve the expected functions of operational strategies. The implementation of each operational strategy signifies an effective step towards implementing IT-based business strategies, which have been designed and developed in this study. Identifying and implementing the functional requirements and movements in the path of expected functions of operational strategies is necessary for designing a macro-level strategy, and havinf some degree of certainty about its implementation.

Findings

The following proposed model was utilized to design a matrix for enhancing the quality of service in IT strategies at Mellat Bank. It cascades from high-level strategies to technical requirements (or IT tools required for each strategic subject).

Figure 1.
The Triple Stages of QFD for Moving from High-Level Strategies towards Technical Requirements (IT Tools Related to Each Strategic Subject)



(Source: Researcher's Findings)

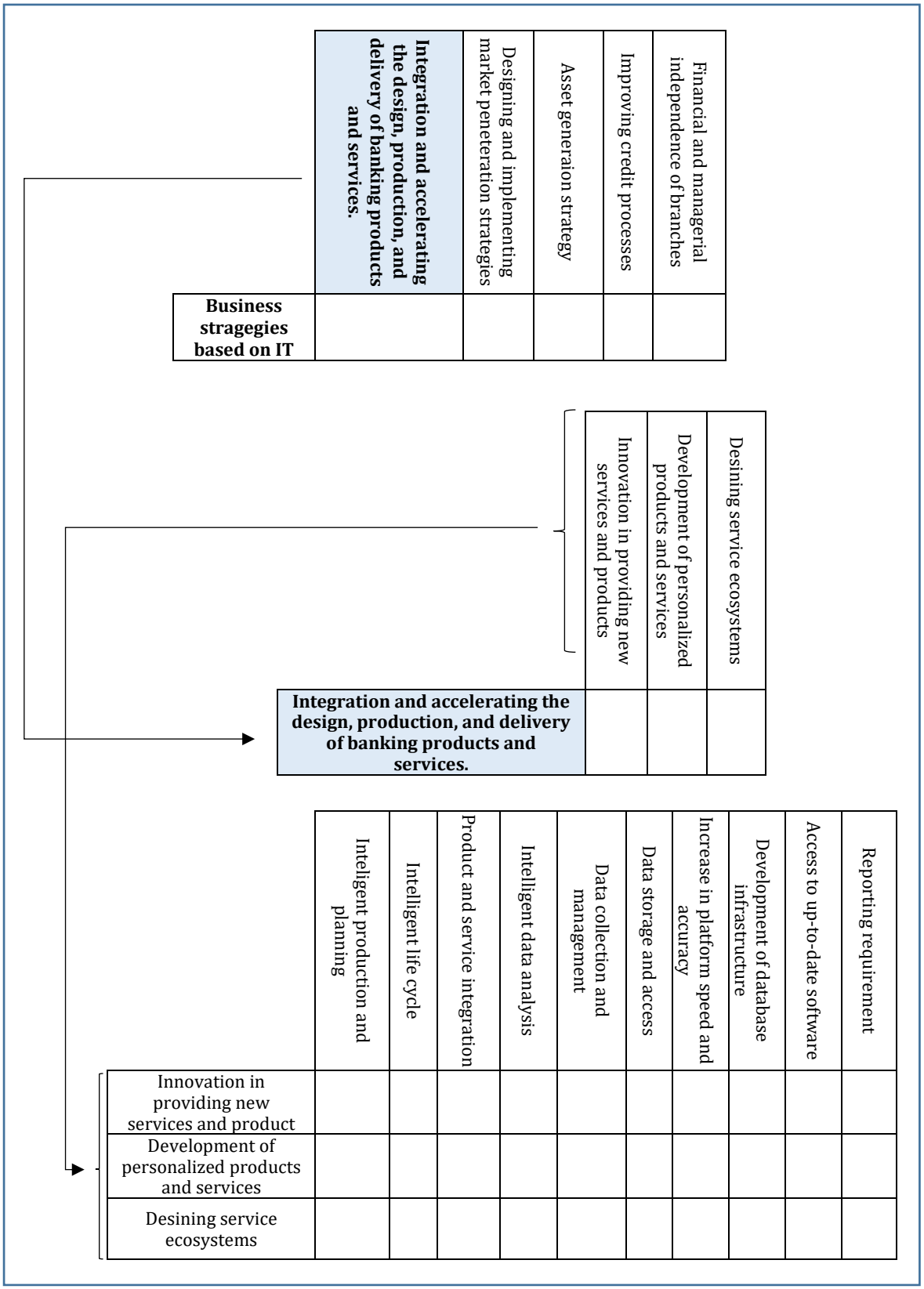
On this basis, in continuation, this process was carried out 5 times for each of the main designed subjects, including integration and acceleration of design, production and delivery of banking products and services, design and implementation of market penetration strategies, asset generation, improvement of credit processes, financial and managerial independence of branches and functions related to each of the main strategic subjects (Loghman Estarki et al., 2019). The first matrix is common in all subsequent stages, but the subsequent matrices change according to the strategies.

The Strategy Matrix First Subject: Integration of Accelerating the Design, Production, and Delivery of Banking Products and Services

In this section, the QFD matrix is designed as follows:

Figure 2.

The Strategy Matrix First Subject: Integration of Accelerating the Design, Production, and Delivery of Banking Products and Services



(Source: Researcher's Findings)

After determining the technical requirements for the integration and acceleration of the design, production, and delivery of banking products and services, the list of technical requirements was submitted for approval by experts. It was found that specific requirements are needed for each of the expected functions of the strategies. The requirements were obtained through the frequency count of experts' opinions. Experts were asked to indicate the technical requirements necessary to implementat and realize each expected function in each row. Experts filled in the matrices by marking the cells, and then the frequency of filled cells indicated the overall opinion of the experts in what order.

Given that the statistical population of the present study consists of 15 experts from Mellat Bank experts who were required to fill out the questionnaire for the technical requirements needed to operationalize the functions of IT-based strategies, the items that were approved by more than 50 percent of the experts, meaning more than 7 experts, were approved, and items approved by 7 or fewer experts were left blank.

Table 1.
Results of Expert Survey for Validating the Matrix of Expected Functional Requirements of the First Strategy

	Inteligent production and planning	Intelligent life cycle	Product and service integration.	Intelligent data analysis	Data collection and management	؟ Data storage and access	Increase in platform speed and accuracy	Development of database infrastructure	Access to up-to-date software	Reporting requirement
Innovation in providing new services and product	9	9	15	12	15	12	3	9	12	12
Development of personalized products and services	6	6	9	12	9	12	12	6	9	9
Desining service ecosystems	6	9	9	12	15	15	3	12	6	15

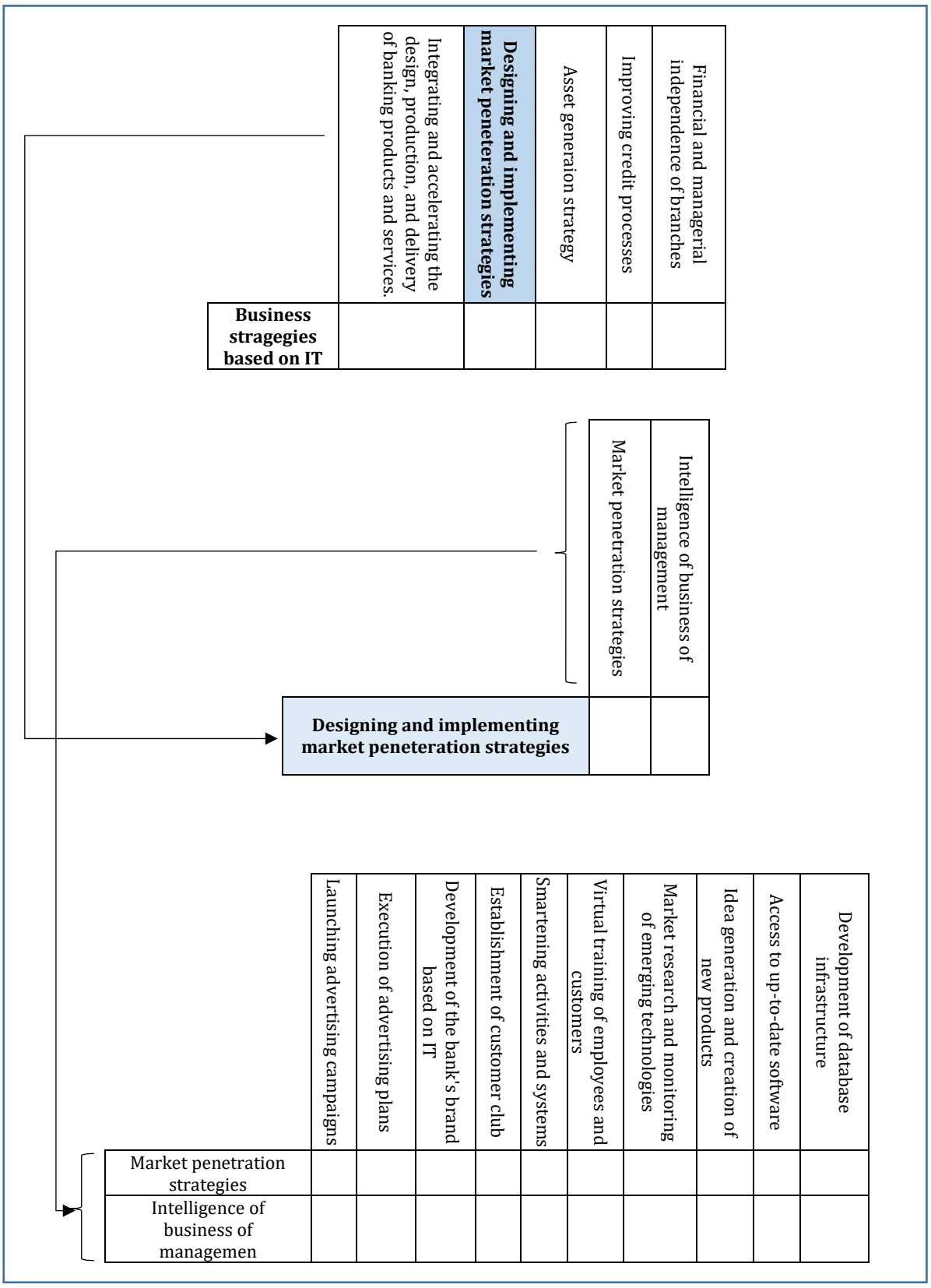
(Source: Researcher's Findings)

Based on the results obtained by experts, the technical requirements of the expected functions of integrating and accelerating the design, production, and delivery of banking products and services have been identified.

The Strategy Matrix Second Subject: Designing and Implementing Market Peneteration Strategies

In this section, the QFD matrix is designed as follows:

Figure 3.
The Strategy Matrix Second Subject: Designing and Implementing Market Peneteration Strategies



(Source: Researcher's Findings)

It was determined that identifying the technical requirements of the design strategy and implementing market penetration strategies are essential. Following the confirmation of the technical requirements list by experts, it was determined that for each of the expected functions of the strategies, specific requirements are necessary.

Table 2.
Survey Results of Experts to Confirm the Technical Requirements Matrix of the Expected Functions of the Second Strategy

	Launching advertising campaigns	Execution of advertising plans	Development of the bank's brand based on IT	Establishment of customer club	Smartening activities and systems	Virtual training of employees and customers	Market research and monitoring emerging technologies	Idea generation and creation of new products	Access to up-to-date software	Development of database infrastructure
Market penetration strategies	9	15	15	9	6	6	15	9	7	12
Intelligence of business of managemen	1	1	3	3	15	12	6	3	15	12

(Source: Researcher's Findings)

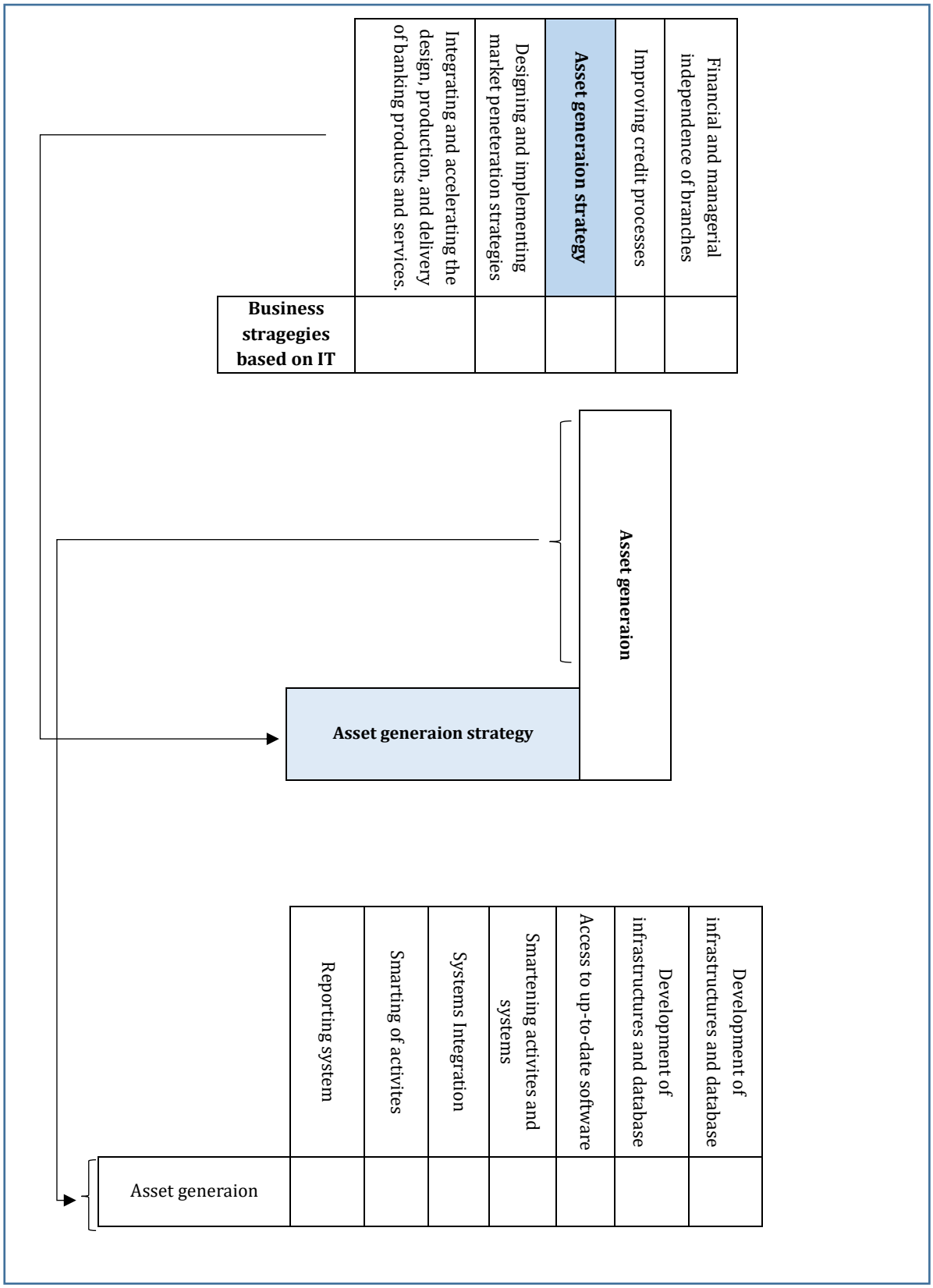
Based on the results obtained by the experts, they identified the technical requirements for designing and implementing market penetration strategies

The Strategy Matrix Third Subject: Asset Generaion Strategy

In this section, the QFD matrix is designed as follows:

After determining the technical requirements of the asset generation strategy, the list of technical requirements was approved by experts and it was found that for each of the expected functions of the strategies, what requirements are needed

Figure 4.
The Strategy Matrix Third Subject: Asset Generaion Strategy



(Source: Researcher's Findings)

After determining the technical requirements of the asset generation strategy, the list of technical requirements was submitted for expert approval, and the requirements needed for each of the expected functions of the strategies were determined.

Table 3.
Expert Survey Results for Confirming the Technical Requirements Matrix of the Expected Functions of the Third Strategy

	Reporting system	Smarting of activites	Systems Integration	Smartening activites and systems	Access to up-to-date software	Development of infrastructures and database	Development of infrastructures and database
Asset generaion	13	11	12	12	12	15	15

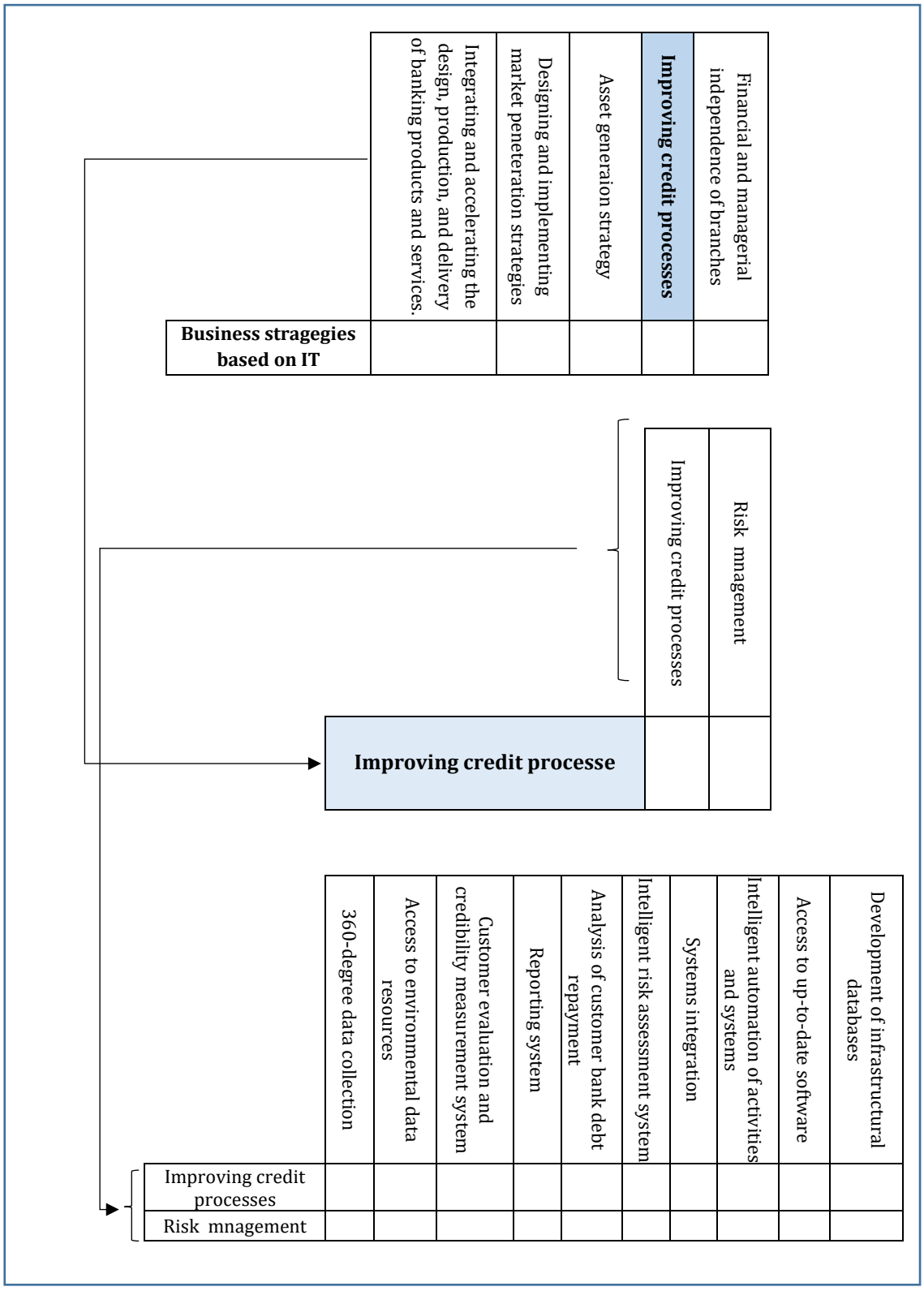
(Source: Researcher's Findings)

Based on obtained the results, the experts identified the technical requirements of the expected functions of asset generation strategy.

Matrix of Subject Matter 4: Improving Credit Processes

In this section, the QFD matrix is designed as follows:

Figure 5.
Matrix of Subject Matter 4: Improving Credit Processes



(Source: Researcher's Findings)

After the technical requirements of the credit process improvement strategy were identified, the list of technical requirements was approved by experts, and the requirements needed for each of the expected functions of the strategies were determined.

Table 4.
Expert Survey Confirmation for Approving the Technical Requirements Matrix of the Expected Functions of the Fourth Strategy

	360-degree data collection	Access to environmental data resources	Customer evaluation and credibility measurement	Reporting system	Analysis of customer bank debt repayment	Intelligent risk assessment system	Systems integration	Intelligent automation of activities and systems	Access to up-to-date software	Development of infrastructural databases
Improving credit processes	9	15	15	15	12	9	12	15	9	15
Risk mnagement	12	12	6	12	9	15	9	9	9	12

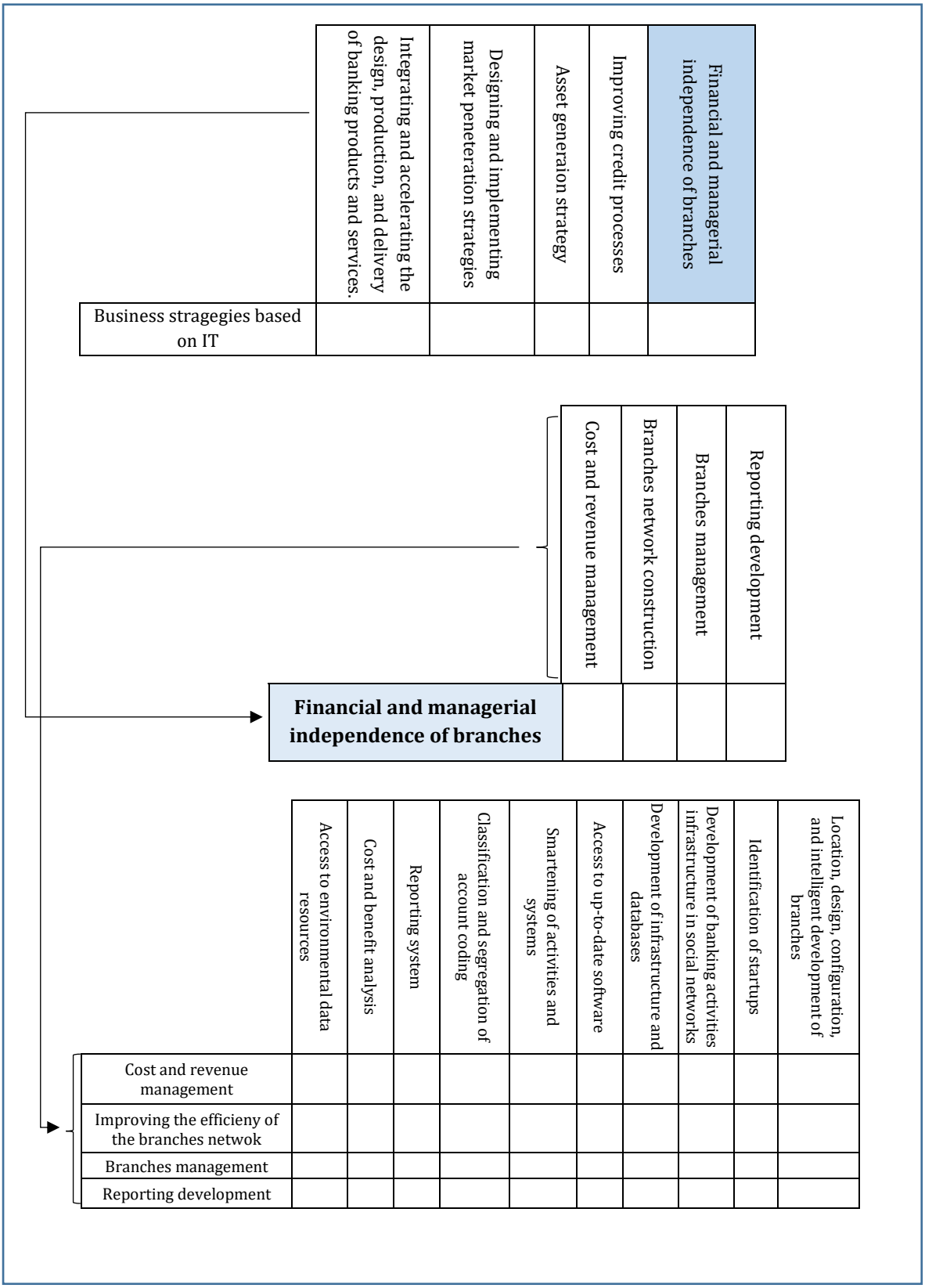
(Source: Researcher's Findings)

Based on the obtained results, the experts identified the technical requirements of the functions for improving the credit processes.

Matrix of Subject Matter 5: Financial and Managerial Independence of Branches

In this section, the QFD matrix is designed as follows:

Figure 6.
Matrix of Subject Matter 5: Financial and Managerial Independence of Branches



(Source: Researcher's Findings)

After determining the technical requirements of the financial and managerial independence strategy of the branches, the list of technical requirements was submitted to the experts for approval, the requirements needed for each of the expected functions of the strategies were determined.

Table 5.
Survey Results of Experts for Confirming the Matrix of Technical Requirements of the Fifth Expected Strategy Functions

	Access to environmental data resources	Cost and benefit analysis	Reporting system	Classification and segregation of account coding	Smartening of activities and systems	Access to up-to-date software	Development of infrastructure and databases	Development of banking activities infrastructure in	Identification of startups	Location, design, configuration, and intelligent development of branches.
Cost and revenue management	9	15	15	12	12	3	9	9	12	6
Improving the efficieny of the branches network	9	6	6	0	15	9	12	3	11	15
Branches management	12	15	9	3	6	6	9	6	6	9
Reporting development	9	0	15	6	3	12	15	3	6	1

(Source: Researcher's Findings)

Based on the results obtained by the experts, the technical requirements of the expected functions of the integrated strategy and acceleration in the design, production, and delivery of banking products and services have been identified.

Discussion and Conclusion

One of the critical challenges for organizations is that many strategic programs are not successfully implemented. By providing the necessary tools and information at various levels of the organization and among top and strategic managers, IT tools enable the organization to implement its strategies effectively. The main objective of this research is to identify the required IT tools for Mellat Bank to implement its strategy through the QFD approach. Based on the results obtained by experts, the technical requirements (IT tools) have been identified to integrate and accelerate the design, production, and delivery of banking products and services, design and implementation of market penetration strategies, asset generation, improvement of credit processes, financial and managerial independence of branches, process agility, diversification and expansion of revenue channels, human capital development, and international banking development.

Given the novelty of the research topic, no cases in the literature have been conducted

in full accordance with the current research to compare their results. In fact, since the results of the present research are obtained through interviews with experts and specialists of Mellat Bank, a precise comparison cannot be made with other studies. Still, in all of the above studies, the importance of IT in strategic management is acknowledged. Hence, in the following, the results of the present research are compared with other studies conducted on a topic close to the present research. In terms of findings, the present study is in line with Meymandpour et al. (2008), Khodari (2017), Rezaei et al. (2018), Galbreath (2003), Ye et al. (2012), Gebczynska (2016), Loghman Estarki et al., (2019), and Strydom and Fourie (2018). In terms of methodology, the present study aligns with Nahavandi (2014). The results of the research suggest that managers emphasize developing infrastructure for database systems to provide an appropriate platform for collecting and managing data from customers, competitors, and the environment. Accordingly, regarding geographical security and environmental factors, a suitable location is required for deploying databases. Additionally, Mellat Bank should procure the necessary hardware and software equipment since it does not have the required technology for constructing them. It should also develop its advertising campaigns and creatively utilize opportunities in social networks. It should expand its purposeful advertising programs and focus its efforts on promoting the role of IT in advancing the strategic goals of Mellat Bank. It is recommended that managers consult with experts in the fields of neural networks, AI, and cognitive sciences from various universities and knowledge-based companies to intelligently automate the activities and processes of Mellat Bank based on the latest findings in computer and cognitive sciences. To improve credit processes and management, it is suggested that Mellat Bank collect necessary environmental data about all essential customer dimensions that can lead to customer credit validation by signing mutual collaboration documents.

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