DOI: 10.71762/0090-5298

Research Paper

Developing a Model for the Adoption of the Internet of Things (IoT) in the Supply Chain: A Case Study of the Iranian Automotive Industry

Ali Jantrani[1], Masoud Barati[2*], Arash Shahin[3], Mohammad Talari[4]

[1]Department of Management, Na.C., Islamic Azad University, Najafabad, Iran

[2]Department of Management, Na.C., Islamic Azad University, Najafabad, Iran

[3]Department of Management, Faculty of Administrative Sciences and Economics, University of Isfahan, Iran

[4]Business Department, Hazrat-e Masoumeh University, Qom, Iran

[*]Email of the Corresponding Author: barati_masoud@iau.ac.ir

Received: February 11, 2025; Accepted: April 29, 2025

Abstract

This study aims to develop a comprehensive model for the adoption of the Internet of Things (IoT) in the supply chain of Iran's automotive industry. Employing a grounded theory approach, qualitative research was conducted through specialized interviews with industry professionals and academic experts in 2021. Data analysis was carried out based on the Strauss and Corbin paradigm model. The findings revealed multiple factors influencing the adoption of IoT, categorized into causal, contextual, and intervening conditions. Key causal factors included organizational, social (environmental), managerial, industrial, and economic (financial) dimensions. Contextual conditions highlighted the maturity of supply chain partners, technological readiness, and supply chain capabilities. Intervening conditions were identified as cultural, security, technical, and financial challenges. The core implementation strategies involved establishing technological infrastructure, fostering an organizational culture, engaging in strategic planning, and promoting institutional specialization. Central themes such as transparency, participation, and technological innovation emerged as critical to the research findings. IoT applications were found to have significant implications across organizational, financial, social, and systemic dimensions. Ultimately, the results underscore the imperative for the automotive industry to embrace the Fourth Industrial Revolution and leverage IoT to enhance productivity and align with global production standards.

Keywords

Internet of Things (IoT), Industrial Internet of Things, Automotive Industry, Supply Chain, Supply Chain Based on Industrial Internet of Things

1. Introduction

The rapid advancement of digital technologies is reshaping the competitive landscape, offering firms substantial benefits through innovations designed to enhance operations, performance, and overall efficiency [1]. Emerging technologies such as the Internet of Things (IoT), artificial intelligence (AI), and virtual reality, which form the backbone of Industry 4.0, are exerting a transformative influence

on the manufacturing and service sectors [2]. IoT, often referred to as the cornerstone of the industrial revolution, connects everyday objects, transforming them into intelligent tools that enable smarter processes. However, the pace of human understanding has not kept up with these advancements, leading to challenges in areas such as security, privacy, and trust [3]. Researchers have approached IoT from three key perspectives: scientific theory, engineering design, and user experience [4].
Concurrently, supply chain management (SCM) has emerged as a vital factor in global markets, with IoT revolutionizing SCM by enabling organizations to monitor, analyze, and optimize their operations in real-time [5]. Today, companies no longer operate as isolated entities; instead, they function within interconnected supply chain networks. This interconnectedness has driven industries to adopt automation and IoT-based solutions to maintain their competitive edge [6]. SCM integrates manufacturing and service providers into unified systems aimed at improving efficiency, reducing waste, cutting costs, and accelerating delivery times. IoT plays an essential role in achieving these goals by enabling real-time tracking of supply chain components and enhancing inventory management, critical for sectors like automotive, where high production volumes demand precision [7].
Despite global strides in Industry 4.0 technologies, such as Tesla's driverless vehicles, the Iranian automotive industry lags considerably behind international standards, struggling even with basic digitization. While global industries advance toward the Fourth Industrial Revolution, Iran's automotive sector remains in the second generation of industrial development. This disparity underscores the urgent need to adopt IoT to improve supply chain integration and productivity.
This study seeks to propose a model for IoT adoption within the Iranian automotive industry's supply chain, recognizing IoT as an essential tool for bridging the gap and facilitating entry into the Fourth Industrial Revolution. Existing frameworks for IoT integration are often unsuitable for Iran and other developing countries, making it necessary to analyze why IoT implementation has been limited before creating a tailored acceptance model. Addressing this gap will enable organizations to achieve higher levels of integration, enhance production efficiency, and improve their competitiveness in global markets. Therefore, the study aims to answer the research question: How can an effective model for IoT adoption in the Iranian automotive industry supply chain be developed? Additionally, this paper focuses on identifying and establishing a suitable model for IoT adoption in this sector.

2. Literature review and research background

The term "Internet of Things" (IoT) was first introduced by Kevin Ashton in 1999 to describe a world where all entities—including humans, animals, plants, and even inanimate objects like cars—can have a digital identity, enabling computers to organize and manage them. While the current Internet connects individuals worldwide, the Internet of Things connects objects, allowing them to be controlled and managed through applications on smartphones and tablets [8]. From a technological perspective, IoT enables the interconnection of objects capable of sensing, processing, and communicating with one another [9]. Zhou et al. (2015) were among the first to explore IoT as part of organizational infrastructure. They demonstrated that IoT simplifies processes, reduces costs and risks, and consequently improves system performance [17].
To better understand IoT adoption, frameworks such as the Technology Acceptance Model (TAM) have been widely utilized. TAM emphasizes how perceived ease of use and perceived

usefulness influence IoT adoption. Similarly, the Diffusion of Innovations (DOI) theory sheds light on how IoT technologies spread across industrial and consumer domains based on factors such as observability, trialability, and compatibility. Such frameworks provide essential insights into the structural elements that drive IoT adoption [18-19].

One particular segment of IoT is the Industrial Internet of Things (IIoT), which emphasizes industrial applications and machine-to-machine communications. The Industrial Internet of Things facilitates automation, enhances the understanding of production processes, and supports efficient and environmentally sustainable manufacturing [10]. Manufacturers, tool companies, agricultural producers, and healthcare providers use IIoT to boost productivity and efficiency through intelligent and remote management systems [11]. For instance, Pal and Yasar (2020) highlighted the integration of IoT and blockchain technology to overcome the limitations of siloed IoT architectures in supply chains. This integration ensures better handling of distributed data across multi-party networks, particularly in industries like the apparel sector [19]. Furthermore, research conducted by He et al. (2020) shows how IoT, big data analytics, and smart connected products improve various supply chain aspects, including consumer behavior analysis, resource allocation, and network governance [20].

2.1 Supply Chain Challenges and IoT Solutions

The supply chain, as defined by the Supply Chain Council (2012), entails the processes and entities—such as suppliers, customers, manufacturers, distributors, and retailers—required to fulfill customer orders. Key supply chain processes include planning, sourcing, making, delivering, returning, and enabling, as outlined in the Supply Chain Operations Reference (SCOR) model [12, 13].

However, supply chain operations face numerous challenges, especially in highly competitive and globalized markets. These challenges include:

- Difficulties for small and medium-sized enterprises (SMEs) in competing with global businesses due to limited resources.
- Inaccurate demand forecasting, long production lead times, and inefficiencies in introducing new products to markets.
- Limited use of advanced technologies for optimizing resources and reducing energy consumption.
- Complexities in waste management and minimizing losses of temperature-sensitive products.
- Lack of transparency in supply chain processes is leading to coordination and communication gaps.
- Rising customer expectations coupled with logistics complications, especially for multinational corporations.
- Risks from unexpected crises, such as natural disasters, strikes, or political instability.
- Human resource challenges include retaining skilled personnel and efficient workforce management.

IoT offers practical solutions to these challenges:

- Real-time tracking: IoT-enabled devices provide real-time monitoring of goods in transit, optimizing routes and delivery timelines to minimize delays.

- Improved quality control: IoT sensors, such as temperature or humidity sensors, reduce spoilage and waste in perishable products by continuously monitoring environmental conditions.
- Enhanced transparency: IoT ensures real-time visibility of supply chain operations, facilitating better coordination across stakeholders and quicker decision-making.
- Predictive maintenance: IoT, paired with big data analytics, helps identify maintenance needs before equipment failures occur, thereby reducing downtime and costs.

For example, Vass et al. [22] investigated IoT adoption in Industry 4.0 settings and demonstrated significant improvements in product movement, communication, and overall business intelligence. They also noted the challenges stemming from high costs and resistance from stakeholders. Moreover, studies such as Delic and Eyers [21] examined how additive manufacturing, combined with IoT technologies, enhanced supply chain flexibility in the automotive sector in Europe, proving that such innovations are essential for increased adaptability and market competitiveness.

2.2 Gaps in the Literature

The literature shows growing interest in IoT adoption across various industries, with three primary focus areas:

1. Identifying adoption challenges,
2. Exploring applications in supply chains, and
3. Proposing IoT implementation models.

However, substantial progress is still needed in understanding the specific factors affecting IoT adoption in certain industries. While prior research, such as that by Rezaei Pandari and Azar (2018), focused on conceptual models for the insurance sector [18], and studies by Delic and Eyers (2020) examined IoT adoption in manufacturing, limited attention has been paid to its applications in the automotive sector, particularly in the context of emerging economies like Iran.

This study seeks to fill this gap by analyzing the challenges and barriers to industrial IoT adoption, emphasizing its potential applications in automotive supply chains, and proposing a comprehensive implementation model tailored to both global trends and local contexts.

3. Materials and methods

This study was conducted using a qualitative approach and grounded theory methodology, which is ideal for developing theories directly from collected data. Grounded theory is a qualitative research method that generates theories by analyzing data, with the fundamental premise that theory emerges from participant experiences rather than pre-existing models [27]. Given the identified shortcomings of existing IoT adoption frameworks in the supply chain, particularly in developing countries, a qualitative approach was deemed appropriate. Since grounded theory is well-suited to answering “how” and “why” research questions [28], this approach enabled an in-depth exploration of the research problem.

The grounded theory method focuses on uncovering behavioral patterns rooted in real-world experiences, offering valuable insights for future practices and research. However, challenges such as the complex presentation of some theories in the literature and varying interpretations of grounded theory methods must be addressed [29]. According to Strauss and Corbin (1990), grounded theory

"provides explanations for actions," making it an effective tool for exploring phenomena in complex environments [30-31].
Data were collected through semi-structured interviews based on six carefully designed questions:

- Why do you believe the Internet of Things should be implemented in the automotive supply chain? (What are its benefits and functionalities?)
- What prerequisites and infrastructures are required to implement IoT in the automotive supply chain?
- What are the obstacles to IoT implementation, and why has it not yet been adopted?
- What steps or phases do you recommend for implementation?
- In your view, what results, benefits, and consequences will follow the implementation of IoT in the automotive supply chain?
- Is there anything else you would like to add regarding IoT implementation challenges or its benefits?

These questions were developed through a comprehensive literature review and validated by subject-matter experts. Interviews were conducted with 12 participants, including experts and professionals familiar with IoT and supply chain management in the Iranian automotive sector. Interviews were either conducted face-to-face or via telephone, depending on participant availability.

The data were analyzed through the grounded theory coding process, including open, axial, and selective coding. In the open coding phase, concepts were identified by breaking the data into smaller units, examining their properties, and organizing them into themes. This process enabled the systematic discovery of concepts and their characteristics. In the axial coding phase, relationships between categories and subcategories were explored, reconstructing data around central concepts to create structure and demonstrate connections within the dataset. Finally, the selective coding phase focused on integrating the main categories around a central phenomenon, while further refining other categories as subcategories. This stage culminated in developing a coherent theory.
The systematic grounded theory approach proposed by Strauss and Corbin (1998) was followed to organize raw data into categories and concepts, resulting in the creation of an axial coding model [32].
The present research was conducted via the following steps in Figure 1.

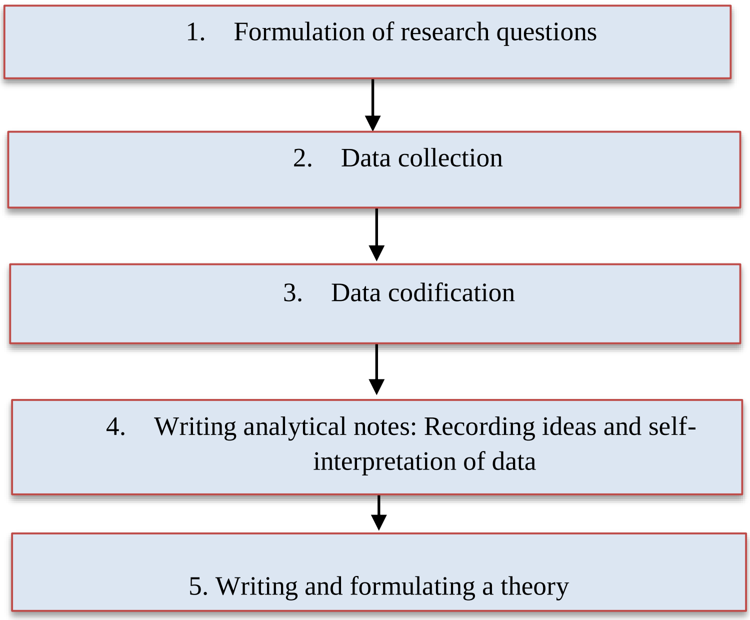

Figure 1. The Research flowchart

The research stages are as follows:

1. The research problem was translated into explicit, investigable questions to provide clear directions for data collection and analysis.
2. Data were gathered from interviews, field notes, or documents, ensuring an unbiased approach suitable for qualitative analysis.
3. The coding process involved three main steps: open coding (identification and labeling of concepts), axial coding (establishing relationships among concepts), and selective coding (final integration of categories into a central phenomenon).
4. Throughout the analysis, insights and interpretations derived from the data were recorded in analytical memos, contributing to the development of a coherent theory.
5. Finally, a data-driven theory was formulated to highlight the relationships among categories and address the research phenomenon.

In qualitative research, achieving perfect validity is theoretically impossible. However, reliability was ensured by consistently applying observation methods that yielded similar results over time. This research gathered data from 12 participants (9 males and 3 females). Among them, 8 held Ph.D. degrees, 3 had master's degrees, and 1 held a bachelor's degree. As detailed in the table below:

Table 1. The participants' demographic data

Row	Education	Expertise	Age	Work experience	Organizational position
1	Ph.D.	Strategic studies	38	14	Director of the Center for Strategic Studies
2	Ph.D.	Information technology	42	17	IT Manager
3	Ph.D.	Strategy researcher	36	12	University professor
4	Ph.D.	Strategic studies	47	20	Director of Strategic Studies
5	Ph.D.	Information technology	32	6	IT Manager
6	Ph.D.	Supply chain researcher	35	11	University professor
7	Ph.D.	Supply chain researcher	40	12	University professor
8	Ph.D.	Information technology	34	7	Deputy of the IT Division
9	Master's degree	Productivity management	37	10	R&D Assistant Manager
10	Master's degree	Production and manufacturing management	45	15	Production manager
11	Master's degree	Artificial intelligence	36	12	Head of IT Division
12	Bachelor's degree	Industrial management	47	22	Warehouse manager

Theoretical saturation was achieved by the ninth interview when no new codes or categories emerged from the data. Nonetheless, three additional interviews were conducted to confirm data adequacy and ensure comprehensive coverage. All interviews were transcribed verbatim and analyzed step-by-step, with key themes and categories extracted immediately after each interview.

This study utilized iterative data collection and analysis to generate grounded concepts and categories. The open coding phase focused on identifying meaningful units, axial coding synthesized relationships among categories, and selective coding finalized the theoretical framework. The qualitative nature of this research allowed for a deep exploration of IoT adoption factors in the Iranian automotive industry's supply chain, addressing research gaps and contributing valuable insights for future development.

4. Results and discussion

4.1 Step 1: Open coding

Open coding is performed in 3 steps. The first step is to encode the significant statements (from the text). In the second step, the open codes were merged in a different form but with the same meaning. Thus, the themes emerge. The third step involves the construction of categories [32]. Given the long text of the interviews, Table 2 presents examples of texts and initial codes extracted from the interviews:

Table 2. Examples of conceptualization of the verbal evidence

Verbal evidence	Open coding
One of the main problems of car manufacturers is spending a lot of money due to the storage of goods, and car companies are always trying to reduce the amount of storage of goods by creating a JIT system.	Economic/Financial
Coordinating the Iranian automotive industry supply chain is difficult due to its diversity and scope. Using the IoT can facilitate this coordination. Timely supply planning can help to reach the maximum projected production level.	Organization
The substantial debts of Iranian automotive manufacturing companies to parts manufacturers have led the companies to supply parts from several sources, reducing the possibility of full cooperation of Iranian automotive manufacturing companies with part manufacturers.	Financial conditions
The Iranian automotive industry also has an extensive supply chain that requires chain integration and management. Given that a car has a lot of parts, it will be very difficult to create a supply chain management with the least cost and without using information technology.	Systemic outcomes
A thing to note is that we have many shortcomings in the part manufacturing sector, and thus we failed to reach an appropriate production capacity. In this case, IoT cannot help.	Organizational conditions
We have good information about the product, market, and customer relationship, but there is little information available about IoT.	Culture building
Some businesses may focus on IoT, and some earn revenues from it, but their main focus is on reducing costs.	IoT capabilities

The results of the second step of open coding, including the secondary codes and the extracted categories, are shown in Table 3. This shows the concepts extracted from the secondary code and the categories extracted from the concepts. A total of 23 components and 110 indicators were identified in this study, as discussed below.

4.2 Causal conditions

The causal conditions identified in this study were organizational, social (environmental), managerial, industrial, and economic (financial) components, as shown in Table 3.

Table 3. Classification of the causal conditions

Category	Indicators	Components
Causal conditions	Corporate ownership (private, public), corporate policy, clear goals and strategies, organizational knowledge, and business model compatibility	Organizational
	Customer/community (stakeholders) expectations, customer/community (stakeholders) requirements, collaboration networks, fear of losing customers	Social/Environmenta l
	Managers’ beliefs, support of senior managers, systems thinking, and creative thinking	Managerial
	The industry’s willingness to adopt IoT, understanding the effectiveness of IoT in the industry, the level of industry familiarity, and the readiness of the industrial infrastructure	Industrial
	Economic savings, reduced operating costs, reduced investment costs, and financial transparency	Economic/Financial

In the Iranian automotive industry, organizational conditions such as organizational knowledge for IoT adoption, clear corporate goals and strategies, corporate policy, and most importantly the corporate company ownership (public, private) need to be specified to decide on whether to adopt or implement social (environmental) issues that are important to supply chain companies in the Iranian automotive industry are stakeholder expectations, collaboration networks, requirements that stakeholders bring with them, and companies' fear of losing customers at a given point in time. To adopt and implement the IoT project in this industry, there are a series of management requirements, including managers' beliefs and the full support of senior managers to implement the IoT project. Thus, systematic and creative thinking is needed by senior managers. Perhaps the most important requirement for the adoption of this technology is the familiarity of the industry with IoT and its readiness to adopt and apply it. Furthermore, understanding the effectiveness of using this system and infrastructural readiness is important. Thus, some measures must be taken so that all companies and supply chain organizations in the Iranian automotive industry come up with an understanding of using IoT, as this system leads to economic savings, cost reduction, and transparency of the financial and information system.

4.3 Underlying conditions

The underlying conditions identified in this study include the maturity components of SC partners, technology infrastructure, and SC capabilities as displayed in Table 4:

Table 4. Classification of the underlying conditions

Category	Indicators	Components
Underlying conditions	SC partners’ capabilities, motivation, participation, trust, and culture	SC partners’ maturity
	Hardware, software, network security, technical support, and executive standards	Technological infrastructure
	SC flexibility, SC transparency, continuous SC improvement, lean and optimal operation, and SC and IoT integration	SC capabilities

One of the most important contextual factors is the maturity of the SC partners, who must have the capability and motivation to adopt the IoT technology. They also need to reach a level of organizational maturity that is capable of collaborative work and culture building. The most important thing is the trust between SC partners in the automotive industry. Another component of the underlying conditions is the existence of the infrastructure to adopt the IoT technology. Thus, the adoption and implementation of IoT require access to the necessary hardware and software. Moreover, facilities for network security and sufficient technical support must be available to implement IoT under global executive standards. SC capabilities are also one of the important aspects of underlying conditions. Accordingly, the supply chain of the automotive industry should be flexible and all its stages should be as transparent as possible. Supply chain management needs to be continuously improved so that this system is always lean and optimal.

4.4 Intervening conditions

The intervening conditions extracted in this study include cultural, security, technical, and financial factors as detailed in Table 5.

Table 5. Classification of the intervening conditions

Category	Indicators	Components
Intervening conditions	Resistance to change (acceptance of change), unwillingness to share information, lack of cooperation (partnership) between SC partners, level of transparency and IoT function, and perceived advantages of IoT	Cultural
	Cyber-attacks, lack of legal regulations, concerns about information disclosure and privacy of partners, data confidentiality, and lack of transparency	Security
	Lack of sufficient knowledge among all partners, access to modern technology, sanctions, technical support challenges, basic architecture, and complexity, weak internet infrastructure, and compatibility with existing processes	Technical
	Financial imbalance among partners, high start-up costs, cost-sharing between SC partners, technology acquisition costs, and cost of continuous system upgrades	Financial

In any business or organization, there is always a phenomenon called resistance to change (due to the members getting used to the current situation of the organization). Thus, some measures should be taken to institutionalize the culture of change among the members of the organization. Reluctance to share data and information is also common in organizations due to the lack of trust in other organizations. This issue should be managed as the basic requirement for implementing IoT technology is access to and sharing of information and cooperation between supply chain stakeholders. Thus, some arrangements need to be made, or pre-implementation meetings should be held to explain the transparency and functioning of the IoT to stakeholders in the supply chain and to understand its benefits. There are always some security concerns about information confidentiality and disclosure. Supply chain partners have privacy, and there are no rules or regulations on these issues, as well as cyber-attacks. Furthermore, the main technical problem is a lack of knowledge and equal access to technology among the partners due to the international sanctions against Iran. There are also some challenges, such as the IoT's complex architecture and initial design, and the incompatibility with the technology currently used, on the one hand, and the weakness of the Internet infrastructure as one of the important infrastructure issues, on the other hand. The financial component, as one of the intervening factors, concerns the financial imbalance between the partners, the high costs of using the IoT technology, the costs of acquiring this technology, and the need to continuously upgrade IoT systems and share the costs among the supply chain partners (that often face some difficulties).

4.5 Strategic conditions

The strategies highlighted in the present study include strategies for prearrangements, culture building, organization, and institutionalization, as shown in Table 6:

Table 6. Classification of the strategic conditions

Category	Indicators	Components
Strategic conditions	Selecting a safe and effective system, SC reconfiguration, domain selection, project execution, fast-tracking of errors and problems	Prearrangements
	Partner training, partner motivation, coordination, and integration meetings, sharing IoT knowledge among partners, and building trust among partners	Culture building
	Change management, management of expectations, establishing cooperation and communication within and between organizations, defining tasks and responsibilities, allocating key resources for implementation	Organization
	Standardization of processes, formulation of relevant laws, the definition of the role of partners, and formation of alliances with partners	Institutionalization

Prearrangements represent one of the strategic requirements for the acceptance and implementation of IoT, which include selecting a reliable and effective system, reconfiguring the supply chain to improve performance, and selecting the correct scope of project implementation for faster operation and fast-tracking of errors and problems and their correction. SC partners need to be trained about the use of IoT and its benefits and advantages to get motivated more. Holding coordination meetings, sharing IoT knowledge, and building trust among partners are important indicators of culture building. After creating culture, it is time to organize the change management that is culture-built among the partners and to manage the expectations until the desired outcome is achieved, so that the partners in the supply chain accompany the project. Other indicators of organization include determining the functions and responsibilities of each individual, partner, and stakeholder, the efficient allocation of key resources needed for implementing the project, and ultimately establishing intra-organizational cooperation. Institutionalization means deepening and consolidating beliefs. To this end, measures should be taken, such as standardizing supply chain processes, formulating laws related to the implementation of technology, defining the role of each partner, and forming an alliance with partners.

4.6 Axial category

The axial conditions identified in this study include components such as transparency, participation, and information technology, as described in Table 7.

Table 7. Classification of the axial conditions

Category	Indicators	Components
Axial category	Stakeholder access to information, access to most information, supply chain transparency, financial and information transparency, and management system transparency	Transparency
	Receiving ideas from internal and external stakeholders, diversity and rotation in information and ideas, cooperation and partnership as the priority of SC partners, exchange of information between all stakeholders, participation, and comprehensive support of managers of organizations	Participation
	Use of up-to-date technologies and systems, necessary support for the use of technology, creation of necessary security against cyber-attacks, use of up-to-date IoT implementation standards, creation and development of legal rules and regulations	Information technology

Transparency is one of the most important components of IoT adoption in the Iranian automotive industry. Transparency indicators include stakeholder access to information and data needed for better decision-making, financial and information transparency in all areas, and transparency of the management system in decisions. The second component is participation. Businesses and organizations in the automotive industry that are partners with domestic and foreign organizations (stakeholders) must regularly receive and refine their ideas and ultimately use them to improve the supply chain management process. This partnership and exchange of information should be institutionalized among all stakeholders in the supply chain as a priority. Information technology is another important feature of the central category that should always be considered by managers in this industry. Given the novelty of the IIoT technology, we need up-to-date systems, and these systems need to receive the necessary support. On the other hand, due to the vitality and sensitivity of IIoT systems, a secure and impenetrable system must be installed and considered for them so that they are not exposed to cyber-attacks and thus prevent system disruptions and heavy costs. Thus, to overcome these problems, state-of-the-art standards in the field of IoT should be used, and laws and regulations should be formulated for security issues inside the country. Accordingly, managers should take into account the axial category or conditions in the adoption of IoT in the automotive industry.

4.7 Outcomes

Outcomes represent the outputs resulting from the application of strategies. Following the results of the study, the outcomes were classified into several categories, including organizational, financial, community, and systemic outcomes, as described in Table 8:

Table 8. The organizational, financial, community, and systemic outcomes

Category	Indicators	Components
Outcomes	Synergistic communication among SC partners, increased customer satisfaction, SCM process integration, customer service optimization, intelligent control	Organizational outcomes
	Increasing SC efficiency, reducing SC partners' costs, financial transparency, creating higher added value	Financial outcomes
	Creating a smart supply chain, dynamic SC process virtualization, improved product traceability, enhanced SC information quality, convenient, fast, and secure data mining, improved inventory management, and intelligent and integrated logistics.	Systemic outcomes
	Environmental protection (adaptation), disaster management and reduction, easy and smart communication with the customer, development of e-businesses, elimination of distances	Community outcomes

The adoption and implementation of IoT technology in the Iranian automotive industry can have important outcomes. Organizational outcomes include synergistic communication among partners, optimization of customer service, greater customer satisfaction with services, integration of supply chain management processes, and more and more accurate control of all supply, production, and distribution processes. The financial outcomes, as the second component, include reducing the costs of partners, creating more added value, and ultimately increasing efficiency. Financial transparency also leads to greater trust among partners. The third component is systemic outcomes with indicators such as creating a smart supply chain, dynamic SC process virtualization, improved product traceability, enhanced SC information quality, convenient, fast, and secure data mining, improved inventory management, and intelligent and integrated logistics. The last component covers community outcomes. Acceptance and implementation of the IoT technology have implications and consequences for society, including environmental protection (adaptation), disaster management and reduction, easy and smart communication with customers, development of e-businesses, and elimination of distances across the supply chain.

4.8 Selective coding

The last coding step, in the grounded theory method, is called selective coding. It involves selecting the core category, systematically linking that core category to other categories, validating the relationships among the categories, and modifying the categories that need further change and development. Reviewing the literature, surveying the experts, and using the data collected through the grounded theory method, a model was developed in this study for the adoption of the Internet of Things (IoT) in the supply chain, as shown in Figure 2:

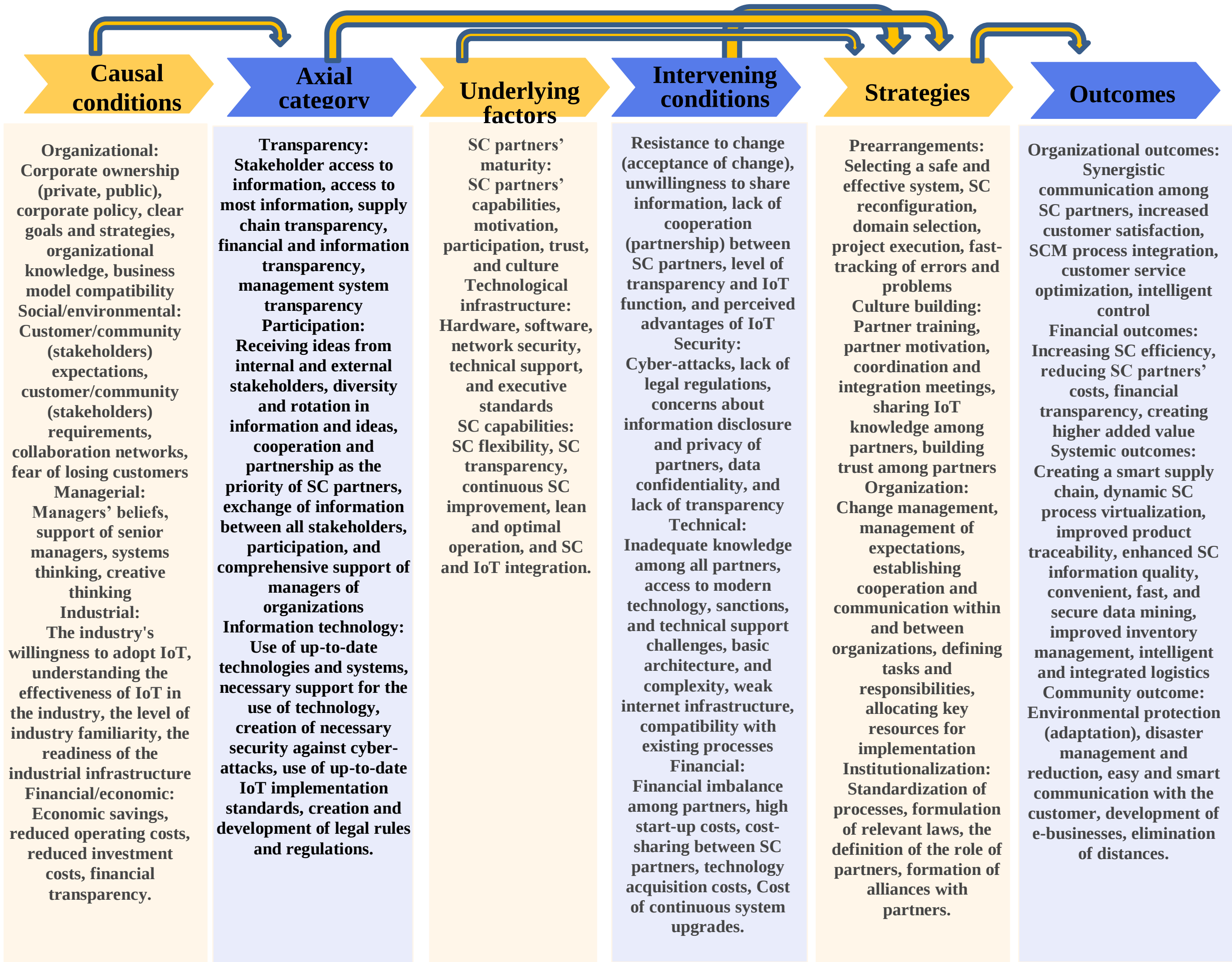

Figure 2. The paradigm model of the study was developed through axial coding for the Iranian automotive industry

The above process model provides a comprehensive picture of the application of the Internet of Things in the automotive industry in a developing country. Causal conditions (organizational, environmental, managerial, industrial, and economic) show the level of readiness to accept the Internet of Things in the automotive supply chain. Intervenors of IoT adoption in the automotive supply chain (financial, technical, security, and cultural) also represent the major obstacles. In this regard, the background factors (maturity of partners, technological infrastructure, and SC capabilities) as platforms for the adoption of the Internet of Things deal with integration between partners from a technical and cultural point of view. The results indicate that the transparency, partnership, and integrated technology of partners are key to the adoption of IoT in the supply chain. The use of the Internet of Things in supply chains enables connection, monitoring, and interaction within a company and between the company and its supply chain partners, thus enabling agility, tracking, and sharing of information throughout the supply chain. Therefore, the integration of the partners of the chain is very important in terms of infrastructure, technology, and culture, and the strategies for adopting the Internet of Things in the supply chain (institutionalization, foundation, culture, and organization) are also in this direction. Finally, the Internet of Things with its role in timely planning, control, and coordination within and between organizations has organizational, financial, systemic, and community consequences.

5. Conclusions

The Internet of Things (IoT) is considered an industrial revolution, poised to create significant changes in production processes, from the beginning of the supply chain and raw material supply to product delivery and even after-sales services. This study aimed to develop a model for the adoption of IoT within the automotive industry supply chain in Iran. The successful adaptation of IoT can lead to a considerable improvement in organizational performance. Specifically, IoT can help organizations determine when a system fails or reaches a dangerous operational state, thereby providing greater control over organizational processes. Furthermore, the use of IoT in the supply chain is increasingly important, as the supply chain plays a vital role in the production process, and its failure can have adverse effects on the organization.

Analysis of interview data indicates that organizational, social (environmental), managerial, industrial, and economic (financial) factors all play a role in the adoption of IoT in the automotive supply chain. The use of IoT in the supply chain is one of the latest developments in information technology and represents a new revolution in the field. It requires paradigm shifts in an organization's macro orientations, its approach to environmental and industrial factors, managerial thinking, and financial conditions. These factors, acting as causal elements, initiate the process of IoT adoption in the automotive supply chain within a developing economy.

The adoption of IoT in the automotive supply chain, with its inherent agility and adaptability, offers tremendous opportunities to effectively solve supply chain challenges. The results show that achieving these capabilities requires transparency in information and communication across the supply chain, close cooperation and participation from supply chain partners, and access to up-to-date technologies for all stakeholders. Therefore, transparency, participation, and technology form the core dimensions of this central category.

In today's business environment, companies do not compete as independent entities, but rather as active members of a broader supply chain consisting of a network of multiple businesses and relationships. Therefore, to support the adoption of IoT in the automotive supply chain, all actors must reach an acceptable level of maturity and develop their technological infrastructure and supply chain management capabilities. Consequently, the maturity of supply chain partners, the technological infrastructure, and supply chain capabilities act as essential background conditions and the main platforms for the adoption of IoT in the automotive supply chain.

Cultural, security, technical, and financial factors are influential as intervening conditions in the adoption of IoT within the Iranian automotive industry supply chain. This means the automotive industry must take effective measures to leverage this technology. The cultural factor is a 'soft' factor that intervenes in the acceptance of IoT among chain partners, focusing on eliminating elements that disrupt transparency and participation. Considering the potential for cyberattacks, security factors are a primary concern for partners exchanging information and establishing transparency. While technical factors also intervene in the adoption and use of IoT in the supply chain, creating a suitable technical platform not only leads to the acceptance of emerging technologies but also largely addresses security concerns. Financial factors are a fundamental consideration in the development of new technologies, especially when used in inter-organizational networks where financial balance between partners is vital. The prevalence of small component manufacturing companies in the automotive supply chain significantly disrupts this balance. Support from automakers and cost-sharing plays an essential role in the successful adoption of IoT.

Pre-arrangements, culture-building, organizing, and institutionalization strategies have been identified as strategies for adopting IoT in the automotive supply chain. Platformisation and culture-building strategies initiate the process of accepting IoT. By using an organization strategy, the use of this technology is developed within the automotive supply chain, and the institutionalization strategy stabilizes it.

Finally, the results show that using this technology has organizational, financial, systemic, and societal consequences for organizations active in the automotive industry and its environment. The most important organizational consequences are greater agility, control, and synergy in the supply chain – fundamental benefits of IoT. Despite the financial burden of new technologies, the financial benefits, such as increased efficiency, reduced costs, and increased value, compensate for the start-up costs. As mentioned, competition today is between interconnected networks, not individual companies; therefore, one of the strategic consequences of using IoT in the automotive supply chain lies in the systemic effects. By making the automotive supply chain intelligent, IoT solves many challenges and creates value for chain partners by improving inventory management, product tracking, and data mining.

The findings of this study are consistent with [18], [23], and [26] from the perspective of a suitable approach to supply chain management. From the perspective of IoT adoption in the supply chain, it is consistent with [16-17], [20-22], and from the perspective of IoT application, it is consistent with [19], [21], and from the perspective of presenting an IoT model in industry, it is consistent with [21], [24-25]. Also, these findings align with observations in most studies [34-35]. Across various applications of IoT or IIoT in other industries. The identified factors are largely consistent. The deployment of IoT improves the movement of goods, information capture, communication among partners, and business intelligence. Challenges facing the adoption of IoT include the cost of purchasing new technology, the reluctance of stakeholders to accept change or share information, and a lack of adequate collaboration between partner systems [34]. Conversely, the advantages of IoT include high operational efficiency, increased productivity, and better management of industrial assets and processes through product customization, intelligent monitoring applications for manufacturing enterprises and health devices, and preventive maintenance of industrial equipment [36]. The use of this technology is associated with requirements such as the need for security systems and high initial costs. Given the vital role of the supply chain, particularly in the automotive industry as a leader in manufacturing and supply chain management, supply chain failure can have adverse organizational effects. Therefore, the application of IoT in production processes is an important issue that requires serious consideration. Accordingly, automotive industry managers are encouraged to use the insights from this study and the proposed model to improve their supply chains and capitalize on the advantages and outcomes of adopting IoT to ensure industry success. Applying this technology will lead to improved performance and reduced delays and errors by increasing the integration of supply chain links and improving communication and information exchange. Furthermore, the use of IoT requires infrastructural development and employee training, as indicated in the proposed model.

At a national and macro-social level, governments can take effective measures to implement IoT to improve the quality and quantity of industrial production, benefit from the transparency created in communications, and better control industrial and tax statistics. While this study proposes a useful framework for the adoption and implementation of IoT in the Iranian automotive industry supply chain, more empirical studies across other industries and communities are needed to confirm and comprehensively explain this model. In addition to conducting comparative studies across different industries and countries, researchers are encouraged to study and mathematically model these findings in their future research and use structural equation modeling to study the effects of IoT in automotive and other industries. Moreover, decision-making factors such as ANP and DANP can be used to assess factors affecting IoT adoption and implementation.

6. References

[1] Balouei Jamkhaneh, H., Shahin, A., Parkouhi, S.V. and Shahin, R. 2022. The new concept of quality in the digital era: a human resource empowerment perspective. The TQM Journal. 34(1): 125-144. doi: https://doi.org/10.1108/TQM-01-2021-0030.

[2] Chiarini, A. 2020. Industry 4.0, quality management and TQM world. A systematic literature review and a proposed agenda for further research. The TQM Journal. 32(4): 603-616. doi:10.1108/TQM-04-2020-0082.

[3] Xu, X., Han, M., Nagarajan, S.M. and Anandhan, P. 2020. Industrial Internet of Things for smart manufacturing applications using hierarchical trustful resource assignment. Computer communications. 160: 423-430. doi:10.1016/j.comcom.2020.06.004., 1-28.

[4] Sadique, K.M., Rahmani, R. and Johannesson, P. 2018. Towards security on internet of things: applications and challenges in technology. Procedia Computer Science. 141:199-206. doi:10.1016/j.procs.2018.10.168.

[5] Sallam, K., Mohamed, M. and Mohamed, A.W. 2023. Internet of Things (IoT) in supply chain management: challenges, opportunities, and best practices. Sustainable Machine Intelligence Journal. 2: 3-1. doi:10.61185/SMIJ.2023.22103.

[6] Valmohammadi, C. 2016. Examining the perception of Iranian organizations on Internet of Things solutions and applications. Industrial and Commercial Training. 48(2):104-108. doi:10.1108/ICT-07-2015-0045.

[7] Ammar, M., Haleem, A., Javaid, M., Bahl, S., Garg, S.B., Shamoon, A. and Garg, J. 2022. Significant applications of smart materials and Internet of Things (IoT) in the automotive industry. Materials Today: Proceedings. 68:1542-1549. doi:10.1016/j.matpr.2022.07.180.

[8] Ashton, K. 2009. That ‘internet of things’ thing. RFID journal. 22(7):97-114.

[9] Nitschke, P. and Williams, S. P. 2021. Conceptualizing the internet of things data supply. Procedia Computer Science. 181:642-649. doi:10.1016/j.procs.2021.01.213.

[10] Dai, H. N., Wang, H., Xu, G., Wan, J. and Imran, M. 2020. Big data analytics for manufacturing internet of things: opportunities, challenges and enabling technologies. Enterprise Information Systems. 14(9-10):1279-1303. doi:10.1080/17517575.2019.1633689.

[11] Diène, B., Rodrigues, J. J., Diallo, O., Ndoye, E. H. M. and Korotaev, V. V. 2020. Data management techniques for Internet of Things. Mechanical Systems and Signal Processing. 138: 106564. doi:10.1016/j.ymssp.2019.106564.

[12] Council, S. C. 2012. Supply Chain Operation Reference Model Revision 11.0. Chicago, IL.

[13] Abdel-Basset, M., Manogaran, G. and Mohamed, M. 2018. RETRACTED: Internet of Things (IoT) and its impact on supply chain: A framework for building smart. secure and efficient systems. doi:10.1016/j.future.2018.04.051.

[14] Czajkiewicz, Z. 2008. Direct digital manufacturing-new product development and production technology. Economics and Organization of Enterprise. 2(2). doi:10.2478/v10061-008-0016-8.

[15] Thomas, A. and Trentesaux, D. 2014. Are intelligent manufacturing systems sustainable?. In Service Orientation in Holonic and Multi-Agent Manufacturing and Robotics. Cham: Springer International Publishing. 3-14.doi:10.1007/978-3-319-04735-5_1.

[16] Manavalan, E. and Jayakrishna, K. 2019. A review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirements. Computers & industrial engineering. 127: 925-953. doi:10.1016/j.cie.2018.11.030.

[16] Zhou, L., Chong, A. Y. L. and Ngai, E. W. T. 2015. Supply chain management in the era of the internet of things. International Journal of Production Economics. 159:1–3. doi:10.1016/j.ijpe.2014.11.014.

[17] Fang, C., Liu, X., Pei, J., Fan, W. and Pardalos, P. M. 2016. Optimal production planning in a hybrisd manufacturing and recovering system based on the internet of things with closed loop supply chains. Operational Research. 16(3):543–577. doi:10.1007/s12351-015-0213-x.

[18] Rezaei Pandari, A. and Azar, A. 2018. Designing Service Supply Chains Management Model by Grounded Theory. Public Management Researches. 11(39):5-32. doi: 10.22111/jmr.2018.4009.

[19] Pal, K. 2020. Internet of things and blockchain technology in apparel manufacturing supply chain data management. Procedia Computer Science. 170:450-457. doi:10.1016/j.procs.2020.03.088.

[20]He, L., Xue, M. and Gu, B. 2020. Internet-of-things enabled supply chain planning and coordination with big data services: Certain theoretic implications. Journal of Management Science and Engineering. 5(1):1-22. doi:10.1016/j.jmse.2020.03.002.

[21] Delic, M. and Eyers, D. R. 2020. The effect of additive manufacturing adoption on supply chain flexibility and performance: An empirical analysis from the automotive industry. International journal of production economics. 228:107689. doi:10.1016/j.ijpe.2020.107689.

[22] De Vass, T., Shee, H. and Miah, S. 2021. IoT in supply chain management: Opportunities and challenges for businesses in early industry 4.0 context. Operations and Supply Chain Management: An International Journal. 14(2):148-161. doi:10.31387/oscm0450293.

[23] Jaferi, F., Shahin, A., Vasili, M. and Hassani, O. B. 2023. An approach utilizing epsilon-constraint and NSGA-II for circular manufacturing supply chain networks. Journal of Modern Processes in Manufacturing and Production. 12(2):53-79. dor:20.1001.1.27170314.2023.12.2.4.9.

[24] Foley, F. 2023. Investigating Predictive Maintenance Strategies for CNC Machine Tools in the Industry 4.0 Era. Journal of Modern Processes in Manufacturing and Production. 12(3), 29-35. dor: 20.1001.1.27170314.2023.12.3.2.9.

[25] Foley, F., O'Donoghue, C. and Walsh, J. 2023. Optimizing the Implementation of a Robotic Welding System. Journal of Modern Processes in Manufacturing and Production. 12(2):39-52. dor: 20.1001.1.27170314.2023.12.2.3.8.

[26] Heidari, SH., Bavarsad, B., Nili Ahmad Abadi, M. and Mola Alizade Zavardehi, S. 2024. Study of the Impact of Supply Chain Sustainability Dimensions on Sustainable Competitive Advantage

with the Mediating Role of Production Flexibility and Strategic Flexibility (Case Study: Dairy Industry of Fars Province). Journal of Modern Processes in Manufacturing and Production. 13(1):23-40. doi: 10.71762/mpmp.2024.996931.

[27] Corbin, J. and A. Strauss 2007. Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory. London: SAGE Publications.

[28] Mello, J. and Flint, D.J. 2009. A refined view of grounded theory and its application to logistics research. Journal of business logistics.30(1):107-125. doi:10.1002/j.2158-1592.2009.tb00101.x.

[29] Markey, K., Tilki, M. and Taylor, G. 2020. Practicalities in doctorate research of using grounded theory methodology in understanding nurses' behaviours when caring for culturally diverse patients. Nurse Education in Practice. 44:102751. doi:10.1016/j.nepr.2020.102751.

[30] Strauss, A. and Corbin, J. 1990. Basics of qualitative research (Vol. 15). Newbury Park, CA: sage.

[31] Crawford, A., Weber, M.R. and Lee, J. 2020. Using a grounded theory approach to understand the process of teaching soft skills on the job so to apply it in the hospitality classroom. Journal of Hospitality, Leisure. Sport & Tourism Educ. 26: 100239. doi:10.1016/j.jhlste.2020.10023.

[32] Strauss, A. and Corbin, J. 1998. Basics of qualitative research techniques. London: SAGE Publications.

[33] Denzin, N. and Lincoln, Y. 1994. Introduction: Entering the field of qualitative research. In N. K. Denzin, & Y. S. Lincoln (Eds.), Handbook of Qualitative Research. California, CA: Sage Publication, Inc. 1-17.

[34] De Vass, T., Shee, H. and Miah, S. 2021. IoT in supply chain management: Opportunities and challenges for businesses in early industry 4.0 context. Operations and Supply Chain Management: An International Journal. 14(2):148-161. doi:10.31387/oscm0450293.

[35] He, L., Xue, M. and Gu, B. 2020. Internet-of-things enabled supply chain planning and coordination with big data services: Certain theoretic implications. Journal of Management Science and Engineering. 5(1): 1-22. doi:10.1016/j.jmse.2020.03.002.

[36] Khan, N., Solvang, W.D. and Yu, H. 2024. Industrial Internet of Things (IIoT) and Other Industry 4.0 Technologies in Spare Parts Warehousing in the Oil and Gas Industry: A Systematic Literature Review. Logistics. 8(1):16. doi:10.3390/logistics8010016.