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Integrated IoT and digital supply chain management strategy for developing the agricultural product

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ABSTRACT

The two factors of food supply and production stability make people use the latest technology in the agricultural sector. The combination of the Internet of Things (IoT) and modern agriculture in the fields of water management, meteorological forecasting, forestry, pest management, plant diseases and the cost of storing agricultural products has a positive impact. Therefore, there is a need for smart agriculture. The IoT and smart digital system will help increase smart agriculture, which works in different domains of agriculture to improve time efficiency, water management and crop monitoring, soil management, pesticide control, and also minimize human efforts. It simplifies agricultural techniques and helps increase smart agriculture. Along with these features, smart agriculture can help market growth and development of agricultural products. In this study, the impact of the integrated IoT system and digital Supply Chain Management (SCM) has been investigated on the performance of agricultural products in the four areas of responsiveness, flexibility, cost and environment. The results showed that the use of digital technology and IoT has significantly improved the response speed and cost of the system and up to 20% can reduce the harmful environmental effects.

Keywords: IoT, Digital supply chain, Agriculture, food supply, environment.
Article type: Research Article.

INTRODUCTION

Forecasts show that the demand for fresh water, energy and food will increase significantly in the future. Today, agriculture has used 74% of fresh water in the whole world and 00% of all land, which puts a lot of pressure on natural resources (1.2419); also 84-94% of water consumption is in the agricultural sector, while this amount reaches 95% in some developing countries (Luthra *et al.* 2018; Reshitov 2023). Water plays a key role in socio-economic development and establishes the relationship between food and energy industries. Industry consumes 22% of water resources, most of which is used for cooling processes in electricity and steel production (Alkahtani *et al.* 2021; Ishenin *et al.* 2021). It can cause deep problems in the not so distant future. Agricultural activities and food production consume a lot of water and energy. Therefore, energy, water and food are the three main resources for the sustainable development of the economy. Agriculture 4.0 is a new title to describe the application of new and technological models in the agricultural sector. In this regard, the use and application of new methods leads to a concept similar to precision agriculture. Based on the European Parliament's definition, agriculture is a type of farm management model that observes, measures, and responds to inter- and intra-farm variability of crops. At

the same time, the goal is to increase the productivity of crops and at the same time ensure greater environmental sustainability. IoT and big data are among the most widely used technologies in agriculture 4.0 (Yadav *et al.* 2021; Hasan *et al.* 2023). Agriculture 4.0 enables farmers to better understand all the parts of the farm, to choose the part that has the most suitable value for investment, and to be able to predict the threats of the farm, including the threats of pests or extreme weather changes (Yadav *et al.* 2022). Agriculture 4.0 also allows the farmer to know what changes in the farm can create the most value (Shariati *et al.* 2013). The supply chain here means a network of activities including product development, marketing, procurement of materials and basic needs, shipping and logistics management, etc. to achieve the goals of the organization. In fact, the supply chain includes all the activities that the goods go through from the raw material stage to delivery to the final consumer. Today, organizations are facing customers who demand more variety, cheapness, quality and access to products. SCM is an essential activity to respond to these needs (Sirenko *et al.* 2023). Supply Chain Management (SCM) is considered as a set of approaches and efforts that support manufacturers, suppliers and distributors and coordinate the value chain in such a way that products are produced and distributed in the right quantities at the right time and in the right place to achieve customer satisfaction as a result (Bhat *et al.* 2021; Khandelwal *et al.* 2021). SCM is the process and activity of providing the required raw materials or other organizational components that the company needs to create a product or service and provide that product or service to customers. As presented in efficient SCM provides data which allows companies to propose and develop just salable products. Effective SCM assist companies and reduce redundant activity, which decreases the cost of production, transportation, insurance and storage of goods that cannot be sold. SCM refers to the transparency and achievement of financial, nature and society goals of system with effective coordination of intra-organizational procedures (Nagarajan *et al.* 2022; Senturk *et al.* 2023). The main issue of implementing SCM contain the sustainability of the SCM with the environmental concerns, and the full acceptance of society responsibilities. Today, by the increase in the supply of agricultural products and the emergence of complex competitive conditions, the need to use new communication and information technologies and methods is felt more and more as one of the most important factors of competition in the agricultural sector. Therefore, considering all the above factors, providing solutions to improve performance management in the agricultural sector in order to reduce costs while paying attention to the issue of sustainability in this sector is of great importance. The research hypothesis are as follows:

- The responsiveness of the digital SCM of agricultural products with IoT is in a good state.
- The flexibility of the digital SCM of agricultural products with IoT is in a good state.
- The cost of the digital SCM of agricultural products with IoT is in a good state.
- The environmental conditions of the digital SCM of agricultural products with IoT are in a good condition.

MATERIALS AND METHODS

Industrial revolutions have also affected agriculture in every era. Today, the agricultural sector is experiencing a new revolution called agriculture 4.0, which is happening simultaneously with the impact of digital technologies on the industry. Fig. 1 shows these main technologies and how they are related. This research is of applied type according to its purpose. In applied research, its results are used to solve practical and real problems, and due to the use of questionnaires to collect data and examine the views and ideas of the target community, the exploratory and descriptive research method is a causal survey. Two methods are used to investigate the research topic. At first, by reviewing the research literature as well as reviewing the previous researches, the most important dimensions and factors affecting digital SCM in agriculture were identified. Then, using statistical analysis, research hypotheses were evaluated in the application of IoT and digital supply chain system in the production of agricultural products. The data collection method is a combination of field and library ones. In the library section, the theoretical foundations and background of the research are collected, but in the field section, the effectiveness of the factors is determined and the hypotheses are tested. The analysis method of this research is a combined method of statistical techniques. The statistical method is used to determine the influencing factors on the digital SCM of agricultural products and to check the hypotheses of the test. The main idea of this research is to clarify the factors affecting digital SCM using IoT in agriculture, in order to prioritize the dimensions and factors affecting sustainable SCM in agriculture. From the point of view of 15 experts who have several years of experience and sufficient experience about they have the subject of research, it was used and it is assumed that the questionnaires have the necessary reliability.

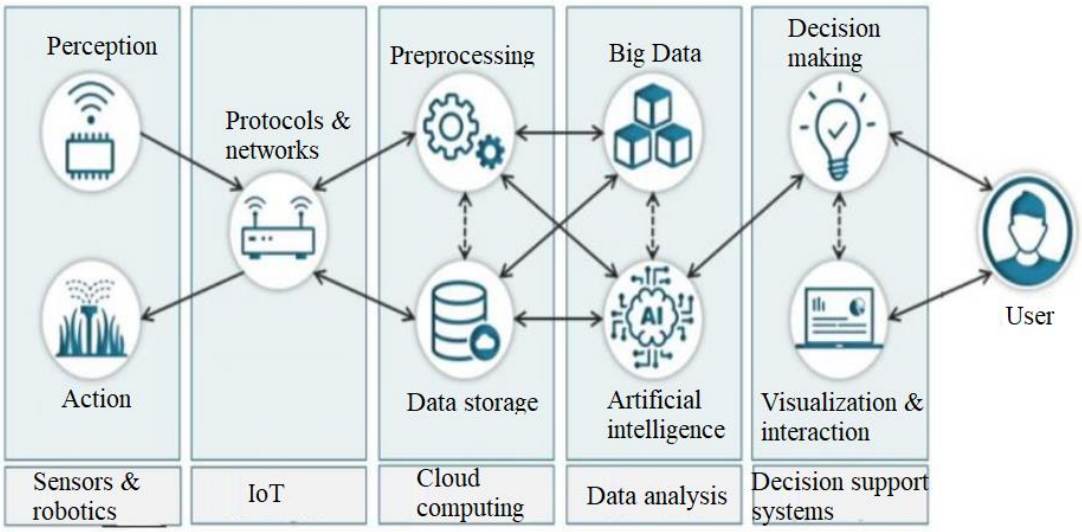

Fig. 1. Main technologies and how they are related in integrated IoT and digital supply chain system.

SCM processes

SCM includes the following main processes:

A: Information management: The correct exchange of information makes the company's activities within a supply chain more coordinated and the performance of the entire chain improves and its efficiency increases. Proper information management among the elements of a supply chain facilitates coordination and improves decisions, saves time and increases the quality of the final product.

B: Logistics management: This part includes all operational activities from the initial stages of the entry of raw materials to the exit of goods or final products from the company. Logistics management plays an important role in SCM. Logistics management can be summarized in five general principles:

1. Paying attention to values and benefits: pay attention to the fact that the product should provide value and benefits to customers. That is, in addition to the efficiency of the product, it must be available to the customer at the right time and place.
2. Systemic thinking: This item should usually be considered by senior managers, and it consists of a general overview and paying attention to all the members involved in the production of the final product or service and optimizing the processes for the entire supply chain.
3. Service orientation: All processes must be focused in order to provide a certain level of service to customers and lower levels of the supply chain.
4. Striving for efficiency: Considering today's conditions and the competitiveness of most activities, the company should be able to convert input into output with the lowest cost and proper quality, without wasting raw materials, by using appropriate technologies.
5. Relationship management: The results of the studies show that a large part of the reasons for failure in the initial stages of the formation of the supply chain are related to the lack of proper understanding of the supply chain members about each other's conditions and false expectations from each other. Therefore, trying to increase trust among all members of the supply chain, increasing the reliability of all elements involved in the chain, is an important and vital issue for achieving success in the entire supply chain.

Suppliers, retails, companies, and vendors, by using SCM networks produce and send data. These networks lead to the creation of many challenges and opportunities in SCM. Digital SCM as shown in Fig. 2, links these parts by social network and based on the digital environment which speed up the process and make it more accessible and transparent for users from suppliers up to costumers, while minimize the environmental hazards of the system.

Application of IoT in agriculture

The Iot-based system in agriculture provides the structure to transparent, easy and fast tracking of the products status, the possible errors and delays in the system. It also can be used as the basement for communication of various SCM parts. They can keep perishable materials safe to a large extent. The IoT can facilitate the tracking of organizational inventories and greatly increase the accuracy of warehousing operations. Solutions that use the IoT and the supply chain can help preserve perishable goods by monitoring storage conditions, which can cause

the better collaboration, providing better services to customers, tracking of sensitive goods, and improving forecasting accuracy. Sensors and robotics fulfill the needs of the system through sensors and operational functions specific to each situation. IoT establishes connection based on protocols and network for data communication. Cloud computing is responsible for data storage and processing.

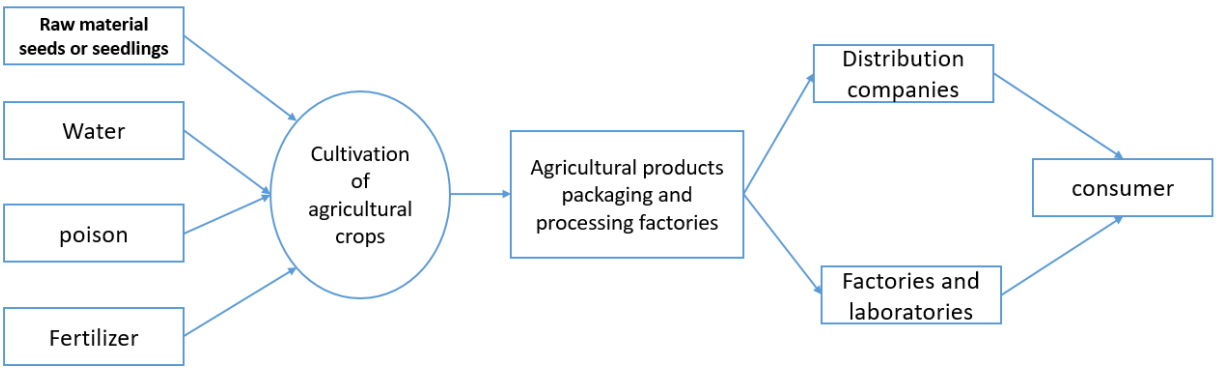

Fig. 2. supply chain procedure of agricultural products.

Data analytics includes algorithms based on artificial intelligence and machine learning to analyze big data. Decision support systems emphasize the visualization of data and the design of guidance functions for decision making and creating a suitable user relationship (Scuderi *et al.* 2022). Industry Basics 0.4 has the potential to revolutionize production capabilities in all sources and sectors, including agriculture. Communication is the foundation of these changes. The IoT is a key technology whose applications in agriculture are continuously expanding. Also, other digital technologies such as cloud computing, artificial intelligence and robotics, 5G and supercomputers have the potential to increase productivity, sustainability and competitiveness in the agricultural sector.

RESULTS

According to the goals, questions and research method, in this chapter, the collected information about the factors affecting the sustainable SCM in agriculture 0.4 will be analyzed and evaluated and the results will be shown. Student t distribution was used for hypothesis testing and SPSS software for data analysis. For the hypothesis test, null and opposite hypotheses have been defined first, and considering that the purpose of checking the appropriateness of the hypotheses is higher than the average, a one-sided test has been used. If the value of t calculated by the software is greater than t in the table, the test statistic is not in the critical region and the hypothesis is confirmed, but if the t calculated by the software is smaller than the t in the table, the test statistic is in the critical region and the hypothesis is rejected.

Table 1. Hypothesis t-test results.

Bound		Mean differences	Significance	df	T	Hypothesis
upper	lower					
2.22	1.15	3.65	0.00	199	11.59	1
2.61	1.55	4.15	0.11	199	18.57	2
1.82	1.08	6.22	0.00	199	13.55	3
3.22	1.88	4.21	0.00	199	13.98	4

According to Table 1, it can be said that because the t value calculated for all four hypotheses of responsiveness, flexibility, cost and environment is greater than the critical t value, therefore it is not in the critical area and the null hypothesis is accepted. In other words, the responsiveness of the digital supply chain of agricultural products using IoT is in a good state. Also, the results showed that the flexibility of the system as the second hypothesis was less significant compared to the other investigated factors, which indicates that flexibility has a weaker performance compared to the three hypotheses of cost, responsiveness and environment. Finally, according to the experts' weighting analysis, the amount of weight of each of the influencing factors on the production and development of agricultural products, can be observed in Fig. 3. As shown in this Fig., the factors of preserving responsiveness, environmental resources, cost, and flexibility are the most important sustainable factors in the application of IoT and green supply chain in the production of agricultural products respectively.

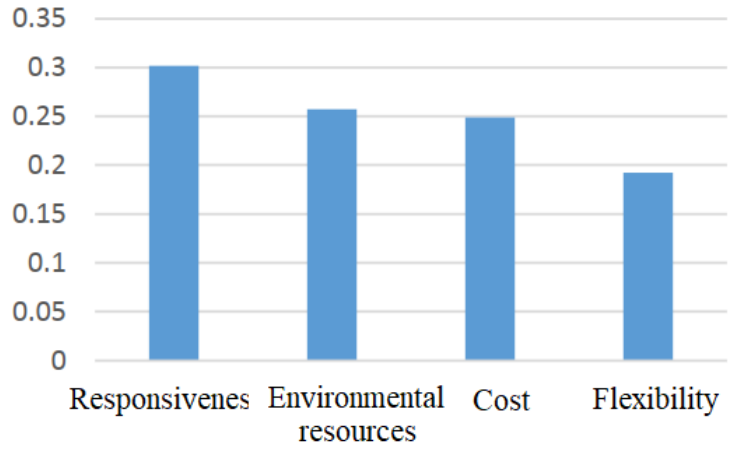

Fig. 3. The final weight of factors affecting the production and development of agricultural products.

Tracking and tracking goods with the help of IoT from farm to table: By the help of IoT, the value chain of agricultural products is made intelligent and increases the transparency and trust of the supply and demand parties.
People and networks: Optimal communication between people and institutions through Internet networks and the speed of communication within the ecosystem is a rich source of information and a suitable platform for sharing knowledge.
Big data and data analysis technologies: Special platforms integrate the flow of data obtained from different sources, connect various stakeholders along the value chain, and enable data analysis as well as explanation and description of past trends along with predicting future trends. Finally, the frequency of information increases through optimal Internet connection and products equipped with data sending equipment to cloud systems. By optimizing the quantity, quality, speed and flow of data, a better experience of using data analysis and machine learning platforms in planting and harvesting will be achieved. Market analysis by farmers and eliminating the need for intermediaries with the help of customized dashboards and customer behavior analysis has an effect on four marketing indicators; i.e., it helps both to optimize products and to improve pricing, distribution and advertising strategies. By the help of local information analysis, it is possible to personalize agricultural recommendations. These recommendations can be about the optimal allocation of agricultural land to different products.
Social media technology: Farmers share their data and information on an online network and form an agribusiness network, benefiting from the benefits of sharing expertise and market transparency. In this way, with the continuous communication of the sector's activists, the agricultural value chain is improved and a platform is provided for the sharing economy in order to share resources. In addition, by the help of social media, a suitable situation is created for e-commerce, which will lead to the elimination of middlemen and the shortening of the value chain, as well as the realization of prices. Finally, on the platform of social media, fundraising will be facilitated and accelerated.

CONCLUSION

Innovative ideas and technological advances help the agricultural industry to increase production and allocate more resources. Nowadays, IoT is used to produce more agricultural products with lower costs and optimal consumption of resources. IoT can play a role from launching a smart and comprehensive solution in agriculture to producing a special sensor for the market. In this article, the role of IoT and the digital supply chain in the promotion of the agricultural industry and its analysis from the perspective of cost factors, environment, responsiveness and flexibility of the system, as well as the challenges faced by farmers in the field of water shortage, along with the use of smart irrigation systems were focused on. When the IoT enters the field of agriculture by using tools to optimize production, farms and greenhouses are moving from accurate models to a micro-accurate model in the production of agricultural products. Distributed, pervasive computing and monitoring equipment can provide suitable conditions for growth and life of plants and animals. On the other hand, the food supply chain, equipped with wireless sensor network (WSN) equipment, radio wave identification system (RFID) capable of monitoring every stage of a product's life, automatic reasoning about a defective product and increasing the consumer's sense of security through transparency. Product life cycle information system. In general, the use

of the IoT will bring many capabilities and advantages to farmers, such as optimizing energy consumption, increasing production capacity, reducing costs and financial efficiency, preventing environmental problems, and providing access to information. Each specific field and range, analysis of possible errors during the period, prediction of crop performance before harvest, prediction of the prevalence of pests in the region, the possibility of displaying information on the phone, laptop and website and improving irrigation strategies can be mentioned.

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