POLITECNICO DI TORINO

Master's Degree in Engineering and Management

Prioritizing of Agile Food Supply Chain Implementation Strategies Using Hybrid Multi-Criteria Fuzzy Decision Making

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Chapter 1: Introduction

1.1 Statement of problem

In today's ever-changing world, achieving goals and success is not only possible through proper management, but also requires businesses to be directly or indirectly involved in the management of organizations and companies that supply and distribute their products[1]. Such a necessity has led to the emergence of supply chain management. Organizations that implement supply chain take steps to meet the demand of their customers in a timely and appropriate manner by creating integration throughout the supply chain[2]. Today, the shortening of the product life cycle, it has caused a lot of ambiguity and has led to high risk in supply chain management and intense competition in the external environment of organizations[3]. Agile thinking is a well-known paradigm that allows businesses to respond to variable demand by enabling them to respond quickly[4]. Therefore, in the supply chain implementation process, it is necessary to use agile production to respond to the changing needs of customers in a timely manner. In this research, supply chain agility is studied and the factors affecting it in order to upgrade and improve supply chain management identify models and indicators of supply chain agility assessment.

1.2 Necessity of research

One of the biggest challenges facing organizations today is the need to respond to increasing levels of demand volatility[5]. For a variety of reasons, product life cycle and technology have been shortened, competitive pressures have repeatedly imposed product changes, and consumer diversity has become more diverse than ever before[6]. To address this challenge, organizations need to focus their efforts on greater agility because of agility responds to both volume and variation changes in the least amount of time[7]. Agility enables the chain to respond quickly to changes in the environment. To achieve a favorable

competitive position in a changing business environment, companies must align with suppliers and customers for operational efficiency and work together to achieve a level of agility beyond monopolies[8].

An agile supply chain seeks to enrich and satisfy customers and employees. Therefore, an agile supply chain is able to respond appropriately to changes that occur in the workplace, and in situations where market demand for the product is highly variable and volatile, agile philosophy by increasing the speed and flexibility in product diversity causes improved supply chain responsiveness[9]. On the other hand, with agile supply chain processes, the organization will be more sensitive to the market, will have a greater ability to match supply and demand, and will be able to achieve a shorter product delivery cycle. Organizational supply chain agility is a critical factor affecting the overall competitiveness of the organization. Therefore, the discussion of supply chain agility is very necessary[10]. A product footprint analyzes variables such as carbon footprint, water footprint, use of non-renewable resources, and others to determine the environmental effect of your product from conception to disposal. It is founded on the life cycle evaluation approach. The amount of carbon dioxide released throughout the production chain for a single quantity of a product is known as its carbon footprint. For instance, the entire net quantity of carbon dioxide released during the production, consumption, and disposal of a single can of cola is the carbon footprint of cola.

1.3 Research Goals

1. Identification of agility indices of five axes model affecting the agile supply chain in a food Supply chain
2. Providing a model for evaluating agile supply chain in Food Supply chain
3. Determining the priorities of indicators and implementation strategies of agile supply chain in Food Supply chain

4. Minimizing our environmental footprint involves understanding our environmental impacts

1.4 Research questions and hypotheses

1.4.1 Research questions

1. Are product development flexibility indicators effective in evaluating agile supply chain in Food Supply chain?
2. Are production and manufacturing flexibility indicators effective in evaluating agile supply chain in Food Supply chain?
3. Are logistics flexibility indicators effective in evaluating agile supply chain in Food Supply chain?
4. Is IT flexibility indicators effective in evaluating agile supply chain in Food Supply chain?
5. What are the priorities of indicators and strategies for implementing agile supply chain in Food Supply chain?
6. How to calculate the footprint in the supply chain?

1.4.2 Research hypotheses

1. Product development flexibility index is effective in evaluating agile supply chain.
2. Manufacturing flexibility index is effective in evaluating agile supply chain.
3. IT flexibility index is effective in evaluating agile supply chain.
4. Logistics flexibility index is effective in evaluating agile supply chain.
5. Procurement flexibility index is effective in evaluating agile supply chain

1.5 Definitions of research terms and variables

1.5.1 Supply chain:

All activities related to the flow and conversion of goods from the stage of raw material extraction to delivery to the consumer and also related information flows are said, and in total, from the conversion of materials to the stage of delivery of final goods to the consumer, there are three financial flows, information and the goods are in it[3].

1.5.2 Supply chain management:

Strategic and systematic coordination of traditional business operations aims to improve long-term efficiency. In addition, supply chain management includes coordination, production, inventory, position and transportation between different parts of a supply chain, which on the one hand increases accountability and On the other hand, it increases efficiency for the target market[11].

1.5.3 Agile supply chain:

Agile supply chain is a supply chain that has the ability to respond quickly to market changes and customer demands in the supply chain[12].

1.5.4 Product development flexibility:

Ability to develop or improve the product in a cost effective and timely manner to meet customer or market needs or take advantage of market opportunities [13].

1.5.5 Procurement flexibility:

The role of procurement to respond promptly and cost-effectively to changes raw material needs that improve responsiveness and increase customer satisfaction[14].

1.5.6 Flexibility in production and construction:

Different scope of available choices and the ability of the production process to implement them effectively, which leads to the production of quality products in response to changes in product characteristics, supply of materials and demand or increase the use of technological processes [15].

1.5.7 Logistic flexibility:

In order to adjust the process of managing the movement and storing of raw materials, finished products, services, and associated information from source to destination in reaction to shifting market circumstances, a variety of options must be available and successfully implemented [16].

1.5.8 IT flexibility:

The capacity of a company's extensive IT system to adjust to and support the shifting requirements of the business to adaptable aspects including product development, product procurement, and transportation as well as other strategic objectives [17].

1.5.9 Integration in the process:

Process integration involves cooperative planning, universal access to knowledge and information via the Internet, real-time sales data, effective client responsiveness, data mining skills, and common values and objectives. The new wave of networked software emphasizes outsourcing, paperless trades, and high levels of collaboration. Process integration, which serves as the foundation of the supply chain, denotes the network of linked individuals that makes up the supply chain [18].

1.5.10 Network integration:

Network integration includes senior management commitment to agile actions, decentralized decision-making, emphasis on core competencies, trust-based goals and metrics, trust-based relationships.

1.5.11 Participatory relationship management:

This is a supply chain strategy to attract buyers and suppliers to work collaboratively, product development collaboratively and information sharing [19].

1.5.12 Customer and market promotion:

As an agile supply chain strategy, customer and market upgrades include the ability to quickly identify and respond to customer real needs. It also aims to become proficient in change and uncertainty. Rapid introduction of a new product, responding to real demand, demand for customized products, maintaining and increasing the level of customer relationships, customer-centric criteria, quality improvement, cost reduction, frequency increase, product improvement are effective factors in market and customer promotion [20].

Chapter 2: Theory and Literature Review

2.1 Introductions

In many volatile markets today, maintaining survival and success requires certain characteristics. The main factor in many markets today is the availability and level of service, which has led to the emergence of new patterns such as agility or rapid response. Today, a successful organization is an organization that has a competitive advantage in new environments and can quickly adapt to customer needs and market changes. New organizational structures have made more factors important in the issue of agility, and therefore, decision-making and selection and prioritization of indicators affecting agility has become more complex. In this chapter, we will discuss the definitions, history and important

and effective principles on agility and agile supply chain, finally, we will discuss the methods and models of agile supply chain in the literature.

2.2 Agile models history

The history of agility goes back to the US industrial downturn. In the wake of the US manufacturing downturn and the well-documented loss of competitiveness in the 1980s, in 1990 the US Congress decided to take the necessary action. As a result, Congress instructed the Department of Defense to establish an agency to examine US industry with a view to making them more competitive. A team of experts and academics at Lee University in Pennsylvania on behalf of the Department of Defense conducted a study on thirteen major manufacturing organizations such as General Motors, General Electric and IBM to answer this question. What will be the characteristics of successful organizations in 2006. After that, more than a hundred other organizations were studied, and the results of the above research were published in a book in 1995. The results of this research included the following points:

- New competitive environments have brought about many changes in production systems and organizations.
- Organizations that have a competitive advantage in these new environments and can quickly produce products that meet customer needs are agile.
- Agility and speed require the following features:

1. Flexible production system
2. Knowledgeable workforce
3. Management structure that encourages team innovations both inside and outside the organization.

- If American organizations fail to move toward agility, living standards in this country will be jeopardized.

2.3 The concept of agility and agile production

In the dictionary, the word Agile means fast and agile movement, as well as the ability to think fast and in an intelligent way. It means maximum flexibility. New competitive environments have created many changes in production systems and organizations. Organizations that have a competitive advantage in these new environments and can quickly produce products according to customer needs are agile. The agility or agility of the organization means maximum flexibility so that it cannot only respond to changes in product and market and customer needs, but also provide opportunities to be known as a superior organization by making changes among competitors. Agility is a comprehensive strategy for fundamental and irreversible changes that lead to organizational excellence.

Agile production is a type of production strategy that is based on new products to rapidly evolving markets, as well as enabling the organization to respond to continuous and unpredictable changes in the competitive environment. At first it was thought that the path of flexibility in manufacturing and production, to better respond to changes in volume or type of product, passes only through automation; but later the idea expanded to a broader concept and the concept of agility was created as a direction of the organizational model. Agility is a broad business capability that incorporates organizational structures, information systems, transportation processes as well as the way people think. Agility means using market knowledge and virtual companies to take advantage of profitable opportunities in volatile markets.

Some of the environmental characteristics that current business organizations must contend with include quick technical advancements, rising risks, globalization, and standards of privatization. Agility provides a competitive edge that can be strengthened by a reputation for quality and ingenuity in order to thrive in this climate. The agile organization streamlines consumer

requirements based on its high-quality goods and services in a reasonable amount of time by synchronizing its internal processes and personnel with cutting-edge technology. Given the novelty of the agility debate, there is no one-size-fits-all definition. Many researchers have worked in this field, and each has come up with several definitions.

2.4 Agile pattern limitations

The purpose of the agile model is to increase the level of service; but the use of agility tools requires spending more and increasing the price of the product, which according to the pure pattern of this price increase is a waste.

Also in the agile model, we may have to consider more assurance inventory or additional capacity to increase customer response and service level.

2.5 Agile production

Agile production is a new concept that may consist of new techniques. In agile manufacturing, general techniques, and methods such as lean and flexible manufacturing are implemented in a centralized manner, thus providing great product improvement, customer response, and flexibility.

Agile manufacturing concentrates on the organization's quick organization-wide start-up to create various products. This entails maintaining a close eye on consumer demand, spotting new product market opportunities, quickly developing products in collaboration with other organizations, simultaneously developing production operations, and using a physical distribution system that is responsive and adaptable for product delivery.

2.6 Principles of agile production

Agile production is based on four basic principles:

1. Organize to be a leader in change

An agile organization is organized in a direction that is able to overcome unpredictable developments and changes. Therefore, its human and physical resources are organized in such a way that it can quickly cope with the changing environment and existing opportunities. Be consistent in the market.

2. Leverage the impact of information and people

Agile organization tries to take advantage of the impact of information on people and on the other hand, encourages innovation and innovation. So that management provides the information resources needed by people at the right time.

3. Collaborate to increase competition

In order to bring products to market quickly, competing organizations have to work together.

4. Respect customers

Customers recognize these organizations as producers of products that meet their needs. The pricing of goods is not based on cost, but on the value they have gained in response to customer needs.

2.7 Agility models

So far, different models have been presented in order to better understand agile production, and each of these models has different strengths and weaknesses. In fact, each of them has addressed the issue of agility from a different angle:

Model 1: Dimensions of agility from the perspective of Metz et al

Agile organization is a complex concept that four strategies have been proposed to achieve it:

1. Customer enrichment: Customer enrichment means the continuous provision of products and services for which the customer pays monetary value. This dimension is a condition for the firm to survive in the competition. Firms must

have a correct understanding of their customers and products and Provide services that create value in their lives.

2. Collaborate to increase competitiveness: No organization has all the skills, knowledge and resources needed for all market needs. Adopt.

3. Managing change and ambiguity: The most important challenge that companies face today is rapid and continuous change. These changes in the field of production of more diverse products, customer relations, business environment, technology, social conditions and environmental laws Therefore, in order to survive and thrive in a changing environment, organizations must be organized in such a way that they have flexible and innovative organizational structures and the ability to make quick decisions.

4. Increasing the effectiveness of information and human resources: Knowledge and skills of employees are the most important assets of the organization. Agile organization should make a basic investment in training and improving its human resources. Free information is another feature of agility.

Model 2: Gunasekaran model

In 1998, Gunasekaran presented a comprehensive model in which he examines an agile manufacturing firm in four dimensions:

1. Value-based pricing strategy to enrich customers
2. Cooperation to improve competitiveness
3. Control and management of changes and uncertainty in the organization
4. Investing to strengthen the impact of people and information

Based on this and in order to enable agile production instruments, he presents his conceptual model based on the four dimensions mentioned above. The capable instruments proposed in the conceptual model are:

Tools and criteria for forming a virtual enterprise, distributed work teams, tools and criteria for rapid formation of partnerships, simultaneous engineering of

integrated information systems (product-business-production), tools for rapid prototyping and e-commerce.

Model 3: Model Ramasesh et al

In this model, three main features for an agile organization are considered, which are:

Product or output, transportation system, inputs or market invoices

This model has a holistic structure that is not suitable for implementation in manufacturing organizations and is often used in the introduction of agile structures and theoretically. This model also has solutions to accelerate the process of setting up and installing equipment within the organization has provided.

Model 4: Kid model

This model suggests that agile production can be considered as a structure that has the ability to develop its products and business strategies within each company [21]. Three primary sources are supported:

1. Innovative management structures, organizations
2. Capable people, with high knowledge and skills
3. Intelligent and flexible technologies

These three sources are integrated by a methodology. In other words, agile production can be considered as the integration of the organization, people with high knowledge and skills and advanced technologies to achieve innovation and cooperation in response to customer needs.

Model 5: Model Sharp et al

The theoretical model is for agile production and has three levels. The first level is the basis of the model and consists of a set of practical and executive

principles. The second level includes the ability of the model instruments. Today, they have been proposed in this model as a competitive foundation. At the end of the third level, it is the output of the model.

1. Focus on core competencies: Because firms are not able to meet all customer needs on their own due to lack of resources and facilities, temporary networks of independent companies are equipped with information technology, competencies, infrastructure, and business processes. This is done with the aim of satisfying the specific needs of the market and dismantled after the completion of the project.

2. Virtual enterprise: In an agile production environment, to effectively control production, production information systems must have access to a number of private data sources and databases and equipment in which information in a standard format, understandable, effective and Used for people who need it.

3. Rapid prototype construction: Prototyping is the design and creation of a product version quickly, which is done with the help of advanced technologies, design and production by computer or engineering by computer.

4. Simultaneous engineering: is a systematic approach to the simultaneous design of products and processes and responds to the need for a shorter product development cycle and therefore responds to changing markets as quickly and as possible.

5. Flexible and multi-skilled people: In addition to knowledge, skills, and competence to do the job, these people have quick flexibility in performing other tasks (when necessary) and are the result of training programs.

6. Continuous improvement: The iterative process of planning, changing, evaluating, and improving elements within an organizational structure that sometimes includes external customers and suppliers.

7. Teamwork: A team consists of members who are committed to a common goal and set of work goals and the way in which those people hold themselves accountable.
8. Change and risk management: The process of changing organizational culture is a traditional values and practices and reflects new ideas and beliefs.
9. Information technology: The meaning and concept of e-commerce is the use of electronic tools in business that take into account the geographical distribution of customers and their needs and improve the response time to customer demand.
10. Empowerment: Empowered staff includes people who form an informal network (when needed) and are able to do so effectively.

Model 6: The model of Yusuf and his colleagues
This model presents four basic concepts for agile production.
1. Management of core competencies: Management, which has a special responsibility to acquire basic knowledge and skills, must identify the core capabilities of the firm and find the missing links and create them through linking.
2. Virtual enterprise: In agile production, the term virtual enterprise is used with different meanings and means joint ventures with other companies that have complementary and specific basic competencies, i.e. basic competencies are selected from several companies and then within a single phenomenon are combined.
3. Agile firms can easily shift dramatically in focus, diversify, reshape and reorganize their business and offer a specific and fast goal as an open window to opportunity.

4. The workforce of agile organizations must be motivated, trained, and strengthened with the full set of skills, expertise, and knowledge to be considered a vital element.

Model 7: Model Jane and her colleagues

Based on the model of Jane and her colleagues, it is possible to implement agile production using integration, strategic processes and information technology. This model tries to streamline the organization at both management and technology levels in the organization.

Model 8: Hormozy model

The design of an agile production system is another model that has been presented in this field. This model tries to streamline the organization by using a static structure using environmental factors, planning systems, flexible production infrastructures and a multi-skilled workforce. In this model, Hormozi has not designed any feedback to improve and use the implementation results.

Model 9: Sharifi and Zhang model

This model consists of three parts and has studied different dimensions of agile production and implemented in manufacturing industries.

The first part includes agility incentives. Incentives are those changes that lead the firm to a new position in the business and the search for competitive advantage and provide a reason to reconsider the strategy and restructure the firm.

Agility capabilities, which are the second part of this model, include the essential capabilities that are needed to respond to change. Sharifi introduces responsiveness, flexibility, competence, and speed as the four main capabilities.

The last part of the conceptual model is the agility providers by which capabilities are created and supported, and includes tools, techniques, and methods that are applied at different levels of the organization.

Model 10: Sharifi and Zhang Supplementary Model

In this model, the previous model of agile production was completely re-described by Sharifi et al. at 2001. The four main aspects of agile production in this model are:

1. Agility stimuli
2. Agility capability
3. Provides agility
4. Agility strategy

Agility drivers prompt the organization to review the current strategy, add agility requirements, and adopt an agile strategy. Agility capabilities such as responsiveness, competitiveness, speed, and flexibility are identified as the main characteristics of an agile organization. Agility providers are obtained. Agility providers can come from four areas: organization, technology, staff, and innovation [21].

Model 11: Model Lane et al

According to the different models presented, each of which has looked at the concept of agile production from a different perspective, it can be seen that different models have asymmetric structures in different dimensions of organizational agility. The degree of agility required by each company will also vary. This degree is called the required level of agility, which is a direct function of various factors, including the degree of turmoil or change in the business environment of the organization and the internal conditions of the organization's own characteristics, such as the level of perfection of the

organization. This means that the more variable the conditions for doing business, the more agility the organization needs.

2.8 Supply Chain Management

One of the nascent management disciplines, supply chain management is constantly growing and changing as it seeks to further shorten the time it takes to produce goods and deliver services to consumers while raising the caliber of both. The development of storage management is supply chain management. By analyzing and integrating the internal relationships between storage and transit in the 1960s, specialists were able to decrease their inventory. Distribution management is the name given to the outcome of these investigations. The goals of modern supply chain management software are to reduce supply chain uncertainty and risk. Nevertheless, it positively affects inventory levels, cycle times, business processes, and customer service. This chain is a dynamic process in which simultaneous activities, continuous evaluations by the parties involved, and technologies used. Needs are met not only by the last adherent to the customer (which is the final product of his output), but also by other upstream suppliers. This sequence of suppliers to meet the needs of a customer is called supply chain. Integrated and coordinated is called supply chain management.

With increasing competition and consequently improving production capabilities in the 90s, managers gradually realized that the inputs of materials and services provided by suppliers have major effects on the organization's ability to meet customer needs and cannot simply manage their organization properly. To achieve this, they must also participate in the management of the network of all upstream companies that provide inputs (directly or indirectly) and the network of downstream companies that provide delivery and after-sales service. In the book "Introduction to Supply Chain", supply chain is defined as

all activities related to the physical flow of materials and its conversion into the final product from raw materials to the final consumer, as well as related information flows.

2.9 Define supply chain management

In the 1990s, the word supply chain management gained popularity after it was first used in the late 1980s. Terms like transportation and operations management were in use before this time. Here are a few meanings of logistic chain:

The coordination of businesses that sell goods or services is known as a supply chain.

All the stages that are directly or indirectly engaged in satisfying customer demand are included in a supply chain. Along with makers and suppliers, the supply chain also includes transportation, storage, retailers, and even the actual consumers. Based on the definitions provided for supply chain, supply chain management can be defined as what is done to influence the supply chain and achieve the desired results:

- Systematic and strategic coordination of traditional business segments as well as tactics used in these segments, whether within a particular company or throughout the chain, with the aim of long-term improving the performance of each company and the entire supply chain.
- Supply Chain Management Synchronizing production, inventory, location, and transportation between components of a chain is the best combination of responsiveness and efficiency for the target market.

The ideas of supply chain management and conventional transportation are distinct from one another. Typically, supply chain refers to networks of businesses that collaborate and coordinate their activities in order to transport the product to the market, whereas logistics refers to activities that take place

within a company. Traditional logistics also concentrates on tasks like supply, distribution, upkeep, and inventory management, but supply chain management also includes marketing, new product development, finance, and customer support considerations in addition to all traditional logistics divisions. These extra steps have been incorporated into the supply chain reasoning process as part of the processes required to calculate client specificity. Supply chain management looks at the supply chain and the organizations within it as a whole. This management provides a systematic way to manage the various activities required to coordinate the flow of products and services in order to provide better services to the end customer. This systematic approach provides a framework for responding more appropriately to the needs of the business between which there is a potential for conflict. The different demands and requirements of the supply chain, at a glance, often have conflicting needs. For example, confusion with high levels of customer service will result in high levels of inventory, but the need for efficient performance will lead to lower levels of inventory. Solutions to strike an equilibrium between their various expectations can only be found when these requirements are seen collectively and as a component of a bigger image.

In order to run a supply chain effectively, member businesses must simultaneously increase their internal activity effectiveness and client service proportion. A high degree of customer service entails frequent order fulfillment, prompt dispatch, and a very low rate of customer-returned goods. Internal efficiency, on the other hand, refers to an organization's ability to lower its running and sales expenses while still achieving favorable rates of return on investment.

The following is a basic model for applying supply chain management. Although each supply chain has its own unique market expectations and operational specifications, the themes of this model are essentially the same for

each case. Companies in each supply chain must decide individually or in partnership in the following five areas, depending on their type of activity:

I. Production: What products does the market need? How much of what product and when should it be produced? Production plans that take into account factors such as factory capacity, line balance, quality control, and equipment maintenance and repair as part of production activity are considered.

II. Inventory: What type of inventory should be maintained at which stage of the supply chain? How much inventory of raw materials, semi-finished products and finished products should be maintained? The primary purpose of inventory is to create a reserve to deal with supply chain uncertainty. Because inventory maintenance can be costly, it should be considered what the optimal inventory levels and optimal ordering points are.

III. Transportation: How should inventories be transferred from one place in the supply chain to another? Air freight or trucking is usually fast and reliable but expensive at the same time. Rail and sea transportation are less expensive but generally have more time and lower reliability. This uncertainty must be remedied by storing higher levels of inventory. When is it best to use any of the above transportation methods?

IV. Location: Where should inventory production and maintenance equipment be located? Where are the best neighborhoods in terms of cost to produce and store inventory? Can exist equipment be used, or should new equipment be purchased? After deciding on the above, possible, and available routes to deliver the product to the end customer are determined.

V. How much data and information should be gathered and disseminated? Better collaboration and decision-making are made possible by timely and precise information. Effective choices about what to create, how much to produce, where to keep inventory, and the best ways to transport goods can be made with the correct information.

The choices made are what decide the supply chain's capacity and efficiency. The efficiency of a company's supply chain has a significant impact on its operations and methods of market competition. The firm needs a supply chain that is cost-efficiently optimized if its business plan is to dominate the entire market and fight on price. The business needs a supply chain that is streamlined based on suitable and quick reaction if its plan is to participate in a market sector and compete by offering clients better services and facilities. The supply chain and target market of a company determine the characteristics of that company and how it operates.

2.9.1 Five steps of supply chain management

It can be said that the concept of supply chain is a combination of five stages of management, each of which is briefly explained:

1. Decentralization of Procurement: This stage was formed in a period from the late nineteenth century to the early 1960s. During this period, the field of logistics was recognized as an important source of competitive advantage. Basically, logistics as an intermediary task with Inventory and delivery management were well known, and firms felt that logistics could not be profitable and, therefore, that high investment was not worth it.

2. Cost management: It became evident in the middle of the 1960s that organized administration, structure, and purpose in logistics could give a business a competitive edge. Cost management is the second phase of the supply chain, which serves as a reflection on two important aspects. The first emphasis is the concerted effort made by businesses to consolidate transportation operations under a separate management system. It is possible to lower the expenses connected with transit, inventory, and actual distribution by combining previously dispersed activities into one sector, while also improving the effectiveness of the logistics system as a whole. The expectation that

businesses will concentrate on implementing the idea of complete cost to logistics is the second crucial point. By concentrating on lowering the prices of one or two particular logistics tasks, such as transportation or warehousing, this approach seeks to reduce the overall cost of logistics.

3. Integration of functions: In the 1980s, business leaders recognized that managing the delivery route by concentrating on total transportation expenses was a good strategy. By this point, the majority of leaders saw operations as a tactical task, and the company's strategy organization had little effect on the program. Strategic value can be greatly increased while undergoing constant process development and closer collaboration with logistics partners.

4. Supply Chain Management: To adapt to new market conditions, businesses created the ideas of integrated logistics and supply channel management during the 1990s. Beyond transportation, supply chain also includes other tasks like dealing with numerous businesses. Build a superior product, promote it, and offer greater service to more people.

5. Electronic supply chain management: With the help of information technology, the scope of supply chain management performance has been expanded.

2.9.2 Agile supply chain

The world underwent significant changes at the start of the twenty-first century, particularly in terms of rivalry, the market for technical advancements, and consumer demands. As consumer demand and standards grew quickly, mass marketplaces looked to segment their markets. The organizational and corporate strategic visions and business objectives have undergone significant development. Agility was discovered to be crucial to a company's existence and success. So, in order to achieve an appropriate degree of agility, which is jointly understood as agile supply chain, businesses must coordinate with vendors and

consumers to combine operations and work together to achieve a competitive edge in the global market. As components of supply chain agility, performance of flexibility, adaptability, and reactivity are noted.

In addition to the above factors, speed and competence are also known as the main dimensions of the agile supply chain.

In other words, the agile supply chain looks at flexibility from an external perspective and focuses on responding to unpredictable market changes and taking advantage of these changes through rapid change and flexibility in product volume and type, and for this purpose technologies and uses new tools such as advanced information technologies such as electronic data interchange and virtual companies. Individuals and inter-organizational relationships are also important in this model.

Responding to shifts and turning them into chances are the two major components of agility, according to Zhang and Sharifi (2000) [23]. Therefore, agility is an enterprise-level reaction to a dynamic and fiercely competitive world that adheres to four fundamental principles. Slowly: Improve the user experience, manage change and unpredictability, and improve human resources and participation's competitiveness.

Swaford et al. Have defined supply chain agility as the ability of the supply chain to adapt quickly to a changing market environment. The framework considered by Swaford et al. Construction logistics, distribution and logistics are formed.

Christopher believes that an agile supply chain should have distinctive features.

In this way, agility can be described as a "management concept in relation to responding to turbulent and dynamic markets and customer demands." To be accountable, companies must have flexible capabilities in several areas such as product development, manufacturing, and logistics.

Companies that are formally independent but practically interdependent are included in an agile supply chain. These businesses include distributors, makers, designers, and vendors. Information feedback movement is linked to the material front. The nimble supply chain places a strong emphasis on encouraging agility and flexibility and has the capacity to react swiftly and successfully to shifting market conditions.

Agile supply chain eliminates the linear and traditional organizational structure and uses network technology to form a group of firms. This reduces the delivery time to the market.

The organization's supply chain mobility allows for the creation of a more competitive position for the company, allowing it to react more swiftly and effectively to changes in the market and other challenges. Additionally, businesses that use a network method in terms of agility, ability to manage supply and demand, and ability to complete brief time cycles, supply businesses outperform the market. It can be inferred that supply chain agility is a crucial element that impacts total competitiveness, as well as their delivery to consumers. Perhaps one of the reasons for choosing supply chain agility is the role that it plays in advancing supply strategies and achieving its goals. The concept of supply chain agility emphasizes the ability to respond. The agility literature refers to it as a general concept that is often only related to production. The supply chain provides a practical context for assessing agility capabilities.

The main pillars of the agility approach are very similar to the pillars of the agile supply chain. Agility is summarized in responding to the customer, people and information, in-company and inter-company cooperation and preparing a company for change. An agile supply chain is really necessary Distinctive features such as sensitivity to market changes, virtual presence, process integration and networking.

Parallel advances in agility and supply chain management have led to the emergence of agile supply chains [24]. Agility has been widely accepted by experts as an effective strategy for corporate growth and survival in business environments. It has become an effective step in logistics and corporate support [25].

Another reason for choosing agility is to compare it with leanness and its special features. Lean supply chain depends on the predictability of market conditions, while agile supply chain in turbulent and unpredictable markets to customer satisfaction and competition Deals with manufacturers. The quantity required of a product to be produced in certain periods is determined by the demand of customers in the lean supply chain, the products have low variety, the product life cycle is long, and the customer only pays attention to the price. Today's changing markets are agile due to the possibility of diversifying products with short life cycle and the need to access products as soon as possible. In this chain, the speed of change in the market and customer needs is high and of course the price of products is high. Fashionable clothes can be called products that need an agile supply chain. In this chain, the customer wants to buy his desired design before it becomes obsolete, instead of waiting for months for the import of one type of clothing from the exporting countries. And use. It is natural competitive market environment leads to t Product type and the emergence of newer products at any time and the need for appropriate and rapid response intensifies.

2.9.3 Laying agility across the supply chain

To achieve agility, a supply chain must have a number of distinctive features. The main elements and capabilities of an agile supply chain are divided into four categories:

1. Networks of cooperative relationships: This supply chain approach has the potential to draw suppliers and customers together to create products and information systems.
2. Process Integration: By integrating processes, a network of partners can work toward a common objective by carrying out particular tasks in concert. The central supply chain is one of these partners.
3. The ability to share data using information technology between vendors and customers forms the backbone of the supply chain and makes it possible to build an effective virtual supply chain. Remember that the foundation of the virtual supplier network is Instead of being dependent on a collection, it is information-based.
4. Customer Sensitivity: This, as the basis of the supply chain, includes the ability to perceive, recognize and respond to current customer needs, as well as change and uncertainty.

2.9.4 Conceptual framework of agile supply chain

A nimble supply chain has been introduced as a result of concurrent developments in agility and supply chain management. The concept of developing an agile supply chain is a logical move for companies, as agility has been widely acknowledged as a winning strategy for development and even as a foundation for survival in some business environments. Agility in a supply chain According to Ismail & Sharifi (2006) theory is the ability of the entire supply chain and its members to quickly coordinate with networks and related operations to adapt to turbulent requirements and needs and dynamic customers. The main focus is on implementing business activities in network structures and considering a sufficient level of agility to respond to change in a way that is able to anticipate change and seek emerging opportunities.

Based on an overview of the existing research literature, Lane et al. (2006) developed a conceptual framework of agile supply chain that incorporates many of the suggestions of previous research.

The ultimate goal of the agile supply chain is to enrich and satisfy customers. In the context of Lane et al. (2006), customer satisfaction goals are represented from four perspectives, which include cost, time, performance, and stability. The main driving force of agility is the force of change. Agility drivers are changes or pressures in the business environment that force organizations to seek new ways of doing business in order to maintain their competitive advantage. Motivation to change the starting point of this work is conceptual. Natural stimuli can be described by five elements Janke and Sharifi, 2000:

- Changes in the market such as the growth of specialized markets, increasing the growth rate in product models, shortening the product life cycle
- Changes in customer needs and wants such as demand for customized products and services, faster delivery time and shorter design time to product delivery to the market and increased quality expectations
- modifications to the competitive factors, such as the creation of new groups and cooperative methods (for example, increasing pressures on cost, increasing the rate of innovation, increasing the pressure of global market competition)
- Technology changes include the introduction of new goods, manufacturing techniques, design tools, as well as production centers that are more effective, quick, and economical. New software technologies and raw materials are also introduced.
- Changes in social structures such as people's well-being and standard of living, policies, laws (e.g., environmental pressures, changes in social contracts, labor expectations, work environment expectations and cultural problems).

How external and environmental changes lead to a sense of the organization's need for organizational development, the human resource process, and the like

to achieve agility can be tested by referring to information obtained from optimization metrics presented by Goldman et al. 1995. In this document, Goldman lists 10 distinct forces that lead the organization toward agility. These forces are:

- Market segmentation
- Production according to the order in the desired production sizes
- Information capacity to manage a large number of customers completely separately
- Shortening the product life cycle
- Overlap of products and services
- Global production networks
- Simultaneous cooperation and competition between companies

Distributed infrastructure for mass-scale customization

- Reorganization of companies
- Pressure to internalize the prevailing social values

According to Lane et al 2006.'s conceptual framework, an agile supply chain is a distinct capability that can enlighten and satisfy customers. Four essential components make up these important characteristics:

Responsiveness, it is the ability to identify changes and respond quickly to them, whether in a stretching or reactive manner, as well as covering the conditions resulting from the change.

Competence: it is the ability to efficiently and effectively understand organizational goals

Flexibility and adaptability: it is the ability of the organization to implement different processes and use different facilities to achieve the same goals.

Speed: it is the ability of the organization to perform an activity in the fastest possible time

Lane et al. 2006 goes on to say that to have a truly agile supply chain, key elements must be classified into four groups:

- Partnership relationships under the title of supply chain strategy
- Process integration as the basis of supply chain
- Information integrity as the basis of supply chain
- Customer and market sensitivity and marketing process as a supply chain mechanism

Elements of an agile supply chain

For a supply chain to be truly agile, it must have the following specifications:

1. Agile supply chain is market sensitive, and this means that supply chain is able to identify and respond to real demand. In an agile supply chain, most organizations are demand-driven because they have little market share. In the past, organizations used to predict market demand by examining documents related to the past years and decades, and by examining the point of sale, etc., but today this issue has changed. In an agile supply chain, organizations are able to Listen to the voice of the market and respond immediately.

2. Virtuality: The use of information technology and information system between buyers and suppliers creates a virtual supply chain. Agile supply chain is more information-based than inventory.

3. Process integration: Complete process integration is brought about by information systems used by supply chain stakeholders. Process integration entails joint creation of goods and information systems, as well as cooperative work between buyers and vendors. Day by day, this kind of collaboration in the supply chain It is spreading in popularity.

4. Network-based: In a supply chain, the partners are connected to each other continuously, united and in a coordinated manner in a network, and an agile supply chain is formed through the fourth characteristic.

2.9.5 Agile supply chain models

Researchers have developed a set of conceptual approaches to supply chain agility, which include various references and evolved models.

Model 1: Christopher and Van Hooke

Christopher and Van Hook 2000 have measured supply chain agility. Therefore, based on other relevant works, the main pillars and capabilities of agility are divided into four categories:

1. Partnerships: This supply chain approach has the potential to draw suppliers and customers together to create products and information systems.
2. Process integration: Process integration serves as the foundation of the supply chain, making it the focal point of the businesses that are linked together via a network and, through the performance of specific tasks, collectively seek a given objective.
3. Information integration: The capacity to use information technology to exchange data between buyers and suppliers and thereby successfully build virtual supply chains is included in this instance as the basis of the supply chain. Inventory is not the basis for information.
4. Customer Sensitivity: This includes the basis and axis of the supply chain, the ability to perceive or recognize and respond to current customer needs, as well as comprehensive change and uncertainty.

Model 2: Model Van Hooke et al

The components of the agile supply chain from the perspective of Van Hook et al. In 2001 are as follows:

• Customer sensitivity that emphasizes customers and the market.
• Virtual integration that emphasizes achieving, interpreting, and responding to immediate demand.

Process integration emphasizes maximizing autonomy and responsiveness to self-management performance.

•Network integration that relies on fluidized clusters of network communications.

Model 3: Zayn et al

In their model (2005), Zayn et al. provide a five-factor framework by looking at Goldman's model for evaluating supply chain agility.

• Enrich customers

• Organize to create a competitive advantage

• Alignment of people and information

• Responsiveness

Model 4: Christopher and Tuile model

This model was proposed by Christopher and Tuile in 2001. They proposed an integrated model for agile supply chain design. It is a three-tier model that summarizes the concepts associated with agile supply chain.

In this model, level one includes the basic concepts of agile supply chain. The second level includes separate programs such as lean manufacturing, organizational agility and rapid response, the implementation of which is necessary to achieve the principles set at level one. The third level is the separate actions taken to support second-tier applications. Not all of the components shown in this model may be necessary in a particular market or manufacturing area. However, it is likely that a chain Agile supply includes many of these components, too.

Model 5: Power and Sohal model

In their paper, Power and Sohal analyzed the results of 962 Australian industrial companies to identify some of the critical factors for success in supply chain agility, and listed the key factors for success and maintaining an agile supply chain as follows:

• Participatory leadership style
• Computer based technologies
• Resource management
• Continuous improvement enablers
• Communication with suppliers
• Timely production method
• Use or desirability of technology

The two found in their study that the observance of the above factors helps to create and maintain an agile supply chain. According to Power and Sohal article, observing the mentioned factors, which are the same as independent variables, create dependent variables themselves, which are:

1. The current level of performance of the company in terms of customer satisfaction
2. The current level of performance of the company in terms of average process change time
3. The current state of the company in terms of productivity
4. The current level of performance of the company in terms of delivery on time exactly
5. The current level of performance of the company in terms of competitive technology ratio
6. The current situation of the company in terms of the ratio of annual sales to the total average of the warehouse
7. Competitive advantage in terms of process technology
8. Competitive advantage in terms of new product development ability

9. Degree of performance in the field of product innovation

In their paper, Power and Sohal measured the correlation between independent and dependent variables in very agile and less agile organizations.

Model 6: Model Van Hooke et al

Van Hooke observes that three characteristics and features can directly link supply chain operations to agility, and he introduces these three characteristics in his model:

• Skills in the use and efficiency of fluctuations

• fast response

• Unique responsiveness or responsiveness even in limited volumes

Model 7: Model Lane et al

Lane et al. Proposed a conceptual model of agile supply chain in 2006 consisting of four main components: drivers, capabilities, enablers, and agility goals. Business environment includes:

1. Market instability
2. Intense competition
3. Changes in customer needs
4. Faster technology change
5. Changes in social factors

The organization's needed degree of agility can be decided based on the assessment of the business environment. The agile supply chain is aware of change, ambiguity, and unpredictability in the business world, and it reacts correctly to bring about change. Consequently, a flexible supply network needs unique skills. In fact, capabilities are the capabilities that must be created in the organization to have the power needed to respond to change. These capabilities, based on previous research, include four main elements:

• Responsiveness, which is the ability to identify changes and react quickly and take advantage of them.

Competence includes a wide range of capabilities that provide productivity and efficiency and effectiveness of activities in the direction of the goals and objectives of the organization.

• Flexibility, which is the ability to process different products and achieve different goals with the same features.

• Speed, ability to perform tasks and operations in the shortest possible time.

Characteristics of Agility Equipment's the content aspects of agility are assumed and determined to determine the overall supply chain behavior. Based on previous research and the findings of these studies, supply chain agility equipment's are classified into four categories:

• Partnerships: This is a supply chain plan to entice customers and vendors to cooperate, advance, and exchange knowledge.

Information Integration: This component of the supply chain's infrastructure allows vendors and consumers to exchange data using information technology. As a result, it successfully establishes a virtual delivery network.

Process Integration: As the basis of the supply chain, process integration means that the supply chain is a union of interconnected members in a network.

• Customer sensitivity and marketing: As a supply chain mechanism, it includes the ability to identify and respond to the real needs of the customer. It is also to become proficient in change and uncertainty.

Model 8: Model Agraville et al

In 2006, Agraville and colleagues used brainstorming to determine supply chain variables in a car factory. The purpose of their brainstorming sessions was to determine the relationships between supply chain variables. In this study, 15 variables related to supply chain agility have been identified, which are:

1. Market Sensitivity: The supply chain is able to predict and respond to meet real demand.

2. Delivery speed: The ability to deliver goods or services returns faster than competitors.

3. Data accuracy: Data accuracy is one of the important factors that affect the performance of the supply chain and refers to the data accuracy that is used by different business partners in their decisions.

4. Introducing a new product: The ability to introduce a new product has become very important for supply chains that want to compete competitively.

5. Centralized participatory planning: Effective supply chain integration and coordination reduces excess inventory, reduces delivery time intervals, and increases sales and customer service.

6.Process integration: Common information between chain members is obtained using process integration.

7. Using IT tools: Using IT to share data between buyers and suppliers actually creates a virtual supply chain.

8. Reducing Delivery Intervals: Reducing delivery intervals, from the time the order is placed to delivery, is a time-based competition mechanism in the supply chain.

9. Upgrading the level of service: Upgrading the level of service provided to the customer leads to improving the performance of the supply chain.

10. Minimize costs: Minimize costs by identifying ways that make firm exchanges more efficient and help firms reduce costs by helping firms and their partners find other ways to reduce production costs.

11. Customer Satisfaction: Customer satisfaction is affected by the perception of the value received and also the perception of the value of products offered by competitors.

12. Quality improvement: Quality improvement is recognized as a prerequisite for success in the international competitive market by the management of businesses around the world.
13. Minimize Uncertainty: Uncertainty spreads along the supply chain, leading to inefficient processing and value-added activities.
14. Increase trust: Trust between business members in relation to intra-organizational relationships, enhances communication and discourse, and creates shared strategic visions.
15. Minimize resistance to change: Resistance has always been recognized as the main cause of conflict, which is itself an undesirable factor and is important for the health of any organization.

Model 9: Model of Ganaskaran et al

Key success factors for the responsive supply chain, according to Ganaskaran and colleagues include:

• Timely sharing of information
• Reduce the entire life cycle
• Coordination of labor in different parts of the supply chain
• Optimal decision support system
• Reduce latency in material information flow
• Integrate information in the area of operations and grant capacity

Model 10: The model of Swaford et al

This model defines an agile supply chain in five-dimensional flexibility. In his 2006 model, Swaford et al. Based on this research, the identified flexibility structures that affect supply chain agility are defined as:

1. Product development flexibility
2. Production and manufacturing flexibility

3. IT flexibility

4. Logistic flexibility

5. Procurement flexibility

Based on the concept introduced by Slack in 1983, which defined flexibility with two dimensions, in the model of Swaford et al., Two dimensions of change amplitude and adaptability were chosen for flexibility. Flexible choices are defined in each of the supply chain dimensions obtained with available resources, and adaptability is defined as the ability to change the number of states in each of the supply chain dimensions, leading to greater flexibility. Flexibility criteria in this model each of the following criteria are composed of more than:

2.9.5.1 Product development flexibility

I. The number of technologies used by the current production

II. Modular level

III. Number of products introduced each year

IV. The number of different operating systems in the design at a given time

V. Number of product generations in the design at a given time

VI. Number of different projects in the design at a given time

VII. Percentage of assets with the possibility of reuse

VIII. Number of technologies used in the product

IX. Degree of subscription of each section

X. Ability to allocate development resources globally

XI. Ability to design multiple products

XII. Product scale capability

XIII. Possibility to reduce the product development life cycle

XIV. Ability to perform design activities simultaneously

XV. Ability to delay product differentiation in the global supply chain

XVI. Ability to postpone design decisions

XVII. Ability to outsource designs

XVIII. Ability to design global products

XIX. Ability to adapt product designs to global markets

2.9.5.2 Flexibility of construction and production

I. The range of volume levels at which production can operate

II. Number of methods available to increase capacity

III. Number of different products

IV. Number of production options for each product

V. Number of processes available to produce products

VI. Number of products produced in each facility

VII. Number of product changes per month and per facility

VIII. A range of workforce capabilities

IX. Ability to change the volume

X. Ability to change product composition

XI. Ability to implement ECOs

XII. Ability to produce new products quickly

XIII. Ability to change the production time power

XIV. Ability to change process features and capabilities

XV. Ability to change the capability of the workforce

XVI. Ability to move products between global facilities

XVII. Ability to move and relocate processes between global facilities

2.9.5.3 IT flexibility

I. Percentage of the global supply chain that is directly supported by IT

II. Degree of IT system subscription for product development flexibility

III. Degree of IT system subscription for logistics flexibility

IV. Degree of IT system sharing for manufacturing flexibility

V. Degree of IT system subscription for logistics flexibility

VI. Four IT-supported flexibilities

VII. A number of IT-supported methods for analyzing the global competitive environment

VIII. The ability of the IT system to adapt to support changing needs

IX. The ability of the IT system to adapt to support new products

X. The ability of the IT system to communicate with other systems (e.g. the Internet)

XI. The ability of the IT system to adapt to the use of suppliers worldwide

XII. The ability of the IT system to adapt to support global distribution channels

XIII. The ability of the IT system in the field of adaptability to support new production facilities globally

2.9.5.3 Logistic flexibility

I. Number of delivery modes for each product

II. Global storage capacity range

III. Number of delivery policies

IV. Number of products in each delivery mode

V. Number of carriers in each delivery mode

VI. Number of items per facility

VII. Number of storage facilities worldwide

VIII. Range of queue sections in each order capacity

IX. The number of customers that are served in each in the center

X. Number of distribution channels

XI. Ability to add / remove delivery sections

XII. Ability to add / remove delivery modes

XIII. Ability to change delivery policies

XIV. Ability to change scheduled delivery modes

XV. Ability to change scheduled delivery times

XVI. Ability to track shipments worldwide

XVII. Ability to fill orders from alternating global facilities

XVIII. Ability to change the total storage capacity

XIX. Possibility to change the delivery capacity

XX. Ability to move product across global storage equipment

2.9.5.4 Procurement flexibility

I. Range of order size (min., maximum, number of scenarios)

II. Range of delivery frequencies

III. Number of different episodes

IV. A number of supplier-buyer communication options

V. Number of suppliers (tier 1 and tier 2 global or local)

VI. Level of strategic relationship between purchase and construction

VII. Ability to purchase for the global demand repository for orders

VIII. Ability to receive variable order size

IX. Ability to receive variable delivery schedule

X. Ability to influence the performance of the supplier

XI. Ability to change suppliers worldwide

XII. Ability to receive run ECOs

XIII. Technology outsourcing capability

XIV. Ability to retain suppliers in the long run

XV. Worldwide logistics

Model 11: Model Faisal et al

In their 2007 model, Faisal et al. created the following categories in relation to indicators related to supply chain agility instruments:

• Integration in the process includes:

Collaborative planning, Internet-based knowledge access, information that can be updated at any time, information related to immediate sales, effective customer reaction, data mining capabilities, shared values and objectives, high degree of collaboration, and focus Outsourcing, electronic document sharing, and novel networked software.

• Unity in the process includes:

Joint product development, lack of supply chain reserves, multitasking teams, multi-managerial inventory, infrastructure to encourage innovation, updating the mix of production processes in the supply chain.

• Network integration includes:

Senior management commitment to agile actions, decentralized decision-making, emphasis on core competencies, trust-based goals and criteria, trust-based relationships.

• Market sensitivity includes:

Quick introduction of new product, responding to real demand, demand for customized products, maintaining and increasing the level of customer relationships, customer-centric criteria, quality improvement, cost reduction, frequency increase, product improvement.

2.10 The Carbon Footprint of Food Supply Chains

GHG emissions are produced by food supply chain networks at every step of the food life cycle, including pre-farming, farming, production, transportation, selling, consumption, and refuse disposal. The following three groups can be used to classify the primary carbon-related actions that occur across FSCs: Pre-farm processes include the production and distribution of inputs to the farm, such as seed, animal feed, fertilizers, pesticides, growth substrates, pharmaceuticals, machinery, buildings, and other capital goods. On-farm

processes include agricultural production of crops, livestock, fisheries, and other products, as well as the related carbon-intensive or chemical-based farming activities.

Although there are significant differences in this trend between various institutions or nations, the worth of the CF changes significantly across various FSC activities. More precisely, high-income nations tend to place more emphasis on the post-production phases, while in other instances, particular economic subsectors take on greater significance, such as China's high GHG contribution from fertilizer production [26]. Garnett (2011) has given a graphical qualitative depiction of the average GHG emissions at various phases in the FSC.

More precisely, the methane (CH4) released during ruminant digestion, rice farming, and anaerobic soils is shown in the left side of the depicted pie chart. Nitrous oxide (N2O) from soil and animal processes is also shown. Additional activities like the production of fertilizers, the use of fossil fuels in equipment, and refuse burning are also thought to contribute less to CO2 emissions. The light gray area on the left depicts the extra carbon dioxide (CO2) emissions that result from land use change brought on by agriculture. The CO2 emissions from post-farm activities are shown in the right side of the pie chart, where they are primarily caused by the use of fossil fuels for electricity as well as emissions from refrigeration processes. The environmental effect of each FSC process is discussed in the passages that follow, along with key takeaways from recent, up-to-date writings that highlight the current CFM issues that must be resolved by both science scholars and the related decision-makers in the food industry.

2.10.1 Carbon Footprint of Pre-farm Processes

During the past ten years, agricultural intensification has drastically increased the use of a number of inputs, including seeds, livestock feed, fertilizer,

herbicides, growth media, and medicines for disease control (Tilman et al., 2011). Since fertilizers have grown by over 800% in the past 45 years and are now subject to more stringent environmental regulations in industrialized nations, they are recognized as the main carbon-carriers. According to Wood and Cowie (2004), the production of fertilizers is responsible for 1.2% of all global greenhouse gas emissions. These emissions are primarily attributable to energy-intensive production procedures as well as N2O emissions from nitrate fertilizer manufacturing processes.

However, the amount of energy needed and the resulting greenhouse gas pollution for the manufacturing of various kinds of fertilizers vary greatly. The uncertainty in the GHG emissions from output has a range of 30% in the event that the fertilizer's provenance is known [27]. In contrast to the ambiguity of other types of emissions, such as soil emissions, this uncertainty is notably thought to be minor. Recently, organic fertilizer CF modeling has also received attention [28]. Roots, cereals, and open-air veggies' CF are significantly influenced by agricultural yield and the quantity of nitrogen fertilizer used [29]. The transportation of fertilizers to the fields and their ultimate application using equipment both result in additional GHG emissions. According to indications, the production of fertilizers resulted in CO2 emissions of between 28 and 475 Mt in 2007, whereas crop protection emissions are only estimated to produce between 3 and 140 Mt of CO2 annually globally [30]. When it comes to the greenhouse gas (GHG) emissions produced by the production of feed for cattle and aquaculture, these are either directly caused by the cultivation, shipping, and processing of feed or tangentially caused by land change.

2.10.2 Carbon Footprint of On-farm Processes

The agricultural output of crops, animals, and fisheries, as well as all primary and intermediate farming operations, are all included in the CF of on-farm

processes. It primarily pertains to emissions associated with land use change, soil emissions, emissions from energy use on farms, greenhouses, livestock housing, and other sources. Additionally, the primary source of GHG emissions from agricultural energy use is the combustion of fuels used for field equipment, farm transit, and product preparation and storage (drying, heating, lighting, ventilation etc.). Livestock contributes the most to the overall food system emissions, which comprise 7,300–12,700 million tonnes of CO2 equivalent annually and make up 80–86% of the food system emissions . 50–70% of farm emissions are direct emissions from agricultural operations (United States Environmental Protection Agency, 2012). Methane (CH4) and nitrous oxide (N2O) emissions, which naturally result from practices like irrigation and the rearing of numerous ruminants, make up the majority of these emissions. It is known that livestock rearing greatly contributes to GHG emissions, primarily through emissions of CO2, CH4, and N2O. [31]. Although they contribute very little to GHG emissions, fisheries and aquaculture do have an effect on the climate in other ways [32].

On the other hand, since their real volume relies on a number of variables, estimates of the GHG emissions of land use shifts are likely the most uncertain when evaluating the environmental effect of FSCs [33], [34]. Despite this ambiguity, land use change is regarded as a significant source of world greenhouse gas pollution. Despite the fact that deforestation and degradation's proportional addition to anthropogenic carbon emissions has been decreasing over the past few years, deforestation and land use change account for 30–50% of agricultural emissions [35].

The main source of greenhouse gas emissions in agriculture is soil emissions, which are influenced by a number of variables including soil characteristics, climate, the type of product, and agricultural practices. However, it is costly and difficult to measure N2O emissions from vast fields, and these emissions exhibit

significant spatial and temporal variability [29]. For an overview, Few studies to date have taken into account carbon emissions from soil organic matter changes in CF estimates of agricultural items. According to Röös et al. (2010) and Röös et al. (2011), emissions resulting from variations in soil carbon are taken into account when determining the carbon footprint of potatoes and macaroni.

It's interesting to note that a number of strategies for lowering the CF of agricultural production processes have been reported in recent literature, most of which are focused on improving carbon removals, optimizing nutrient use, increasing productivity, utilizing outputs, and using alternative energy sources [36], [37], [38].

Certain practices for mitigating GHGs have been proposed in relation to livestock production, including increasing animal production efficiency, decreasing CH4 emissions and emissions from manure management, sequestering soil carbon, altering human consumption of animal-sourced foods, and taxing mechanisms [39], [40].

2.10.3 Carbon Footprint of Post-Farm Processes

Primary and secondary food processing in industrial facilities, transportation operations (transport/distribution, storage, refrigeration, packing), wholesale, retail, and catering activities, household food preparation and consuming, and refuse disposal are all examples of post-farm processes. Generally speaking, high-income countries have more post-farm phases of FSC emissions than low-income nations [39]. The computation of the food CF and the tracking of GHG emissions are badly hampered by the increased intricacy of food production at the post-farm phases of FSCs [41]. Traditional logistics management focuses on the architecture of the transportation network as well as two primary goals: cost effectiveness and increased speed. However, due to inherent qualities of food items and processes, such as perishability and sustainability problems, the main organizational objectives must be extended to include quality and environmental concerns. Due to this requirement, decision assistance tools that

combine economic factors with quality and environmental safety in FSCs are required [42].

Chapter 3: Methodology

3.1 Introductions

The goal of all sciences is to know and understand the world around us. In order to know the issues and problems of the social world, scientific methods have found considerable changes. The scientific method should be used. One of the characteristics of scientific study, which aims to find the truth, is the use of a suitable research method. The suitable research method depends on the objectives, nature and subject of the research and implementation facilities, and the purpose of research is accurate access and it is easy to answer research questions. Research method, statistical population and sample, data collection method and tool, validity and reliability of research tool, scope of research, data analysis method, use of research result and research steps are among the topics discussed in this research. The research method is the practical plan for the implementation of the work. Making any decision about the research method depends on the purpose of the study, the nature of the problem under investigation, and appropriate methods, which also define the limits and direction of the study. The third chapter of the thesis includes the method that has been used to provide the necessary context for data analysis and answer the questions raised in this research. In this chapter, the type of research and its steps are described in detail and in Next, the statistical population of the research is introduced, followed by the data collection tools used in this research, and finally, the data analysis method used in this research is mentioned.

3.2 Research Methods

The current research is practical in terms of its purpose because its purpose is to solve practical and real problems and it leads to expansion of knowledge and improvement of agility in the supply chain of Nestle Company. It is also a survey in terms of data collection method. The research references include books, academic theses, and articles, as well as expert opinions, in which the validity of the basic criteria presented in the research model is first determined, and then according to the obtained criteria and using the chain analysis process method Fuzzy Hierarchy (AHP FUZZY), which is one of the fuzzy multi-criteria decision-making methods, weights are given to criteria and sub-criteria and strategies are ranked. On the other hand, this research has a field nature, which means that the major part some of the information is collected by experts through interviews and completing questionnaires.

3.3 Statistical population and sample size

The statistical population that has been investigated was limited and included the managers of the supply chain department of this company. The number of these people is 8 people, including the manager of the innovation department, the manager of logistics and warehouses, the manager of production planning and materials, the manager of production, the technical manager, the manager Purification has been the director of the laboratory and R & D and quality management, from which 5 people were randomly selected. Therefore, the sampling method used is simple random probability sampling.

3.4 Methods and tools for collecting information

In order to collect the required information in this research, library information, Persian and Latin articles, and information sites on the global Internet network, as well as the use of questionnaires and interviews, have been used.

In this way, at the beginning of the research, by referring to libraries, sites and databases, as well as by reading articles and research about agile supply chain, different models of agile supply chain, literature and research background were collected and then with The use of existing models of agile supply chain strategies, criteria and sub-criteria have been identified. In order to ensure the validity of the criteria and sub-criteria presented in the research model, Likert questionnaire and One Sample-Test were used, and then decision tree was used. Another questionnaire, which is included in Appendix 2, was designed to evaluate and rank the sub-criteria, criteria and strategies of the research model, in which a four-level hierarchy was used. The mentioned questionnaire was designed based on hourly paired comparisons and decision makers were asked to make their paired comparisons in it and finally the data were weighted and ranked. These four levels are:

1. The first level: the first level of the goal or the selection of agile supply chain implementation strategies
2. The second level: the main criteria affecting the agile supply chain
3. Third level: sub-criteria related to the main criteria
4. Fourth level: choosing the desired option

3.4.1 Characteristics of the second, third and fourth levels:

The second level: This level includes general criteria extracted from library studies and data collection and includes five criteria of product development flexibility, manufacturing and production flexibility, logistics flexibility, information technology flexibility and procurement flexibility.

- Flexibility of product development: In this model, the flexibility of product development is the ability to develop diverse products and upgrade the product in a cost-effective and timely manner in order to respond to customer or market needs or exploit market opportunities effectively has been defined. By

increasing the flexibility of product development, the organization can introduce the required product in a better and more effective way to meet the changing needs of the customer.

- Production and manufacturing flexibility: The manufacturing and production system can adapt to shifts in demand, product design, process technology, material availability, etc. thanks to manufacturing flexibility.
- Swafford in his studies, the flexibility of manufacturing and production, the range of different choices available and the ability of the manufacturing and production process to implement them effectively, which leads to the production of quality products in response to changes in product characteristics, supply of materials and demand, or increase in It defines the use of technological processes.
- Logistics flexibility: To adapt the process of controlling the flow and storage of materials, finished goods, services, and related information from source to destination in response to environmental conditions, Swafford defines logistics flexibility as having access to a variety of options and the capacity to effectively implement them. The marketplace is evolving.
- If an organization has high logistics flexibility, it can respond to customer needs at a better level by paying attention to the delivery of goods.
- Flexibility of information technology: In his article, Swafford defines flexibility of information technology as the ability of an organization's comprehensive information technology system to adapt and support changing business requirements in terms of flexibility, including product development, procurement, manufacturing, and logistics. It states other strategic goals.
- Procurement flexibility: Procurement flexibility measures the ability to change procurement decisions in order to optimize the effects of the required change. It also helps and facilitates quick response in uncertain situations.

Therefore, procurement flexibility affects It will have a positive effect on the flexibility of construction. (Gotta and Summers, 1992)

Swafford sees procurement flexibility as the availability of a wide range of options and the ability of the purchasing process to operate in a timely and cost-effective manner to changes in raw material requirements, which results in improved responsiveness and increased customer satisfaction.

The third level: includes the sub-criteria related to the general criteria, which were extracted and analyzed through library studies and using the A-questionnaire and the One Sample-Test test in SPSS software. These sub-criteria are:

• Ability to reduce product development cycle time
• Ability to design multiple products
• Percentage of assets with the possibility of reuse
• The ability to change the composition of the product
• Speed in producing new products
• The number of methods available to increase capacity
• The number of capable suppliers for each material and in each period
• Penetration on supplier performance
• Speed of cooperation with a new supplier
• Percentage of supply chain directly supported by IT
• IT ability to adapt in support of distribution channels
• The number of methods available in IT systems to analyze the competitive environment and discover changes
• Ability to add or remove delivery channels
• The ability to change the overall capacity of the logistics network
• Number of warehouses available for storage

The fourth level: choosing the most effective strategy for implementing the agile supply chain is placed at the fourth level of the decision tree. These strategies are:

- Integration in the process: Common beliefs and goals, high level of coordination, emphasis on outsourcing, exchanges without using paper, are the new generation of networked software. Integration in the process includes collaborative planning, access to information and knowledge through the Internet and information that can be updated at any time, data related to real-time sales, efficient customer response, and data mining capabilities.

As the basis of the supply chain, process integration means that the supply chain is a union of interconnected members in a network.

- Network integration: Network integration includes senior management's commitment to agile actions, decentralized decision-making, emphasis on core competencies, trust-based goals and criteria, trust-based relationships.
- Collaborative relationship management: The goal of this supply chain approach is to get vendors and customers to collaborate on product development and information sharing.
- Information integration: As a supply chain infrastructure, it includes the ability to use information technology to share data between buyers and suppliers. Therefore, it effectively creates a virtual supply chain.
- Customer and market promotion: As a supply chain strategy, customer and market promotion includes the ability to quickly identify and respond to real customer needs. It is also to become skilled in change and uncertainty. Rapid introduction of new products, responding to real demand, demand for customized products, maintaining and increasing the level of customer relations, customer-oriented criteria, improving quality, reducing costs, increasing frequency, and improving products are effective factors in improving the market and customers.

According to the criteria of the research model based on the Swafford model, it was provided to the experts and the importance of the criteria was evaluated through the questionnaire attached 1. After the factors affecting the agile supply chain were identified, a decision tree was drawn by categorizing them into criteria and sub-criteria groups, and finally, a pairwise comparison questionnaire was prepared using the final decision tree. To calculate the final weight of each sub-indicator, which shows the importance of each sub-indicator based on the opinion of experts, Fuzzy Hierarchy Analysis (FAHP) method has been used.

3.5 Analysis method

The decision-making method with multiple indicators is used when the options are predetermined, and the goal is to choose one of the available options by comparing them in the presence of multiple indicators affecting the preference of the options. Among the various methods that in the field of decision making with multiple indicators, the fuzzy AHP method was chosen for this research. This method was introduced by Saati. This method is widely used as one of the multi-criteria decision-making methods in many decision-making processes.

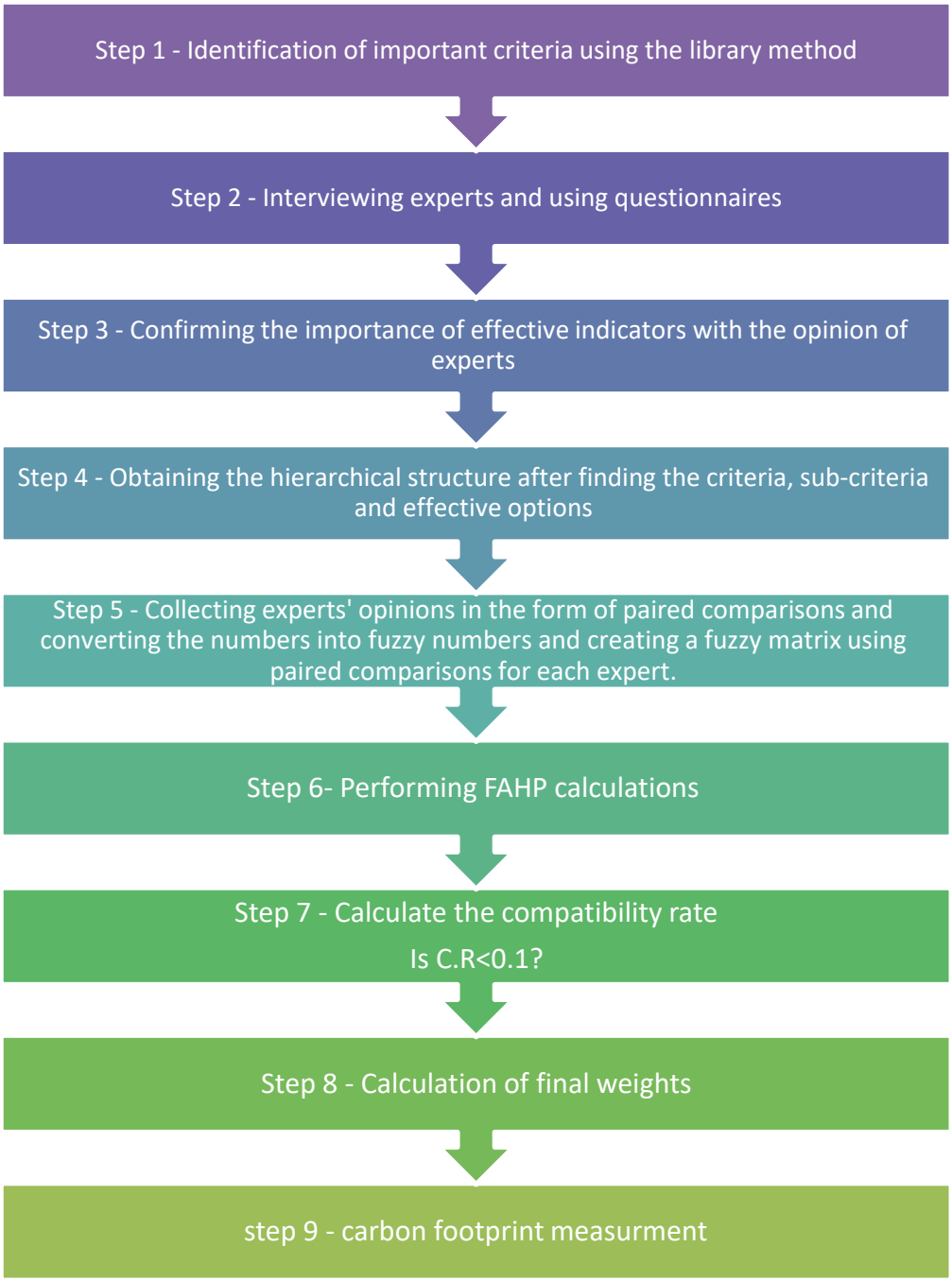
In this thesis, the effectiveness of the indicators and sub-indices of the research model was proved by the T-student test method, and then the indicators and five agile supply chain implementation strategies were ranked using fuzzy AHP. In this study, the analytical method and Data analysis can be classified as follows:

1. Using the T-Student inferential test method to determine and identify effective factors and indicators using SPSS software tools
2. Using the FAHP method for evaluating and prioritizing the indicators related to the subject and also prioritizing the strategies for implementing the agile supply chain.

3.6 Implementation steps of the research

The implementation steps of this research are briefly shown in Figure 1-3 and then explained in detail in different steps.

Figure 3.1. research execution diagram



1. Identifying important criteria using the library method and collecting experts' opinions with the help of a Likert questionnaire:

At this stage, after identifying the indicators, criteria, and sub-criteria effective on the problem of prioritizing agile supply chain implementation strategies in

the form of five criteria, fifteen sub-criteria and five options, which were obtained from the literature review and the opinions of knowledgeable experts in this issue. Questionnaire No. 1 was presented to the experts and the experts were asked to give their opinion about the factors.

2. Examining the opinions of experts using the T-Student test method and confirming the criteria

Hypotheses testing was done using experts' opinions in questionnaire number 1 and based on the T-Student statistical test, the results of which included five main criteria and fifteen sub-criteria and were examined in five options which are the desired strategies.

3. Preparing hierarchy levels of criteria and sub-criteria and options along with coding

After finding the criteria, sub-criteria and effective options of hierarchical levels are obtained and coded as shown in Table 3-1.

Table 3.1. Identification table of criteria, sub-criteria and options

Options code	The fourth level of options	Substandard code	The third level of sub criteria	Second level standard	Criterion code	First level Target
AH_1	Process integration	A_1 A_2 A_3		Product development flexibility	A	Evaluation and prioritization of agile supply chain strategies
BH_2	Customer and market promotion	B_1 B_2 B_3		Manufacturing flexibility	B	
CH_3	Information integration	C_1 C_2 C_3		Information technology flexibility	C	
DH_4	Network integration	D_1 D_2 D_3		Logistics flexibility	D	

EH_5	Participatory Management	E_1 E_2 E_3		Procurement flexibility	E	

4. Creating a hierarchical tree model after knowing the criteria and sub-criteria and effective tools

5. Creating a fuzzy AHP questionnaire according to verbal scales

The 9-point triangular fuzzy scale based on the hourly scale was proposed by Tesfamariam and Sediq. In this scale, after collecting the answers of the experts in a 9-point scale and in the form of some linguistic items, it is necessary to add the said answers to a scale with the ability Analyze the answers because it is impossible to perform mathematical operations on the qualitative expressive variables. Therefore, the expressive variables must be converted into a fuzzy scale. The use of triangular fuzzy scales helps to improve the decision-making process. Table 3-2 Numbers It shows the corresponding phase of verbal scales taken from Tesfamariam and Sadiq's research:

Table 3.2. Fuzzy numbers corresponding to the verbal scale

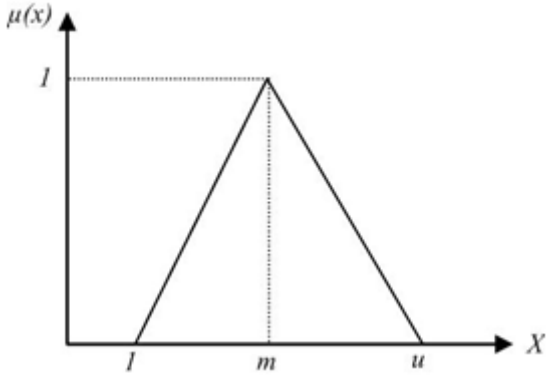
The corresponding fuzzy number scale	Fuzzy number	variable
(1،1،1)	$\tilde{1}$	the same
(1،2،3)	$\tilde{2}$	in between
(2،3،4)	$\tilde{3}$	A little more important
(3،4،5)	$\tilde{4}$	in between
(4،5،6)	$\tilde{5}$	more important
(5،6،7)	$\tilde{6}$	in between
(6،7،8)	$\tilde{7}$	Much more important
(7،8،9)	$\tilde{8}$	in between
(9،9،9)	$\tilde{9}$	Definitely more important

6. Collecting experts' opinions in the form of fuzzy numbers and forming fuzzy paired comparison tables and summarizing opinions.

A triangular fuzzy number is shown as (i, m, u). Parameters i, m, u represent the lowest possible value, the medium possible value, and the highest possible value, respectively.

$$\widetilde{a_{ij}} = (l_{ij}, m_{ij}, u_{ij}) = \widetilde{a_{ij}^{-1}} = \left(\frac{1}{u_{ij}}, \frac{1}{m_{ij}}, \frac{1}{u_{ij}}\right) \quad (3\text{-}1)$$

I,j=1,2,…,n and $i \neq j$



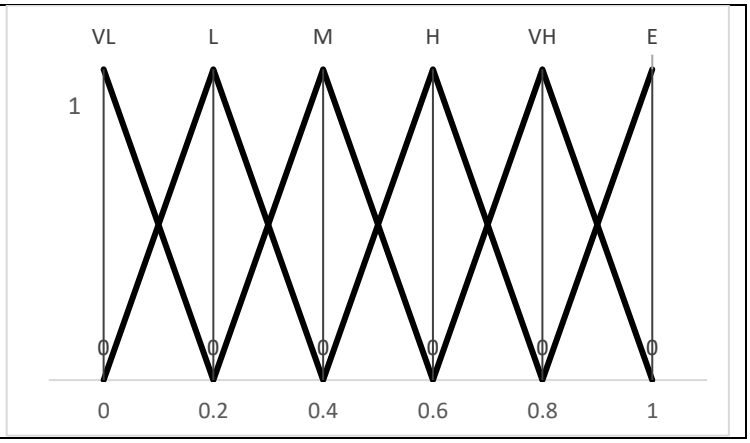
Every triangular fuzzy number has a membership function according to what is mentioned above. The fuzzy pairwise comparison matrix is given in this relation.

$$\begin{cases} \frac{x-1}{m-1} & 1 \ll x \ll m \\ \frac{u-x}{u-m} & m \ll x \ll u \\ 0 & ,otherwise \end{cases} \quad (3\text{-}2)$$

In this research, to prevent ambiguity caused by uncertainty in human decisions, in all three stages, triangular fuzzy numbers 1, 3, 5, 7, 9 are used to show the results of pairwise comparison in AHP. A triangular fuzzy number which is denoted by (i,m,u)= A(l≪m≪u) has the following function as shown in Table 3-3:

Table 3.3. Selected membership function for fuzzy numbers

Linguistic variables	Fuzzy numbers	Fuzzy numbers

Very low (VL) Low(L) Medium(M) High(H) Very high(VH) Excellent(E)	(0, 0, 0.2) (0, 0.2, 0.4) (0.2, 0.4, 0.6) (0.4, 0.6, 0.8) (0.6, 0.8, 1) (0.8, 1, 1)	

Calculating compatibility rate checks

The steps to calculate the compatibility rate are:

Performing fuzzy pairwise comparisons among all criteria

Performing a fuzzy pairwise comparison between options according to each criterion

Examining the compatibility of pairwise comparisons

Before aggregating the opinions of each expert regarding pairwise comparisons, one must be sure of the consistency of the opinions of the people. But checking the consistency of the tables of fuzzy pairwise comparisons is not as simple as checking the consistency of the definitive tables. To solve this problem, if $\tilde{A}$ = [a_ij] of the comparison matrix If there is a pair of triangular fuzzy numbers A=(l,m,u), it is enough to form the matrix A=(M) and check its compatibility. If A is compatible, then $\tilde{A}$ will also be compatible.

But when the decision matrix is not completely compatible, the compatibility index of the pairwise comparison matrix is obtained from the following equation after forming the middle values of the tables and calculating the largest eigenvalue λ_max:

$$CI = \frac{\lambda_{max} - n}{n-1} \qquad (3\text{-}3)$$

If the matrix under consideration is fully compatible, λ_max=n. The closer the matrix is to the fully compatible state, the value of λ_max will be closer to n, that is, the number of factors that are compared with each other. The compatibility index is the degree of compatibility of the decision matrix. As you can see, this index depends on n. To make this index independent from n, we divide it by another index called R.I random index. This index is from the average compatibility index of decision matrices. which are randomly generated. Table 3-4 shows the values of R.I. for different values. We call the new index C.R. compatibility rate and the relationship by Saati 1980 is as follows:

$$\mathrm{CR} = \frac{CI}{\mathrm{RI}} \qquad (3\text{-}4)$$

Table 3.4. random incompatibility indexes

Number of criteria	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
RI	*0*	*0*	*0.58*	*0.9*	*1.12*	*1.24*	*1.32*	*1.41*	*1.45*	*1.49*

After calculating the compatibility rate, comments are collected.

8. Collecting the results of performing fuzzy AHP calculations and final conclusions

3.7 Research validity

The concept of validity answers the question of how well the measurement tool measures the desired characteristic. Without knowing the validity of the measurement tool, one cannot be sure of the accuracy of the data obtained from it.

There are several methods to determine the validity of a questionnaire, one of these methods is content validity. Content validity is a type of validity that is

used to check the components of a measurement tool. The content validity of a measurement tool is based on the constituent questions. It depends. If the questions of the questionnaire represent the characteristics and skills that the researcher intends to measure, the test has content validity. To ensure the validity of the content, it is necessary to act in such a way that the questions that make up the measuring instrument represent the selected content parts. Therefore, content validity is a structural feature of the measurement tool that is woven into it at the same time as the test is developed. The content validity of a test is usually determined by people in the subject being studied. The content validity of this questionnaire has been confirmed by the consultants and managers of Nestle Company which has the necessary credibility.

Reliability or reliability is one of the technical characteristics of a measuring instrument. The mentioned concept deals with the extent to which the measuring instrument obtains the same results under the same conditions.

The range of reliability coefficient is from zero (no correlation) to +1 (complete correlation).

Among the mentioned methods for calculating reliability are the following:

1. Retry execution (retry method)
2. Parallel method (peer)
3. Ballad method (halving)
4. Coder-Richardson method
5. Cronbach's alpha method

In this research, in order to determine the reliability of the test, Cronbach's alpha method is used. This method is used to calculate the internal consistency of the measurement tool that measures different characteristics. To calculate the Cronbach's alpha coefficient, first, the variance of the scores of each It calculated the subset of questionnaire questions and the total variance. Then, using the following formula, we calculate the value of the alpha coefficient.

$$r_\alpha = \frac{J}{J-1}\left(1 - \frac{\sum_{j=1}^{n}(S^2 j)}{S^2}\right) \qquad (3\text{-}5)$$

Where in:

J = the number of subsets of questionnaire or test questions

Variance of subtest J = 〖"S²" 〗_"j"

S² = total variance of questionnaire or test

In order to measure reliability, Cronbach's alpha method has been used using SPSS software, which is 0.721 to determine the reliability, which shows that the questionnaire has acceptable reliability.

Table 3.5. Cronbach's alpha results

Reliability Statistics

Cronbach's Alpha	N of Items
0.721	20

3.8 Description of research methodology

According to what has been mentioned so far, in this research, the T-Student test is used to confirm the effectiveness of the criteria and sub-criteria, and the FAHP method, or fuzzy hierarchical analysis, is used to rank the target. The FAHP method is one of the most widely used techniques. It is a multi-criteria decision-making which is simple yet highly accurate. After calculating the results of the AHP method, we will examine the desired results. The advantage of the AHP method over other similar methods, such as Pro Methee, is simplicity in application and compared to the Electre method. It is possible to fully rank the options.

In this section, we will first get acquainted with the T-Student test, and then we will have a brief overview of the triangular fuzzy numbers and the AHP

technique and its related calculations, and finally, considering the conceptual model of the research, we will examine the steps of conducting the research.

3.8.1 T-Student test

In general, to test the hypothesis that the mean of a sample with its original mean; That is, whether the average of the population is consistent or not, in the case that the standard deviation of the population is unknown, they use the one-sample t-student test. It is assumed that the distribution of the population is always normal; usually the single sample t-test is used when the number of samples is less than 30 and the variance of the population is unknown. The statistics of this test are as follows:

$$t = \frac{\bar{X}_n - \mu}{S_n/\sqrt{n}} \quad (3\text{-}6)$$

Where:

$$S_n^2 = \frac{1}{n-1}\sum_{i=1}^{n}(X_i - \bar{X}_n)^2 \quad (3\text{-}7)$$

In this test, the average of a population is compared with a fixed value. The null hypothesis and the opposite hypothesis are defined as follows:

Zero hypotheses: the population mean is smaller and equal to the test value.

Counter hypothesis: the population mean is greater than the test value.

This test is used to test descriptive hypotheses. For this purpose, the 5-option Likert scale is used and measured. In the null hypothesis, it considers the population means to be less than a hypothetical number.

If the significance level is lower than the error level, the null hypothesis is rejected. In order to find out that the average of the community is higher than the tested value or lower than it, one should pay attention to the upper limit and the lower limit in the output of the software. In the one-sample T test, if the upper limit and the lower limit are both positive, it means that the average of the population for that variable is greater than the value under test. Also, if the first

is positive and the second is negative, the average of the population is approximately It is a test. Also, the minus sign of these two values means that the average of the desired variable in the society is less than the test value.

3.8.2 Triangular fuzzy numbers

Triangular fuzzy number which is a special type of trapezoidal fuzzy number is very famous in fuzzy applications. Triangular fuzzy number is a number with membership function $(X)_a\mu$ on R defined as the following relation:

$$(X)_a\mu = \begin{cases} \frac{X-L}{M-L} & L \ll X \ll M \\ 1 & X = M \\ \frac{X-L}{M-U} & M \ll X \ll U \end{cases} \qquad (3\text{-}8)$$

In the relation above, [L,U] is the support interval and D(M,1) is the vertex.

A triangular fuzzy number with three numbers (M, L, U) and membership function $(X)_a\mu$ is shown in Figure 2-3.

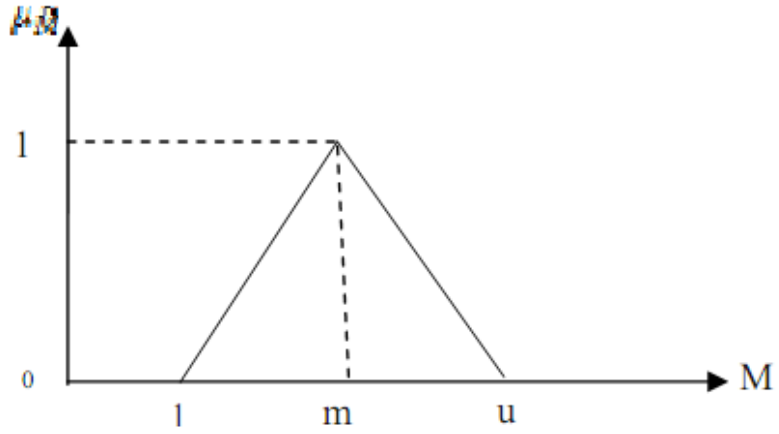


Figure3.2. Triangular fuzzy numerical representation in the form of three components

So that A_l is the left leg and A_u is the right leg of triangular fuzzy numbers.

Due to the fact that experts and decision makers have different perceptions towards each of the qualitative indicators and criteria, the scores they give are definitely different from each other. Methods or in better words, several

operators (average, median, minimum maximum and combination operators) have been proposed to aggregate decision makers' fuzzy evaluations. Since the average operator is more general than other operators, this operator has been used in the presented model. Therefore, to achieve a general value for each The index or criterion is used to calculate the average of fuzzy opinions of people. Assuming that E_{ij} is a triangular fuzzy number, the average of triangular fuzzy numbers is obtained from the following formula:

$$f(x) = (\frac{1}{m})R(E_{ij1} + E_{ij2} + \cdots + E_{ijm}) \quad (3\text{-}9)$$

The ternary form of the triangular fuzzy number E_(ij) is: $E_{ij} =$

$$(LE_{ij}, ME_{ij}, UE_{ij}) \quad (3\text{-}10)$$

According to the allowed algebraic operations on fuzzy numbers, the average fuzzy number E_(ij) can be calculated as follows

$$LE_{ij} = \frac{\sum_{k=1}^{m} LE_{ij}^{k}}{m} \quad (3\text{-}11)$$

$$ME_{ij} = \frac{\sum_{k=1}^{m} ME_{ij}^{k}}{m} \quad (3\text{-}12)$$

$$UE_{ij} = \frac{\sum_{k=1}^{m} UE_{ij}^{k}}{m} \quad (3\text{-}13)$$

In this way, by integrating the experts' opinions, a fuzzy number is obtained, which is the result of the average of the decision makers' opinions.

- Fuzzy Analytical Hierarchy Process (AHP).

Hierarchical analysis process was proposed for the first time in 1980 by Saati. This approach examines issues similarly to how the human brain does it. Decision-makers can take into account the concurrent interplay of numerous complicated and uncertain circumstances using hierarchical analysis. With the aid of this process, decision-makers can establish priorities that completely take into account their emotions and judgments while also basing them on their

goals, knowledge, and experience. A hierarchical structure must be meticulously specified, thoroughly explained, and illustrated in order to handle decision issues using AHP. Despite the many capabilities of this method in solving problems, the AHP method uses a pair matrix in order to rank preferences, which data Its input is certain, and in cases where the input data faces some kind of ambiguity or uncertainty, this method cannot be used to achieve the desired results. To solve this problem, Professor Lotfi Asgarzadeh (1965) developed the fuzzy theory in relation to the resulting uncertainty. The most important feature of the set is its ability to show Dan is important and uncertain data.

The fuzzy AHP technique is one of the MADM multi-criteria decision-making techniques and has the advantage of being able to evaluate different options according to various criteria that do not have the same units. This is an important advantage over traditional methods that all criteria must be Convert to the same units.

Although the AHP method considers the knowledge of experts, the traditional AHP method actually does not fully reflect the opinions of people and their risk. In the decision-making environment of the AHP method, the input information and the relationships between criteria and alternatives are illogical and ambiguous. In order to improve these disadvantages, researchers have proposed the use of fuzzy logic in the AHP method. Therefore, the development of the AHP method is called fuzzy AHP.

The fuzzy version of the AHP technique includes situations that are ambiguous or not properly defined. Many fuzzy AHP methods have been proposed by different people, which are systematic approaches to option selection using the concept of fuzzy set theory and Analysis of the hierarchical structure.

As an analytical method, Saati in 1980 combined fuzzy sets with analysis hierarchy to provide a suitable method for solving multi-criteria decision

problems. Therefore, fuzzy AHP as an extension of AHP was presented.in solving fuzzy hierarchical problems.

Vanlahoven and Petrich (1983) introduced triangular fuzzy numbers based on vector operations in order to express the decision maker's opinions about alternatives for each criterion. Chang (1996) introduced triangular fuzzy numbers as a new approach in fuzzy AHP. This approach uses triangular fuzzy numbers for pairwise comparisons in fuzzy AHP. Then Zhou et al. (1999) discussed the development analysis of this method and its applications. They proved the theory of triangular fuzzy numbers and improved the formulation of triangular fuzzy number comparisons.

Fuzzy AHP method has been used in many evaluation and selection problems. Many researchers have used the fuzzy AHP method for evaluation and selection. Below are the ranking steps using the FAHP technique as follows:

- The first step - drawing the decision tree:

At this stage, a decision tree should be drawn in which the three levels of the objective, criteria and options are available.

- The second step - making pairwise comparisons:

In this step, in addition to the mutual comparison of the verified variables, each of the industries should be compared based on each variable. Since the paired comparison table must be completed by fuzzy triangular numbers in order to be solved through fuzzy hierarchical analysis, this table should also be completed by the fuzzy number M(l,m,u). But since it is very difficult to collect this information, the range from 0 to 10 can be used to complete these tables. Meanwhile, each of these, the numbers represent a triangular or trapezoidal number that must be converted into fuzzy numbers after completing the tables in the form of numbers. Also, since the fuzzy hierarchical analysis technique proposed in this research only uses fuzzy triangular numbers, then it should be also converted trapezoidal numbers into triangular ones. Table 3-6 shows the equivalent fuzzy numbers with linguistic variables.

Table 3.6.Fuzzy numbers equivalent to fuzzy variables

Very much	**Much**	**More or less**	**medium**	**More or less**	**Low**	**Very low**	**variable**
Trapezoidal	**Triangular**	**Trapezoidal**	**Triangular**	**Trapezoidal**	**Triangular**	**Trapezoidal**	**Fuzzy number type**
(0.8,0.9,1,1)	(0,0.7,0.8,0.9)	(0.5,0.6,0.7,0.8)	(0,0.4,0.5,0.6)	(0.2,0.3,0.4,0.5)	(0,2,0.2,0.3)	(0,0,0.1,0.2)	fuzzy number
(0.8,0.95,1)	(0.7,0.8,0.9)	(0.5,0.65,0.8)	(0.4,0.5,0.6)	(0.2,0.35,0.5)	(0.2,0.2,0.3)	(0,0.05,0.2)	Fuzzy triangular number

- The third step - performing calculations in FAHP

In this step, using the definitions presented in the previous sections, the coefficients of each of the matrices of pairwise comparisons are calculated. For this purpose, the formulas required at this stage will be as follows:

After collecting the opinions of experts, these opinions should be formed in the form of fuzzy numbers so that the calculation process can be done. For this purpose, the formulas required at this stage will be as follows.

$$l_{ij} = \left(\prod_{k=1}^{k} l_{ijk}\right)^{\frac{1}{k}} \qquad (3\text{-}14)$$

$$m_{ij} = \left(\prod_{k=1}^{k} m_{ijk}\right)^{\frac{1}{k}} \qquad (3-15)$$

$$u_{ij} = \left(\prod_{k=1}^{k} u_{ijk}\right)^{\frac{1}{k}} \qquad (3\text{-}16)$$

In this step, the matrix of pairwise comparisons is obtained as follows:

$$\begin{bmatrix} (1,1,1) & (l_{a_{12}}, m_{a_{12}}, u_{a_{12}}) & \dots & (l_{a_{1n}}, m_{a_{1n}}, u_{a_{1n}}) \\ \left(\frac{1}{l_{a_{12}}}, \frac{1}{m_{a_{12}}}, \frac{1}{u_{a_{12}}}\right) & (1,1,1) & \dots & (l_{a_{2n}}, m_{a_{2n}}, u_{a_{2n}}) \\ \vdots & \vdots & \vdots & \vdots \\ \left(\frac{1}{l_{a_{1n}}}, \frac{1}{m_{a_{1n}}}, \frac{1}{u_{a_{1n}}}\right) & \left(\frac{1}{l_{a_{2n}}}, \frac{1}{m_{a_{2n}}}, \frac{1}{u_{a_{2n}}}\right) & \dots & (1,1,1) \end{bmatrix}$$

For each line of paired comparisons, the value of s_i, which is itself a triangular fuzzy number, is calculated as follows (Asgharpour, 2017):

$$s_i = \sum_{j=1}^{n} M_{g_i}^{i} \otimes \left[\sum_{j=1}^{n} \sum_{i=1}^{m} M_{g_i}^{j}\right]^{-1} \qquad (3\text{-}17)$$

where j and i represent the options and indices respectively. In the mentioned method, after calculating the s_i, their relative magnitude should be obtained. In general, if S_(1) and S_(2) are two triangular fuzzy numbers , the degree of magnitude of S_(1) over S_(2), which is represented by V(S_(1)≫S_(2)), is defined as follows:

$$\begin{cases} V(S_1 \gg S_2) = 1 & if: \ m_1 \gg m_2 \\ V(S_1 \gg S_2) = hgt\,(M_1 \cap M_2) & otherwise \end{cases} \qquad (3-18)$$

$$hgt(M_1 \cap M_2) = \frac{l_2 - u_1}{(m_1 - u_1) - (m_2 - l_2)} \qquad (3-19)$$

$$V(S_1 \gg S_2) = \begin{cases} 1 & m_1 \geq m_2 \\ \dfrac{l_2 - u_1}{(m_1 - u_1) - (m_2 - l_2)} & m_1 < m_2 \end{cases} \qquad (3-20)$$

$$V(S_1 \gg S_2, \dots, S_k) = \text{Min}\,[V(S_1 \gg S_2), \dots, V(S_1 \gg S_k)] \qquad (3-21)$$

$$W'(S_i) = \text{Min}[V(S_i \gg S_k), k = 1, \dots, n, k \neq i] \Rightarrow W' = [W'(S_1), \dots, W'(S_n)] \qquad (3-22)$$

$$w_i = \frac{w_i'}{\sum w_i'} \qquad (3\text{-}23)$$

$$A_{n*n} = F_{n*n} * W_{n*n} \qquad (3\text{-}24)$$

F: The weight of the options

W: weight related to criteria

A: The final weight of the options

- Fourth step- prioritizing the options

After the weight of each option is determined, the options can be sorted based on their weight.

3.9 Carbon footprint

A carbon footprint calculates the volume of carbon dioxide (CO2) that a person, business, or society releases into the atmosphere as a consequence of its operations. We'll be examining a case study's ecological impact in this instance. However, for the sake of simplicity, the following emissions are typically converted to CO2 or its equivalent to produce a carbon footprint, in accordance with the Kyoto Protocol (an international agreement to limit and reduce

production of greenhouse gases (GHG) across the EU). There are other emissions to take into account in addition to carbon dioxide.

Depending on how "direct" they are, various categories of GHG emissions are defined:

Scope 1 emissions are direct emissions from case study. This includes emissions from combustion of fuels from furnaces and vehicles, as well as emissions from chemical production.

Scope 2 emissions are unavoidable emissions caused by the use of purchased electricity from non-owned utility suppliers. This encompasses steam, heating, power, and cooling.

All secondary emissions that are not covered by scope 2 fall under scope 3 emissions. This includes everything connected to your company's operations that is not under your direct control or ownership, including your entire supply chain, employee and business travel, waste production, purchased goods and materials, office technology, assets, and investments, as well as customer use of your goods and services. basically, anything not covered by scopes one and two. The greatest GHG effect is typically caused by scope 3 pollution for most companies. You must cut carbon emissions across all three areas if you want to perform a thorough emissions inventory.

It can take a lot of effort and skill to report and reduce carbon emissions.

For case study organization, it should begin with the creation of an emissions inventory, documenting each activity, service, and product in order of highest to lowest emissions. You will be able to determine the worst violators by gathering this information on energy use and carbon pollution. It's important to keep in mind that just because something uses less energy, it doesn't necessarily mean that its pollutants are lower.

- The following list includes some of the major producing regions. They can be determined using their individual bills or by asking your utility providers for information:
- transport fleets
- fuel for vehicles
- manufacturing
- staff travel
- electricity
- gas and oil
- office equipment
- air conditioning maintenance
- specialist equipment maintenance
- water
- waste

Generally, the equation you want to end up with is:

'Total energy consumption (fuel, electricity) x Emission Factors (fuel, electricity) = carbon dioxide equivalent (CO2e)'

Chapter 4: Results Analysis

4.1 Introduction

In the previous chapters, the theoretical foundations and method of conducting this research were examined in detail. In this chapter, the method of analyzing the collected data is described and the research steps are also described in detail. In this chapter, by using statistical tests appropriate to the research method and the type of variables explained in the third chapter, we will deal with the main mission of the research, which is to answer the research questions and achieve the research goals based on the obtained data. It includes fuzzy hierarchical

analysis. It should be noted that the statistical population of this research includes food industry experts.

According to the criteria identified in the relevant literature and based on the Swafford model, 15 criteria were identified, which were given to the experts of the food industry company through the questionnaire attached 1, and in this way, the importance of the criteria was determined.

After the factors affecting the choice of strategy (criteria) were identified, a decision tree was drawn by categorizing them into criteria and sub-criteria groups, and finally, using the final decision tree, a pairwise comparison questionnaire was prepared. Then using the method FAHP, criteria and sub criteria are weighted and finally strategies are prioritized.

4-2 Obtaining a hierarchical structure from finding criteria and sub-criteria and effective options in the problem

As mentioned before, this research intends to rank the options using the FAHP method and identify the most important ones. From the confirmation of the effectiveness of the criteria and sub-criteria, the conceptual and hierarchical model for evaluating and ranking the options is shown in Figure 1-4. As mentioned in the second chapter in the conceptual framework of the research, this model is derived from Swafford model and Lane model in 2006 and Faisal model in 2007. In this section, according to the research questions and research hypotheses for determining and choosing the effective criteria and sub-criteria, the test of the criteria's assumptions was investigated separately. The other criteria and sub-criteria are the same, the initial information of which was collected in the form of a questionnaire in Appendix No. 1 from experts according to the Likert scale, and then it was examined and analyzed through a one-sample Student's t-test.

Hypothesis 1: The flexibility of product development as the main criterion has a positive and significant effect on the choice of agile supply chain implementation strategy.

The assumptions of the test are:

$H_0 : \mu \ll 3$

The impact of product development flexibility index on the choice of agile supply chain implementation strategy is not high.

$H_1 : \mu > 3$

The impact of product development flexibility index on the choice of agile supply chain implementation strategy is high.

Table 4.1. The result of the hypothesis test of product development flexibility criterion

One-Sample Test

	Test Value = 3					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
c1	3.162	4	.034	1.00000	.1220	1.8780

Considering that based on the One Sample T-Test and at the error level of 0.05, the obtained significance level was less than 0.05 and the statistical value was positive, the statistical hypothesis H_(0) is rejected and the hypothesis H_1 is confirmed. In other words, with 95% confidence, it can be said that the product development flexibility index is effective on the agile supply chain. Similarly, in the following tables, the hypothesis test results of all the main criteria and sub-criteria of the problem were obtained.

Table 4.2. The result of the test of the hypothesis of the criterion of manufacturing and production flexibility One-Sample Test

	Test Value = 3					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
c2	3.162	4	.034	1.00000	.1220	1.8780

Table 4.3. The result of the hypothesis test of information technology flexibility criterion

One-Sample Test

	Test Value = 3					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
c3	3.162	4	.034	1.00000	.1220	1.8780

Table 4-4 The result of the hypothesis test of logistics flexibility criterion

One-Sample Test

	Test Value = 3					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
c4	3.207	4	.033	1.20000	.1611	2.2389

Table 4.5. The result of the hypothesis test of procurement flexibility criterion

One-Sample Test

	Test Value = 3

	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
C5	3.207	4	.033	1.20000	.1611	2.2389

In the same way, table 4-6 was obtained for the results of the hypothesis test under the criteria of the problem.

Table 4.6. Hypothesis test results based on sub-criteria of the problem

Test Value = 3				
Resullt	**Sig. (2-tailed)**	**t**	**Mean**	**Sub criteria**
Confirmed	.025	3.500	4.4000	Ability to reduce product development cycle time
Confirmed	.034	3.162	4.0000	Ability to design multiple products
Confirmed	.034	3.162	4.0000	Percentage of assets with the possibility of reuse
Confirmed	.034	3.162	4.0000	The ability to change the composition of products
Confirmed	.034	3.162	4.0000	Speed in the production of new products
Confirmed	.034	3.162	4.0000	The number of methods available (available) to increase capacity
Confirmed	.034	3.162	4.0000	Percentage of supply chain directly supported by IT
Confirmed	.034	3.162	4.0000	IT's ability to adapt to support new distribution channels
Confirmed	.033	3.207	4.2000	The number of methods available in IT systems to analyze the competitive environment and discover changes
Confirmed	.034	3.162	4.0000	Ability to add or remove delivery channels
Confirmed	.033	3.207	4.2000	The ability to change the overall capacity of the logistics network

Confirmed	.034	3.162	4.0000	Number of warehouses available for storage
Confirmed Confirmed Confirmed	.033	3.207	4.2000	Number of capable suppliers for each material and in each period
	.034	3.162	4.0000	Permeability on supplier performance
	.033	3.207	4.2000	The speed of starting cooperation with a new supplier

Finally, the effective criteria and sub-criteria are shown.

Table 4.7. Indicators and sub-indices affecting strategy selection

Sub-index	**Index**
Ability to reduce product development cycle time	Product development flexibility
Ability to design multiple products	
Percentage of assets with the possibility of reuse	
The ability to change the composition of products	Manufacturing flexibility
Speed in the production of new products	
The number of methods available (available) to increase capacity	
Percentage of supply chain directly supported by IT	Information technology flexibility
IT's ability to adapt to support new distribution channels	
The number of methods available in IT systems to analyze the competitive environment and discover changes	
Ability to add or remove delivery channels	Logistics flexibility
The ability to change the overall capacity of the logistics network	
Number of warehouses available for storage	
Number of capable suppliers for each material and in each period	Procurement flexibility
Permeability on supplier performance	
The speed of starting cooperation with a new supplier	

Figure 4-1 shows the hierarchical tree of decision-making levels, which was created based on conducting interviews and surveys with experts. The first level includes the goal, the second level includes the main indicators of agile supply chain implementation, and the third level includes the following their indicators. The overall goal is to choose a better strategy for implementing an agile supply chain. The strategies are:

Process integration, information integration, network integration, customer and market promotion, participatory management

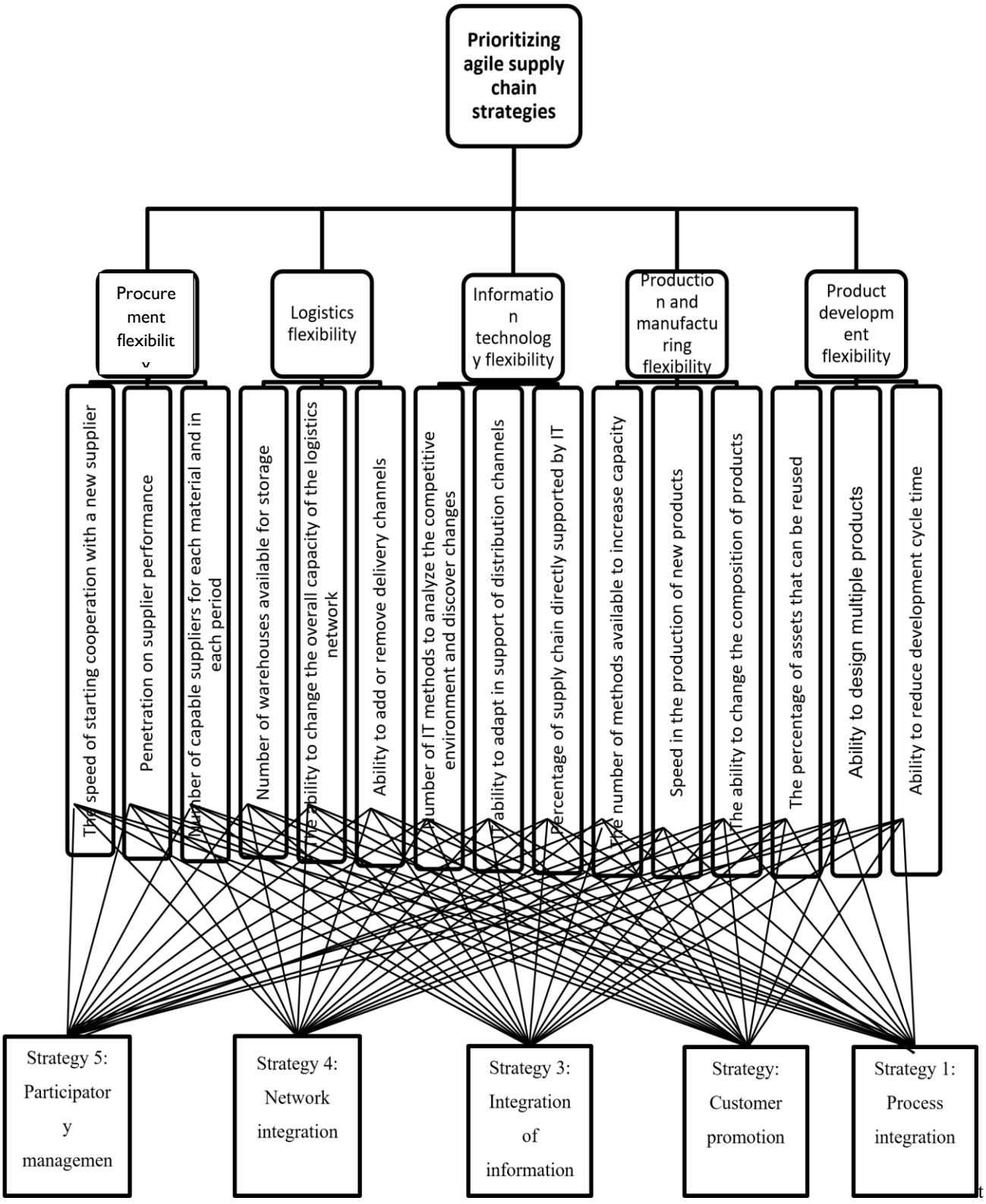


Figure 4.1. Hierarchical tree of decision levels

After determining the effective criteria and options, the next step is to evaluate and rank the criteria and options based on the methods and methodology described in the third chapter.

4-2-1- Collecting the opinions of experts in the form of fuzzy numbers and creating fuzzy paired comparison tables and summarizing the opinions of experts.

After determining the criteria and sub-criteria affecting the agile supply chain which are shown in Table 4-8, in order to determine the weight of different parameters, survey forms including all the above indices and sub-indices were prepared and given to 8 experts. In this form, the experts were asked to express the importance of each parameter according to the verbal variables in the table below.

Table 4.8. of fuzzy spectrums used in AHP (source: Lin, 2010)

Corresponding triangular fuzzy numbers	Linguistic criteria
(1،1،1)	the same
(1،2،3)	medium
(2،3،4)	A little more important
(3،4،5)	medium
(4،5،6)	more important
(5،6،7)	medium
(6،7،8)	Much more important
(7،8،9)	medium
(9،9،9)	Definitely more important

In this way, the tables of fuzzy pairwise comparisons were completed from the opinions of all experts. As mentioned in the sections on the necessary steps to conduct research, in this step we must make sure that the opinions of the experts are consistent. To check the consistency of the summation of experts' opinions, a matrix is formed from the middle numbers of the pairwise comparison table. To calculate the eigenvalue λ_max, we calculate the determinant of the

corresponding matrix. The determinant of the corresponding matrix is the value of λ_max .

$$= \frac{\lambda^{max} - n}{n-1} \quad \textbf{(4-1)}$$

$$\textbf{CR} = \frac{CI}{\_} \quad \textbf{(4-2)}$$

In this research, the value of R.I based on n=5 is equal to 1.12. After checking the compatibility rate of judgments of each person, it was found that in 2 cases the compatibility rate was higher than 0.1. For this reason, the questionnaire was returned to them and they were asked to do pairwise comparisons again. Finally, after determining the inconsistency rate of paired comparisons made by experts, all the questionnaires had inconsistency rate less than 0.1, from which we conclude that the combination of opinions is consistent for the paired comparison tables.

For the sake of brevity, the expression of the matrix of pairwise comparisons of all experts is omitted and the matrix of pairwise comparison of a group is shown. Of course, in order to clarify this topic, in this part, as an example of the pairwise comparison matrices of one of the experts in Pairwise comparisons between main indicators are given.

• Pairwise comparisons between main indicators

Table 4.9. Matrix of pairwise comparisons of the main indicators for the first expert

Procurement flexibility			**Logistics flexibility**			**Information technology flexibility**			**Production manufacturing and flexibility**			**Product development flexibility**			
0.11	0.11	0.11	0.11	0.11	0.11	0.17	0.14	0.13	0.17	0.14	0.13	1.00	1.00	1.00	Product development flexibility
0.17	0.14	0.13	0.50	0.33	0.25	1.00	1.00	1.00	1.00	1.00	1.00	7.69	7.14	5.88	Production and manufacturing flexibility
0.11	0.11	0.11	0.25	0.20	0.17	1.00	1.00	1.00	1.00	1.00	1.00	7.69	7.14	5.88	Information technology flexibility
0.17	0.14	0.13	1.00	1.00	1.00	5.88	5.00	4.00	4.00	3.03	2.00	9.09	9.09	9.09	Logistics flexibility
1.00	1.00	1.00	7.69	7.14	5.88	9.09	9.09	9.09	7.69	7.14	5.88	9.09	9.09	9.09	Procurement flexibility
0.003															Incompatibility rate

To calculate the pairwise comparison matrix of a group, the geometric mean is used, which causes the corresponding levels to be combined in all the pairwise comparison matrices. Also, to calculate the relative weight of each pairwise comparison matrix, Chang's developmental analysis method is used.

Table 4.10. Matrix of group pairwise comparisons of main indicators

Procurement flexibility			**Logistics flexibility**			**Information technology flexibility**			**Production and manufacturi flexibility**			**Product development flexibility**			
3	2	1	3	2	1	4	3	1.5	2.5	2	1	1	1	1	Product development flexibility
1	0.5	0.4	2	0.66	0.5	1	0.5	0.33	1	1	1	1	0.5	0.4	Production and manufacturing flexibility
0.4	1.5	1	4	2.5	3	1	1	1	3	2	1	0.66	0.33	0.25	Information technology flexibility
2.4	1	3	1	1	1	0.33	2.5	0.25	2	1.5	0.5	1	0.5	0.33	Logistics flexibility
1	1	1	0.33	1	2	1	0.66	2.5	2.5	2	1	1	0.5	0.33	Procurement flexibility

After the formation of the pairwise comparison matrices, the weight vectors should be determined using the fuzzy hierarchical analysis method, and these calculations are as follows in Table 4-11.

Table 4.11. calculation $\square M_{gi}^{j}$

S_i for each row of the pairwise comparison matrix is equal to

$$\mathbf{S_i} = \sum_{j=1}^{n} M_{g_i}^{i} \otimes \left[\sum_{j=1}^{n} \sum_{i=1}^{m} M_{g_i}^{j}\right]^{-1} \qquad \textbf{(4-3)}$$

where j and i represent the options and indicators respectively. The relevant calculations are shown in Table 4-12:

Table 4.12. Calculation of S_i for criteria

S_i			$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$				$\sum_{j=1}^{m} M_{gij}$			
0.5135	0.3110	0.1337	0.038037277	0.031104199	0.024319066		13.500	10.000	5.500	S_1
0.2282			0.0982	0.0639	0.038037277	0.031104199	0.024319066		6.000	3.160	2.630	S_2
0.3446			0.2279	0.1519	0.038037277	0.031104199	0.024319066		9.060	7.330	6.250	S_3
0.2559			0.2021	0.1235	0.038037277	0.031104199	0.024319066		6.730	6.500	5.080	S_4
0.2217			0.1604	0.1660	0.038037277	0.031104199	0.024319066		5.830	5.160	6.830	S_5

$j=1$

$\sum_{j=1}^{m} M_{gi}^{j}$			Logistics flexibility			Logistics flexibility			Information technology flexibility			Production and manufacturing flexibility			Product development flexibility			
13.500	10.000	5.500	3	2	1	3	2	1	4	3	1.5	2.5	2	1	1	1	1	Product development flexibility
6.000	3.160	2.630	1	0.5	0.4	2	0.66	0.5	1	0.5	0.33	1	1	1	1	0.5	0.4	Production and manufacturing flexibility
9.060	7.330	6.250	0.4	1.5	1	4	2.5	3	1	1	1	3	2	1	0.66	0.33	0.25	Information technology flexibility
6.730	6.500	5.080	2.4	1	3	1	1	1	0.33	2.5	0.25	2	1.5	0.5	1	0.5	0.33	Logistics flexibility
5.830	5.160	6.830	1	1	1	0.33	1	2	1	0.66	2.5	2.5	2	1	1	0.5	0.33	Logistics flexibility
41.120	32.150	26.290	$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}$															
0.0380	0.0311	0.0243	$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$															

The degree of magnitude of each of them will be as follows:

$$V(S_1 \gg S_2) = \begin{cases} 1 & m_1 \geq m_2 \\ \frac{2 - 1}{(m_1 - u_1) - (m_2 - l_2)} & m_1 < m_2 \end{cases} \quad (4\text{-}4)$$

$$V(S_1 \gg S_2, \dots, S_k) = \text{Min}\,[V(S_1 \gg S_2), \dots, V(S_1 \gg S_k)] \quad (4\text{-}5)$$

$V(S_1 \gg S_2)=1$ $V(S_1 \gg S_3)=1$ $V(S_1 \gg S_4)=1$ $V(S_1 \gg S_5)=1$
$V(S_2 \gg S_1)=0.30$ $V(S_2 \gg S_3)=0.37$ $V(S_2 \gg S_4)=0.50$ $V(S_2 \gg S_5)=0.49$
$V(S_3 \gg S_1)=0.71$ $V(S_3 \gg S_2)=1$ $V(S_3 \gg S_4)=1$ $V(S_3 \gg S_5)=1$
$V(S_4 \gg S_1)=0.52$ $V(S_4 \gg S_2)=1$ $V(S_4 \gg S_3)=0.80$ $V(S_4 \gg S_5)=1$
$V(S_5 \gg S_1)=0.36$ $V(S_5 \gg S_2)=1$ $V(S_5 \gg S_3)=0.50$ $V(S_5 \gg S_4)=0.70$

$$W'(S_i) = \text{Min}[V(S_i \gg S_k), k = 1, \dots, n, k \neq i] \Rightarrow W' = [W'(S_1), \dots, W'(S_n)] \quad (4\text{-}6)$$

$$\mathbf{w_i = \frac{w'_i}{\sum_i w'}} \quad \mathbf{(4\text{-}7)}$$

Table 4.13. Calculation of the relative weight of criteria

Normalized weight	Weight is not normalized	
0.342	1	Product development flexibility
0.105	0.307494	Production and manufacturing flexibility
0.245	0.717438	Information technology flexibility
0.181	0.52893	Logistics flexibility
0.126	0.368911	Procurement flexibility

Therefore, the relative weight of each of the criteria is determined, which is shown in Table 4-13. Also, Figure 4-2 shows the relative importance of the main criteria of the problem in comparison with each other graphically. In order of importance are:

Flexibility of product development, flexibility of information technology, flexibility of logistics, flexibility of procurement and flexibility of manufacturing and production

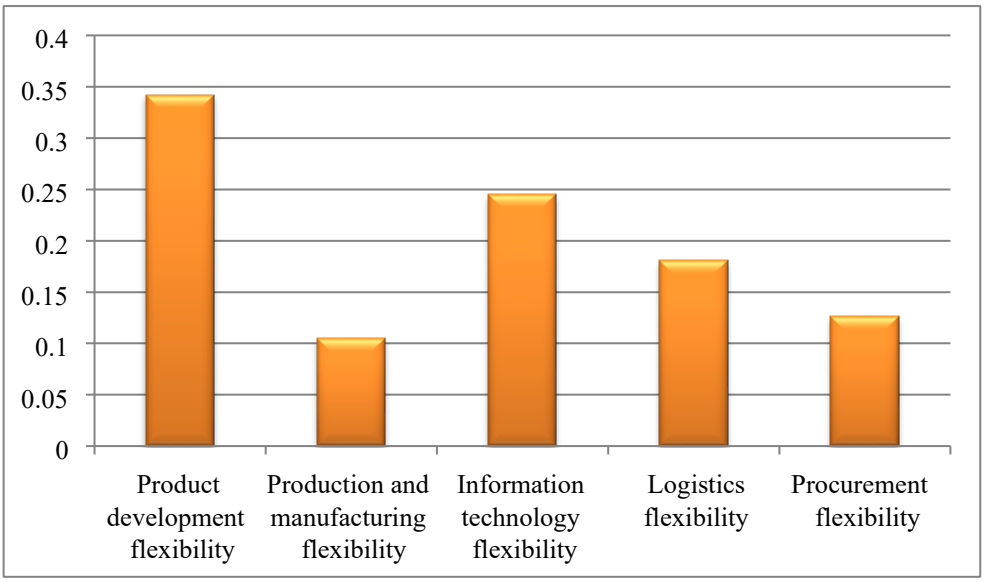


Figure 4.2. Ranking chart of main indicators

- **Pairwise comparisons between sub-indices**

To calculate the relative weight of each of the sub-indices, we act in the order described in the previous section. Here, for the sake of brevity, the relative weight of each sub-criterion after calculation is included in the last column of the pairwise comparison table, which is shown in table number 4-14 to 4-18.

Table 4.14. .Matrix of pairwise comparisons of product development flexibility index

Weight	Percentage of assets with the possibility of reuse			Ability to design multiple products			Ability to reduce product development cycle time			
0. 27	3.78	3.16	2.49	1.55	1.25	0.98	1.00	1.00	1.00	Ability to reduce product develoment cycle time
0. 36	5.72	4.66	3.57	1.00	1.00	1.00	1.02	0.80	0.64	Ability to design multiple products
0. 36	1.00	1.00	1.00	0.28	0.21	0.17	0.40	0.32	0.26	Percentage of assets with the possibility of reuse

Table 4.15. Matrix of group pairwise comparisons of production and manufacturing flexibility index

Weight	The number of methods available (available) to increase capacity			Speed in the production of new products			The ability to change the composition of products			
0.34	3.29	2.53	1.89	1.32	1.00	0.76	1.00	1.00	1.00	The ability to change the composition of products
0.32	3.10	2.37	1.74	1.00	1.00	1.00	1.32	1.00	0.76	Speed in the production of new products
0. 34	1.00	1.00	1.00	0.57	0.42	0.32	0.53	0.40	0.30	The number of methods available (available) to increase capacity

Table 4.16. matrix of group pairwise comparisons of information technology flexibility index

Weight	The number of methods available in IT systems to analyze the competitive environment and discover changes			IT's ability to adapt to support new distribution channels			Percentage of supply chain directly supported by IT			
0.35	1.15	0.95	0.82	0.87	0.72	0.61	1.00	1.00	1.00	Percentage of supply chain directly supported by IT
0.35	2.17	2.04	1.89	1.00	1.00	1.00	1.64	1.38	1.15	IT's ability to adapt to support new distribution channels
0.30	1.00	1.00	1.00	0.53	0.49	0.46	1.22	1.06	0.87	The number of methods available in IT systems to analyze the competitive environment and discover changes

Table 4.17. Matrix of pairwise comparisons of logistics flexibility index

Weight	Number of warehouses available for storage			The ability to change the overall capacity of the logistics network			Ability to add or remove delivery channels			
0. 28	2.22	1.71	1.35	1.15	0.86	0.66	1.00	1.00	1.00	Ability to add or remove delivery channels
0. 67	4.70	3.68	2.64	1.00	1.00	1.00	1.51	1.17	0.87	The ability to change the overall capacity of the logistics network
0. 04	1.00	1.00	1.00	0.38	0.27	0.21	0.74	0.58	0.45	Number of ware houses available for storage

Table 4.18. Matrix of paired group comparisons of flexibility index of procurement flexibility

Weight	The speed of starting cooperation with a new supplier			Permeability supplier performance on			Number of capable suppliers for each material and in each period			
0.38	3.57	2.95	2.30	3.87	3.27	2.64	1.00	1.00	1.00	Number of capable suppliers for each material and in each period
0.38	1.89	1.37	1.00	1.00	1.00	1.00	0.38	0.31	0.26	Permeability on supplier performance
0.24	1.00	1.00	1.00	1.00	0.73	0.53	0.44	0.34	0.28	The speed of starting cooperation with a new supplier

- **Comparison between options based on sub-indexes**

Tables 4-19 to 4-33 are related to the comparison between options and sub-indices:

Table 4.19. Matrix of paired group comparisons of options based on the index of the ability to reduce product development cycle time

Weight	Strategy :5 Participatory Management			Strategy:4 Network integration			Strategy :3 Information integration			Strategy :2 Customer and market promotion			Strategy: 1 Process integration			
0.27	3.10	2.71	2.41	2.22	1.69	1.32	2.00	1.55	1.15	3.30	2.80	2.37	1.00	1.00	1.00	Strategy: 1Process integration
0.15	5.10	4.08	3.03	1.55	1.22	1.00	0.54	0.42	0.35	1.00	1.00	1.00	0.42	0.36	0.30	Strategy: 2 Customer and market promotion
0.25	4.10	3.50	2.86	1.89	1.72	1.52	1.00	1.00	1.00	2.90	2.38	1.84	0.87	0.65	0.50	Strategy: 3 Information integration
0.04	3.10	2.37	1.74	1.00	1.00	1.00	0.66	0.58	0.53	1.00	0.82	0.64	0.76	0.59	0.45	Strategy: 4 Network integration
0.27	1.00	1.00	1.00	0.57	0.42	0.32	0.35	0.29	0.24	0.33	0.25	0.20	0.42	0.37	0.32	Strategy: 5 Participatory management

Table 4.20. Matrix of paired group comparisons of options based on the index of ability to design multiple products

Weight	Strategy:5 Participatory Management			Strategy:4 Network integration			Strategy:3 Information integration			Strategy:2 Customer and market promotion			Strategy: 1 Process integration			
0.29	3.38	2.94	2.57	5.40	4.36	3.29	2.00	1.84	1.64	1.18	0.89	0.70	1.00	1.00	1.00	Strategy: 1Process integration
0.13	1.75	1.47	1.26	3.03	2.71	2.35	1.89	1.37	1.07	1.00	1.00	1.00	1.43	1.13	0.85	Strategy:2 Customer and market promotion
0.16	5.10	4.08	3.03	2.05	1.90	1.74	1.00	1.00	1.00	0.93	0.73	0.53	0.61	0.54	0.50	Strategy:3 Information integration
0.29	2.35	1.90	1.52	1.00	1.00	1.00	0.57	0.53	0.49	0.43	0.37	0.33	0.30	0.23	0.19	Strategy:4 Network integration
0.11	1.00	1.00	1.00	0.66	0.53	0.43	0.33	0.25	0.20	0.79	0.68	0.57	0.39	0.34	0.30	Strategy:5 Participatory Management

Table 4.21. Pairwise comparison matrix of options based on the index of the percentage of assets with the possibility of reuse

Weight	Strategy:5 Participatory Management			Strategy:4 Network integration			Strategy:3 Information integration			Strategy:2 Customer and market promotion			Strategy: 1 Process integration			
0.20	3.03	2.41	1.74	0.76	0.51	0.38	1.32	1.25	1.15	4.34	3.32	2.30	1.00	1.00	1.00	Strategy: 1Process integration
0.15	0.66	0.58	0.53	0.33	0.24	0.20	1.74	1.24	0.87	1.00	1.00	1.00	0.44	0.30	0.23	Strategy:2 Customer and market promotion
0.18	0.87	0.64	0.50	0.49	0.42	0.39	1.00	1.00	1.00	1.15	0.81	0.57	0.87	0.80	0.76	Strategy:3 Information integration
0.33	2.93	2.37	1.85	1.00	1.00	1.00	2.58	2.36	2.02	5.04	4.09	3.03	2.64	1.95	1.32	Strategy:4 Network integration
0.12	1.00	1.00	1.00	0.54	0.42	0.34	2.00	1.56	1.15	1.88	1.72	1.52	0.57	0.42	0.33	Strategy:5 Participatory Management

Table 4.22. Matrix of pairwise comparisons of options based on the index of the ability to change the composition of products

Weight	Strategy:5 Participatory Management			Strategy:4 Network integration			Strategy:3 Information integration			Strategy:2 Customer and market promotion			Strategy: 1 Process integration			
0.14	1.74	1.24	0.87	1.32	1.00	0.76	1.25	1.00	0.81	0.94	0.71	0.57	1.00	1.00	1.00	Strategy: 1Process integration
0.22	2.86	2.14	1.52	1.25	1.11	1.00	0.76	0.51	0.38	1.00	1.00	1.00	1.74	1.41	1.06	Strategy:2 Customer and market promotion
0.35	2.64	2.07	1.52	3.29	2.67	2.00	1.00	1.00	1.00	2.64	1.95	1.32	1.24	1.00	0.80	Strategy:3 Information integration
0.16	2.64	1.93	1.32	1.00	1.00	1.00	0.50	0.37	0.30	1.00	0.90	0.80	1.32	1.00	0.76	Strategy:4 Network integration
0.11	1.00	1.00	1.00	0.76	0.52	0.38	0.66	0.48	0.38	0.66	0.47	0.35	1.15	0.81	0.57	Strategy:5 Participatory Management

Table 4.23. Matrix of pairwise comparisons of options based on speed index in the production of new products

Weight	Strategy:5 Participatory Management			Strategy:4 Network integration			Strategy:3 Information integration			Strategy:2 Customer and market promotion			Strategy: 1 Process integration			
0.36	1.25	1.07	0.93	4.34	3.32	2.30	3.29	2.67	2.00	3.65	2.90	2.30	1.00	1.00	1.00	Strategy: 1Process integration
0.24	0.65	1.43	0.51	0.82	0.57	0.44	0.44	0.30	0.23	1.00	1.00	1.00	0.44	0.34	0.27	Strategy:2 Customer and market promotion
0.23	1.55	1.22	1.00	2.49	2.14	1.74	1.00	1.00	1.00	4.32	3.35	2.30	0.50	0.37	0.30	Strategy:3 Information integration
0.09	0.94	0.71	0.57	1.00	1.00	1.00	0.57	0.47	0.40	2.30	1.76	1.22	0.44	0.30	0.23	Strategy:4 Network integration
0.06	1.00	1.00	1.00	1.74	1.41	1.06	1.00	0.82	0.64	1.97	0.70	1.54	1.08	0.93	0.80	Strategy:5 Participatory Management

Table 4.24. Matrix of pairwise comparisons of options based on the index of the number of available methods to increase capacity

Weight	Strategy:5 Participatory Management			Strategy:4 Network integration			Strategy:3 Information integration			Strategy:2 Customer and market promotion			Strategy: 1 Process integration			
0.11	1.13	0.99	0.91	1.19	0.99	0.81	1.12	0.93	0.74	1.00	0.80	0.67	1.00	1.00	1.00	Strategy: 1Process integration
0.09	1.32	1.00	0.76	0.82	0.64	0.53	0.72	0.51	0.40	1.00	1.00	1.00	1.50	1.25	1.00	Strategy:2 Customer and market promotion
0.46	3.57	2.95	2.30	1.52	1.24	1.00	1.00	1.00	1.00	2.48	1.94	1.40	1.34	1.08	0.89	Strategy:3 Information integration
0.31	2.64	1.93	1.32	1.00	1.00	1.00	1.00	0.80	0.66	1.88	1.56	1.22	1.24	1.01	0.84	Strategy:4 Network integration
0.01	1.00	1.00	1.00	0.76	0.52	0.38	0.44	0.34	0.28	1.32	1.00	0.76	1.10	1.01	0.88	Strategy:5 Participatory Management

Table 4.25. Pairwise comparison matrix of options based on the percentage index of the supply chain that is directly supported by IT

Weight	Strategy:5 Participatory Management			Strategy:4 Network integration			Strategy:3 Information integration			Strategy:2 Customer and market promotion			Strategy: 1 Process integration			
0.07	1.09	0.82	0.66	0.80	0.64	0.52	0.68	0.54	0.43	0.93	0.72	0.58	1.00	1.00	1.00	Strategy: 1Process integration
0.16	1.15	1.00	0.87	0.72	0.58	0.49	0.54	0.42	0.35	1.00	1.00	1.00	1.72	1.39	1.08	Strategy:2 Customer and market promotion
0.50	5.53	4.51	3.48	2.49	2.14	1.74	1.00	1.00	1.00	2.90	2.38	1.84	2.34	1.85	1.46	Strategy:3 Information integration
0.17	3.10	2.37	1.74	1.00	1.00	1.00	0.57	0.47	0.40	2.03	1.72	1.40	1.93	1.56	1.25	Strategy:4 Network integration
0.08	1.00	1.00	1.00	0.57	0.42	0.32	0.29	0.22	0.18	1.15	1.00	0.87	1.50	1.21	0.92	Strategy:5 Participatory Management

Table 4.26. Pairwise comparison matrix of options based on IT ability index to adapt in supporting new distribution channels

Weight	Strategy:5 Participatory Management			Strategy:4 Network integration			Strategy:3 Information integration			Strategy:2 Customer and market promotion			Strategy: 1 Process integration			
0.17	1.89	1.47	1.15	1.32	1.25	1.15	0.94	0.71	0.57	1.64	1.24	0.93	1.00	1.00	1.00	Strategy: 1Process integration
0.07	1.74	1.55	1.32	1.18	0.89	0.70	1.00	0.84	0.71	1.00	1.00	1.00	1.08	0.80	0.61	Strategy:2 Customer and market promotion
0.57	4.00	3.38	2.70	3.37	2.62	2.00	1.00	1.00	1.00	1.41	1.19	1.00	1.74	1.41	1.06	Strategy:3 Information integration
0.03	1.89	1.37	1.00	1.00	1.00	1.00	0.50	0.38	0.30	1.43	1.13	0.85	0.87	0.80	0.76	Strategy:4 Network integration
0.14	1.00	1.00	1.00	1.00	0.73	0.53	0.37	0.30	0.25	0.76	0.64	0.57	0.87	0.68	0.53	Strategy:5 Participatory Management

Table 4.27. Pairwise comparison matrix of options based on the index of the number of methods available in IT systems to analyze the competitive environment and discover changes

Weight	Strategy:5 Participatory Management			Strategy:4 Network integration			Strategy:3 Information integration			Strategy:2 Customer and market promotion			Strategy: 1 Process integration			
0.2 2	1.00	1.00	1.00	6.00	5.00	4.00	1.00	1.00	1.00	0.50	0.33	0.25	1.00	1.00	1.00	Strategy: 1Process integration
0.2 9	4.00	3.00	2.00	0.50	0.33	0.25	4.00	3.00	2.00	1.00	1.00	1.00	4.00	3.03	2.00	Strategy:2 Customer and market promotion
0.1 2	4.00	3.00	2.00	0.50	0.33	0.25	1.00	1.00	1.00	0.50	0.33	0.25	1.00	1.00	1.00	Strategy:3 Information integration
0.2 9	4.00	3.00	2.00	1.00	1.00	1.00	4.00	3.03	2.00	4.00	3.03	2.00	0.25	0.20	0.17	Strategy:4 Network integration
0.0 7	1.00	1.00	1.00	0.50	0.33	0.25	0.50	0.33	0.25	0.50	0.33	0.25	1.00	1.00	1.00	Strategy:5 Participatory Management

Table 4.28. Pairwise comparison matrix of options based on the index of ability to add or remove delivery channels

Weight	Strategy:5 Participatory Management			Strategy:4 Network integration			Strategy:3 Information integration			Strategy:2 Customer and market promotion			Strategy: 1 Process integration			
0.02	1.28	1.06	0.85	0.45	0.41	0.39	0.64	0.61	0.60	2.91	2.23	1.68	1.00	1.00	1.00	Strategy: 1Process integration
0.10	0.87	0.72	0.61	0.31	0.23	0.19	0.38	0.27	0.21	1.00	1.00	1.00	0.66	0.53	0.43	Strategy:2 Customer and market promotion
0.32	2.17	1.72	1.32	0.87	0.67	0.54	1.00	1.00	1.00	3.54	2.97	2.30	1.31	1.19	1.08	Strategy:3 Information integration
0.50	1.78	1.53	1.32	1.00	1.00	1.00	1.24	1.00	0.80	5.32	4.39	3.27	2.83	2.55	2.16	Strategy:4 Network integration
0.05	1.00	1.00	1.00	0.57	0.53	0.49	0.86	0.69	0.57	2.46	2.05	1.64	1.62	1.32	1.08	Strategy:5 Participatory Management

Table 4.29. Matrix of paired group comparisons of options based on the index of the ability to change the overall capacity of the logistics network

Weight	Strategy:5 Participatory Management			Strategy:4 Network integration			Strategy:3 Information integration			Strategy:2 Customer and market promotion			Strategy: 1 Process integration			
0.3 3	2.38	2.14	1.86	1.19	0.96	0.77	2.06	1.73	1.46	2.63	1.96	1.41	1.00	1.00	1.00	Strategy: 1Process integration
0.2 1	2.00	1.55	1.15	1.06	0.84	0.66	1.89	1.55	1.22	1.00	1.00	1.00	0.76	0.58	0.46	Strategy:2 Customer and market promotion
0.0 1	0.76	0.58	0.46	0.61	0.49	0.41	1.00	1.00	1.00	0.94	0.80	0.70	0.52	0.44	0.37	Strategy:3 Information integration
0.2 7	2.17	1.72	1.32	1.00	1.00	1.00	1.73	1.48	1.24	2.46	2.05	1.64	1.08	0.83	0.66	Strategy:4 Network integration
0.1 6	1.00	1.00	1.00	0.87	0.73	0.61	2.16	1.73	1.32	1.43	1.11	0.87	0.53	0.44	0.38	Strategy:5 Participatory Management

Table 4.30. Matrix of paired group comparisons of options based on the index of the number of warehouses available for storage

Weight	Strategy:5 Participatory Management			Strategy:4 Network integration			Strategy:3 Information integration			Strategy:2 Customer and market promotion			Strategy: 1 Process integration			
0.25	4.76	3.71	2.63	3.36	2.82	2.21	3.83	3.41	2.91	3.13	2.43	1.86	1.00	1.00	1.00	Strategy: 1Process integration
0.25	1.43	1.12	0.86	1.25	1.00	0.81	1.89	1.55	1.22	1.00	1.00	1.00	0.61	0.49	0.40	Strategy:2 Customer and market promotion
0.15	2.17	1.72	1.32	0.76	0.58	0.46	1.00	1.00	1.00	0.82	0.64	0.53	0.32	0.27	0.24	Strategy:3 Information integration
0.24	1.52	1.18	0.94	1.00	1.00	1.00	1.64	1.38	1.15	1.64	1.25	0.92	0.53	0.44	0.38	Strategy:4 Network integration
0.09	1.00	1.00	1.00	1.06	0.85	0.66	0.76	0.58	0.46	1.08	0.80	0.61	0.46	0.35	0.29	Strategy:5 Participatory Management

Table 4.31. Pairwise comparison matrix of options based on the index of the number of capable suppliers for each material and in each period

Weight	Strategy:5 Participatory Management			Strategy:4 Network integration			Strategy:3 Information integration			Strategy:2 Customer and market promotion			Strategy: 1 Process integration			
0.26	1.19	0.96	0.77	1.22	1.00	0.82	1.00	0.88	0.76	2.84	2.42	2.08	1.00	1.00	1.00	Strategy: 1Process integration
0.14	1.32	1.12	0.93	1.74	1.24	0.87	0.61	0.49	0.41	1.32	1.25	1.15	0.56	0.49	0.43	Strategy:2 Customer and market promotion
0.28	1.00	0.86	0.76	2.35	1.90	1.52	0.87	0.80	0.76	2.46	2.05	1.64	1.08	0.89	0.76	Strategy:3 Information integration
0.11	0.66	0.46	0.35	1.00	1.00	1.00	0.66	0.53	0.43	1.74	1.25	0.87	1.17	1.00	0.85	Strategy:4 Network integration
0.19	0.87	0.80	0.76	2.16	1.73	1.32	1.00	0.93	0.87	1.08	0.89	0.76	1.08	0.83	0.66	Strategy:5 Participatory Management

Table 4.32. Matrix of pairwise comparisons of options based on supplier performance penetration index

Weight	Strategy:5 Participatory Management			Strategy:4 Network integration			Strategy:3 Information integration			Strategy:2 Customer and market promotion			Strategy: 1 Process integration			
0.33	1.00	1.00	1.00	4.00	3.00	2.00	1.00	1.00	1.00	4.00	3.00	2.00	1.00	1.00	1.00	Strategy: 1Process integration
0.00	0.50	0.33	0.25	1.00	1.00	1.00	0.50	0.33	0.25	1.00	1.00	1.00	0.50	0.33	0.25	Strategy:2 Customer and market promotion
0.15	0.50	0.33	0.25	1.00	1.00	1.00	1.00	1.00	1.00	4.00	3.03	2.00	1.00	1.00	1.00	Strategy:3 Information integration
0.08	0.50	0.33	0.25	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.33	0.25	Strategy:4 Network integration
0.42	1.00	1.00	1.00	4.00	3.03	2.00	4.00	3.03	2.00	4.00	3.03	2.00	1.00	1.00	1.00	Strategy:5 Participatory Management

Table 4.33. Matrix of paired group comparisons of options based on the speed index of starting cooperation with a new supplier

Weight	Strategy:5 Participatory Management			Strategy:4 Network integration			Strategy:3 Information integration			Strategy:2 Customer and market promotion			Strategy: 1 Process integration			
0.42	2.91	2.48	2.07	3.46	2.94	2.38	2.01	1.58	1.20	3.22	2.82	2.46	1.00	1.00	1.00	Strategy: 1Process integration
0.22	1.19	1.00	0.84	0.78	0.57	0.45	0.35	0.26	0.21	1.00	1.00	1.00	0.41	0.35	0.31	Strategy:2 Customer and market promotion
0.33	1.73	1.50	1.28	2.91	2.23	1.68	1.00	1.00	1.00	4.85	3.89	2.83	0.83	0.63	0.50	Strategy:3 Information integration
0.01	1.00	0.76	0.59	1.00	1.00	1.00	0.59	0.45	0.34	2.20	1.74	1.28	0.42	0.34	0.29	Strategy:4 Network integration
0.00 6	1.00	1.00	1.00	1.68	1.32	1.00	0.78	0.67	0.58	1.19	1.00	0.84	0.48	0.40	0.34	Strategy:5 Participatory Management

Calculation of the relative and final weight of the options Next, the final weight of each option was calculated, the results of which are shown in Table 4-34:

Table 4.34. Final weight of options

Weight Strategy 5C*SC*A5	Strategy:5 Participatory Management	Weight Strategy4 C*SC*A4	Strategy:4 Network integration	Weight Strategy3 C*SC*A3	Strate gy :3 Information integration	Weight Strategy2 C*SC*A2	Strategy :2 Customer and market promotion	Weight Strategy =1 C*SC*A1	Strate gy :1 Process integration	Weight subindex es (SC)	Subindex	Weight of main indicators (C)	Original indicators
0.025	0.273	0.004	0.047	0.023	0.252	0.014	0.154	0.025	0.273	0.270	Ability to reduce product development cycle time	0.342	Product development flexibility
0.013	0.111	0.036	0.293	0.020	0.166	0.016	0.136	0.036	0.293	0.3 60	Ability to design multiple products		
0.015	0.123	0.040	0.331	0.022	0.185	0.019	0.156	0.025	0.204	0.3 60	Percentage of assets with the possibility of reuse	0.105	
0.004	0.114	0.005	0.160	0.012	0.357	0.007	0.224	0.005	0.145	0.3 40	The ability to change the composition of products		Production and manufacturing flexibility
0.002	0.067	0.003	0.090	0.007	0.233	0.008	0.249	0.0121	0.362	0.3 20	Speed in the production of new products		
0.0004	0.012	0.011	0.313	0.016	0.466	0.003	0.097	0.004	0.113	0.3 40	The number of methods available (available) to increase capacity		
0.006	0.081	0.014	0.172	0.043	0.503	0.014	0.168	0.006	0.076	0.3 50	Percentage of supply chain directly supported by IT	0.245	Information technology flexibility
0.012	0.143	0.003	0.037	0.049	0.572	0.006	0.078	0.014	0.170	0.350	IT's ability to adapt to support new distribution channels		

0.005	0.076	0.021	0.290	0.008	0.120	0.021	0.292	0.016	0.223	0.3 00	The number of methods available in IT systems to analyze the competitive environment and discover changes		
0.002	0.052	0.025	0.504	0.016	0.321	0.005	0.100	0.001	0.021	0.280	Ability to add or remove delivery channels	0.181	Logistics flexibility
0.02	0.167	0.032	0.270	0.002	0.019	0.025	0.213	0.040	0.331	0.670	The ability to change the overall capacity of the logistics network		
0.0007	0.099	0.001	0.248	0.001	0.150	0.001	0.251	0.001	0.251	0.0 40	Number of Warehouses available for storage	0.126	Procurement flexibility
0.009	0.191	0.005	0.119	0.013	0.280	0.06	0.145	0.012	0.265	0.3 80	Number of capable suppliers for each material and in each period		
0.02	0.427	0.0003	0.083	0.007	0.157	0.0001	0.003	0.015	0.330	0.3 80	Permeability on supplier performance		
0.0001	0.006	0.0004	0.014	0.010	0.335	0.006	0.222	0.012	0.423	0.2 40	The speed of starting cooperation with a new supplier		
0.12		**0.20**		**0.24**		**0.20**		**0.22**			**Total points**		

The weight of each of the criteria and options according to the calculations is given in Table 4-35.

Table 4.35. Ranking of options by FAHP method

Rank	Weight	
2	0.224	Strategy :1 Process integration
3	0.205	Strategy :2 Customer and market promotion
1	0.249	Strategy :3 Information integration
4	0.20	Strategy :4 Network Integration
5	0.122	Strategy :5 Participatory Management

From the results obtained from table 4-35, it can be seen that the first option i.e. integration of information in standards and sub-standards has more weight than other strategies and process integration, customer and market promotion, network integration and collaborative management in the next ranks are located.

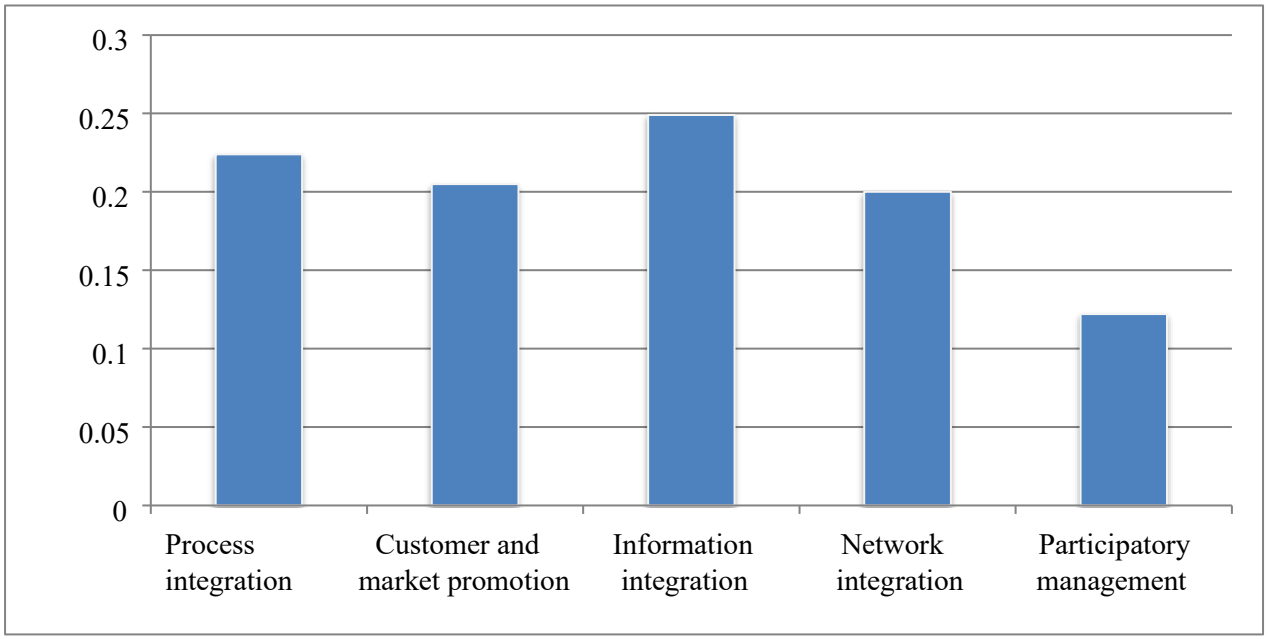


Figure 4.3. Ranking chart of supply chain implementation strategies

Chapter 5: Conclusion

5.1 Introduction

The purpose of the current research is to identify the effective indicators in the agile supply chain and to evaluate and prioritize the strategies of the agile supply chain according to the indicators determined in the food industry company. The statistical population that has been investigated is limited and includes people who are somehow involved with the supply chain and are familiar with the concept of agility, which includes the managers of the supply chain department in the food industry company.

In the previous chapters, we explained the topic, examined the theoretical foundations, research methodology, and analyzed real data using the fuzzy hierarchical analysis method, and finally, based on the obtained numbers, the results were extracted. In this chapter, while presenting Some of the limitations of conducting research, according to the results, we draw conclusions, analyze the results, and also provide suggestions for the next researcher .

5.2 Answers to research questions

5.2.1 Are the mentioned indicators and sub-indices effective in the implementation of agile supply chain?

According to the criteria identified based on the Swafford model, the criteria and sub-criteria were examined by the experts using the questionnaire attached 1 to confirm their effectiveness in the implementation of agile supply chain strategies in the food industry company. After receiving the questionnaires, based on the T-Student test and with the help of Spss software, the Sig criterion was measured for all the criteria and sub-criteria, the results of which were mentioned in Tables 1-4 to 6-4 in the fourth chapter. Based on these calculations, the Sig criterion for all criteria and sub-criteria was less than 0.05. Therefore, the hypothesis of their effectiveness was confirmed.

5.2.2 How is the prioritization of strategies based on the indicators determined in the studied organization using the fuzzy AHP technique?

As it was said, the prioritization and selection of the best strategy for implementing the agile supply chain in the food industry company was done using the fuzzy AHP method. The strategies were identified under the identified indicators. Regarding the final results, it can be said that the results of the relative importance of the main criteria of the research from pairwise comparisons in the fuzzy AHP method and from the experts' point of view show that the criteria in order of importance are:

Flexibility of product development, flexibility of information technology, flexibility of logistics, flexibility of logistics and flexibility of manufacturing and production.

The weighted value of these five criteria shows that, from the point of view of the experts, the flexibility criterion of product development has almost 34.2% of the total relative importance.

Also, based on the results of the calculations of the weight of agile supply chain implementation strategies, the prioritization of these strategies in the food industry company is as follows:

Information integration, process integration, customer and market promotion, network integration and collaborative management.

5.3 Suggestions based on research results

•Based on the high degree of importance of information integration strategy in supply chain agility, according to experts in this company, strengthening and improving information integration through the use of information technologies in data sharing between buyers and suppliers is proposed as the first suggestion

•In the next degree, the plan to improve and strengthen the process integration strategy by creating public access to information and knowledge through the Internet and updating data related to instant sales, effective customer response, improving data mining capabilities, creating beliefs and Common goals, increasing the level of coordination, emphasis on outsourcing, exchanges without the use of paper and using the new generation of online software are on the agenda .

•In the next priorities, strengthening the customer and market promotion strategy through the rapid introduction of new products, responding to real demand, demand for customized products, maintaining and increasing the level of customer relations, paying attention to customer-oriented criteria, improving quality, reducing costs, increasing frequency Product improvement will be important.

•In the fourth priority, strengthening the network integration strategy, including senior management's commitment to agile actions, decentralized decision-making, emphasis on core competencies, trust based goals and criteria, trust-based relationships, and finally improving the collaborative management strategy to attract buyers and Suppliers are encouraged to work collaboratively, develop products collaboratively, and share information.

•Due to the proximity of the weight calculated for the customer and market promotion strategy and the network integration strategy, the organization can plan the level improvement program of these two strategies simultaneously and in line with each other.

•Strengthening the flexibility in order of priority and based on the obtained weight in order to improve and strengthen the level of agility in the food industry company, including:

1. Flexibility of in order to successfully react to customer or market requirements and take advantage of market possibilities, product development

refers to the capacity to create a variety of products and upgrade products in a timely, cost-effective way.

2. Increasing information technology adaptability by enhancing an organization's overall information technology system's capacity to adjust to and support shifting business needs.

3. Logistics flexibility in terms of having access to a variety of options and being able to use them to adjust the movement and storing of raw materials, finished products, services, and associated information from the source to the destination in reaction to the shifting market environment.

4. Procurement flexibility by increasing the ability to change procurement decisions in order to optimize the effects of the required change

5. Flexibility manufacturing and production is defined as the expansion of the range of options available and the capacity of the manufacturing and production process to successfully implement them in response to changes in product characteristics, supply of materials, and demand, or by escalating the use of technological processes.

5.4 Research proposals

- The current research can be an effective tool to improve the level of agility in the food industry company. Order and continuity in the implementation of the presented model, and if necessary, its improvement will lead to achieving an agile supply chain and improving the level of agility in the organization.
- It is suggested that the current research and especially the data obtained from the fuzzy AHP method be done with other or a combination of methods such as FANP and TOPSIS. Comparing its results with the results presented in this research will be valuable research.
- The present research deals with the prioritization and implementation strategies of agile supply chain using the combination of Lean, Faisal and Swafford model

in 2006 in the food industry company. Examining more samples in similar organizations is recommended to further validate the model presented in this research.

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