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A Proposed Hybrid Model for Cost Management of Agility Smart Supply Chains Using Nanotechnology- Case Study

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Abstract

The purpose of this paper is to present a proposed hybrid model for managing the cost of agility smart supply chains using Nanotechnology. The paper concentrates on a case study of the Egyptian Electric Cables company related to the new implementation of Nanotechnology in Egypt's industrial sector. The data was collected through interviews with company officials specializing in Nanotechnology since 2022. The paper constructs a model for managing the cost of an agile smart supply chain using the Fuzzy Model. The methodology involves defining specific capabilities and attributes, establishing linguistic scales for performance evaluation, and computing fuzzy performance indices. These indices aim to quantify the performance of agile attributes and capabilities within the context of Nanotechnology's application in smart supply chains, culminating in an overall Fuzzy Performance Index. The Egyptian Electric Cables company's utilization of Nanotechnology within their agile smart supply chain demonstrates remarkable effectiveness, as indicated by the fuzzy performance index values. Their success appears in adeptly managing various factors: flexibility, allowing adaptability to market demands and diverse product ranges; responsiveness, ensuring strong supplier relationships and swift adjustments to market fluctuations; competence, exhibited through effective collaboration, product quality, and skilled workforce development; cost management, focusing on controlling expenses throughout the sourcing, manufacturing, and delivery processes; and performance, emphasizing efficiency, increased output, and resource optimization. These practical results prove the company's success in integrating Nanotechnology to efficiently manage costs within its agile smart supply chain model.

It is believed that there is no study to date examining the effect of using Nanotechnology on the cost management of agility smart supply chains. This paper contributes to the limited literature on Nanotechnology and cost management of agility smart supply chain. It develops a fuzzy model that integrates Nanotechnology within the scope of capabilities (Flexibility, Responsiveness, Competence, Cost, and performance) in sourcing, manufacturing, and delivery within the agile smart supply chain, the construction of this fuzzy model was guided by the researchers' creation of the suggested hybrid model for agile smart supply chains, integrating Nanotechnology and leveraging advanced technologies.

Keywords: Nanotechnology, Cost Management, Nano Supply Chains, Agility Supply Chains, Smart Supply Chains, Value Chains, RFID, 3D printing.

1. Introduction

The historical development of managerial accounting is related to economic conditions, technical developments, and the development of business organizations. Researchers and professionals have developed many tools and techniques that are compatible with the strategic directions of managerial accounting. Scientific research presents Nano supply chains based on the use of digitization strategies such as big data, Blockchains, and Machine learning (Golan, 2021). The paper defined Nanotechnology as the field of understanding and manipulating matter at tiny scales, typically ranging from 1 to 100 Nanometers(nm) that show different characteristics from the same materials in large quantities (Ghernaout, 2018). In this paper, we explain the influence of using Nanotechnology on the cost management of agility smart supply chains. Cost management for agile smart supply chains contains methodologies that help in the analysis of all costs within the modern supply chain and that lead to agile supply chains that quickly adapt to dynamic environment changes in real-time**.**

The main objective of our paper is to present a proposed hybrid model for managing the cost of agility smart supply chain using Nanotechnology. We also aim to contribute to improving ways to benefit from Nanotechnology in managing the cost of agility smart supply chains using Nanotechnology. The proposed hybrid model for cost management in an agile smart supply chain utilizing Nanotechnology and containing various components: supplier selection impacting Nanotechnology component availability and supply chain agility, Nanotechnology integration in manufacturing across design and assembly plants, leveraging Nanoscale structures, Nanotechnology applications in the distribution phase for packaging, tracking, and tracing, and the innovative use of Nanotechnology in design for optimized costs and enhanced performance. The model also includes Nano supply chain practices—like cloud computing, big data, IoT, 3D printing, cyber-physical systems, RFID, robotics, blockchain, artificial intelligence, and machine learning—to enhance agility and cost optimization. Supporting the Nanotechnology value chain through accessibility and joint planning involving Nanomaterials, Nano intermediates, and Nano-enabled products holds the potential to increase supply chain agility and cost-effectiveness.

The research question addressed in the study was shaped by the gaps identified in the extant literature and we formulated the main question as follows:

What is the proposed model for managing the cost of agility Smart supply chains using Nanotechnology?

Despite extensive prior literature that presents cost management and modern supply chains, there is little research on how Nanotechnology affects the cost management of agile smart supply chains. Supply chains appear as a complex function that causes a high level of risk involved in core operations and affects the performance of the production department (Yanuar, 2018). The advantage of Nanotechnology is that it moves beyond just creating new capabilities for supply chains, but rather expands to include sensors that take the quality and other characteristics of products throughout the supply journey and send instructions in the event of any deterioration (Shanmuganatan & Nakkeeran, 2013). The core problem that faces the first stage of implementing Nanotechnology is the high cost of Nanotechnology and the high cost of establishing Nano factory (Sharify, 2010). However, once the product is produced and revenue is generated, the profits in the Nano environment are higher due to the very low production costs and other variable costs, unlike the traditional manufacturing environment, the production costs are large and thus profits accumulate at a slower pace (Dutta & Lawson, 2006).

The researchers show a model of cost management of agility smart supply chains using Nanotechnology and this model explains new opportunities to benefit from Nanotechnology during the supply chain journey. Nanotechnology can be used to provide new capabilities for the properties of advanced technologies. These technologies include cloud computing, IoT, Big Data, 3D printing, and RFID, which can enhance cost management in agile supply chains. In the same model, it shows how it contributes to enhancing value chains.

The motivation for studying the effect of using Nanotechnology on the cost management of agility smart supply chains in the Egyptian Electric Cables company is that this company is subject to strict regulatory laws and financial supervision. Consequently, the results will be more accurate and on the other hand study to what extent the Nanotechnology sector contributes to solving current financial and savings problems in Egypt. The reason for studying two variables Nanotechnology and cost management of agility smart supply chains is that Nanotechnology can participate in reducing raw materials consumption by entering Nanomaterial and at the same time reducing inventory management costs (Just in time production). There is also a scarcity of research that deals with the relationship between Nanotechnology and the cost management of agility smart supply chains.

This is the first paper about a proposed hybrid model for cost management of agility smart supply chains using Nanotechnology. This paper is the first that show the effect of using Nanotechnology on the cost management of agility smart supply chains in the Egyptian environment. The paper presents a significant and innovative contribution through its proposed model, which introduces novel ways of utilizing Nanotechnology in agile smart supply chains. Additionally, it advances this model by employing a fuzzy model, enhancing its adaptability and flexibility in handling complexities within the supply chain context in the Nanotechnology environment. We are the first to provide new evidence that Nanocomposites with improved properties may lead to lighter and more durable products, potentially reducing transportation costs and waste, thus offering long-term cost savings and sustainability benefits. Nanoparticles enhance the performance and characteristics of materials, leading to improved product quality and performance.

The paper proceeds as follows. Section 2 reviews the prior literature. In section 3, we describe the cost management of agility smart supply chains. Concepts, applications, and barriers of Nanotechnology are discussed in section 4. Section 5 describes the agility of smart supply chain cost management and Nanotechnology. Section 6 shows the research methodology. Section 7 discusses the results. Section 8 shows the discussion. Section 9 represents conclusions and suggested future research.

2. Literature Review

Referring to Table (1) in the appendix, we can say that:

-Considerable attention has been given to examining the impact of the implementation of Nanotechnology (Ali, 2022); (Golan, 2021); (Ali O. A., 2019); (Rababah, 2017). Other research concentrated on the importance of Nanotechnology in industrial development (Unhelkar, 2022); (Agburuga, 2019). The framework emphasized by (Maher, 2017) clarified that the integration of Nanotechnology throughout the entire product life leveraged the properties of Nanoscale and Nanomaterial throughout all stages of the product life cycle to minimize environmental impacts, reduce costs, and simultaneously improve product quality.

-These papers find that implemented Nanotechnology led to a reduction in time for providing materials, supported strategic cost management and cost savings, reduced inventory costs, integrated advanced technology led to increased supply chain efficiency, prevention of unwanted substances and pollutants, supported product quality, and modification workforce structure (Unhelkar, 2022); (Ali, 2022); (Dai, 2022); (Golan, 2021) (Ali O. A., 2019); (Rababah, 2017).

-There is an agreement among studies that Nanotechnology contributed to cost reduction, improved efficiency, and enhanced supply chain resilience.

-However, these studies did not take into account any case studies or practical applications to prove the results and ratios they presented (Dai, 2022); Unhelkar, et al., 2022; (Ali O. A., 2019) and this was what we tried to address in this paper by executing the practical application on companies that implemented Nanotechnology in their manufacturing process, and we did this with a clear methodology using python programming language and fuzzy logic.

-There was a scarcity of studies that presented the relationship between Nanotechnology and cost management of agility smart supply chains. Studies mentioned the relationship between Nanotechnology and cost management or between Nanotechnology and supply chains. However, studies did not clarify that there is a direct relationship between Nanotechnology and agility supply chain.

-Previous studies have mentioned that advanced technologies (machine learning, big data, and artificial intelligence) help in the implementation of Nanotechnology (Dai, 2022); (Golan, 2021), but they did not present how these technologies support Nanotechnology (The link between Nanotechnology and advanced technologies was not established).

-Despite the emergence of Nanotechnology and Nanomaterial for a long time, they have not yet been widely implemented despite their proven benefits, especially in Arab countries.

-In this paper, the researchers use the studies by (Shariati, 2017); (Matwale, 2012); (Seyedhoseini, 2010) in constructing a model using the fuzzy model. Those studies were crucial in integrating performance and cost factors into the assessment of Nanotechnology. Within the smart supply chain, the capabilities of the fuzzy model encompass essential elements such as Flexibility, Responsiveness, Competence, Cost, and Performance, serving as key components in evaluating and optimizing the supply chain's agility and efficiency.

3. Cost management of agility smart supply chains

In this section, we define the cost management of agility smart supply chain and discuss the framework for the implementation of Industry 4.0 and 5.0 in the supply chain.

3.1 Definition of cost management of agility smart supply chain

Before going into the detailed definition of cost management for an agile supply chain, it is clear that the concept of supply chain cost management has improved over time to include more than one concept: proactive cost management, lean management accounting, supply chain costing, and interorganizational cost management (Securing, s., 2002). Supply chain cost refers to the logistic costs that are involved throughout the whole process of the supply chain, which starts with the supply of raw materials and ends with the delivery of final products to the customer (Ramos, 2020). Proactive cost management encompasses several strategies including responsiveness means swiftly interpreting market signals and adjusting accordingly, efficiency involves overcoming potential and actual disruption, and finally supply chain resilience refers to the capacity of a disrupted supply chain to recover and emerge even stronger than before (Gunasekaran, 2015). Lean management accounting is described as a management philosophy and business strategy focused on optimizing production flow with the aim of cost reduction its primary objective is to ensure that customers receive precisely what they require, at the requested time, and in the desired quantity (Alvim & Oliveira, 2020). Interorganizational cost management depends on two types of control mechanisms, The first mechanism involves customers using informal control measures to improve supplier confidence, and the second mechanism is Supplier Performance Management, which plays an essential role in measuring supplier performance, providing feedback, and making informed decisions by customers (O'Connor, 2020).

Similarly, (Oliveira-Dias, 2022) determine the key characteristics of an agile supply chain as flexibility, responsiveness, competency, and quickness, Flexibility pertains to the chain's capacity to effectively adapt and adjust to alterations, while responsiveness signifies its swift and apt reactions to market changes. Competency reflects the chain's capability to achieve objectives and meet goals successfully, and quickness encapsulates its ability to rapidly and efficiently execute tasks and activities. According to the study by (Yusuf, 2014), supply chain agility includes a lot of processes such as planning, sourcing, manufacturing, delivery, and returns handling, which reflects the ability of the agile supply chain to effectively meet the demands of a dynamic and changing business environment. It can achieve this by reconfiguring, adjusting, and changing its resources to meet the evolving demands of key supply chain operations. On the other hand, according to (AlMulhim, 2021), Modern (Smart) supply chains are characterized as a network of various activities that include different customers & and suppliers. The integration of the latest (advanced) technologies leads to technical solutions & and best practices. Based on this, we can summarize the comprehensive definition of Cost Management for an agile smart supply chain as follows: it comprises methodologies that facilitate the analysis and regulation of all costs within the modern supply chain. It includes strategies that facilitate the supervision of all costs in the modern supply chain. This modern supply chain is quickly adapting to dynamic environmental changes in real-time.

3.2 Framework for the implementation of Industry 4.0 and 5.0 in the supply chain

Industry 4.0 cast its shadow over the supply chain, it is notable in increasing digitalization and agility across all stages of the supply chain. Digital supply chain networks are a combination of technologies that are used to create efficient systems through all stages of the supply chain. According to a study by (Ghadge, 2020), there are a lot of advantages and disadvantages related to the appearance of Industry 4.0. The disadvantages of implementing Industry 4.0 involve funding limitations, insufficient leadership support, aversion to transformation, absence of proficiency, and non-existence of supportive policies from the government. on the other hand, there are benefits resulting from Industry 4.0 are dynamic planning, sophisticated scheduling methods, diverse alternatives, order delivery, Accuracy, and productivity. On the other hand, Industry 4.0 facilitates extensive automation throughout the supply chain, reducing the need for human interventions at various stages. The integration of the Industry 4.0 concept with supply chain management has given rise to SCM 4.0, representing a new stage of development in the field (Hofmann, 2019). According to a study by (Tripathi & Gupta, 2020), the development of smart supply chains has gone through four stages of progress: The first stage stasis aims to attain profitability by maximizing efficiency through the utilization of digital storage. The second stage, product or service enhancement is undertaken to enrich the customer value perspective. The third stage, Operation enhancement, involves implementing instrumentation for real-time monitoring and minimizing product complexity without incurring additional costs. Finally, a resilient supply chain focuses on establishing continuous and non-stop flow in the supply chain.

In Industry 5.0 there is a blend between humans and advanced manufacturing automation systems (Integrating human intelligence with robots) resulting in the appearance of the phenomena of Cobots. The concept of Cobots is driven by the implementation of IOT, artificial intelligence, and big data. (Chander, 2022). In Industry 5.0, customer experience and organizational agility become key sources of competitive advantage. According to research by (Javaid & Haleem, 2020), Industry 5.0 comprises seventeen essential components. These components include big data, collaborative robots (cobots), smart sensors, the Internet of Things (IoT), artificial intelligence (AI), multi-agent systems and technologies, digital ecosystems, digital manufacturing, complex adaptive systems, smart materials, 3D printing, 4D printing, 5D printing, 3D scanning, holography, cloud computing, and virtual reality.

4. Concepts, applications, and barriers of Nanotechnology

In this section, we define the Nanotechnology concept, present Nanotechnology applications, and show Barriers related to Nanotechnology.

4.1 Nanotechnology concept

A study conducted by (Ghernaout, 2018) exhibits that Gases, liquids, and solids, when examined at the Nanoscale, can display remarkable physical, chemical, and biological characteristics that often distinguish them significantly from those of the same material in larger quantities. The study defined Nanotechnology as the field of understanding and manipulating matter at highly small scales, typically ranging from 1 to 100 nanometers(nm). The National Nanotechnology Initiative (NNI) in the United States exposes Nanotechnology that spans dimensions from 1 to 100 Nanometers (nm) and depicts Nanotechnology as the practice of science, engineering, and technology at the Nanoscale. This scale-dependent realm gives rise to distinctive phenomena that break into innovative applications across varied domains including chemistry, physics, biology, medicine, engineering, and electronics (www.nano.gov). Based on the above discussion, it can be inferred that Nanotechnology incorporates two key aspects. Firstly, the novelty of Nanotechnology arises from its ability to employ the potential of small things. Secondly, it involves the handle of structures through precise shaping at the Nanometer scale. Consequently, there is a differentiation between the conception of Nanoscience and Nanotechnology. Nanoscience refers to the analysis of structures and molecules at the scale of Nanometers, embracing from 1 to 100 nm. The practical implementation of this knowledge finds its manifestation in the field known as Nanotechnology (Bayda, 2019).

4.2 Nanotechnology applications

Nanotechnology's diverse applications span multiple sectors, presenting its critical role in various industries. In advanced materials, Nanotechnology enables the development of enhanced properties, exemplified by the use of Nanostructured graphitic foams in phase-change materials, enhancing thermal conductivity for improved thermal response in thermal storage (Adegbaye, 2022). In the realm of food and agriculture, Nanotechnology contributes to food preservation, safety enhancement, nutrient delivery, contaminant detection, and improved packaging, storage, and transportation of food products (Sharma, 2019). In healthcare and biotechnology, Nanotechnology plays a crucial role in targeted drug delivery, imaging, diagnostics, tissue engineering, and real-time monitoring through Nanosensors, offering early disease detection capabilities (Bajwa, 2017). Moreover, Nanotechnology finds application in Environmental Remediation, utilizing Nanocatalysts to transform waste into valuable resources like ethanol, employing Nanoparticle coatings to prevent biological fouling on pipes and membranes, and utilizing Nanofiltration to reduce costs and eliminate the need for chemicals (Taran, 2021). However, these applications merely scratch the surface of Nanotechnology's vast potential, necessitating further exploration for a comprehensive understanding across diverse sectors and industries.

4.3 Barriers Related to Nanotechnology

The hurdle of technology transfer has been a significant barrier to the adoption and advancement of any technological field. Nanotechnology, with its financial risks, presents a major challenge for investors due to the lengthy marketing process it entails. Accordingly, a study by (Lim, 2021) indicates that Nanotechnology requires, for the successful implementation of infrastructure, a high cost, and this is considered a fundamental challenge, especially in the primary stage, According to rapidly advancing Nanotechnology, It needs laboratories and equipment, to foster further improvement in this field. On the other hand, there exists a popular perception among the general public regarding the potential risks related to Nanotechnology. The deficiency of experts in the field of Nanotechnology presents a significant barrier to its broad acceptance. , Small companies also face a shortage of resources needed to develop the necessary equipment for integrating Nanotechnology into their processes. According to the Organization for Economic Co-operation and Development (OECD), Nanotechnology involves basic risks, these risks include environmental danger associated with the spring of Nanoparticles into the environment, safety concerns concerning the exposure of workers and consumers to Nanoparticles, and the marketing of Nanotechnology products. (www.OECD.org).

Based on the above discussion, it can be concluded that People lack an understanding of the potential advantages and disadvantages of the various implementations of Nanotechnology, Poor regulatory experience and strategies hinder Nanotechnology products from being marketed, and as a result, the products of Nanotechnology are still in the laboratory, Despite the importance of the field of Nanotechnology the investment in research and development for Nanotechnology products and services is low, There is insufficient information about the environmental effects of Nanomaterial and their impact on human life.

5. Agility of smart supply chain cost management and Nanotechnology

In this section, we investigate Nanotechnology for effective cost management in manufacturing systems, Analyze Nanotechnology's effect on the value chain, and present the agility of smart supply chain cost management using digital technologies in the Nano environment.

5.1 Nanotechnology for effective cost management in the manufacturing system

The paradigm shift in manufacturing cost management, highlighted by (Ostaev, 2019), has arisen due to the inadequacies of traditional costing methods in determining precise product costs among modern technical complexities. The deficiencies in allocating overhead costs have fueled errors in cost calculations, especially related to indirect costs, necessitating innovative approaches such as Nanotechnology integration ((Sahani & Sharma, 2021). Nanomaterial implementation promises cost reductions through efficient resource utilization and improved quality, reshaping production processes, and enabling rapid product transitions within Nano factories (Ali O. A., 2019). However, the adoption of Nanotechnology poses challenges in cost evaluation and allocation, surpassing the capabilities of conventional costing systems (Ali, 2022). However, its implementation presents numerous benefits, including reduced waste, enhanced product quality, and minimized material wear and tear, aligning with the findings (Maher, 2017). To manage costs effectively within agile supply chains, advanced systems like ABC11, an evolution of activity-based costing, are recommended, as they offer better product cost insights aligned with customer needs (Yu, 2021). Furthermore, the integration of RFID technology across organizational stages, as outlined by (Smart, et al., 2010), and the application of techniques like just-in-time production and inventory optimization (Dewi & Meirina, 2020); (Simchi-Levi, 2018) play pivotal roles in enhancing cost management strategies within agile supply chains in the era of Nanotechnology implementation.

5.2 Nanotechnology effect on the value chain

Nanotechnology's impact on the product value chain is deep, extending beyond cost reduction and quality enhancement to the elimination of various expenses, particularly in the initial stages of the product life cycle, such as storage, distribution, shipping, and labor costs. This influence is especially pronounced in sectors like the food and drink industry, where maintaining food freshness during long-distance transportation necessitates efficient packaging (Cruz-Lopes, 2021). Green supply chain management aligns with this by aiming to enhance resource efficiency and minimize environmental impacts throughout the product life cycle, emphasizing collaborative customer relationships for improved risk management, cost control, and quality (Song & Gao, 2018). Nanotechnology significantly contributes to supply chain management by preserving product quality from packaging to end consumption by employing Nanosensors to monitor and maintain quality and temperature throughout the supply chain journey (Shanmuganatan & Nakkeeran, 2013). Furthermore, Nanotechnology's integration alters the dynamics of the value chain, necessitating new raw materials, suppliers, and services, while revolutionizing manufacturing techniques to control Nanomaterial size and shape, ultimately enhancing material properties and functionalities (Eschimese, 2019); (Souza & Rosa, 2021). Nanotechnology's attention to environmental impacts and safe production methods underscores its pivotal role in shaping value chains and consumer perceptions (Rizvi, Amir, & Gupta, 2021); (Puiu, 2020). This evolution through Nanotechnology implementation not only improves product design and characteristics but also prompts shifts in distribution channels, confirming the transformative influence of Nanotechnology across industries (Koc & Bozdag, 2017); (Mubeen, 2021).

5.3 Agility of smart supply chain cost management using digital technologies in the Nano environment

Industry 4.0 technologies present various benefits to companies, enhancing flexibility, quality, sourcing throughput, security, and cost-effectiveness within supply chains. For instance, IoT ensures high-quality distribution and production, while 3D printing reduces inventory needs and global transportation demands. Cloud computing, in turn, minimizes environmental footprints across supply chains (Zhang, 2022). Machine learning aids in predicting material characteristics and production footprints of Nanomaterials, while AI facilitates the discovery of eco-friendly Nanomaterials. Robotics improves supply chain efficiency, quality, and speed (Konstantopoulos, 2022). Moreover, RFID technology enhances cost reduction and customer responsiveness, while blockchain enables secure financial transactions within smart supply chains (Ivanov, 2019). The Nano supply chain emphasizes precise supplier selection, localized facilities, and cost-effective design processes, enabling multifunctional part sourcing and efficient distribution ((Palathinkal, 2008), 2008).

According to Figure (1) agility in the smart supply chain helps to respond quickly to changes in customer and market demands and the value chain of Nanotechnology involves the production of Nanomaterials, which are further processed into intermediate products with reasonable characteristics. These intermediate products are used later in the manufacturing of finished goods that incorporate Nanotechnology. Figure (1) presents a proposed hybrid model for cost management of agility smart supply chains using Nanotechnology that consists of the following components: suppliers, as the selection of suppliers that provide the components of Nanotechnology can impact the agility of the supply chain; manufacturing, including the adoption of Nanotechnology in design, assembly plants, and the use of Nanoscale structures in unprocessed forms; distribution phase of the supply chain, which can benefit from Nanotechnology, for example in packaging and also in tracking and tracing; design, as incorporating Nanotechnology in the design phase can lead to innovative and agile supply chain solutions, optimizing costs and enhancing performance; dealers; Nano supply chain, as the implementation of Nanotechnology-specific supply chain practices and technologies, such as cloud computing, big data, IoT, 3D printing, cyber-physical systems, RFID, robotics, blockchain, artificial intelligence, and machine learning, can enhance supply chain agility and optimize costs; Accessibility and Joint Planning support Nanotechnology value chain; Nanomaterials and Nano intermediate; finally, Nano-enabled products as finished goods that incorporate Nanotechnology can offer unique capabilities, potentially improving supply chain agility and cost-effectiveness. Please review the punctuation and make the necessary adjustments accordingly.

The suggested hybrid model can be further developed by focusing on several key areas. Firstly, investing in research and development will facilitate the creation of new Nanotechnology advancements that can effectively reduce overall costs. Additionally, ensuring compliance with regulations will play a significant role in the successful implementation of Nanotechnology, supporting ethical practices and social responsibility. The utilization of predictive analytics, powered by advanced technologies, will enable better alignment with customer demands. Develop performance measurement metrics to evaluate the impact of Nanotechnology on supply chain performance. Lastly, expanding the use of robotics in the supply chain will enhance quality control measures

6. Research methodology

6.1 Data collection and objective

The study focuses on conducting a case study on the Egyptian Electric Cables Company due to several factors, including the recent implementation of Nanotechnology in the industrial sector in Egypt, The Importance of the Electric sector in Egypt, and the complexity of the topic. This study aims to build a model for managing the cost of agility smart supply chain in the Nanotechnology environment. To achieve this objective, the fuzzy model was utilized, and data was collected through personal interviews with some officials within the company. The company began the practical implementation of Nanotechnology in 2022

The study by (Shariati, 2017) uses the fuzzy model and determines the cost and performance as the main criteria in the application of Nanotechnology. On the other hand, the study conducted by (Seyedhoseini, 2010), and (Matwale, 2012) utilized a fuzzy model to evaluate the agile smart supply chain derived from the agile-capable attribute-criterion hierarchy. The contribution of this research lies in integrating the use of the Fuzzy model into agility smart supply chain and Nanotechnology as an additional innovation of this study involves the utilization of the fuzzy model within Nanotechnology in the context of responsive smart supply chains.

6.2 Fuzzy Model Description

According to (Figure 2), Smart supply chains include sourcing, manufacturing, and delivery. The fuzzy model capabilities in the smart supply chain include Flexibility (C1), Responsiveness (C2), Competence (C3), Cost (C4), and Performance (C5). A study by (Shariati, 2017) uses Cost and performance as indicators to evaluate Nanotechnology, and other studies use flexibility, responsiveness, competence, and cost to assess the agility of smart supply chains (Seyedhoseini, 2010); and (Matwale, 2012). In this study, we combined the use of agility smart supply chain and Nanotechnology through the Fuzzy Model.

6.3 Fuzzy Model Steps

The steps presented below are based on the findings and contributions of the previous studies (Shariati, 2017); (Seyedhoseini, 2010); and (Matwale, 2012).

Step1: Determination of the capabilities and attributes of Nanotechnology and Agility in smart supply chains. The goal of this step is to establish a framework for evaluating these capabilities and attributes in the context of a smart supply chain. The significance of these capabilities and attributes (see Table 6 and Figure 3)

Step2: Determination of the linguistic scale for assessing the performance ratings and importance weight for agile and Nanotechnology. This step focuses on determining the linguistic scale for assessing the performance ratings and importance weights for both agility and Nanotechnology in the context of smart supply chains. Each fuzzy number is represented as a range within square brackets and consists of four values, with the fifth value representing a level of importance. The weights associated with each linguistic variable are used to assign different levels of importance to the linguistic variables when making assessments or calculations in the fuzzy model. The linguistic variables are used to describe the performance or importance levels qualitatively, each linguistic variable corresponds to a range within the fuzzy and can be used to determine how well a specific data belongs to a particular category within the linguistic variable (see Table 2)

Step3: Determination of Fuzzy Performance Index:

-The fuzzy index for each agile attribute has been calculated as follows:

$$U_{i,j} = \frac{\sum_{k=1} \left(w_{i,j,k} \otimes U_{i,j,k}\right)}{\sum_{k=1}^{n} w_{i,j,k}} \longrightarrow 1$$

Where:

$U_{i,j,k}$: represent aggregated fuzzy performance measure (rating)) (Nanotechnology attribute)

$w_{i,j,k}$: represent aggregated fuzzy weight corresponding to the agile criterion $C_{i,j,k}$

-The fuzzy index for each agile capability has been calculated as follows:

$$\mathrm{U_i} = \frac{\sum_{j=1}^{n} (\mathrm{w_{i,j}} \otimes \mathrm{U_{i,j}})}{\sum_{j=1}^{n} \mathrm{w_{i,j}}} \longrightarrow 2$$

$U_{i,j}$: represent computed fuzzy performance measure (rating) obtained from equation 1

$\mathrm{w_{i,j}}$: represent aggregated fuzzy performance measure (rating)(Nanotechnology capability)

$\mathrm{U_{i,j}}$: represent aggregated fuzzy weight corresponding to the agile criterion Ci j k

-The fuzzy performance index has been calculated as follows:

$$\mathrm{U(FPI)} = \frac{\sum_{i=1}^{n} (\mathrm{w_i} \otimes \mathrm{U_i})}{\sum_{i=1}^{n} \mathrm{w_i}} \mathrm{U} \longrightarrow 3$$

Where:

Ui: Computed fuzzy performance rating of agile capability (Ci) obtained from equation 2

w_i: Aggregated fuzzy weight of agile capability

i: 1, 2, 3……….n

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This step involves the determination of the fuzzy performance index, which is a method for calculating the overall performance of agile attributes and capabilities with a specific focus on Nanotechnology capabilities and attributes within the context of smart supply chains. Equation one aims to calculate the fuzzy index for each agile attribute related to the Nanotechnology attribute, the formula summing the weighted performance measures for each attribute, and this sum is then divided by the sum of the fuzzy weights, see (Tables 3 and 5). Equation two shifts from individual attributes to the overall capabilities related to Nanotechnology, The formula calculates the fuzzy index for each agile capability by summing the weighted performance measures for the attributes within that capability, and this sum is then divided by the sum of the fuzzy weights, see (Tables 3and 4). Equation three goal is to calculate the fuzzy performance index which represents the overall performance of the entire system considering all agile capabilities, the formula calculates the fuzzy performance index by summing the weighted performance rating for each capability, and this sum is then divided by the sum of the fuzzy weights for all capabilities, see (Table 3). Fuzzy Performance Index becomes: (0.45, 0.62, 1.50, 1.80; 0.80), (0.45, 0.62, 1.50, 1.80; 1.00) and Table 6 explains elements of capabilities, attributes, and criterions of agility and Nanotechnology in the context of the smart supply chain.

7. Results

The fuzzy performance index (FPI) is an important metric that evaluates the performance of agility smart supply chains using Nanotechnology (Shariati, 2017); (Seyedhoseini, 2010); and (Matwale, 2012), The values of the fuzzy performance index in our case study Egyptian Electric Cables are (0.45, 0.62, 1.50, 1.80; 0.80), (0.45, 0.62, 1.50, 1.80; 1.00) refer to a high level of effectiveness from the following aspects:

-Flexibility as indicated in Table 5 with its high level of importance index, plays an essential role in smart supply chains, impacting sourcing, manufacturing, and delivery. It allows for adaptability to changing market demands, with multiple supplier options, the ability to adjust order quantities and diversify product types. Manufacturing benefits from adaptable systems and techniques, accommodating various product types and quantities. Delivery flexibility involves meeting customer demands, adjusting quantities, and providing post-purchase support, See Table 6

-Responsiveness, as expressed in Table 5 with its high level of importance index, plays a significant role in smart supply chains across sourcing, manufacturing, and delivery processes. In terms of sourcing, responsiveness involves the capability to adapt delivery times according to suppliers' needs, managing and monitoring suppliers' delivery schedules, and maintaining strong supplier relationships. Manufacturing responsiveness focuses on reducing the time required to change manufacturing components and quickly adjusting production in response to market fluctuations. Delivery responsiveness entails ensuring on-time deliveries as promised, expediting the introduction of new products to the market, and providing exceptional customer service, See Table 6

-Competence, as shown in Table 5 and considering its high level of importance index, plays a crucial role in smart supply chains. This encompasses cooperation and maintaining a balance between internal and external collaboration. In terms of manufacturing competence, it involves effectively bringing new products to the market, ensuring high product and service quality, integrating various processes effectively, and reducing the time required to develop new products. Human resources also contribute to competence by developing and maintaining a skilled workforce, See Table 6

-Cost, as indicated in Table 5 and considering its high level of importance index, is a critical factor in smart supply chains. In terms of sourcing, managing the cost of sourcing Nanomaterial is essential. Manufacturing involves managing the cost of manufacturing products, expenses related to setting up manufacturing operations, and controlling expenses associated with changing manufacturing components, particularly Nanomaterial. In terms of delivery, managing the cost of delivering products is crucial, See Table 6. The high level of importance index for cost highlights its success in integrating agility and Nanotechnology in a smart supply chain.

-Performance, as displayed in Table 5 and considering its high level of importance index, is a crucial aspect of a smart supply chain integrated with Nanotechnology. In terms of sourcing performance, evaluating the efficiency and effectiveness of sourcing activities is essential. Manufacturing performance involves evaluating the effectiveness of the manufacturing process, increasing output while maintaining or improving quality, and effectively managing resources such as Nanomaterial and modern techniques to reduce reliance on manual labor. Delivery performance focuses on evaluating the effectiveness of delivery performance, See Table 6

According to the practical results displayed above, we can conclude that Egyptian Electric Cables is successful in using Nanotechnology to manage the cost of an agility smart supply chain.

8. Discussion

There is an agreement between previous studies, the study question and the practical results of the study indicating that Nanotechnology contributes to cost management of agility smart supply chain as the previous studies indicate that Nanotechnology can be used to manage the cost of smart supply chain and the practical result prove that using Nanotechnology led to achieving greater efficiency and control to all processes in the smart supply chain and finally result in increasing agility of the supply chain. Nanotechnology applications according to previous studies present innovative solutions for enhancing manufacturing processes and through practical results, we find that Nanotechnology was successfully implemented in the Egyptian Electric Cables. Based on the above discussion, we can answer the question of the research: what is the proposed model for managing the cost of agility in smart supply chains using Nanotechnology? We illustrate this approach through a fuzzy model, which can serve as an important model for companies seeking to improve their supply chain performance by incorporating Nanotechnology.

9. Conclusions and suggested future research

- The study aims to contribute to presenting a proposed hybrid model for cost management of agility smart supply chains using Nanotechnology. The integration of Nanotechnology into the practices of cost management has the effect of improving cost efficiency, competitiveness, and agility in smart supply chains.

- Industrial cost accountants, researchers in the field of Nanotechnology, supply chain managers, and stakeholders and investors will be interested in the results of this study.

- Future research should better cover new parts related to exploring the application of Nanotechnology in detecting financial fraud and enhancing auditing procedures (Nanosensors), investigating how Nanotechnology supports risk assessment in financial accounting, and Nanotechnology should expand the implementation of Nanotechnology in other fields such as agriculture field, energy, and communication fields.

- The study's scope was confined to managing the cost of agility in smart supply chains using Nanotechnology in Egypt, specifically concentrating on a single company within the industrial sector listed on the Egyptian Stock Exchange. Consequently, generalizing the results regarding the successful application of Nanotechnology in the industrial sector to other sectors becomes challenging. Furthermore, due to the differences in the Egyptian environment compared to others, additional studies are necessary.

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Table1: Literature Review

Reference	Research issue	Findings
Unhelkar, et al., (2022)	Investigated the importance of Radio Frequency Identification (RFID) technology in the supply chain especially with implementing big data.	Utilization of RFID led to a nearly 60% reduction in time for providing materials and an 84% reduction in transportation and lag time resulting in an overall improvement of supply chain efficiency of almost 80%
Ali, et al., (2022)	Examined the impact of Nanotechnology on several commodities and materials.	-Implemented Nanotechnology supported strategic cost management, Cost management is an important approach for reallocating indirect costs based on product specifications to meet consumer demands -Strategic cost management techniques enabled organizations to remain competitive and allowed them to reduce costs without compromising product quality.

Dai, et al., (2022)	Evaluated a supply chain system based on Nano-voice technology.	-Voice big data-enhanced transparency and standardization in the supply chain process, leading to cost savings and improved economic advantages for supply chain enterprises. -Voice big data analysis reduced inventory costs by approximately 21% and improved static productivity by around 24%
Golan, et al., (2021)	Explored the utilization of Nanotechnology in the design of the supply chain and concentrated on its potential to reduce risk during covid-19 pandemic.	Integrated Nanotechnology with advanced technologies like artificial intelligence and machine learning helped to face unexpected disruptions like covid-19 pandemic and improved adaptability and resilience of supply chains.
Ali, (2019)	Analyzed the impact of Nanotechnology on decreasing production costs for industrial companies.	-Founded that Nanotechnology decreased total costs related to the product life cycle by 80 to 90% enabling the quick development of new Nanoparticles with similar properties -resulted in cost reduction by minimizing labor inputs and eliminating expenses related to storage, shipping, and distribution.
Agburuga, (2019)	Presented the importance of Nanotechnology in industrial development by applying accounting innovations capable of translating new technological knowledge into job opportunities and industrial development.	Nanotechnology has supported economic growth and improved industrial development in the face of technological advancements.
Shariati, et al., 2017	The paper revolves around the evaluation of critical factors in applying Nanotechnology within the construction industry. The aim is to identify key aspects that significantly impact the utilization of Nanomaterials in construction, considering factors like performance enhancement, structural safety, energy efficiency, and cost reduction	The paper introduces a novel model combining intuitive fuzzy sets (IFS) and analytical network processes (ANP) techniques. The model proves to be highly effective in evaluating and prioritizing critical factors within the context of applying Nanotechnology in construction.

Maher T.Alshamkhani, (2017)	Presented a framework for using Nanotechnology in the design and control of product life cycle.	-Nanotechnology led to the prevention of unwanted substances and pollutants. -The initial costs of research and development for Nanotechnology have been higher in the initial stage but in the long term, benefits included reduced quality costs, distribution, and production.
Rababah, (2017)	Addressed the impact of Nanotechnology on the cost structure of industries and risks related to its implementation.	-Nanotechnology supports product quality -Nanotechnology led to reduced costs by reducing waste and enhancing resource utilization.
Iraj Ahmadi, et al., (2014)	The impact of Nanotechnology applications on production costs during the manufacturing process.	Nanotechnology resulted in dynamic changes like improvement in the quality of capital stock, modification in the workforce structure, and shifts in consumption patterns.
Matwale, et al., 2012	The research seeks to establish a comprehensive metric for estimating the agility level of supply chains and aims to develop a procedural hierarchy tailored to evaluate the overall performance of an agile supply chain within the Indian context. Utilizing the principles of generalized interval-valued fuzzy numbers (IVFNs).	The research explores the concept of 'degree of similarity' between fuzzy numbers to rank various agile criteria based on their performance levels, providing insights into prioritizing areas for enhancement within the supply chain.
Seyedhoseini, et al., 2010	The study focuses on developing an innovative method utilizing the Adaptive Neuro-Fuzzy Inference System (ANFIS) to measure various agility capabilities (such as flexibility, competency, cost, responsiveness, and quickness) within an ambiguous environment.	The study's implementation within a large-scale automobile manufacturing company in Iran demonstrates the practical applicability of the proposed approach. Statistical analyses affirm the effectiveness of the developed procedure, showing no significant differences between the opinions of experts and the outcomes derived from the proposed ANFIS-based method.
Palathinkal, et al., (2008)	Demonstrated advanced supply chain strategies that enable companies to adapt to new market conditions.	Tata Motors' results were increased by providing cutting-edge Nano-coating for painting various car models, including Mercedes and the company had no available stock.

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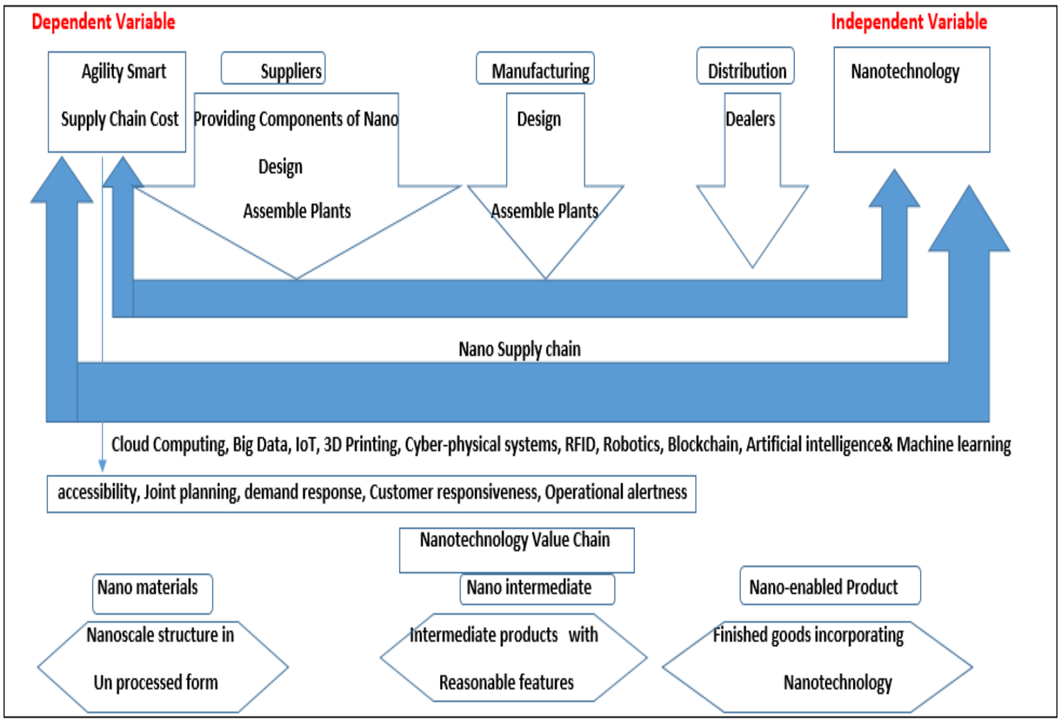

Fig1: A proposed hybrid model to clarify the relationship between agility smart supply chain cost and Nanotechnology

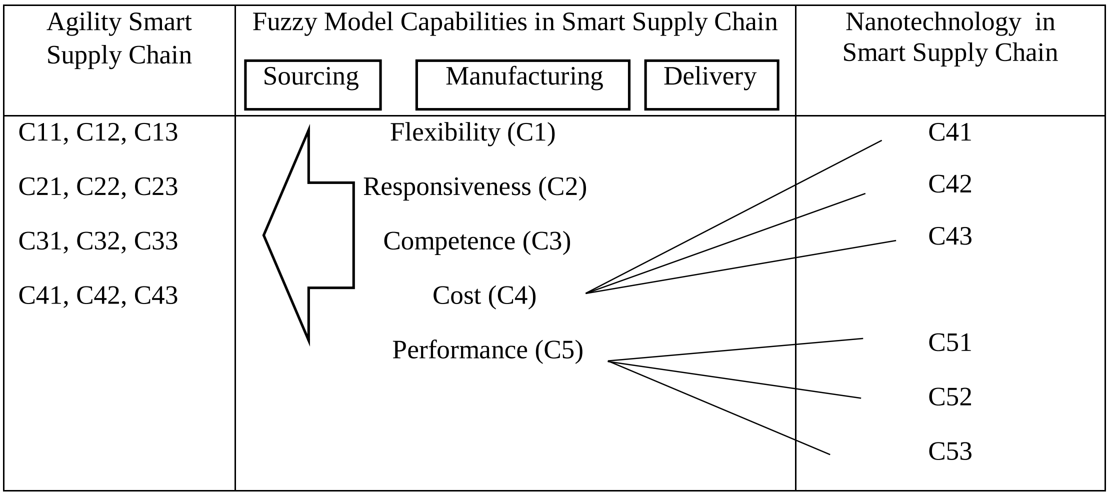

Fig2: The Fuzzy Model integrates Nanotechnology with agility in the Smart Supply Chain (Source: Prepared by researchers)

Capabilities of Agility Smart Supply Chains			
Flexibility (C1)	Responsiveness (C2)	Competence (C3)	Cost (C4)
1-Sourcing C11 2-Manufacturing C12 3-Delivery C13	1-Sourcing C21 2-Manufacturing C22 3-Delivery C23	1-Sourcing C31 2-Manufacturing C32 3-Delivery C33	1-Sourcing C41 2-Manufacturing C42 3-Delivery C43

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Capabilities of Nanotechnology in Smart Supply Chains	
Cost (C4)	Performance (C5)
1-Sourcing C41 2-Manufacturing C42 3-Delivery C43	1-Sourcing C51 2-Manufacturing C52 3-Delivery C53

Figure 3: The capabilities and attributes of Nanotechnology and Agility in smart supply chains

Table 2: The linguistic scale for assessing the performance ratings and importance weight for the agile

Linguistic Variables	weights	Generalized-interval-valued trapezoidal fuzzy numbers
Absolutely Poor (AP)	Absolutely Low (AL)	[(0, 0, 0, 0; 0.8), (0, 0, 0, 0; 1)]
Very Poor (VP)	Very Low (VL)	[(0, 0, 0.02, 0.07; 0.8), (0, 0, 0.02, 0.07; 1)]
Poor (P)	Low (L)	[(0.04, 0.10, 0.18, 0.23; 0.8), (0.04, 0.10, 0.18, 0.23; 1)]
Medium Poor (MP)	Medium Low (ML)	[(0.17, 0.22, 0.36, 0.42; 0.8), (0.17, 0.22, 0.36, 0.42; 1)]
Medium (M)	Medium (M)	[(0.32, 0.41, 0.58, 0.65; 0.8), (0.32, 0.41, 0.58, 0.65; 1)]
Medium Good (MG)	Medium High (MH)	[(0.58, 0.63, 0.80, 0.86; 0.8), (0.58, 0.63, 0.80, 0.86; 1)]
Good (G)	High (H)	[(0.72, 0.78, 0.92, 0.97; 0.8), (0.72, 0.78, 0.92, 0.97; 1)]
Very Good (VG)	Very High (VH)	[(0.93, 0.98, 1, 1; 0.8), (0.93, 0.98, 1, 1; 1)]
Absolutely Good (AG)	Absolutely High (AH)	[(1, 1, 1, 1; 0.8), (1, 1, 1, 1; 1)]

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Table 3: Aggregated weight and computed rating of agile attributes

Agile attributes $C_{i,j}$	Aggregated weight of agile attributes	Computed rating of agile attributes
C11	(0.82,0.88,0.93,0.98;0.80),(0.82,0.88,0.93,0.98;1.00)	(0.78,0.89,1.17,1.30;0.80),(0.78,0.89,1.17,1.30;1.00)
C12	(0.84,0.97,0.96,0,.99;0.80),(0.84,0.97,0.96,0.99;1.00)	(0.59,0.70,0.93,1.18;0.80),(0.59,0.70,0.93,1.18;1.00)
C13	(0.71,0.76,0.92,0.98;0.80),(0.71,0.76,0.92,0.98;1.00)	(0.68,0.78,1.11,1.18;0.80),(0.68,0.78,1.11,1.18;1.00)
C21	(0.83,0.97,0.95,0.98;0.80),(0 .83,0.97,0.95,0.98;1.00)	(0.54,0.66,0.99,1.22;0.80),(0.54,0.66,0.99,1.22;1.00)
C22	(0.88,0.92,0.95,0.99;0.80),(0.88,0.92,0.95,0.99;1.00)	(0.77,0.88,1.09,1.33;0.80),(0.77,0.88,1.09,1.33;1.00)
C23	(0.66,0.72,0.88,0.94,0.80),(0.66,0.72,0.88,0.94;1.00)	(0.61,0.73,0.97,1.14;0.80),(0.61,0.73,0.97,1.14;1.00)
C31	(0.90,0.96,0.96,0.99;0.80),(0.90,0.96,0.96,0.99;1.00)	(0.31,0.40,0.64,0.78;0.80),(0.31,0.40,0.64,0.78;1.00)
C32	(0.82,0.88,0.93,0.98;0.80),(0.82,0.88,0.93,0.98;1.00)	(0.72,0.84,1.20,1.38;0.80),(0.72,0.84,1.20,1.38;1.00)
C33	(0.79,0.85,0.91,0.96;0.80),(0.79,0.85,0.91,0.96;1.00)	(0.66,0.79,1.22,1.43;0.80),(0.66,0.79,1.22,1.43;1.00)
C41	(0.95,0.91,0.98,0.99;0.80),(0.95,0.91,0.98,0.99;1.00)	(0.84,0.94,1.14,1.25;0.80),(0.84,0.94,1.14,1.25;1.00)
C42	(0.76,0.92,0.95,0.99;0.80),(0.76,0.92,0.95,0.99;1.00)	(0.60,0.72,0.96,1.23;0.80),(0.60,0.72,0.96,1.23;1.00)
C43	(0.82,0.88,0.93,0.98;0.80),(0.82,0.88,0.93,0.98;1.00)	(0.67,0.80,1.20,1.41;0.80),(0.67,0.80,1.20,1.41;1.00)
C51	(0.94,0.90,0.97,0.98;0.80),(0.94,0.90,0.97,0.98;1.00)	(0.83,0.93,1.13,1.24;0.80),(0.83,0.93,1.13,1.24;1.00)
C52	(0.82,0.88,0.93,0.98;0.80),(0.82,0.88,0.93,0.98;1.00)	(0.78,0.89,1.17,1.30;0.80),(0.78,0.89,1.17,1.30;1.00)
C53	(0.75,0.91,0.94,0.98;0.80),(0.75,0.91,0.94,0.98;1.00)	(0.61,0.73,0.97,1.24;0.80),(0.61,0.73,0.97,1.24;1.00)

Table 4: Aggregated weight and computed rating of agile enablers

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Agile enablers Ci	Aggregated weight of agile capabilities	Computed rating of agile capabilities
C1	(0.95,0.91,0.98,0.99;0.80),(0.95,0.91,0.98,0.99;1.00)	(0.54,0.69,1.27,1.61;0.80),(0.54,0.69,1.27,1.61;1.00)
C2	(0.99,1.00,1.00,1.00;0.80), (0.99,1.00,1.00,1.00;1.00)	(0.52,0.67,1.26,1.64;0.80),(0.52,0.67,1.26,1.64;1.00)
C3	(0.82,0.88,0.93,0.98;0.80),(0.82,0.88,0.93,0.98;1.00)	(0.45,0.59,1.16,1.53;0.80),(0.45,0.59,1.16,1.53;1.00)
C4	(0.81,0.86,0.94,0.99;0.80),(0.81,0.86,0.94,0.99;1.00)	(0.58,0.74,1.27,1.61;0.80),(0.58,0.74,1.27,1.61;1.00)
C5	(0.80,0.85,0.93,0.98;0.80),(0.80,0.85,0.93,0.98;1.00)	(0.57,0.73,1.26,1.60;0.80),(0.57,0.73,1.26,1.60;1.00)

Table 5: Estimation of (FPII) of agile criterions

Agile criterion $C_{i,j,k}$	$w'_{i,j,k} = [(1,1,1,1;1) - w_{i,j,k}]$	Fuzzy Performance Importance Index (FPI) $w'_{i,j,k} \otimes U_{i,j,k}$
C111	(0.000,0.000,0.108,0.128;0.800), (0.000,0.000,0.108,0.128;1.000)	(0.000,0.000,0.108,0.128;0.800),(0.000,0.000,0.108,0.128;1.000)
C112	(0.130,0.180,0.320,0.380;0.800),(0.130,0.180,0.320,0.380; 1.000)	(0.122,0.162,0.302,0.372;0.800),(0.122,0.162,0.302,0.372;1.000)
C113	(0.152,0.204,0.350,0.408; 0.800),(0.152,0.204,0.350,0.408;1.000)	(0.144,0.194,0.342,0.404;.0.800),(0.144,0.194,0.342,0.404;1.000)
C121	(0.174,0.228,0.380,0.436;0.800),(0.174,0.228,0.380,0.436;1.000)	(0.145,0.184,0.331,0.396;0.800),(0.145,0.184,0.331,0.396;1.000)
C122	(0.000,0.000,0.120,0.170;0.800),(0.000,0.000,0.120,0.170;1.000)	(0.000,0.000,0.113,0.150;0.800), (0.000,0.000,0.113,0.150;1.000)
C123	(0.130,0.180,0.320,0.380;0.800), (0.130,0.180,0.320,0.380;1.000)	(0.172,0.175,0.316,0.378;0.800),(0.172,0.175,0.316,0.378;1.000)
C131	(0.196,0.252,0.410,0.464;0.800),(0.196,0.252,0.410,0.464;1.000)	(0.164,0.209,0.370,0.437;0.800),(0.164,0.209,0.370,0.437;1.000)
C132	(0.000,0.000,0.000,0.000;0.800),(0.000,0.000,0.000,0.000;1.000)	(0.000,0.000,0.000,0.000;0.800),(0.000,0.000,0.000,0.000;1.000)
C133	(0.130,0.180,0.320,0.380;0.800), (0.130,0.180,0.320,0.380;1.000)	(0.122,0.162,0.302,0.372;0.800),(0.122,0.162,0.302,0.372;1.000)

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C211	(0.412,0.476,0.640,0.706;0.800),(0.412,0.476,0.640,0.706;1.000)	(0.351,0.423,0.614,0.695;0.800), (0.351,0.423,0.614,0.695;1.000)
C212	(0.118,0.148,0.240,0.296;0.800), (0.118,0.148,0.240,0.296;1.000)	(0.110,0.129,0.206,0.262;0.800),(0.110,0.129,0.206,0.262;1.000)
C213	(0.130,0.180,0.320,0.380;0.800),(0.130,0.180,0.320,0.380;1.000)	(0.117,0.150,0.186,0.341;0.800),(0.117,0.150,0.186,0.341;1.000)
C221	(0.112,0.132,0.196,0.240;0.800), (0.112,0.132,0.196,0.240;1.000)	(0.109,0.125,0.188,0.236;0.800),(0.109,0.125,0.188,0.236;1.000)
C222	(0.152,0.204,0.350,0.408;0.800),(0.152,0.204,0.350,0.408;1.000)	(0.151,0.203,0.350,0.408;0.800),(0.151,0.203,0.350,0.408;1.000)
C231	(0.112,0.132,0.100,0.254,0.800),(0.112,0.132,0.100,0.254;1.000)	(0.109,0.125,0.192,0.249;0.800),(0.109,0.125,0.192,0.249;1.000)
C232	(0.130,0.180,0.320,0.380;0.800), (0.130,0.180,0.320,0.380;1.000)	(0.125,0.172,0.313,0.377;0,800),(0.125,0.172,0.313,0.377;1.000)
C233	(0.130,0.180,0.320,0.380;0.800), (0.130,0.180,0.320,0.380;1.000)	(0.111,0.135,0.237,0.294;0.800),(0.111,0.135,0.237,0.294;1.000)
C311	(0.118,0.148,0.240,0.296;0.800), (0.118,0.148,0.240,0.296;1.000)	(0.105,0.116,0.169,0.209;0.800),(0.105,0.116,0.169,0.209;1.000)
C321	(0.196,0.252,0.410,0.464;0.800),(0.196,0.252,0.410,0.464;1.000)	(0.169,.0.219,0.385,0.453,0.800),(0.169,0.219,0.385,0.453,1.000)
C322	(0.130,0.180,0.320,0.380;0.800), (0.130,0.180,0.320,0.380;1.000)	(0.122,0.162,0.302,0.372;0.800),(0.122,0.162,0.302,0.372;1.000)
C323	(0.130,0.180,0.320,0.380;0.800), (0.130,0.180,0.320,0.380;1.000)	(0.130,0.180,0.320,0.320;0.800),(0.130,0.180,0.320,0.320;1.000)
C324	(0.112,0.132,0.196,0.240;0.800), (0.112,0.132,0.196,0.240;1.000)	(0.110,0.128,0.191,0.232;0.800),(0.110,0.128,0.191,0.232;1.000)
C331	(0.152,0.204,0.350,0.408;0.800),(0.152,0.204,0.350,0.408;1.000)	(0.140,0.185,0.334,0.401;0.800),(0.140,0.185,0.334,0.401;1.000)
C411	(0.112,0.132,0.100,0.254,0.800),(0.112,0.132,0.100,0.254;1.000)	(0.110,0.129,0.197,0.252;0.800),(0.110,0.129,0.197,0.252;1.000)
C421	(0.152,0.204,0.350,0.408;0.800),(0.152,0.204,0.350,0.408;1.000)	(0.125,0.156,0.278,0.339;0.800),(0.125,0.156,0.278,0.339;1.000)
C422	(0.174,0.228,0.380,0.436;0.800),(0.174,0.228,0.380,0.436;1.000)	(0.153,0.100,0.358,0.426;0.800),(0.153,0.100,0.358,0.426;1.000)
C423	(0.000,0.000,0.120,0.170;0.800),(0.000,0.000,0.120,0.170;1.000)	(0.000,0.000,0.118.0.166;0.800),(0.000,0.000,0.118.0.166;1.000)
C431	(0.130,0.180,0.320,0.380;0.800),(0.130,0.180,0.320,0.380; 1.000)	(0.123,0.166,0.306,0.373;0.800), (0.123,0.166,0.306,0.373;1.000)

C511	(0.130,0.180,0.320,0.380;0.800), (0.130,0.180,0.320,0.380;1.000)	(0.122,0.162,0.302,0.372;0.800),(0.122,0.162,0.302,0.372;1.000)
C521	(0.000,0.000,0.000,0.000;0.800),(0.000,0.000,0.000,0.000;1.000)	(0.000,0.000,0.000,0.000;0.800),(0.000,0.000,0.000,0.000;1.000)
C522	(0.152,0.204,0.350,0.408;0.800),(0.152,0.204,0.350,0.408;1.000)	(0.151,0.203,0.350,0.408;0.800),(0.151,0.203,0.350,0.408;1.000)
C523	(0.112,0.132,0.100,0.254,0.800),(0.112,0.132,0.100,0.254;1.000)	(0.110,0.129,0.197,0.252;0.800),(0.110,0.129,0.197,0.252;1.000)
C531	(0.174,0.228,0.380,0.436;0.800),(0.174,0.228,0.380,0.436;1.000)	(0.153,0.100,0.358,0.426;0.800),(0.153,0.100,0.358,0.426;1.000)

Table 6: The conceptual Model for agility and Nanotechnology in smart supply chains

Goal	Capabilities	Attributes	Criterions
Agility in smart supply chain	Flexibility (C1)	Sourcing flexibility C11	C111 Numerous suppliers to choose from
			C112 Capacity to adjust the quantity of goods ordered
			C113 Capability to diversify the types of products sourced
		Manufacturing Flexibility C12	C121 Adaptable Manufacturing systems
			C122 Advanced techniques in manufacturing system
			C123 Variety of product types and quantities
		Delivery Flexibility C13	C131 Capability to meet customer demands with various supply schedules
			C132 Capacity to adjust the quantity of delivered products
			C133 Offering post-purchase customer support

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Responsiveness (C2)	Sourcing Responsiveness C21	C211 Capability to adapt delivery times as needed by suppliers
		C212 Managing and monitoring suppliers' delivery schedules
		C213 Maintaining and enhancing relationships with suppliers
	Manufacturing Responsiveness C22	C221 Reducing the time it takes to change manufacturing components
		C222 Quickly adjusting production in response to market fluctuations
	Delivery Responsiveness C23	C231 Ensuring that deliveries are made on time as promised
		C232 Speeding up the introduction of new products to the market
		C233 Providing exceptional customer service
Competence (C3)	Cooperation and Internal- External Balance C31	C311 Ensuring a balance between internal and external collaboration
	Manufacturing Competence C32	C321Effectively bringing new products to market
		C322 Ensuring high product and service quality
		C323 Integrating various processes effectively
		C324 Reducing the time it takes to develop new products
	Capabilities of Human Resources C33	C331 Developing and maintaining a skilled workforce

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	Cost (C4)	Sourcing Cost C41	C411 Managing the cost of sourcing Nanomaterial
		Manufacturing Cost C42	C421 Managing the cost of manufacturing products
			C422 Managing the expenses related to setting up manufacturing operations
			C423 Controlling the expenses associated with changing manufacturing components (Nanomaterial)
		Delivery Cost C43	C431 Managing the cost of delivering products
Nanotechnology in smart supply chain	Performance (C5)	Sourcing Performance C51	C511 Evaluating the efficiency and effectiveness of sourcing activities
		Manufacturing Performance C52	C521 Evaluating Effectiveness of Manufacturing Process
			C522Increasing the output of manufacturing processes while maintaining or improving quality
			C523 Effective management of resources in manufacturing such as Materials (nanomaterial) and modern techniques have replaced the need for manual labor
		Delivery Performance C53	C531 Evaluating the effectiveness of delivery performance