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The strategies of hub facility location and its utilization in managing the supply chain of perishable products for sustainability and uncertainty mitigation: A literature review

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A B S T R A C T

Sustainable development in supply chain management is of great importance, as it emphasizes that the procurement process in sustainable supply chains addresses not only current needs but also future requirements. This subject, by improving processes, reducing waste and energy consumption, increasing efficiency, and establishing sustainable relationships with suppliers and customers, contributes to the sustainability and success of companies in international competition. Moreover, hub location is crucial for optimizing distribution processes and reducing costs in the supply chain, especially for perishable products with a defined and limited shelf life, which imposes various constraints on the supply chain. Additionally, to bring mathematical models closer to reality, uncertainty approaches can be employed, and strategies to deal with uncertainty can be considered. This research delves into these issues in the realm of supply chain management, focusing on sustainability and uncertainty, and provides a review of research conducted in the literature of this field.

1. Introduction

At present, within the realm of supply chain management, there is an increasingly pressing need for decision-making and strategizing, particularly concerning the distribution of perishable products. These items, with their finite and defined lifespans, hold significant importance as they cease to be usable upon reaching the end of their useful life, thereby imposing considerable constraints on the supply chain. Therefore, one of the fundamental issues in this area is paying attention to timely delivery, quality, and freshness of products. The importance of decision-making in the supply chain stems from various reasons, some of which will be addressed in this section: With the advancement of technology and increased competition in the market, supply chains have become more complex, requiring intelligent and strategic decision-making in areas such as production, distribution, inventory management, and supplier selection. Rapid changes in markets and customer needs also emphasize the importance of decision-making in the supply chain. This decision-making can help companies respond quickly and consider changes in a timely manner. Effective decision-making in the supply chain can contribute to cost reduction and performance improvement. For example, inventory optimization, selecting quality suppliers, and optimal distribution management can reduce costs and enhance performance. Furthermore, appropriate decision-making can assist companies in managing risks associated with material and product procurement. This includes risks related to timely delivery, price fluctuations, quality issues, and changes in demand. Given the importance highlighted regarding the distribution of perishable products and the significance of supply chain management, location selection emerges as a crucial and influential factor in fundamental supply chain decisions. The concept of hub location in recent years has garnered considerable attention as a significant subfield in this domain. Hub location refers to the selection of suitable sites for establishing collection and distribution units within a supply chain. These hubs serve as primary centers for the collection and distribution of goods, playing a vital role in enhancing efficiency and reducing supply chain costs. The selection of appropriate locations for these hubs should be based on factors such as geographical location, market access, customer needs, transportation costs, capacity, and demand. In the context of managing the supply chain of perishable products, leveraging hub facilities can be highly effective.

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Today, businesses are expected to move towards sustainable development. The supply chain, as a complex system of processes and communications, plays a vital role in the performance and sustainability of organizations. Given the increasing competition, market fluctuations, and changes in customer needs and expectations, the importance of sustainable supply chain and organizations' ability to manage this sustainability has become one of the fundamental and vital issues for business success. A sustainable supply chain refers to a framework in which activities, processes, and measures related to the supply of raw materials, production, distribution, and consumption of goods and services are designed in a way that contributes to preserving natural resources, reducing environmental impacts, improving social conditions, and creating economic value in the long term.

This article discusses the importance of sustainability in the supply chain and the challenges and opportunities it creates.
The next topic addressed in this research is uncertainty. Most mathematical models used in previous studies have been deterministic and did not consider real-world events. In reality, multiple events can lead to changes in deterministic data. To bring the model closer to reality, it is necessary to incorporate uncertainty into the modeling. One of the fundamental issues in supply chains is meeting customer demand. This issue creates many challenges due to the uncertainty of demand and problems in the procurement, production, and distribution processes. In the continuation of this research, the introduced topics will be elaborated on, and articles published in these areas will be examined in detail.

1.1. Supply Chain

A supply chain is a set of interconnected processes and activities that includes selecting suppliers, transforming raw materials into final products, transporting these products, and distributing them to end consumers. It encompasses all stages from sourcing raw materials to distributing the final product. Essentially, the supply chain is a complex network of processes, organizations, individuals, resources, and technologies that collaborate to manage various elements related to sourcing, production, transportation, warehousing, and distribution. While the supply chain often refers to tangible and specific products, it can also include digital products or other services depending on how products are delivered. The goal of a supply chain is to ensure efficiency, reduce costs, and meet customer needs. By optimizing the supply chain, factors such as order delivery time, product quality, and service levels can be improved. However, it's important to note that supply chains may face challenges such as unstable raw materials, delivery delays, changes in customer demand, and others. Supply chain managers need to implement appropriate strategies and solutions to address these challenges. Typically, a supply chain includes the following elements:

1) Suppliers: Companies that provide the materials and components needed for manufacturing goods.
2) Manufacturers: Companies engaged in producing goods or providing services.
3) Distributors: Companies or organizations responsible for transporting goods from manufacturers to end customers.
4) Warehouses: Locations where goods are stored temporarily before being delivered to end customers.
5) Customers: Individuals or organizations seeking to purchase and use goods or services.

Products reach customers through three methods. Customers may receive the product directly from the factory without intermediaries, or the product may reach the customer through distribution centers with intermediaries. Additionally, the product may be delivered to the customer by third-party logistics (Cintron et al., 2010). Third-party logistics or Third-Party Logistics (3PL) essentially means utilizing the capacity and capabilities of other companies for transportation and distribution of products. Third-party logistics companies are specialized in transportation and warehousing, and manufacturing and service organizations may outsource all or part of their logistics activities to these companies. Some outsourcing methods in the logistics sector can have a significant impact on reducing logistics costs. Moreover, competitive pressure leads organizations to focus on areas where they have greater expertise and capabilities and delegate tasks that others do better to them. In these organizations, the focus of factories is on their key capabilities, meaning they have been able to increase their production efficiency (Hodder and Dincer, 1986). Supply Chain Management (SCM) is a concept that has evolved and grown in the manufacturing industry. During World War II, the need for optimal supply and resource management to support wars and military attacks can be considered as early examples of supply chain management. In the 1960s and 1970s, global trade and industrial development increased significantly. This increase was accompanied by challenges such as cost reduction, inventory optimization, quality improvement, and ensuring timely supply. In the early 1980s, the concept of Supply Chain Management was first introduced to the literature by Oliver and Weber, who were both logistics consultants. Supply Chain Management involves the strategic coordination of planning, execution, and oversight of supply chain activities to optimize efficiency. It encompasses the management of all stages of product flow, from sourcing raw materials to delivering finished goods to consumers. It represents an integrated methodology for orchestrating the movement of materials and information seamlessly from suppliers to end-users (chopra, 2015).

The main process of Supply Chain Management, as defined by the World Supply Chain Assembly, is as follows:

1) Customer Relationship Management
2) Customer Service Management
3) Demand Management

4) Order Fulfillment
5) Production Flow Management
6) Supplier Relationship Management
7) Product Improvement and Commercialization
8) Return Management.

1.2. Closed Loop Supply Chain

In the past decade, due to global climate changes, the importance of logistics, especially in managing its reverse flow, has significantly increased. Reverse logistics is a vital part of the supply chain that deals with controlling and managing the flow of materials, products, and information from the consumer back to the producer. In essence, reverse logistics involves processes such as product returns from customers to producers, operations for repairing and recycling products, waste material disposal and recycling management, and establishing reverse distribution centers. Over the past two decades, certain factors have led many reputable companies such as Dell, General Motors, etc., to increase activities like repairs, refurbishment, and overall revitalization and recycling of products at the end of their supply chain and their useful life, achieving considerable success in this field. When both forward and reverse logistics networks are considered simultaneously, a closed-loop supply chain system is formed (Alinezahd, 2019). A closed-loop supply chain refers to a structure or network of supply and distribution where the process of recycling and returning used products to the initial production stage is considered. In this system, instead of disposing of a product as waste after use, it is collected, recycled, repaired, and ultimately reintroduced to the market to minimize resource consumption and preserve the environment. Closed-loop supply chain management encompasses all logistics flows within the chain (such as material sourcing, production, and distribution), as well as reverse logistics flows for collecting and processing returned products (such as used or defective products) or parts of these products, to ensure sustainable socio-economic and environmental recovery.

1.3. Progress and Evolution Trends in the Supply Chain in Recent Decades

In recent decades, the supply chain has experienced significant transformations and advancements due to technological progress and changes in communication capabilities. These changes have occurred more broadly in the following areas:

1) Artificial Intelligence and Automation: The use of artificial intelligence, smart machines, and robots in supply chain processes has led to improved efficiency, reduced errors, increased speed, and enhanced accuracy in decision-making.
2) Internet of Things (IoT): By connecting devices and equipment to the internet, there is greater visibility and control throughout the supply chain. Examples of IoT applications include monitoring equipment status and functionality, sending alert signals in case of malfunctions, and improving demand forecasting.
3) Blockchain: Blockchain technology, by establishing an immutable and trust-building information system, has provided greater security and transparency in the supply chain. The impact of blockchain on the supply chain is significant and noteworthy. As a distributed and tamper-proof information system, blockchain can connect all supply chain members in a network and facilitate the transfer, recording, and validation of transactions. By using blockchain in the supply chain, information related to production, transportation, distribution, and sales of products becomes verifiable and transparent. This helps supply chain managers to have a more accurate awareness of different stages of the chain and quickly identify risks and deficiencies. Blockchain, with the capability of creating smart contracts and automating transaction execution, can contribute to greater trust and confidence among parties in the supply chain. Additionally, by adopting blockchain technology, the possibility of fraud and data tampering in the supply chain is minimized, and all transactions are publicly accessible to network members.
4) Development of Sustainable Energy Resources: In the supply chain industry, the use of sustainable energy sources, such as solar and wind energy, particularly in the transportation sector, is widely practiced, leading to reduced environmental pollution and operational costs.

These transformations have led to improved capabilities, increased efficiency, and, of course, new challenges in the supply chain. Over time and with the development of technology, supply chain management plays a more crucial role in large businesses. This chain must not only meet daily needs but also adapt to customer preferences and changes in product portfolios. These factors contribute to the complexity of the supply chain.

1.4. Risk in the Supply Chain

In recent years, attention to risk and uncertainty in the supply chain has become increasingly attractive and important for researchers and scholars. Risk in the supply chain refers to unforeseen events that may disrupt the natural flow of materials and information within the chain, consequently causing disruptions in chain performance (Jüttner, 2005). Risk in the supply chain refers to any threat, danger, or uncertainty that may affect the performance and operations of the supply chain. These risks can arise from both internal and external sources of the supply chain and include factors such as delays in raw material delivery, product quality defects, supplier instability, changes in laws and regulations, currency exchange rate fluctuations, and more.

As the supply chain involves numerous members and stages, risks can be transferred from one part to other members and disrupt the flow of materials and information. These disruptions can lead to decreased efficiency, increased costs, delays in product and service delivery, financial losses, and damage to the company's reputation. One of the fundamental characteristics of the supply chain is the relationship between all its members. Therefore, the risk associated with one segment is transferred to other members as well. For example, when a supplier goes bankrupt, it directly impacts not only the next link but all members of the chain (Christopher, 2003). Identifying, managing, and controlling various risks in the supply chain is vital because there is a wide spectrum of risks that may have negative impacts on supply chain performance and efficiency.

In the preceding section, we conducted an in-depth exploration of the fundamental principles of the supply chain, laying the groundwork for a comprehensive review of the literature on its various subcategories.

2. Literature review

In this section, topics introduced in the previous section, including perishable product supply chains, hub location, uncertainty management and coping methods, sustainable supply chains, and the combination of hub location and perishable product supply chains, are examined and categorized. In each subsection, relevant articles related to the topic under review are summarized and reviewed.

2.1. Perishable products

Perishable products are commodities that degrade with time, meaning they lose their quality and characteristics prior to their expiration date, ultimately becoming completely unusable upon expiry. In recent times, the management of perishable inventory has gained significant importance, attributed to technological progressions, the presence of competitive markets, and the heightened demands of consumers. Perishable products encompass goods with a predetermined lifespan, after which they are deemed unfit for consumption. Alternatively, they are defined as items with a limited shelf life, susceptible to spoilage or decay if not stored correctly. Such products include perishable food items like fresh produce, dairy, meat, seafood, and cooked meals. Additionally, perishable goods may also comprise pharmaceuticals, vaccines, organ transplants, blood, flowers, and certain chemicals. Although flowers and specific medicinal and chemical substances are also perishable, discussions on the storage of perishable goods typically center around the food industry and products such as meat, fish, dairy, fruits, and vegetables. The perishability of these products is primarily due to their composition, moisture, and susceptibility to biological, chemical, or physical deterioration over time. There are two completely different types of bacteria that can be present in food: pathogenic bacteria that cause foodborne illnesses and spoilage bacteria that cause food to spoil and develop unpleasant odors, flavors, and textures. These two families of bacteria are entirely distinct from each other.

Elements like temperature, humidity, light exposure, and oxygen levels have a considerable influence on the quality and safety of perishable products. Preserving freshness and prolonging the shelf life of perishable goods necessitates proper storage conditions and preservation methods. These conditions encompass maintaining precise temperature control throughout the supply chain, employing cold chain management strategies, and utilizing specialized packaging materials like insulated containers or refrigerated transportation to uphold product integrity. Vigilant monitoring and prompt distribution are imperative for ensuring perishable goods reach consumers in optimal condition. Effective inventory management, accurate forecasting, and efficient logistics play a vital role in minimizing spoilage and product waste. In addition to logistical hurdles, perishable items present unique risks to supply chain stakeholders, including potential product recalls, compromised product quality, escalated costs linked to refrigeration and transportation, and the imperative to adhere to rigorous health and safety regulations. To mitigate these risks and maximize the value of perishable goods, supply chain participants must institute robust quality control measures, establish efficient communication channels, and foster close collaboration with suppliers, distributors, and retailers. This entails implementing real-time monitoring systems, conducting routine inspections, and adhering to appropriate management and storage protocols.

Categorized by the perishability traits of products, inventory models fall into two main groups: (1) models with fixed lifespans and (2) models with stochastic lifespans (Kouki et al., 2013). Products whose lifespans cannot be predetermined at the time of inventory are recognized as stochastic lifespan products (Goyal & Giri, 2001).

The subsequent articles in this domain are examined.

Ghare (1963) pioneered the development of inventory models specifically tailored for perishable items and introduced an economic order quantity model designed for perishable products. Goyal and Giri (2001) conducted a review of research conducted in the 1990s focusing on inventory management of perishable products. Blanco et al. (2005) presented a planning model aimed at maximizing profits in a fruit packaging facility located in Argentina. Naso et al. (2007) examined the coordination challenges between production and distribution activities across various independent supply hubs, particularly emphasizing the timely delivery of perishable goods. Major obstacles involved scheduling, routing, product spoilage, and notable disruptions. Lodree and Uzochukwu (2008) Proposed a nonlinear inventory model spanning two periods for vegetables, accounting for stochastic demand and non-zero lead time, with the objective of profit maximization. Ouyang et al.

(2009) Explored an economic order quantity model integrating time delays., particularly relevant for perishable items like fruits and vegetables where the retail selling price per unit substantially exceeds the purchase price. Zhang and Luo (2011) analyzed a two-tier supply chain handling perishable product, considering demand fluctuations caused by stockouts. They found that utilizing quantity discount contracts improved supply chain coordination under conditions of symmetric information. Amorim et al. (2012) developed a dual-objective model focusing on maximizing product freshness while minimizing transportation and spoilage expenses. Grunow and Piramuthu (2013) explored the application of Radio Frequency Identification (RFID) technology in mitigating waste within the perishable food supply chain, employing RFID tags and specialized sensors to gather environmental data pertaining to food conditions.

Herbon et al. (2014) Managed inventory via dynamic pricing based on time-temperature indices, while assigning each item a randomly distributed useful life. Muriana (2015) Explored the influence of time-temperature indices on variations in the quality of food items throughout inventory management, while accounting for a widely acknowledged random distribution for product shelf life. Hajimirzajan et al. (2015) presented a supply chain model for the production and distribution of perishable goods, involving farms, refrigeration facilities, and wholesalers, with demand fulfillment via imports. Chung and Kwon (2016) proposed a comprehensive supply chain management framework to explore the extensive influence of product perishability across producers, distribution centers, wholesalers, and demand markets. Devapriya et al. (2016) addressed issues related to spoilage of perishable products, integrating production and distribution planning within limited planning horizons to minimize overall production and distribution costs. Tiwari et al. (2018) introduced an inventory management model for perishable goods with a sustainable approach to cost reduction and environmental impact mitigation.

Shafiee et al. (2021) developed a sustainable three-tier supply chain for a dairy company, optimizing total costs while considering environmental and social concerns, with delivery time and FIFO policy being crucial factors. Jabarzadeh et al. (2020) investigated an optimization problem for a closed-loop supply chain of perishable agricultural products, aiming to achieve sustainability goals such as reducing total network costs, carbon dioxide emissions, and enhancing demand responsiveness. Rajabi et al., (2021) devised a novel two-tier game model for pricing and inventory management in a competitive supply chain, involving a dominant producer of a single perishable product and two followers facing nonlinear pricing. Alemany et al. (2020) examined optimization models, both centralized and distributed, for multi-farm product planning amid uncertainty, demonstrated through a case study of the fresh tomato supply chain in Argentina. Gerdrodbari et al. (2022) introduced a multi-objective approach to managing the distribution of perishable products within a closed-loop supply chain. They employed robust optimization (RO) to address model uncertainty and devised the Non-dominated Sorting Genetic Algorithm II (NSGA-II) for tackling large-scale challenges. Zarouri et al. (2022) explored dynamic pricing strategies in a two-period supply chain scenario involving a manufacturer and a retailer. They proposed a price discount policy to handle quality-dependent random demand by segmenting the selling period into two distinct phases and offering different selling prices.

2.2. Hub Location

Traffic congestion and inadequate transportation can cause delays in delivering goods to customers. These delays can lead to increased customer dissatisfaction and reduced trust in suppliers. Additionally, in some cases, delivery delays can lead to increased demand for similar products in the market, resulting in increased production and transportation costs. Utilizing urban hubs and collaborating to ensure timely delivery of goods can help alleviate traffic problems and delivery delays. Moreover, timely and high-quality product delivery can increase customer satisfaction and build trust in suppliers, ultimately leading to increased sales and profits for companies. Hub location problems are a subset of network optimization problems aimed at designing optimal transportation networks. Hakimi (1964) published the first paper on node optimization, influenced by similar concepts of the hub location problem. The hub location problem was first introduced by Goldman (1969) and has a relatively short history (Damgacioglu et al., 2015). Toh (1985) Explored the utilization of hub location networks within airline companies and the aviation sector, marking it as the inaugural study of its kind in this domain. The mathematical formulation and solution method for the hub location problem were first proposed by O'Kelly (1986). Subsequently, Campbell proposed multiple mathematical formulations for the hub location problem (Campbell, 1994a; Campbell, 1994b; Campbell, 1996). Bryan and O'Kelly (1999) examined the applications of the hub location problem in the telecommunications and aviation transportation industries. Campbell et al. (2002) developed fundamental definitions, classifications, mathematical models, and solution methods for the hub location problem relative to previous research.

The hub location problem is a dynamic domain within location theory. In this scenario, individuals, goods, or information traverse between origin-destination pairs to fulfill demand. Hubs serve to diminish the quantity of transportation connections between origin and destination nodes. By using hubs, the required number of links to serve all origin-destination pairs decreases. For example, in a fully connected network, the number of origin-destination pairs is equal to $k(k-1)$. (k: the number of origin and destination points, and round trip is not considered the same.)

By selecting a hub node, the number of links decreases to $2(k-1)$. This concept can be expanded to encompass a network featuring multiple hub nodes, referred to as a multiple hub network, enabling more efficient servicing of demand pairs with reduced resource utilization (Zanjirani Farahani et al., 2013).

Fig.1. illustrates an example of the presence and impact of hubs.

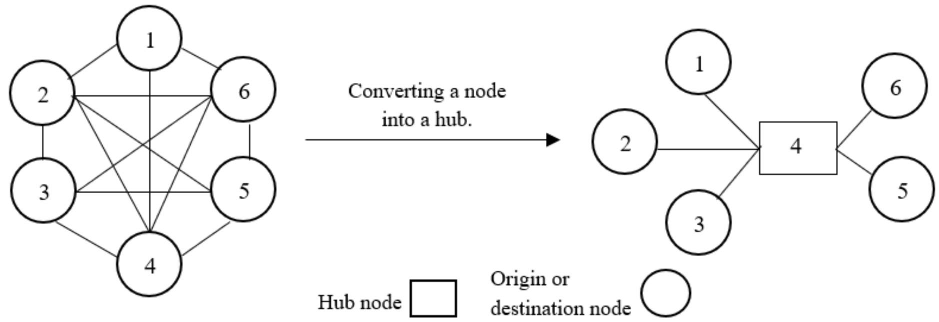

Fig. 1. Connecting Origin and Destination Nodes in the Presence and Absence of Hubs

The Hub Location Problem is investigated in various forms due to its complex nature. These forms include the following models:

1) Solution space: It can be discrete or continuous.
3) Number of hubs: It can be single or multiple, and the number of hubs can be known or unknown.
4) Hub capacity: It can be unlimited or limited.
5) Hub establishment and deployment costs: It can be fixed or variable.
6) Fixed costs of connecting non-hub nodes to hubs.
7) Method of connecting non-hub nodes to hubs: It can be single allocation or multiple allocation.

Mathematical Models and Classification of Hub Location:

2.2.1 Single-Hub Location Problem

O'Kelly (1987) modeled this problem in a Mini-Sum criterion where non-hub nodes are connected to hub nodes, and non-hub nodes cannot be connected to each other. The predetermined number of hubs for placement is fixed at one, with no associated costs for establishment or construction of hub facilities. The designated hub possesses unlimited capacity, and the scenario constitutes a single allocation problem, as the objective is to locate only one hub.

2.2.2 P-Hub Location

In this scenario, every non-hub node needs to be linked to a single hub node, rendering it a single allocation problem, as initially suggested by O'Kelly (1987). The model employs the Mini-Sum criterion for optimization. Hub nodes are fully connected to each other, and each non-hub node is connected to one hub node with no non-hub connections between them. The predetermined number of hubs to be situated is represented by P. For travel between two non-hub nodes, at least one or a maximum of two hub nodes must be accessed. Moreover, there are no associated costs for establishing hubs, the hubs boast unlimited capacity, and the model yields binary outcomes.

2.2.3 P- Hub Median Location with Multiple Allocation

Campbell (1996) introduced a linear mathematical formulation akin to the P-Median approach, termed the P-Hub Median Location problem. Unlike single allocation problems, where each non-hub node is linked to a single hub node, this model allows for multiple allocations, where each non-hub node can be assigned to one or more hub nodes.

2.2.4 P- Hub Center Location

One of the pivotal location quandaries is the P-Hub center Location problem, which finds applications in emergency facility siting, among others. In this scenario, pairs of origin-destination nodes from the hub location problem are treated as demand nodes in the P-Hub center Location problem. This problem is framed according to the Mini-Max criterion, with the objective of minimizing the highest cost among origin-destination pairs. Originally introduced by Campbell (1994a), the P-Hub center Location problem holds relevance in transportation networks associated with perishable goods.

2.2.5 P- Hub Coverage Location

P- Hub Coverage Location is a complex problem in the field of spatial coverage seeking to locate hub stations in such a way that each pair of non-hub nodes is covered by a set of hub nodes. In fact, to cover origin-destination pairs, there is a need for hub stations at certain distances from their links. If the cost, time, or distance along this path is less than a threshold (coverage radius), the origin-destination pairs are covered by the hubs. In general, urban services and public transportation are examples of hub-coverage services. This problem was initially proposed by Campbell (1994b); Kara and Tansel (2003); Wagner, (2008) presented new mathematical formulations for it with single allocation and the P-Coverage spatial location problem with limited path length.

Subsequent articles in the field of hub location are reviewed.

In their study, Contreras et al. (2009) explored the capacitated hub location problem with single assignment by employing the Lagrangean relaxation method. They established both upper and lower bounds, conducting computational experiments using benchmark instances drawn from existing literature alongside some larger, novel instances. Their findings revealed significantly favorable outcomes, with the best-known solution being achieved or improved upon across all tested instances, spanning from 10 to 200 nodes. Notably, the duality gap between upper and lower bounds never surpassed 3.4%. Ilic et al. (2010) introduced a novel approach to tackle the uncapacitated median P-hub location problem with single assignment and no capacity constraints in networks. Employing the neighborhood search method, the method identifies hub facilities within the network to minimize traffic between all source-destination pairs. Experimental findings demonstrate superior solution quality and computational efficiency compared to established methods, delivering satisfactory outcomes swiftly for problem instances comprising 1000 nodes. Contreras et al. (2010) proposed the tree hub location problem, wherein a fixed number of hub locations must be determined, connected by a tree structure. This problem integrates elements of location, network design, and routing, finding potential applications in communication systems and transportation, particularly in scenarios where communication link costs prohibit full hub connectivity. Mohammadi et al. (2011) presented a queuing system-based model for the hub covering problem, representing hubs as M/M/c queueing systems capturing network congestion. Initially, a nonlinear mathematical programming approach seeks an optimal solution, followed by transforming the nonlinear constraints into linear ones. Given the resulting model's computational complexity, competitive and genetic algorithms are proposed to find near-optimal solutions.

In paper Hwang and Lee, (2012), the emphasis is on how a hub can maximize covered demand within a set travel time. The paper introduces an integer programming formula for the hub covering model, facilitating the optimization of non-hub node allocation to hub nodes. Yang et al. (2013) introduces a novel fuzzy P-hub center problem with uncertain travel times. They develop a hybrid algorithm, combining genetic algorithms and local search (GALS), to tackle the mixed-integer parametric programming problem effectively. Rodriguez-Martin et al. 2014) delved into the hub location and routing predicament, where decisions involve hub placement, node-to-hub allocation, and routing between allocated nodes to minimize overall transportation cost. Each center operates a vehicle that cyclically visits all allocated nodes. The paper presents a mixed-integer programming formulation strengthened with valid inequalities. Results demonstrate the formulation's efficacy, with the branch-and-cut algorithm solving instances containing up to 50 nodes.

Sadeghi et al. (2015) focused on minimizing total transportation cost while maximizing network flow capacity, addressing scenarios where transportation routes may face disruption due to various factors like daily traffic, earthquakes, floods, etc. In the study by Sadjadi et al. (2015), a three-tier supply chain network was explored. The study simultaneously examines the optimization problem encompassing facility location, demand allocation to retailers, and inventory decisions, aiming to minimize total location, transportation, and inventory costs. To enhance realism, undesirable factors such as demand and lead time, which follow Poisson and exponential distributions respectively, were taken into account. A queuing approach was employed to derive performance metrics under steady-state conditions. Musavi and Bozorgi-Amiri (2017) introduced a novel and sustainable model for hub location and vehicle routing, considering responsiveness and environmental impacts. This model limits the number of transport vehicles at hub nodes providing customer services, while also considering product perishability in the food supply chain and greenhouse gas emissions produced by the network. The objective is to optimize total transportation costs, product freshness and quality at delivery, and reduce greenhouse gas emissions to promote environmental sustainability. This problem is formulated as a multi-objective mixed-integer linear programming.

In the paper authored by Rostami et al. (2018), a two-phase formulation for the single allocation hub location problem has been devised, incorporating the reallocation of resources to a backup hub in the event of hub failure. Additionally, a branch-and-cut framework employing Benders decomposition has been devised to effectively solve large-scale instances.

Mohammadi et al. (2019) highlighted the vulnerability of hub transportation networks to uncertainties like natural disasters. This study investigated P-hub location problems with single allocation and the effects of uncertainties in deliveries. Introducing a reliable two-objective P-hub location model with limited capacities, considering uncertainties in hubs and links, aims to minimize all costs while maximizing the maximum transportation time. Furthermore, a novel hybrid metaheuristic algorithm is developed to tackle the extended model. Modeling and analysis of the French transportation network demonstrate notable enhancements in cost and delivery performance. A study conducted by Leung (2020) indicates that selecting appropriate locations for hubs can lead to reductions in transportation costs, delivery times, and levels of final inventory in the supply chain. Additionally, hub location can play a significant role in improving service to customers and increasing their satisfaction, as examined in a study conducted by Zang (2019).

In their study, Ghodratnama et al. (2020) developed an innovative hub location-allocation model that takes into account congestion considerations and integrates production planning. The research premise is based on the assumption that both production and distribution activities, involving raw materials as well as semi-finished or finished products, are centralized at hubs such as industrial estates. The main aim is to minimize overall expenses and diminish the aggregate waiting time for processing goods at factories and warehouses. Rahmati et al. (2021) introduced a two-stage robust optimization algorithm for the capacity-unconstrained hub location problem, taking into account demand uncertainty and budget allocation uncertainty controlling the level of protection. The paper utilizes the Benders decomposition acceleration algorithm to address the problem. Blanco and Puerto (2021) proposed an expansion of the capacity-unconstrained hub location problem wherein potential hub locations are not predetermined but allowed to belong to a surrounding area of an initial discrete node set. The paper offers a general framework where hub setup costs depend not only on hub location but also on the size of the area. In their study, (Li, 2022) investigated the hub location problem for fresh agricultural products, considering product perishability and uncertainty in customer demand. Initially, they explored and solved a capacity-unconstrained model for locating hubs for fresh agricultural products with uncertain demand using the Lagrangean relaxation approach. Subsequently, they presented a robust optimization model for the hub location problem incorporating corresponding capacity constraints.

2.3. Utilizing hub facilities in the supply chain of perishable products.

The significance of hub location in the supply chain has been explained. On the other hand, perishable products also impose constraints on the supply chain, some of which can be alleviated through the use of hubs. However, research conducted in this area is very limited, and few researchers have ventured into this topic.

A literature review of the combination of these two fields:

In their study, Li (2022) explored the topic of hub location for fresh agricultural products, taking into account product perishability and uncertainties in customer demand. First, using the Lagrange liberalization approach, a capacity-free model for hub location for fresh agricultural products with uncertain demand was investigated and solved. Then, a robust optimization model was presented for the hub location problem with the corresponding capacity. Golestani et al. (2021) investigated the green problem of hub placement with the ability to simultaneously distribute several products at several different storage temperatures and also achieve the two goals of minimizing the cost of the entire system and maximizing the quality of the product delivered to the customer is. The importance of society's attention to the health of perishable products is one of the reasons for combining these two fields. In their study, Musavi and Bozorgi-Amiri (2017) proposed a novel and sustainable framework for hub location and vehicle routing, taking into account responsiveness and environmental impacts. This model restricts the number of transport vehicles at hub nodes servicing customers while simultaneously addressing the perishability of products in the food supply chain and the emission of greenhouse gases. The objective is to optimize overall transportation costs, product freshness and quality upon delivery, and minimize greenhouse gas emissions from vehicles to achieve environmental sustainability. This problem is formulated as a multi-objective mixed linear programming task.

Etemadnia et al. (2015) investigated the positioning of wholesale locations (hubs) in food supply chain systems, recognizing that population growth poses challenges to food accessibility. To address the imbalance between supply and increasing demand, a greater volume of food must be transported from production to consumption sites. Through efficient coordination with hubs, a mixed integer linear programming (MILP) problem is formulated to minimize total network costs, encompassing freight expenses. In their study, Etemadnia et al. (2013) tackled the issue of wholesale center location in the food supply chain. The objective is to devise an optimal hub location network to serve food consumption markets efficiently by establishing effective links with production sites. These optimized locations are compared with existing hub sites to assess potential efficiency gains. The model is mathematically formulated as a mixed integer programming problem aiming to minimize total network costs, including both goods transportation and hub construction expenses.

2.4. Uncertainty management and coping methods

Uncertainty in the supply chain is a significant challenge faced by businesses across various industries. This uncertainty can stem from various sources, including changes in customer demand, fluctuations in market conditions, disruptions in transportation and logistics, supplier reliability issues, natural disasters, and geopolitical events, among others. The presence of uncertainty can lead to inefficiencies, increased costs, delays, and ultimately, a negative impact on customer satisfaction and profitability. Businesses must actively manage and mitigate uncertainty in their supply chains to maintain competitiveness and resilience. To address uncertainty, companies often implement strategies such as inventory optimization, flexible manufacturing processes, agile supply chain practices, supplier diversification, and real-time monitoring and visibility tools. Additionally, advanced analytics, predictive modeling, and scenario planning techniques can help businesses anticipate and proactively respond to potential disruptions. Overall, recognizing and managing uncertainty in the supply chain is crucial for ensuring operational stability, responsiveness, and long-term success in today's dynamic business environment. Uncertainty in the supply chain refers to the occurrence of problems, risks, and events that may affect each stage of the supply chain, from supply to demand and the target market (Davis, 1993).

Following are a few articles from this area that are introduced and examined.

In the realm of mathematical programming, the assumption typically prevails that data are precise and certain, yet in reality, we frequently encounter uncertainty. This matter holds significant importance within mathematical programming, where even slight uncertainty in the data can yield entirely divergent interpretations of the optimal solution (Behzadi & Seifabrghy, 2018). To contend with uncertainty in optimization problems, three primary approaches have emerged: stochastic, fuzzy, and robust methods. Additionally, there exist amalgamated techniques and alternative methodologies for navigating uncertainty in such problems. Stochastic optimization models were initially pioneered by Dantzig and Infanger (1995), characterizing uncertainty in problem data and parameters through the lens of probability distributions. Essentially, stochastic programming endeavors to formulate optimal decisions across all conceivable uncertainty scenarios, leveraging probabilistic insights. Despite widespread utilization, stochastic models often face limitations due to the necessity of ample historical data and computational intricacies, particularly in scenarios with myriad contingencies (Farrokh, 2016). Broadly speaking, stochastic programming finds applicability where it is feasible to ascertain the probability distribution of uncertain parameters. Fuzzy logic, or fuzziness, constitutes a branch of mathematical logic tailored to model and resolve issues marked by ambiguity and uncertainty. Introduced by Professor Lotfi Zadeh in the 1960s, fuzzy logic employs fuzzy numbers (values ranging from 0 to 1) to signify the degree of membership of a variable within a fuzzy set. This methodology aids in making more informed decisions in the face of data and problem uncertainties. Fuzzy logic permeates various scientific and industrial domains, encompassing automatic control systems, managerial decision-making, disease diagnosis, marketing strategies, and beyond. Robust optimization, on the other hand, entails seeking solutions resilient enough to uphold satisfactory performance amidst alterations and uncertainties in the input conditions of an optimization quandary. This approach strives to craft decisions and solutions capable of maintaining acceptable performance even under worst-case scenarios. Typically, robust optimization is articulated through probability distributions or sets of potentialities in problem modeling.

The concept of robust optimization emerged in the 1970s in the field of linear optimization. A pivotal milestone occurred in 1973 when Soyester devised a pessimistic robust programming method to grapple with imprecise linear programming challenges (Soyster, 1973). The multifaceted nature of robust optimization was delineated by Mulvey et al. (1995) along two dimensions: Feasibility Robustness and Optimality Robustness. Feasibility Robustness dictates that the solution must remain viable across all or a majority of potential parameter uncertainty cases. Optimality Robustness, meanwhile, stipulates that the objective function value for the robust solution aligns closely with its optimal value across all or a majority of parameter uncertainty cases, thereby minimizing deviation from optimality.

2.4. Sustainable supply chain

In today's era, there is mounting pressure on organizations to showcase sustainable development within their operations. These demands emanate from a variety of sources, including consumers, government entities, the media, investors, and stakeholders.(Gualandris et al., 2015; Luthra et al., 2014; Zailani et al., 2012; Roy et al., 2020). Sustainable development encompasses a broad concept spanning economics, environment, and society, aiming to strike a balance between meeting current societal needs and preserving resources and the environment for future generations. Over the past few decades, this concept has garnered significant attention as a primary strategy in global economic and social development. It consists of various key elements, each fulfilling a specific role in environmental preservation and enhancing human life quality. These elements include:

1) Economic Sustainability
This concept refers to the ability of the supply chain to maintain its financial and economic viability over the long term. In other words, economic sustainability of the supply chain addresses its ability to provide sufficient income for all chain members over an extended period.
2) Social Sustainability
This concept relates to the commitment of the supply chain to social and human values, including labor rights, social welfare, and fairness in employment relationships. Socially sustainable supply chains should address social and ethical issues and ensure that economic performance is aligned with respect for human rights.(Carter & Rogers, 2008)
3) Environmental Sustainability
This concept refers to the efforts of the supply chain to reduce negative environmental impacts, including natural resource consumption, waste generation, and environmental pollution. Environmentally sustainable supply chains should focus on reducing energy consumption, optimizing resource use, and selecting green materials and products (Seuring and Müller, 2008).
4) Intergenerational interactions: This highlights the importance of interaction and collaboration between different generations, emphasizing our responsibility to future generations by preserving resources and the environment for their benefit.
The integration of these elements in sustainable development facilitates the creation of a balanced and sustainable development model for communities and the globe, ensuring the current quality of human life while laying the groundwork for future generations' well-being. Sustainable supply chain management encompasses all phases of product and service production, processing, transportation, and distribution, while considering social, environmental, and economic responsibilities. In this process, stakeholders and partners collaborate to enhance social, environmental, and economic conditions throughout

the supply chain, emphasizing resource recycling, efficiency, pollution reduction, and raising awareness of social and environmental responsibilities. Furthermore, this approach can lead to cost reduction and increased efficiency in production and distribution processes, aligning with current business imperatives. Given the rise in customer demand for eco-friendly products and the legal requirements for environmental standards compliance, the concept of green supply chain management has emerged as a significant consideration (Stonebraker & Liao, 2006; Christopher, 2016; Seuring & Müller, 2008). Over recent decades, companies have endeavored to adopt an approach that addresses the economic, social, and environmental issues linked to their supply chains simultaneously (Carter & Easton, 2011). The approach of Sustainable Supply Chain Management (SSCM) offers companies of various sizes and sectors the effective amalgamation of social, economic, and environmental factors. This integration is now recognized as a pivotal strategic imperative for competing in the expanding global market (Carter & Rogers, 2008; Seuring & Müller, 2008a).

Many scholars (e.g. Carter & Rogers, 2008; Seuring & Müller, 2008; Ahi & Searcy, 2013) have elucidated the notion of sustainable supply chain management (SSCM) and underscored the importance of integrating sustainable development initiatives into supply chain management (SCM) practices to improve present and future organizational performance (Sanchez-Flores et al., 2020). Carter and Rogers (2008) utilize a supplementary definition of supply chain and an extensive review of sustainability literature to present their own interpretation of sustainable supply chain management:

“The strategic measurement and attainment of an organization's environmental, social, and economic objectives through the systematic coordination of key inter-organizational business processes to enhance the long-term performance outcomes of the focal company and its supply chains”.

Other definitions of sustainability have also been presented in the literature on the subject. The most widely embraced and frequently cited definition of sustainability originates from the Brundtland Commission (World Commission on Environment and Development, 1987, p. 8). Sustainability is defined as "development that fulfills present needs without jeopardizing the capacity of future generations to meet their own needs." This comprehensive definition encompasses a range of issues, including understanding the environmental consequences of economic activities in both developing and industrialized countries (Ehrlich & Ehrlich, 1991, 1991). ensuring global food security (Lal et al., 2016), meeting basic human needs (Savitz, 2006), and conserving non-renewable resources (Whiteman & Cooper, 2000).

Following is a brief review of articles in the field of sustainable supply chain management.

Saberi et al. (2018) authored a paper exploring blockchain technology and smart contracts, aiming to assess their potential applications in supply chain management. The study is motivated by governmental mandates, societal concerns, and the growing demand from local and global consumers for achieving sustainability objectives. These factors underscore the need for researchers to conduct a comprehensive investigation into the influence of blockchain on the sustainability of supply chains to yield more accurate findings. Nasrollahi et al. (2020) delve into the examination of mandatory and non-mandatory incentives' effects on the sustainability and performance of supply chains, considering the intermediary supervisory and collaborative roles within an automotive company. Karmaker et al. (2021) employ diverse methodologies such as Pareto analysis, fuzzy theory, and interpretive structural modeling to explore the impact of sustainable supply chain incentives in managing disruptions in the Bangladeshi supply chain amid the COVID-19 pandemic. Results highlight the significance of governmental financial backing and collaboration among supply chain partners in mitigating immediate disruptions. Furthermore, the formulation of policies grounded in health protocols and automation is deemed crucial for ensuring the long-term sustainability of the supply chain.

This study is a comprehensive review of the literature on the fundamental aspects of sustainable supply chain management, with a specific focus on hub location, perishable products, and uncertainty management.

3. Conclusion

In conclusion, this review highlights the multifaceted nature of sustainable supply chain management, emphasizing the significance of addressing both present needs and future requirements. By improving processes, reducing waste, and fostering sustainable relationships, companies can enhance their competitiveness in the global market. Moreover, the strategic positioning of hubs plays a pivotal role in optimizing distribution processes, particularly for perishable goods. Additionally, incorporating uncertainty management strategies is essential for aligning mathematical models with real-world supply chain dynamics.

Future Directions:

Moving forward, there are several avenues for further research and practical implementation:

- Exploration of innovative technologies: Investigate how emerging technologies such as blockchain, IoT, and AI can be leveraged to enhance sustainability and mitigate uncertainty in supply chains.

- Integration of circular economy principles: Explore how circular economy principles can be integrated into supply chain management to promote resource efficiency and minimize environmental impact.
- Stakeholder collaboration: Emphasize the importance of collaboration among stakeholders including suppliers, manufacturers, distributors, and consumers to foster sustainable practices throughout the supply chain.
- Risk management strategies: Develop robust risk management strategies to address uncertainties arising from geopolitical events, natural disasters, and global pandemics, ensuring resilience and continuity in supply chain operations.

Practical Implications:

- Implementation of sustainability initiatives: Encourage companies to adopt sustainable practices such as green procurement, eco-friendly packaging, and energy-efficient transportation to reduce their environmental footprint and enhance corporate social responsibility.
- Investment in infrastructure: Advocate for investment in infrastructure to improve transportation networks, warehousing facilities, and logistics hubs, enabling more efficient and sustainable supply chain operations.
- Education and training: Promote education and training programs to equip supply chain professionals with the knowledge and skills needed to effectively manage sustainability and uncertainty challenges.

By addressing these future directions and practical implications, businesses can not only optimize their supply chain performance but also contribute to a more sustainable and resilient global economy.

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