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Global Supply Chain Nervousness (GSCN)

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Abstract: In today's competitive environment, managing supply chains (SCs) is becoming increasingly challenging. Demand uncertainty, globalization, shorter product and technology lifespans, and growth in the number of logistics partners result in more sophisticated global supply relationships, which in turn, increase SC vulnerability. Generally, nervousness reduces SC effectiveness because SC instability is primarily caused by events that are external to the business domain. This tension creates uncertainty, increases the cost of maintaining supply chains, and makes relationships with suppliers and customers unpredictable. This study analyzed global SC nervousness (GSCN) components in terms of drivers, consequences, indicators, and pillars, and proposed solutions. A questionnaire was used to study and evaluate the characteristics of the GSCN, and the DELPHI–FAHP was used to analyze the results and designate the factors that most impact nervousness mitigation in the supply chain. To this end, a framework is presented to discuss the interactions of nervousness in a SC with an integrated solution. The results indicate that demand planning, sourcing strategy, collaboration, risk management, and sustainable SC, along with technological innovation applications, represent essential demands for a smarter future GSC vision.

Keywords: global supply chain; nervousness; FAHP; DELPHI; SC solutions

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1. Introduction

Managing supply chains in today's highly competitive and intelligent world is becoming increasingly challenging. The increase in supply and demand uncertainty, globalization, competitiveness, shorter product life cycle, and the number of logistics partners cause complicated global supply relations, resulting in increased exposure to supply chain (SC) risks. The SC is not always based on mutual benefits; therefore, it is important to realize the risk that organizations face with their partners. SC risks include financial risks owing to overstocking, obsolescence, decrease in customer demand, and out-of-stock products. Risk and uncertainty lead to SC confusion because of excessive reaction and interference, re-estimation (under- and overestimation), doubt, and biased information exchange through the SC. The bullwhip effect is a pattern of SC confusion. This kind of instability leads to ineffectiveness in terms of decisions, costs, and inventories.

SC instability occurs owing to changes in demand and order rescheduling with respect to setup time and order quantity. Instability exists in all SCs, even with steady customer demand; it occurs because of a continuous reaction to demand change when the desired trade-off between responsiveness, cost, and instability occurs. Planning uncertainties in SC typically lead to nervousness. SC nervousness is affected by instability, uncertainties, and disruptions in supply and demand, resulting in variations in production planning and delivery schedules, as well as increases in safety stock and in predictable costs.

The main factors that cause nervousness include fluctuations in demand, lead time, changes in customer requirements, inventory level and control systems, transportation allowances, production schedules, the introduction of new technologies, product redesign, material and energy prices, supplier and customer distribution, supplier performance, returned goods, required customer service level and fill rate, and TL/LTL freight shipping. In addition, other factors cause more frequent changes in SC decisions, such as natural hazards and environmental, social, political, and economic issues [1]. Nervousness negatively affects SC strategies, costs, time, competitiveness, productivity, utilization, service levels, responsiveness, decision systems, morals, and SC planning systems.

The global supply chain (GSC) is exposed to political, geographical, social, business, and economic changes. These factors, combined with SC interruptions, increase the number of partners, fierce rivalry, unexpected surges in demand and supply, environmental concerns, and delays in response and monetary transactions, and cause SC instability, leading to nervousness in SC decision systems. Supply chain nervousness (SCN) negatively affects global supply chain performance, prices, and operations. Nervousness causes a slew of issues, including increased inventory, delays, and costs, as well as distrust among businesses, suppliers, and customers. This makes the supply chain ineffective, especially as most SC instability is driven by external events that are beyond the organization's control.

Adjustment in response to nervousness involves modifying the original plan more frequently, which requires an update in the SC factors to respond to unexpected demand changes; however, nervousness increases with the modified plan. Strategies and decisions are significantly affected by nervousness and lead to variations in SC costs, service levels, performance, inventory, backorder levels, and responsiveness.

Nervousness solutions include the integration of SC information, the utilization of new technologies, external consultation, coordination with all SC partners, and a constant order policy. The impact of nervousness may be reduced by using smart systems and developing a stabilized decision support system (DSS). DSS can be used to determine the best optimal order and inventory policies and find innovative solutions, such as bypassing a process, changing destinations, and changing the transportation mode, to decrease the effect of demand fluctuations and external political, social, and economic factors.

To our knowledge, no previous study has considered nervousness in GSC and analyzed its causes, consequences, measurements, pillars, and effective treatments. In particular, the interruptions created by crises, such as the COVID-19 pandemic, have a unique and exceptional impact that has resulted in a great deal of SC instability, as well as a rise in the expenses for maintaining the SC and its relationships. This study presents an analytical investigation of the reasons for SC nervousness and offers potential solutions. The research extends the scope of nervousness effects on GSC by considering the main sources of nervousness, its effects, and its consequences. It also looks at the three main interrelated elements that might make SC operations nervous: fluctuations in supply, demand changes, and reactions to interruptions. A framework is presented to explain nervousness and examine its impact on the efficacy and efficiency of the global supply chain. A questionnaire was developed to explore and evaluate nervousness in the global SC, and an integrated DELPHI–Fuzzy AHP (Analytic Hierarchy Process) was used to analyze the results and identify and rank the components that reduced nervousness in the supply chain.

2. Literature Review

Due to supply shortages, volatile demand, and government response measures, disruptions like the COVID-19 pandemic affected SC activities, operations, procedures, and management. Nervous decisions induce stress and worry, which affect SC processes and performance [2]. SC order delays and inventory accumulation cause SC disruptions, leading to post-instability [3]. An uncertain environment greatly affects SC management and leads to increased SC risks and operational costs. Several factors cause uncertainty, such as price cuts and penalties, shipping, inventory, and manufacturing [4]. Uncertainty in demand is driven by variable customer demand caused by shorter product life cycles, high price competitiveness, difficulties in forecasting, and changes in customer service levels and requirements [5]. SC uncertainty involves uncertainty in demand, supply, and company facilities. Supply uncertainty has several forms, such as disruptions, yield and capacity uncertainties, and lead-time uncertainty [6]. Crises, when combined with instability, affect

SC response [7]. For SC with demand uncertainty, coordination between manufacturers and third parties is an efficient approach [8]. Inter-organizational ICT positively impacts supply chain performance when uncertainty is high [9]. Generally, every decision or process has some type of uncertainty, such as uncertainties in judgments and assessments.

Risk concerns and risk management considerations in the SC process have increased because of the large number of uncertainties, complications, interferences, and interactions in the new SC [10]. SC contains many kinds of risks, especially those resulting from natural disasters, such as earthquakes and tsunamis [11]. SC risk management aims to release, identify, rank, measure, monitor, manage, and mitigate the risks in a global SC [12]. To manage SC risks and disruptions, companies must invest in capability identification, enhance flexibility, improve responsiveness, and increase collaboration with SC partners. SC risks can be classified into demand, supply, and environmental risks [13]. Current and future logistics systems can benefit from connectivity. Wireless data systems are used to enhance the efficiency of transportation data systems by rescheduling destinations, routes, and times of on-road trucks [14]. Transportation systems can greatly utilize improved connectivity as companies can communicate efficiently in real-time. The Internet positively affects and enables SC management and process [10]. However, several operational challenges have forced companies to constantly make important logistics decisions alongside SC operations [14]. These uncertainties, risks, challenges, disruptions, and frequent interfering decisions lead to SCN.

SCN is associated with SC risks and uncertainties. These uncertainties and risks must be managed at the SC level. To design an SC for the future, sustainable supply chain management (SCM) must be incorporated into organizations' daily business [15]. Collaborations in GSC are accelerated by supplier innovation and information sharing [16]. In GSC, sustainable SCM can improve economic, social, and environmental outcomes [17]. SC globalization has several advantages owing to the efficient utilization of low-cost labor from developing nations; however, it has become less stable [18]. Competing effectively in SC requires making the entire supply chain visible [19]. The incorporation of dynamic SC functions allows the current SC DSS to respond rapidly and efficiently to interruptions and changes in the SC [20]. Dynamic replenishment systems can successfully and efficiently respond to both regular and disruptive SC activities [21]. Partnerships, cost reductions, and SCM effectiveness can all benefit from the integration of SC segments with dynamic replenishment [22]. Dynamic response systems have many advantages and improve system responsiveness; however, they usually increase SCN unless a mitigation system is ncorporated.

Numerous disturbances and uncertainties affect the SC, resulting in unexpected interference between decisions, which causes SCN. Nervousness affects efficiency and negatively impacts the overall SC performance. Nervousness has a substantial effect on SC steadiness and resilience, resulting in higher costs and variations in relationships between suppliers and customers [1]. SCN is linked to factors such as tasks, sources, and SC uncertainty [15]. Nervousness stems from the inconsistency of orders issued to suppliers over time, which results in forecast inaccuracies [23]. Systems become nervous when coordinating SC inventories because stochastic demand forces frequent reviews of replenishment choices. [24]. Demand and supply are significantly affected by rapid market changes and product variety. Demand variances are amplified when information is shared with SC parties; therefore, demand-planning accuracy varies significantly among SC partners, and planning nervousness results in the bullwhip effect. [25].

Different methodologies are used to study different aspects of SC. Fuzzy-ELECTRE is employed to reveal Supply Chain strategic Nervousness [26]. Game theory is used to examine the relationship between channel power structures and government subsidy programs in the innovation SC [27], to analyze the SC service investment and price choices made in the context of various power arrangements when demand disruptions emerge [28], and to investigate the effects of initiatives to reduce carbon emissions in the manufacturing SC [29].

Owing to disruptions or unexpected decisions, nervousness in SCM systems is regarded as a source of confusion, uncertainty, and doubt. Nervousness increases, possibly because of frequent decision changes, which cause misperceptions for both staff and consumers, resulting in a loss of trust, morale, and trustworthiness in the SC system. The bullwhip effect is exacerbated by SCN, prompting the SC to improve the buffer in contrast to repeated choice changes. When all these factors are considered, nervousness can lead to a high level of dissatisfaction. Consequently, system nervousness would be accounted for because it can positively or undesirably impact the whole SC, often concurrently for several SC partners and locations [1].

Integrated SC decision making is connected to current SC uncertainty and complexity to reduce operational costs in the SC [30]. Using up-to-date techniques is essential for evaluating the environmental impact and normalization factors that lead to more precise decision-making [31]. Decision making is the main activity in the management of an SC, and each decision contains both analytical and empirical elements [32]. Several quantitative models have been introduced to provide DSS for the management of different SC segments, such as supplier selection, stock control, and production control [33]. Internal and external SC integration enhances agile and lean SC strategies [34]. Technical, cultural, and operational issues, along with resource integration and organizational structure, can facilitate SC process integration to achieve SC capabilities [35]. SC integration utilizes information exchange and technology and increases delivery performance [36]. Integration is a method of responding to SC uncertainty and demand changes [37].

AHP is a multicriteria decision-making (MCDM) strategy that assists decision makers in selecting alternatives. Fuzzy logic is a method of dealing with ambiguous and speculative knowledge. Fuzzy AHP (FAHP) can be used by decision makers when they need to make a judgment under uncertain conditions. FAHP incorporates the fuzzy theory into a fundamental AHP. In many MCDM challenges, AHP, developed by Saaty [38], is a widely used decision-making tool.

FAHP is an MCDM system that is widely used to address decision issues in different sectors. FAHP is suitable because expert opinions are ambiguous and uncertain. A FAHP algorithm is used to analyze the quality of gemstones [39]. FAHP aids in determining the importance of the identified barrier concerns in hazy environments. FAHP is utilized to prioritize the identified constraints that impede SC from attaining sustainable consumption and production trends to improve overall performance [40]. It is used to select and rank the airport for low-cost carriers using different selection criteria [41], prioritize the regions by defining flood risk mitigation plans since flood risk solutions are implemented by local governments [42], assign priority weights to competitive bases to improve SC agility [43], suggest a new consultative process for the triangular FAHP to avoid difficulties in assessing the risk assessment process [44], determine the best supplier regarding the selected criteria [45], address a strategic level challenge of method selection for hydrogen energy storage [46], calculate weights and rankings of obstacles and sub-barriers facing sustainable and renewable energy sources [47], and propose a new approach. This uses a FAHP related to linguistic variables for setting up quantifiable indicators and determining their weights for a tea assessment mechanism [48].

Current and future SC trends must cope with unprecedented changes in the world and in business as companies emphasize managing their SC. Globalization, outsourcing, and volatility in business surroundings create a high level of risk and demand disruption, with more supply and demand variations expected soon. Current and future SCM requires more flexibility to improve the ability to respond rapidly to changes with the acceleration of the business environment [49]. Recognizing the value of supply chain flexibility is critical for creating a long-lasting competitive advantage in dealing with volatility [50]. A flexible supply chain emphasizes the responsibilities of supply chain design, supply chain cooperation, and inter-organizational information systems to reduce undesirable supply chain uncertainty [51]. Implementing supply chain flexibility is essential for gaining strategic advantages and reducing the impact of risks and uncertainties in SCs [52].

Nervousness may be viewed as a source of uncertainty or variability in the SC system resulting from unexpected decisions that interfere with one another. Although nervousness has been discussed in the context of contemporary material requirements planning (MRP) strategy modifications [24], little research has been published on nervousness in the present GSC system or its effect framework. Nervousness is considered the primary source of instability in existing and future SCs because of unpredictable decisions.

This study was driven by a deficiency in research depth in identifying and analyzing SCN for long-term SC development. The proposed GSCN framework could be used to conduct surveys in various industries or consider the uneasiness of the GSC; it would also deliver intriguing information and consideration to GSC managers. Advanced techniques, such as the Fuzzy AHP, can be used to capture the vagueness of expert data collection. This study can aid businesses in devising measures to lessen anxiety in SC, resulting in a more accurate valuation and decision regarding future robust SC.

The literature survey reveals that research regarding SCN is rare. No studies have examined the drivers, consequences, indicators, pillars, or solutions for dealing with nervousness. This study examines the drivers that lead to nervousness in the SC, analyzes the impact of SCN, introduces methods of understanding SCN, and proposes appropriate solutions to this problem. In addition, the integrated DELPHI–FAHP method is used to identify the best solutions and group them based on the order of importance of execution and consideration by companies. Furthermore, given globalization, SC interruptions, and volatility, this study establishes a framework for managing nervousness in the SC to aid decision makers. This ultimately results in a sustainable SC and boosts the resilience, responsiveness, and competitiveness of future SC.

3. Research Contribution and Methodology

This study was motivated by the unpredictable and rapid changes in the business environment brought about by global business and trade disruptions, which have had a substantial influence on SCs. In the case of a pandemic, rapid choices must be made in a challenging environment while considering several factors, such as SC timeliness, costs, and quality. To estimate, evaluate, react to, and quantify the impact of nervousness on demand, supply, and, therefore, SC, businesses need to understand GSCN. Decision makers should consider the key elements and other factors connected to SCN connections to analyze interruptions, respond to them, and propose ways to maintain the continuity of supply and delivery. The proposed framework considers these elements and their interactions to assist companies in creating tools and providing decision-making support.

This study, therefore, seeks to answer the following three essential research questions: What are the drivers of nervousness and their impact on the business, SC, and economy? What strategies and policies should be established to minimize the nervousness effect? How can we enhance our company's ability to face future nervousness and prepare for the worst? These questions should be answered in relation to SC performance, sources of disruptions, flow interruptions, and SC resilience strategies.

The literature survey helps in identifying combinations of factors connected to GSCN and could assist decision makers in comprehending ongoing and upcoming similar disruptions. In this study, the complete framework is constructed by accounting for five criteria and twenty-five pertinent aspects. The emphasis has been on each characteristic's unique contributions to organizational performance and efficiency, even though some of these traits have emerged as key elements in SC management and operations because of the growing literature. This study is unique in that it tries to organize, outline, and integrate these components into a comprehensive framework that academics may use to further knowledge, which will enable decision makers to revise their SCs. This study attempts to make the following contributions:

1. Extend the scope of nervousness influence on GSC by considering the primary drivers of nervousness, related impacts, and consequences. It also examines the primary

interconnected factors leading to nervousness in SC operations: demand changes, supply variations, and responses to disruptions;
2. Examine the main worries and nervousness pillars in contrast to their results to define how they relate to one another, considering accumulated knowledge, new businesses, and economic situations;
3. Include GSCN indications, solutions, and remedies with respect to the existing SCs as part of the investigation's broader scope. It describes the capability-building strategy and important GSCN development areas and procedures.

These parts are connected by the framework's fundamental structure, which enables decision makers to support SCs' future flexibility and competition by ensuring analysis, improvement, and responsiveness. Several open research issues were identified as additional contributions that should be examined in the future. This study's results and recommendations may be applied by logisticians, researchers, planners, and SC experts to assist their firms in crisis decision-making processes and guarantee future nervousness resistance. Numerous industries and related sectors can use this framework. The findings can assist decision makers, practitioners, and managers in focusing on SC implementation, improvement, and sustainability. Future empirical investigations of SCN may use this framework as a theoretical construct. This study paves the way for further research on SCN. To reduce the impact of nervousness on SCs, sustainable supply chain management (SSCM), nervousness management strategies, and an in-depth examination of nervous system management mechanisms are needed.

Several SC and logistics experts were engaged to ensure that the suggested model components were reasonable and workable. These findings may be used by academics and industries to enhance decision-making procedures and facilitate readjustment and restoration during SCN. Additional prospective research directions are introduced and discussed.

Figure 1 describes the research methodology. This study included an analysis of recent SCN, influencing factors and stressors, pillar and indicator methods and solutions, an analysis using the combined DELPHI–FAHP technique, and a framework for managing SCN. The questionnaire method has been adopted by several experts in the SC field to determine the drivers of nervousness. Three sections constitute the analysis. In the first section, a thorough literature review, data collection, and GSCN characteristics analysis are conducted to identify and summarize GSCN in previous studies. In the second section, the survey results and teams of experts determine the GSCN elements and model components, and conduct FAHP analysis. Factors and solutions are identified in the context of GSCN using the improved Delphi method. The FAHP is used to evaluate the weights and levels of the main SCN solutions. Similar techniques may be employed with the traditional AHP, although AHP occasionally produces biased findings because of an imbalanced scoring scale. However, FAHP is more capable of handling uncertainties and fuzzy judgments involved in MCDM. Finally, this study introduces the framework and presents the corresponding results.

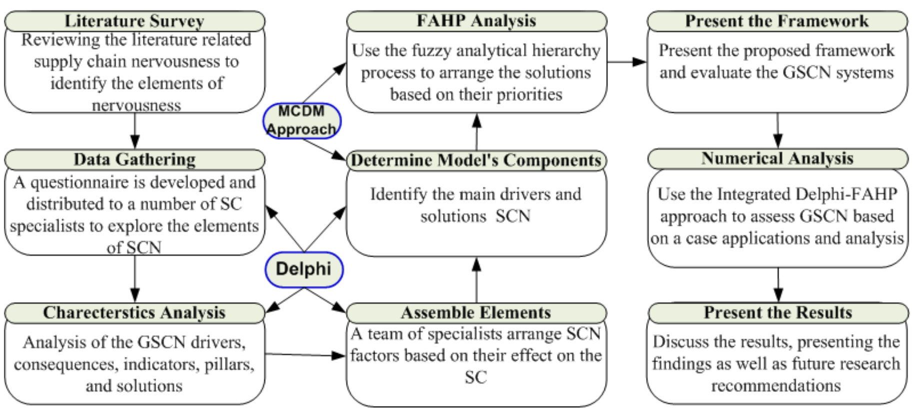

Figure 1. Research methodology.

The remainder of this paper is organized as follows. Section 4 suggests a framework to understand SCN in terms of GSCN drivers, consequences, indicators, pillars, and related solutions, and Section 5 discusses the proposed DELPHI–FAHP approach steps. Section 6 uses the Modified Delphi to complete solutions and uses FAHP for numerical analysis, and Section 7 discusses the findings and recommendations for further investigation.

4. Global Supply Chain Nervousness Framework

4.1. Supply Chain Nervousness

SCN is defined as frequent changes in decisions resulting from fluctuations in demand, revolutions in technologies, and variations in customer requirements. Any change in procurement decisions, plans, or schedules in SC's higher level/echelon will result in a significant increase in times and quantities in the lower echelons. Frequent changes in system planning require remaking the decisions several times in a specific period. The planning process is affected by rapid variations in market, demand, and products. There is a direct relationship between these changes and the bullwhip effect, in which planning nervousness causes bullwhips. Nervousness phenomena occur in parts of SC network segments and echelons where planning precision differs among partners. To stabilize the system, the planning process should be segregated based on the life cycle, communication with customers and vendors should be enhanced, and accurate information sharing should be enabled.

Nervousness might be seen as a source of uncertainty or instability in the SC system resulting from unexpected decisions that interfere with each other [49]. Nervousness is exemplified by decisions that are taken repeatedly and overlapping, so that a decision is made, and then, it is changed by another decision, resulting in confusion, tension, and distrust. Additionally, there is a cost increase, low effectiveness, and lack of competition. Nervousness is the result of a sudden change in the demand/request, either positively or negatively (i.e., an increase or decrease), the cancellation or initiation of requests, a change in the type of materials required, a change in delivery times, or a change in the specifications of the required materials. Nervousness is driven by both inside and/or outside sources.

Many regions, such as the Middle East and North Africa (MENA) region, suffer from agitation, which is caused by several reasons powered by internal, external, or surrounding conditions [1]. Although nervousness can exist in any SC, many regions are vulnerable to this type of phenomenon, which requires the development of appropriate solutions to reduce its impact. In this section, the framework examines the interrelationships and reviews the drivers, consequences, dimensions, pillars, and proposed solutions for the GSCN problem.

4.2. GSCN Framework

Nervousness affects the SC and causes difficulties in performance and efficiency. Overlapping decisions lead to confusion, hesitation, and a lack of trust in partnerships, especially among SC partners. This framework aims to clarify the SCN and explain the inter-relationships so that decision makers have a clear basis that helps them make decisions and take appropriate measures for their GSC. Particularly, the inability of any organization to work alone in the current marketplace and increase its ability to resist future crises increases responsiveness and competitiveness. The pentagonal framework illustrates five GSCN factors, as shown in Figure 2. The framework discusses the most important causes that lead to SCN, the effects caused by nervousness that led to negative consequences for the SC, and the indicators that can be used to measure SCN, followed by a presentation of the most important solutions that can mitigate the effect of nervousness. The fifth part outlines the pillars to be taken to reduce the influence of nervousness on the GSC. These data were built on the results of the questionnaire, expert opinions, and literature reviews. The following subsections discuss the main themes of the framework.

Figure 2. GSCN framework.

4.2.1. Drivers of GSCN

SCN affects a company's GSC effectiveness, performance, and costs. SCN can lead to confusion, tension, and distrust. Companies lose trust and credibility with consumers, especially considering their commitment to continuously supplying goods. Fluctuations in the planning process led to a bullwhip effect, as well as continuous changes in partner plans and decisions. SCN results in increased costs and reduced effectiveness. The special effects of extra inventories, price unpredictability, idle stores, warehouse spaces, and demand flotation can extend throughout an SC. SCNs also affect SC responsiveness, competitiveness, and customer satisfaction.

SCN interferes with decision making, resulting in confusion among employees, decreased efficiency of the SC, increased costs, and increased mistrust between the SC ends. Many reasons result in nervousness, but based on the expert team's opinion and the results of the questionnaire, the remaking decisions may be due to one of the following reasons:

1. *Supply disruptions:* The availability, supply, and price of raw materials are affected by their geographic location and scarcity. Many raw materials come from sole sources, making decisions difficult because they are affected by relationships with suppliers, politics, and availability. Suppliers' business risks, failures, disruptions in material flow, bullwhip effects, customers' opportunistic behaviors, suppliers' relations, supply

networks, and suppliers' inability to react to technology or product design changes are all factors to consider. Companies must guarantee the supply of raw materials and resources for a specific period. Conflicts of interest create huge economic uncertainty; global growth, intercontinental monetary systems, shipping paths, sanctions, and unpredictability in the international oil market, which is directly affected by trade wars, considerably disrupt the international SC. Populism by countries' leaders impacts international trade and SC, as uncertainties and disruptions reach a great level. Domestic and international economic factors and changes constitute a source of SCN, as any change in the SC's inputs can lead to failure. The nervousness phenomenon is mainly caused by changes; therefore, economic change causes SCN, especially in current GSC systems;

2. *Demand disruptions:* Owing to fluctuations and changes in demand, adjustments must be made to the production plan, inventory, stock strategy, and bullwhip effect to respond to customer demand changes. SC instability causes changes in order quantity and time, necessitating a modification in production and other activity schedules. There is instability even with constant or unchanged demand. Instability arises because planned flexibility is required to respond to client demands and order changes, and a compromise must be made between responsiveness and instability. Planning instability results in disruptions in production plans, delivery, inventory buffers, rescheduling, and planning costs. Thus, planning instability results in decision interference, which leads to SCN. Nervousness planning is like planning stability, in which plans are not altered and are consistent with the actual requirements. A main factor affecting order scheduling is demand variability, which leads to repeated updating of decisions, causing nervousness and leading to an increased SC cost and decreased performance;
3. *Crises:* Local and global crises increase SCN. Disasters, accidents, and emergencies may result in sudden changes. Natural disasters, pandemics, socio-political crises, civil unrest, terrorism, border delays, and shutdowns are examples of such crises. There are three types of disasters: natural disasters like earthquakes, manmade disasters caused by sociopolitical conflicts, and technological crises such as radioactive contamination from nuclear sources, chemical mishaps, bacterial spread, power outages, climate change, natural gas explosions, unforeseen urbanizations, and so on;
4. *Legislation and regulation:* Sudden changes in regulations, legislation, legal and bureaucratic issues, and government decisions are considered the main sources of nervousness. Roles change frequently, resulting in violations of ethical norms, authority decisions, administrative impediments, import/export quotations, shipping paperwork, costs, and customs time. Furthermore, environmental criteria, trade barriers (such as tariffs), and local content requirements are not met. Changes in internal and external state policies affect the steadiness of the SC, and politics often affect suppliers' choices. Countries generally restrict or eliminate trade cooperation with countries in conflict with them. UN resolutions are also related to imposing economic sanctions on countries. There are economic sanctions, some of which have not been announced or declared in many countries. Additionally, there are restrictions on the supply of many materials, sub-products, subsystems, and systems, especially those related to dual-use items, for fear of their use in terrorist operations or manufacturing internationally prohibited weapons. Some countries and unions exercise economic blockades. All these reasons, most of which are political, have resulted in instability of the SC, either between the company and its suppliers, or between the company and its customers.
5. *Infrastructure:* SCN and instability are also caused by the infrastructure that the firm uses for operations, such as sociotechnical accidents, machine breakdowns, equipment malfunctions, industrial accidents, labor strikes, and information technology infrastructure risks such as cyber-attacks, software bugs, and hardware failures, interruptions in the water or power supply, and local human-centered issues. With the precedential improvements in technology, smart systems, and customer require-

ments, such as the increased demand for quick responsiveness, low prices, and quality products, companies have no choice but to survive, guarantee business success, and compete in current and future markets. Any security disturbance in the SC results in more severe measures that affect the smooth flow of materials throughout the chain. Security can be related to facilities, transported goods, stored goods, data, and information. SCs are usually subjected to external and internal attacks targeting materials, facilities, monetary, financial, or data, the objects of which are sabotaging or exploitative theft.

Thus, the five main drivers of nervousness were identified and discussed. The discussions concentrate on the most common reasons owing to the impossibility of listing every possible reason for GSCN. The first two drivers are external SC concerns, whereas the remaining factors can be internal or external.

4.2.2. Consequences of GSCN

In general, the consequences of SCN can be grouped into five main categories.

1. *Increase in SC vulnerability (SCV):* Nervousness increases SC exposure to critical disruptions, in addition to internal risks. Changes in SC decisions regarding supply, demand, and structure can cause SCV. Decision makers must make decisions regarding the number of suppliers, suppliers' geographical locations, number of nodes, suppliers' alternatives, SC relationships, social networks, partnerships, alignment, and coordination. SCV is greatly affected by SCN factors, such as demand volatility, reduction in the supplier base, outsourcing tendency, emphasis on efficiency over effectiveness, globalization of SCs, focused manufacturing and concentrated distribution, and a lack of visibility and control procedures. The SCV is affected by transportation, infrastructure, crises, SC complexity, and sociopolitical and legal issues. As SCN, SCV increases in terms of customer loss, demand fluctuations, limited competitive alternatives, inconsistent strategic goals among SC participants, bad sales reputation, poor personnel quality, weak cultural skills, and inadequate customer satisfaction. SCV is a crucial business matter, and to guarantee SC continuity, SC executives need to ensure that the top executives are aware of the risks they face, consider risk as an integrated part of SCM, have risk awareness among employees, understand the changes, and cope with the emerging technologies and processes;
2. *Increase in SC uncertainty:* Numerous factors affect SC uncertainty, such as cost, time, and risk. Through excessive inventory, poor customer service, and wasteful capital expenditure, SC instability damages businesses, consumers, and the economy. SCN greatly impacts SC uncertainty, as the main drivers of SCN include crises such as natural disasters, transportation problems, socio-political and geographical instability, price hikes, and safety and security issues. The main sources of uncertainty include political, economic, and environmental instability, crises, connectivity, data integration, partner coordination, supplier consistency, and SC visibility. A stable SC is a reliable, predictable, and agile SC capable of meeting customers' required delivery dates, which may differ from one order to the next and from one buyer to another;
3. *Decrease in competition:* SCN results in confusion, tension, and distrust, leading to customer dissatisfaction. Companies lose trust and credibility with consumers, especially considering their commitment to continuously supply goods. The nervousness resulting from changes in decisions also affected GSC partners, 3-5PL, and insurance companies. If not managed properly, factors such as nervousness, instability, uncertainty, crisis, disaster risk, unrest, disruptions, unexpected disturbances, volatility, and vulnerability decrease the company and SC's competitiveness;
4. *Fluctuations in planning processes:* These lead to continuous partner plans and decision changes. The bullwhip effect influences a company's planning process. The major challenge involves managing the huge amount of information and material flows both upstream and downstream of the SC, accompanied by its competitive globalization;

5. *Increase in costs:* There is an increase in costs and a decrease in effectiveness. The special effects of extra inventory, price unpredictability, idle stores, warehouse space, and demand flotation can extend throughout the SC, yielding an increase in total operational costs.

A nervous environment implies the continuous rescheduling of orders, which leads to decreased confidence in the system and bans support for effective operations. Fighting nervousness is challenging because it originates from different sources. One source of uncertainty is the demand for products from the end users. Variations in demand result in alterations that increase (amplify) the levels of SC, producing nervousness. Nervousness can be sensitive to order policies. When a new customer demand or order is placed, the previous order is subject to revision, causing a series of order changes across the SC levels. The outcomes of nervousness include increased operational costs, decreased customer service levels, and a negative effect on employee morale.

4.2.3. SCN Indicators

When measuring the performance of a GSC, the major measurements include cost, time, error, soft value, and quality. Clearly, nervousness costs are difficult to measure. Interference among decisions relies on the time between decisions, the number of decisions in a particular period, or the decisions that influence different decisions in a short period; re-decisions are usually made to improve SC performance and/or in response to changes in customer requirements, and they usually have some positive sides. Re-decisions generally cause nervousness and increase worker dissatisfaction.

Each metric has a goal or objective to achieve as well as a metric that will be measured. For example, the five measures below clearly state the goals.

Costs: They measure the total supply chain costs of nervousness, including the costs (efficiency) resulting from the new decision compared with the previous one. If the cost increases, then nervousness has a negative impact on total GSC costs.
Time: It measures the time interference in response to SC changes and disruptions. It measures steadiness in response to changes in the SC resulting from nervousness.
Quality: It measures the impact of nervousness on SC quality. It also measures the quality of SC responsiveness, the number of GSC partners affected, and the impact on each partner, including suppliers, customers, and employees.
Error: It measures the error resulting from SCN in terms of re-decision errors. It measures the total number of errors, accuracy, negative impacts, interference, and error-free decisions.
Soft matters: It measures the critical qualitative elements resulting from the SCN, including employee morale, the degree of integration, decision completeness, customer satisfaction, SC visibility, and leadership alignment.

4.2.4. SCN Solutions

Both short- and long-term methods have been used to reduce the effects of nervousness. Short-term decisions include route, reroute, skip, and order change costs. Long-term decisions include strategic partnerships, integration, alternative sources, buffer stocks, and warehouse locations. Improving the decision-making process using SC optimization (SC modeling), optimization, and simulations are crucial tools for reducing SCN. Enhancing decision-making concerning process efficiencies is the key to mitigating GSCN. As an example of a nervousness solution, consider that there will be no revisions to decisions throughout the planned horizon. Simulation and modeling are used in many SC cases to determine problems and evaluate solutions, as many SCs, such as healthcare products, are critical.

Several reduction strategies should be used to combat nervousness. Strategies for dealing with GSCN include collaboration, demand planning, supply strategy, risk management, and prospects and approaches for sustainable SC. These five mitigation approaches are briefly discussed below.

1. Collaboration

For effective collaboration and partnerships, cooperation, coordination, and shared information should be based on a win-to-win situation to ensure that all partners gain from the integration. People should win in mutually beneficial collaborations to expand the value chain. The added value of collaboration introduces customer loyalty and the morals of employees and partners in the ecosystem. Collaboration minimizes the impact of disruptions and integration and enhances SC visibility. Collaboration with GSC stabilizes planning and improves visibility. Growing visibility to end-user demand and the skillful use of data increases the overall SC performance.

SC collaboration guarantees the integration, information sharing, and visibility of all critical data throughout the SC. There is a change in the SC over time. This could be a demand, supply, or internal or external change. The organization should consider the historical data to obtain all factors that cause changes in the trends and timing. This analysis will help organizations manage inventory and SC activities, leading to growth in customers and suppliers. Decision models enhance the solutions to SC problems. The integration of decisions via the SC network is a part of reducing the effect of nervousness and regulating the customer–supplier relationship, choosing suppliers, and market issues.

With complex interrelations, globalization, and digitally driven SC, competitive advantage rapidly evaporates, and on-time delivery and smart collaboration are crucial for SC's success and to stay competitive. Collaboration with all SC partners, including suppliers, manufacturers, warehousing, factories, transportation, DCs, retailers, and customers, is a prerequisite for successful integration. A cloud-based management system that utilizes data for constant improvements, the use of blockchain technology, deployment of IoT, automation such as for data collection and processing, and integration should improve connections with employees. Technology-based SC allows complete variability in the choice of capacity levels and increases flexibility, leading to a reduced SCN.

2. Demand planning

Multi-level products and dynamic demands are characteristics of SC. Reorders require rescheduling and disrupt operations more frequently, causing confusion, low morale, and reduced confidence in the system. Maintaining smooth operations at all levels of the SC leads to effective utilization and improved quality of SC systems/operations and activities. Predictability will be a driver of high competitiveness, as it breaks the barriers and makes the SC effect safer and faster by improving responsiveness through increasing accuracy. Demand forecasting and planning are the key solutions for SCN. There have always been changes in demand, customer needs, customer requirements, technologies, criminal techniques, methods, and security planning. Planning nervousness should consider vulnerability at the beginning, providing customer satisfaction and safely generating profits.

3. Sourcing strategy

Organizations should consider long-term sourcing strategies using alternative suppliers. This should include international suppliers based on cost, quality, and delivery and regional suppliers in case of crises from the internal or local supplier; it could be with higher cost and local sourcing. This source is important in case of international crises or disasters like COVID-19, in which all countries care only about themselves, and the airports, seaports, and land ports are closed. Supply ecosystems grow as the economy changes. Locally made structures should be the driving source. Organizations should use alternative materials or alloys because of the scarcity, high cost, and sometimes high weight of the raw materials. They should consider conflict over scarce materials.

Currently, SC professionals have access to a wide range of suppliers and networks. Plunking into the suppliers' network and selecting alternative and standby suppliers from different geographical regions is an unprecedented opportunity to protect against disaster risks to ensure that suppliers and alternative suppliers are distant from each other, so that crises such as natural disasters do not affect all of them simultaneously. Organizations should ensure contingency plans for DCs, transportation routes, shippers, and carriers to guarantee the movement of goods using alternative routes and transportation, if necessary.

4. Risk management

The evaluation of all vendors' security and privacy policies is a step toward risk solutions. It is necessary to evaluate the degree of security provided by suppliers and vendors, implement service level agreements with a commitment to security, conduct self-evaluations, permit customer inspections and audits, buy cyber insurance, or have third parties conduct security audits. Limiting your search to businesses you know are doing well with security, agencies that offer security ratings, conducting in-depth analyses, and examining internal policies and procedures of vendors are important. Companies must consider third-party cyber risk as a business risk that must be managed continuously. By using a third-party risk-management solution, organizations can control those who have access to sensitive data only for approved purposes.

5. Sustainable SC

Sustainable SC generates opportunities and increases competitive advantages by considering the factors affecting SC and logistics networks. These include environmental considerations, risk mitigation, and waste elimination. Organizations have a social responsibility toward environmentally friendly surroundings. Environmental roles and considerations are expanding, and countries are considering the reduction of the environmental impact of all activities. Sustainable GSC reduces exposure to SCN. It decreases transport expenses, emissions, and SC costs, and improves carrier utilization, recycling, and service levels.

Most sustainable SC challenges are external. Most environmental impacts come from SCs. Managers rely on suitability to increase value, improve processes, and achieve greater growth. Customers prefer to buy from sustainable organizations. Some companies have started using sustainability scores to distinguish and select suppliers based on costs and quality. Suppliers should be asked for life cycle assessments. Giving awards to encourage behavior and recognizing organizations in the public may be useful. The key factors that can improve sustainability include industry collaboration, advice from suppliers, smart systems, emerging technologies, and reverse logistics. The main SC sustainability challenges are the monitoring and assessment of complex SCs.

4.2.5. GSCN Reduction Pillars

There are five main factors to consider when preparing to reduce the potential impacts of the GSCN: accurate forecasts, a view of SC disruptions, prioritization of risks, a clear risk plan, and control and correction. The aims of nervousness management and plans for the normal are to achieve transparency, accurately evaluate customer demand, optimize production and distribution, and consider a longer view of resilience. The following factors represent the reduction pillars toward SC targets:

1. Prevention: Contact key suppliers to ensure that their plans can face crises and respond to disruptions. Alternative suppliers should be available in case the main suppliers do not have response plans or if these plans are ineffective. Review contractual liabilities in case of delays, order cancellations, and low-quality goods;
2. Response: Increase inventory levels where possible for critical goods, continue communication with current suppliers, and try to determine the magnitude of disruptions. Modifying orders and delivery-based variations in demand are also important;
3. Recovery: Search for new sources to increase SC resilience. Study the lessons learned, cumulative experience with key suppliers, and possible improvements. Exploring methods for limiting costs and accelerating recovery is also important;
4. Decision: This improves decision systems and processes, leading to a substantial decrease in SCN. Making decisions necessitates reevaluating the GSCN strategy, considering the impact of demand on certain firms and consulting SC specialists;

5. Develop a contingency plan, reduce supply shock, arrange for demand volatility, create a safe work environment, and look ahead. To decrease delays and enable timely supply, organizations must continuously coordinate with suppliers and determine the best sourcing options in cooperation with partners.

5. DELPHI–FAHP Approach

The adapted Delphi method is used to complete and prioritize SCN solutions. This is a systematic method of collecting expert responses through group thoughts and questionnaire surveys. This approach involves professionals from many SC disciplines that exchange ideas, information, perspectives, and expertise to draw conclusions about one another. The foundation for making predictions using the Delphi method is based on the responses to several rounds of questionnaires distributed to the expert group. The experts may modify their replies considering the group's responses after seeing the summary of the previous rounds of questionnaire surveys. This technique combines the advantages of expert analysis and aspects of group knowledge.

The Delphi Method seeks to aggregate the opinions of various experts, which can be performed without bringing everyone together for a physical meeting. As the participants' responses are anonymous, individual panelists do not need to fear any repercussions of their opinions. A consensus can be reached over time as opinions are influenced, making the method very effective.

FAHP is an MCDM method that combines fuzzy theory with the Basic AHP; it was developed by Saaty [53]. As a popular model for MCDM, it addresses difficult and multi-faceted decision-making issues. AHP is a widely employed selection-making device for numerous multicriteria selection-making problems. Fuzzy AHP can be used by decision makers when they need to make a judgment under uncertain conditions. Furthermore, the proposed approach employs a genetic algorithm in the FAHP comparison matrix. The relative weights of various indicators are calculated using the FAHP, and the indicators are dynamically ranked according to their relevance. The FAHP technique is frequently used to resolve MCDM issues in various sectors because of its benefits in handling ambiguous and erroneous evaluations of linguistic factors.

To rank the GSCN solutions, the DELPHI–FAHP approach consists of ten main steps for prioritizing the suggested solutions. Following is a summary of the techniques employed to explain the applications and value of the methodology used [38,39,44,47,48,54–56]:

Step 1: State the research objective

The research questions that emerged from the literature survey served as the foundation for this study's aims. This study aims to study the nervousness of GSC by ranking model alternatives/solutions.

Step 2: Collection of the required data

The data required for the analysis are collected from three main sources: a literature review, a research questionnaire, and experts' opinions. Using the Delphi-based FAHP method, the iterative acquisition of data improves data excellence and ends when data saturation is reached. Another benefit was that it was not biased.

In the first stage, the most relevant driving factors are identified with the assistance of industry experts. The experts improved the driving factors in a hierarchical model with three levels. This objective is achieved through the Delphi study. In Delphi, three revisions were sufficient to saturate the data; after the third iteration, stability was achieved in the response. In the second phase, the FAHP method is used to rank the SCN solutions. Feedback regarding their views on SCN solutions was obtained from a panel of 15 experts.

Step 3: Draw the hierarchical structure.

The SCN factor was determined from the SCN literature. First, we identify all appropriate drivers for the main level and sublevels through questionnaire responses. Subsequently, the solutions are identified. The hierarchy created is reviewed and confirmed by experts.

The main objective is to prioritize the selected alternatives/GSCN solutions based on five criteria (GSCN drivers).

Step 4: Create fuzzy numbers and use them to carry out pairwise comparisons.

After the hierarchical tree is developed, the process continues by defining the scale of the relative importance of the pairwise comparison matrices. A TFN from 1 to 9 is used to improve the traditional nine-point scale. To capture the ambiguity in the qualitative assessment of experts, five TFNs with their respective memberships were used. Table 1 describes the relative importance of the scales used in the pairwise comparison matrix.

Table 1. Comparative importance scale of criteria (Linguistic terms and their corresponding TFN).

Linguistic Values	Equally Important	Weakly Important	Fairly Important	Strongly Important	Absolutely Important	The Intermediate Values between Two Adjacent Values			
TFN	(1,1,1)	(2,3,4)	(4,5,6)	(6,7,8)	(9,9,9)	(1,2,3)	(3,4,5)	(5,6,7)	(7,8,9)

Step 5: Use Fuzzy numbers to build a pairwise comparison matrix.

We create a Fuzzy comparison matrix ($\tilde{A}$) and determine the weight of each alternative compared with the criteria. Where $\tilde{a}_{ij} = \left(l_{ij},\ m_{ij},\ u_{ij}\right)$.

This pair comparison matrix is expressed as follows:

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \ldots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \ldots & \tilde{a}_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \end{bmatrix} \tag{1}$$

As in this case, where there are numerous experts, the elements of an entire comparison matrix employed in the Fuzzy AHP method are the number of TFNs, in which the first element (l) is the minimum comment, the second component (m) is the average number, and the third element (u) is the maximum number. The retrieval of data forms the answers to the FAHP questionnaire. The respondents use a 1–9 scale to rate the relative importance of model elements. Equations (2)–(5) are used to convert the expert's answer to TFN. $\tilde{a}_{ij}$ represents the integrated TFN, which is the answer of the expert k with respect to i^{th} element concerning j^{th} element and can be indicated as a TFN via the following formulation, where l, m, and u are the lower, middle, and upper TFN bound, respectively.

$$\tilde{a}_{ij} = \left[l_{ij},\ m_{ij},\ u_{ij}\ \right] \tag{2}$$

$$l_{ij} = min\left(A_{ij}^{1},\ A_{ij}^{2},\ \ldots,\ A_{ij}^{p}\right) \tag{3}$$

$$m_{ij} = average\left(A_{ij}^{1},\ A_{ij}^{2},\ \ldots,\ A_{ij}^{p}\right) \tag{4}$$

$$u_{ij} = max\left(A_{ij}^{1},\ A_{ij}^{2},\ \ldots,\ A_{ij}^{p}\right) \tag{5}$$

where $i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n; k = 1, 2, \ldots, p.$

Step 6: Consistency check

A crucial step involves examining the consistency of expert opinions. To confirm the applicability and transitivity of the comparison factors, we check their consistency. The consistency of the pairwise comparison matrix is evaluated using the consistency ratio, as shown by the equation below. First, calculate the mean of $\lambda_{max} = average\ (AxX/X)$, where X is the priority vector and a pairwise comparison matrix. Second, calculate the consistency index $CI = \lambda_{max} - n/n - 1$. Third, the consistency ratio (CR) is calculated. $CR = CI/RI$, where RI is a random index calculated by randomly generating matrices of different sizes.

Step 7: Calculate S_i for each row of the pairwise comparison matrix.

S_i is calculated using the following formula:

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} \quad (6)$$

Here , i represents the row number, and j denotes the column number. In the formula, M_{gi}^{j} is the triangular fuzzy number of the pairwise comparison matrices. The values of $\sum_{j=1}^{m} M_{gi}^{j}$, $\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}$, and $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$ is calculated by using the following formulas, respectively,

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \quad (7)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i\right) \quad (8)$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}\left(\frac{1}{\sum_{i=1}^{n} l_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} u_i}\right) \quad (9)$$

Here, l_i, m_i, u_i are the fuzzy numbers in the first, second, and third parts, respectively.

Step 8: Compute the level of S_i having regard to one another.

Generally, if $M_1 = (l_1, m_1, u_1\ )$ and $M_2 = (l_2, m_2, u_2\ )$ are two TFNs, then the magnitude of M_1 with respect to M_2 can be defined as

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M2}(d) = \begin{cases} 1 \ \ if\ m_2 \geq m_1 \\ 0 \ \ if\ l_2 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} \ \ otherwise \end{cases} \quad (10)$$

Instead, the magnitude of the TFN from k can be obtained as another TFN by using the following formula:

$$V(M \geq M_1,\ M_2,\ \cdots, M_k) = V[(M \geq M_1)\ and\ (M \geq M_2)\ and\ \cdots\ (M \geq M_k)] = Min\ V(M \geq M_1),\ i = 1,2,3,\ldots,k \quad (11)$$

Step 9: Calculate the pairwise comparison matrix weights for criteria and options.

Subsequently, the eigenvalues and eigenvectors of the pairwise comparison matrix developed for the GSCN driver are calculated. The following formula is used:

$$d'\ (A_i) = Min\ V(S_i \geq S_k)\ k = 1,2,\ldots,n;\ k \neq i \quad (12)$$

Therefore, the denormalized weight vector can be given as follows:

$$W' = \left(d'\ (A_1),\ d'\ (A_2), \ldots, d'\ (A_n)\right)^T\ A_i\ (i = 1,2,\ldots,n) \quad (13)$$

Step 10: Determine the ultimate weight vector. After normalizing the weight vector from the calculation in the previous step, we compute the final weight vector:

$$W = (d\ (A_1),\ d\ (A_2), \ldots, d\ (A_n))^T \quad (14)$$

Fuzzy AHP employs a range of values to account for the decision makers' uncertainty; thus, decision-makers prefer it over the AHP approach. This enhances the ability of the analytical hierarchy method to handle ill-defined and ambiguous human comparison judgments.

6. Results and Discussion

Using the suggested combined DELPHI–Fuzzy AHP technique, this section deals with computations to rank the solutions based on their relative relevance and impact on SCs. A team of 15 experts was contacted to define the relative weights of criteria and solutions.

The expert team comprised nine managers, four academics, and two executive specialists in the field of SC. They have 10–20 years of experience in their field. The experts defined the objectives, criteria, and alternatives of the model. The elements of the model and their interdependencies are shown in Figure 3. The expert group analyzed and confirmed the model elements.

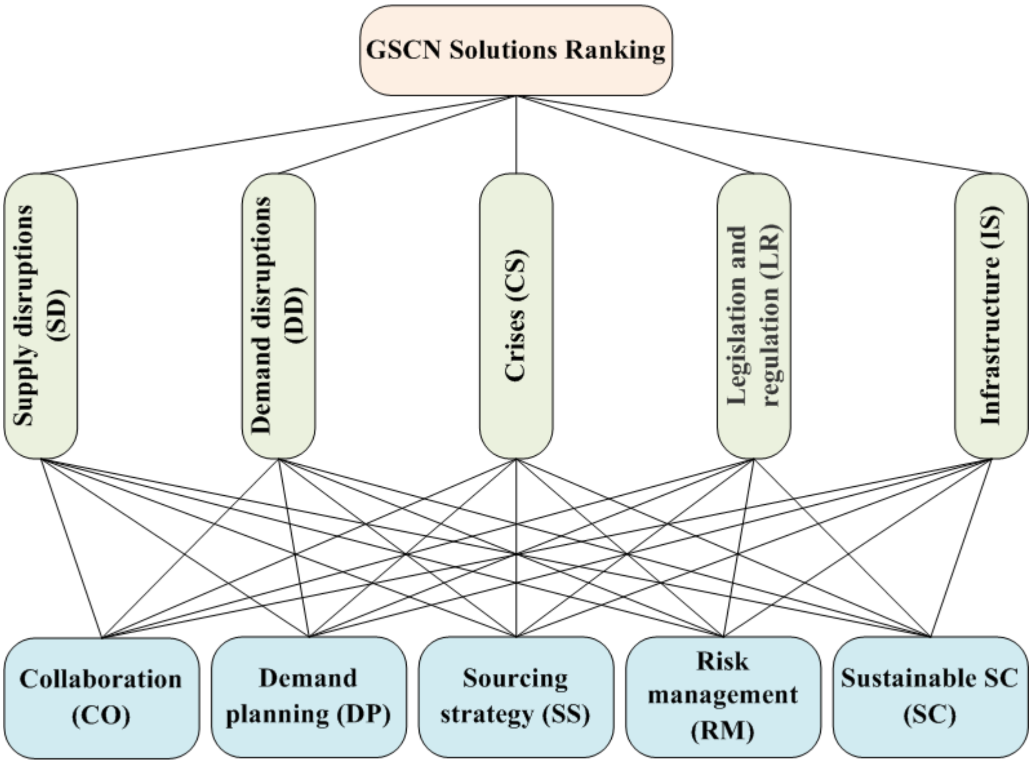

Figure 3. GSCN hierarchy structure.

After screening using the Delphi method, the solutions and evaluation criteria were selected. Therefore, all alternative solutions and evaluation criteria were retained, while the hierarchical structure diagram remained unchanged. These solutions were grouped into five main solutions: collaboration, demand planning, sourcing strategy, risk management, and sustainable SC. Five criteria were identified: demand disruptions, supply disruptions, crises, legislations and regulations, and infrastructure. The following steps comprise the calculation of the preference importance of each factor, fuzzy eigenvalues, preference value of each factor, and nervousness analysis. Figure 3 shows the classification of these GSCN drivers and solutions. A brief description of each element is provided in the framework section.

Table 2 illustrates the relative weight on a 1–9 scale by fifteen experts based on their evaluations of all criteria in relation to the goal. The formulas were used to convert the responses into TFN. The same process was used in the following calculations to convert the respondents' scores into TFN scores. The comparison matrix was calculated using Equations (2)–(5). Table 2 shows the comparison matrix of the criteria-goal matrix. The matrix is reasonably consistent, $CR = 0.097 < 0.1$, indicating the consistency of the matrix. The same CR calculations were performed for other comparison matrices. The weight calculations for the criteria related to the goals are presented in Tables 3–5.

Table 2. Pairwise comparison of criteria.

Goal	Supply Disruptions			Demand Disruptions			Crises			Legislation and Regulation			Infrastructure			Normalized Weights
Supply disruptions	1	1	1	1	1	1	5	6	7	6	7	8	7	8	9	0.414
Demand disruptions	1	1	1	1	1	1	7	7	7	4	6	7	6	7	8	0.403
Crises	1/7	1/6	1/5	1/7	1/7	1/7	1	1	1	1	1	1	1	1	1	0.061
Legislation and regulation	1/8	1/7	1/6	1/7	1/6	1/4	1	1	1	1	1	1	1/3	1/2	1	0.055
Infrastructure	1/9	1/8	1/7	1/8	1/7	1/6	1	1	1	1	2	3	1	1	1	0.066
λ_{max} = 5.44; CI = 0.11; CR = 0.097																

Table 3. Arithmetical average of fuzzy-comparison value.

Criteria	ri		
Supply disruptions	2.914	3.201	3.471
Demand disruptions	2.914	3.117	3.301
Crises	0.459	0.474	0.491
Legislation and regulation	0.359	0.412	0.506
Infrastructure	0.425	0.514	0.590
Total	7.071	7.717	8.360
Reverse	0.141	0.130	0.120
Ascending Order	0.120	0.130	0.141

Table 4. Relative fuzzy weight of each criterion.

wi		
0.349	0.415	0.491
0.349	0.404	0.467
0.055	0.061	0.069
0.043	0.053	0.072
0.051	0.067	0.083

Table 5. Average and normalized weight of criteria.

Mi	Ni
0.418	0.414
0.406	0.403
0.062	0.061
0.056	0.055
0.067	0.066

The weight of each criterion is listed in Tables 6–10. The decision maker determines the fuzzy comparative importance weights of the criteria.

Table 6. Pairwise comparison of all alternatives to supply disruptions.

Supply Disruptions	Collaboration			Demand Planning			Sourcing Strategy			Risk Management			Sustainable SC			Normalized Weights
Collaboration	1	1	1	1	2	3	4	6	7	2	3	4	7	8	9	0.443
Demand planning	1/3	1/2	1	1	1	1	1/4	1/3	1/2	1/3	1/2	1	4	5	6	0.135
Sourcing strategy	1/7	1/6	1/4	2	3	4	1	1	1	1/5	1/4	1/2	1	2	3	0.119
Risk management	1/4	1/3	1/2	1	2	3	2	4	5	1	1	1	6	7	8	0.260
Sustainable SC	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	1/8	1/7	1/6	1	1	1	0.043
λ_{max} = 5.44; CI = 0.11; CR = 0.099																

Table 7. Pairwise comparison of all options on demand disruptions.

Demand Disruptions	Collaboration			Demand Planning			Sourcing Strategy			Risk Management			Sustainable SC			Normalized Weights
Collaboration	1	1	2	3	4	1	2	3	5	6	7	7	8	9	1	0.408
Demand planning	7	8	1	1	1	1/4	1/3	1/2	1/3	1/2	1	3	4	5	7	0.190
Sourcing strategy	1/2	1	2	3	4	1	1	1	2	2	2	7	8	9	1/2	0.256
Risk management	1/6	1/5	1	2	3	1/2	1/2	1/2	1	1	1	1	2	3	1/6	0.105
Sustainable SC	1/8	1/7	1/5	1/4	1/3	1/9	1/8	1/7	1/3	1/2	1	1	1	1	1/8	0.040
λ_{max} = 5.44; CI = 0.11; CR = 0.099																

Table 8. Pairwise comparison of every alternative on crises.

Crises	Collaboration			Demand Planning			Sourcing Strategy			Risk Management			Sustainable SC			Normalized Weights
Collaboration	1	1	1	2	3	4	2	3	4	5	6	7	7	8	9	0.460
Demand planning	1/4	1/3	1/2	1	1	1	1	2	3	4	5	6	6	7	8	0.261
Sourcing strategy	1/4	1/3	1/2	1/3	1/2	1	1	1	1	1	2	3	5	6	7	0.167
Risk management	1/7	1/6	1/5	1/6	1/5	1/4	1/3	1/2	1	1	1	1	1	2	3	0.073
Sustainable SC	1/9	1/8	1/7	1/8	1/7	1/6	1/7	1/6	1/5	1/3	1/2	1	1	1	1	0.039
λ_{max} = 5.44; CI = 0.11; CR = 0.098																

Table 9. Pairwise comparison of all alternatives on legislation and regulation.

Legislation and Regulation	Collaboration			Demand Planning			Sourcing Strategy			Risk Management			Sustainable SC			Normalized Weights
Collaboration	1	1	1	1	2	3	3	4	5	5	6	7	7	8	9	0.447
Demand planning	1/3	1/2	1	1	1	1	2	3	4	3	4	5	6	7	8	0.301
Sourcing strategy	1/5	1/4	1/3	1/4	1/3	1/2	1	1	1	1	2	3	4	5	6	0.136
Risk management	1/7	1/6	1/5	1/5	1/4	1/3	1/3	1/2	1	1	1	1	1	2	3	0.077
Sustainable SC	1/9	1/8	1/7	1/8	1/7	1/6	1/6	1/5	1/4	1/3	1/2	1	1	1	1	0.040
λ_{max} = 5.41; CI = 0.1; CR = 0.090																

Table 10. Pairwise comparison of every alternative in infrastructure.

Infrastructure	Collaboration			Demand Planning			Sourcing Strategy			Risk Management			Sustainable SC			Normalized Weights
Collaboration	1	1	1	2	3	4	2	3	4	4	5	6	7	8	9	0.461
Demand planning	1/4	1/3	1/2	1	1	1	1/3	1/2	1	2	5	6	5	6	7	0.203
Sourcing strategy	1/4	1/3	1/2	1	2	3	1	1	1	2	2	2	4	5	6	0.210
Risk management	1/6	1/5	1/4	1/6	1/5	1/2	1/2	1/2	1/2	1	1	1	2	3	4	0.087
Sustainable SC	1/9	1/8	1/7	1/7	1/6	1/5	1/6	1/5	1/4	1/4	1/3	1/2	1	1	1	0.039
λ_{max} = 5.42; CI = 0.11; CR = 0.094																

The fuzzy weights of the defuzzification criteria and normalized weights were then calculated. Table 11 demonstrates the normalized non-fuzzy relative weights of each alternative for all criteria. Use Equations (6)–(14) to calculate the global weights of the standards. Table 12 reveals the total outcomes for each alternative with respect to each criterion.

Table 11. Normalized non-fuzzy relative weights of each alternative for all criteria.

	Supply Disruptions	Demand Disruptions	Crises	Legislation and Regulation	Infrastructure
Demand Planning	0.44	0.41	0.46	0.45	0.46
Collaboration	0.14	0.19	0.26	0.30	0.20
Sourcing strategy	0.12	0.26	0.17	0.14	0.21
Risk management	0.26	0.11	0.07	0.08	0.09
Sustainable SC	0.04	0.04	0.04	0.04	0.04

Table 12. Combined results for all alternatives according to each criterion.

	Weights	Collaboration	Demand Planning	Sourcing Strategy	Risk Management	Sustainable SC
Supply disruptions	0.41	0.44	0.14	0.12	0.26	0.04
Demand disruptions	0.40	0.41	0.19	0.26	0.11	0.04
Crises	0.06	0.46	0.26	0.17	0.07	0.04
Legislation and regulation	0.06	0.45	0.30	0.14	0.08	0.04
Infrastructure	0.07	0.46	0.20	0.21	0.09	0.04
Total	1.00	0.43	0.18	0.18	0.16	0.04

Figure 4 shows the results of the adjusted Delphi–FAHP methodology. The solutions of SCs with nervousness were evaluated according to the total values of the aggregated outcomes for each alternative according to all criteria. The ranks of the DP–SS–CO–RM–SC factors ranged from the best (most preferable) to the least. From the ranking results in Figure 4, it can be concluded that compared with other alternatives, DP has the best weight value. Therefore, it can be concluded that demand planning has priority of implementation over other solutions.

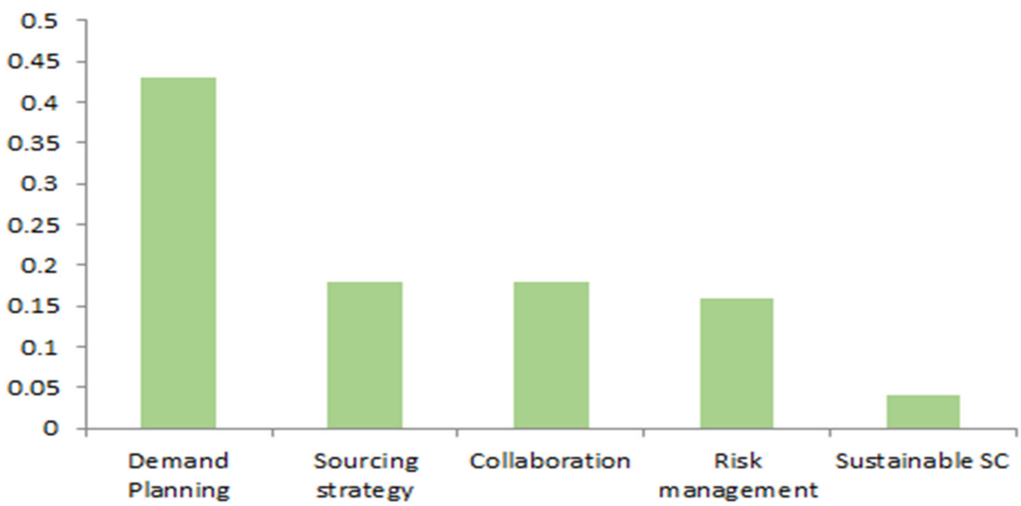

Figure 4. Solutions rank based on their priority.

The results show that the ranking of SCN using the combined method of the best SC expansion areas is demand planning, supply strategy, collaboration, risk management, and sustainable SC (DP > SS > CO > RM > SC). The results were then reviewed by experts who agreed with the MCDM–Modified Delphi–FAHP ranking.

7. Conclusions and Future Work

Natural catastrophes, manmade disasters, and other crises, such as the recent COVID-19 pandemic, have drawn more professional and scholarly attention to the unease surrounding the world's SC today. Nervousness reduces the SC's overall efficacy, especially when most SC instability is triggered by events beyond the company's control. Nervousness results in uncertainty, higher SC costs, and unsteady connections between vendors and clients. This study examined GSCN factors and their features.

A literature review reveals that research on GSCN has been neglected or limited to a specific area. No research has investigated the drivers, consequences, indicators, pillars, or solutions for nervousness in the GSC. This study investigates the reasons for GSCN, analyzes the impact of SCN, introduces methods for assessing SCN, and proposes appropriate solutions. Furthermore, this study establishes a framework for dealing with SCN considering globalization, disruptions, and volatility; supply chain decision makers can capitalize on their nervousness to create sustainable SC and boost future SC resilience, responsiveness, and competitiveness. Additionally, the integrated DELPHI–FAHP technique was utilized to determine the best solutions and prioritize their deployment and consideration by businesses. The findings show that the implementation of demand planning, supply strategies, collaboration, risk management, and sustainability are critical requirements for a brighter future vision.

Demand and supply interruptions, crises, changes in laws and regulations, and infrastructure changes were listed as the five criteria. The options were divided into five primary categories: sustainable SC, sourcing strategy, risk management, and demand planning. The solutions for SCs with nervousness were assessed using an adapted Delphi-FAHP approach based on the total values of the aggregated results for each alternative according to all criteria. The solutions were ranked from the most to the least preferable. The results indicate that demand planning is given priority for adoption over other solutions because it has the best weight value.

The results of this study will aid industrial executives, practitioners, and decision makers in concentrating on SCN issues during the planning phases, enhancing future SC sustainability, and advancing the development of corporate and SC resilience. Future experimental studies on SC innovation could employ this framework as a construct. This study also provides suggestions for reducing SCN. Integration, approaching the issue from an outside viewpoint; collaborating with partners, clients, and suppliers; and reducing instability in the production environment are additional strategies to reduce nervousness.

A case example is provided to demonstrate the credibility and validity of the proposed fuzzy AHP technique. Based on the results of this study, managers can offer ideas for effectively managing the SCN trends.

This study has some limitations. In this study, an analysis framework based on DELPHI–Fuzzy AHP was used, and five main drivers and five solutions were identified to alleviate nervousness in an SC context. The other drivers were not listed or classified. The recommendations of experts were largely responsible for the results of this study. Therefore, the evaluation procedures must be performed with care. Future research can include the study of indicators and nervousness measures, as well as steps to implement solutions in SC.

Future research could also evaluate the stated determinants for the adoption of SCN solutions using various decision analysis methods such as Fuzzy ANP, FELECTRE, FTOPSIS, and FVIKOR. Future research may also use ISM and DEMATEL to study how drivers interact with one another. Additionally, Total Interpretive Structural Modeling (TISM) and Interpretive Classification Process (IRP) methods can be used to understand the relationships between drivers in terms of performance results. Additionally, a combination of several MCDM techniques can be used in the evaluation process. Future research should include feedback from other stakeholders, such as customers, suppliers, and regulators, to provide a more thorough overview and rating of the options based on the criteria for selection.

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