*Proceedings of the 7th North American International Conference on Industrial Engineering and Operations Management, Orlando, Florida, USA, June 12-14, 2022*

# Designing Supply Chain to Hedge Against Disruptions: A Review of Literature in General and Agro Food Supply Chains

**Sherine Beshara**
PhD Student, Production Engineering Department
Alexandria University, Egypt
sherineb@gmail.com

**Hadi Fors**
Assistant Professor, Production Engineering Department
Alexandria University, Egypt
hadifors@alexu.edu.eg

**Nermine Harraz and M. Hamdy Elwany**
Professor of Industrial Engineering, Production Engineering Department
Alexandria University, Egypt
nharraz@alexu.edu.eg, hamdy.elwany@alexu.edu.eg

## Abstract

Recent events unveiled that it has become eminent to understand the wide dimensions of the supply chains disturbance and how to mitigate its effect on the performance. The complexity of globally stretched supply chains of different products and specifically agro food supply chains have increased the sensitivity of the performance if any disturbances occur. This paper reviews the literature from 2017 concerned with resilience in supply chains and agro food supply chains with the aim of building a complete understanding of the strategies to deal with disruptions. The review classifies the risks, decision variables, and objectives considered in the resilient supply chains. The different model types are addressed together with the appropriate solution techniques used. The research gaps were identified and the different research paths were highlighted that are scarce in literature. The results show the dearth in research on agro food supply chains and application of the models on real case studies. Sustainability is rarely addressed and linked with resilience. Limited research addressed resilience as a performance measure although it is of great importance.

## Keywords
Resilience, Supply Chain Management, Agro Food Supply Chain, Sustainability, Review

## 1. Introduction
Nowadays, the novel supply chains in our emerging global economy are interconnected and complex. This is mostly due to the articulation of research about the benefits of adapting strategies like global outsourcing, manufacturing in global destinations, supply base rationalization, just-in-time deliveries, and many more. Applying these strategies shed the light to new complications that the chains are now facing owing to the vulnerability of the chain to exchange rates, disruptions due to strikes, natural disasters and new applied taxes, and any political and economic instability. Moreover, the recent disruptions due to the global spread of COVID-19 drastically affected the world causing a halt to the chains across different echelons due to a number of problems like logistics for supplies and finished products delivery, closure of retails, and scarcity of products. The threshold of the effect of COVID-19 can be clearly noticed across the globe, revealing the urgent need for developing a proactive supply chain design "SCD" to take control of the chain when sudden disruptions of that magnitude occur. Resilience policies are now being the forethought of supply chain study and applications, as resilience signifies strength and flexibility of the chain. There are numerous definitions of supply chain resilience "SCR", (Emenike and Falcone 2020) defines it as the capacity of a supply chain network to overcome stress or system failure and mitigate the impact of disruptions as much as possible. SCR arose

from the general topic of risk management, however resilience plans for greater disruptions that are less likely to occur but threatens the supply chain continuousness itself. In today's globalized supply chains, designing without considering such a disruption that affects the chain in countless number of ways should not be ignored. Research by (Jabbarzadeh et al. 2018a), (Dolgui et al. 2020), (Tolooie et al. 2020) and (Sabouhi et al. 2020) sheds light on how the effective supply chain design leads to higher performance, (Namdar et al. 2017), (You et al. 2019) and (Aguila et al. 2019) pointed out how costs where reduced during disruptions. ElMaraghy et al. (2020) called for more studies concentrating on the first tier of the supply chain which is the supplier.

Resilience in the agro food supply chain "ASC" has been gaining more importance recently with the increasing volatility of the chains across the globe. Firms are trying to cope with the pressures of not only a growing population but one with shifting consumer preferences in which they demand freshness and quality. The Agriculture Organization FAO 2020 stated that COVID-19 is affecting these chains severely at both ends (Sharma et al. 2020). Disruptions due to epidemic events is scarce in the existing literature of ASC (Zanjani et al. 2021) and (Zahao et al. 2020). To this end there are calls for advanced stochastic multi-period models to design a resilient ASC (Esteso et al. 2018) and (Rahimifard et al. 2018) and for quantifying risk mitigating strategies (Li et al. 2020). Finding quantitative measures for the resilience is limited in literature as mentioned by (Ivanov 2017b), (Jabbarzadeh et al. 2018a), (Linkov et al. 2020), and specifically in ASC (Zanjani et al. 2021).

### 1.1 Objectives

To effectively bridge the gap that was mentioned by (Ivanov 2017b), (Hosseinia et al. 2019), and (Abdor 2020) between practical and research needs, one must first study closely the different SCD strategies. The broad objective of this paper is to review the developed studies for designing resilient supply chains to hedge against disruptions while concentrating on ASC. The contributions of this work are threefold, identifying the different risks, strategies, decision variables, and objectives for designing a resilient supply chain, providing guidance on which modelling and solution technique is best used with resilience measures, and finally presenting the different ways to quantify resilience and its relation with sustainability.

## 2. Literature review

### 2.1 Resilience in supply chain management

Abdor (2020) Defined resilience to be "about systems changing as circumstances change, adaptation when necessary, and transformation rather than continuing to do the same thing better". There are two types of supply chain risks, operational risks, which are related to ordinary disturbances like the uncertainties in lead time, demand, and supply, and disruptive risks, which are less frequent risks but their effect has a much greater amplitude on the chain. Disruptive risks like natural disasters and Epidemic outbreaks have a long duration and ripple effects across the chain (El Baz Ruel 2020). To be able to withstand disruption a supply chain should have been already designed for it. All strategies for attaining resilience are in one way or another related to the SCD. For example, (You et al. 2019) considered achieving a resilient supply chain in two steps. The first step is finding the best supply chain network design with planning for extra capacity to increase resilience and the second one is to increase redundancy by having extra facilities or adding extra production capacity.

### 2.2 Resilience in agro food supply chain

The food supply chain is considered one of the infrastructures of a country as it delivers essentials to customers not only profit for companies (Zanjani et al. 2020). Its resilience is concerned with the unbroken flow of safe food from farm to fork. For ASC, the main risks causing the greatest disruptions (affecting supply, demand, and logistics) are either weather or politics related (Zhao et al. 2020). Bottani et al. (2019) grouped the food supply chain into three phases, the supply phase which includes farms, chemicals, and or packaging materials, processing phase including all the processing plants and transformation activities, and distribution phase which includes wholesale centers, retailers, markets, and delivery activities. The ASCs intricacy is owed to their unique vulnerabilities, the product's limited shelf-life, the safety of the product requiring extra measures in transport and storage, and the variability in quality, all these add to the importance of resilience in agro food supply chains.

## 3. Review methodology

The methodology followed for the literature review in this paper is the systematic review procedure described by (Tranfield et al. 2003) and (Denyer and Tranfield 2009) to identify significant contributions to a research field and analyze literature to find answers to research questions. The first step is deciding on the focus of study, which is resilience in supply chain management (SCM) in general and specifically in agro food products. The following keywords were used in searching, supply chain management, resilience, sustainability, agro food supply chain resilience, disruptions. Concisely, our main research questions are: Which SCM issues and strategies are addressed when designing for resilience? What sources of uncertainty are considered? Which decision variables are critical? How are supply chains modeled and solved? How to measure resilience of a supply chain? Which sustainability aspects are tackled? To find the relevant research papers, the papers were retrieved from databases of Web of Science and Google Scholar. The retrieved papers dated from 2017 were later refined. The reviewed papers were analyzed to identify research gaps and future research opportunities.

## 4. Results and discussion

### 4.1 Resilience in supply chain management

There are numerous strategies to aid in making the supply chain more resilient: increasing capacity at manufacturing or creating a capacity buffer, multiple sourcing and contracting with backup suppliers and ports (Jabbarzadeh et al. 2018a). These strategies can be divided into proactive and reactive strategies. The former are preventive actions that should be taken before a disruption occurs even if it never happens, representing the flexibility and readiness of the chain that helps in the visibility and collaboration. It compromises of fortification (reinforcing and protecting some facilities against possible disruption), multiple facility or supplier, technological investments, inventory safety stock and having several transport routes. The latter are the strategies that will be implemented once a disruption occurs, representing the responsiveness of the chain. It compromises of backup facility, supplier, and transport routes, capacity buffer or expansion, and alternative scenarios (Govindan et al. 2017). Looking closely in Figure 1, most of the research considers reactive or combined strategies. This is due to the high cost of implementing the proactive strategies, and thus most firms would prefer to pay this cost only when disruption occurs.

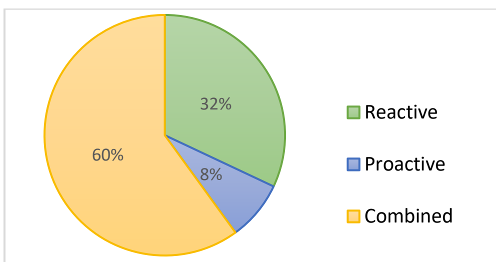



Figure 1. Percentage of supply chain papers considering each strategy

Table 1 presents risks, strategies, and echelons in reviewed supply chain papers. When disruption affects the production, the strategy is to use the capacity buffer or expansion (El Baz and Ruel 2020). Both strategies are used to cover the uncertainty in demand as well (Nooraie et al. 2019) and (Fattahi et al. 2020). It is eminent from the table that when complete disruptions are considered, alternative scenarios are frequently considered like in (Sabouhi et al. 2020) and (Singh et al. 2020). This is due to the fact that numerous strategies should be executed subsequently which leads to high costs, thus it is better to reach the least cost strategy while maintain performance. Regarding the supply chain echelons, the majority of the papers studied the complete chain. Figure 2 shows the frequency of proactive strategies mentioned in reviewed papers. The safety stock strategy is widely used since it is one of the oldest strategies and can be easily modified by time. While Figure 3 illustrates the reactive strategies stated in reviewed papers. Alternative scenarios are by far the most frequent strategy addressed since it compares between different options and gives the most cost effective one.

Table 1. Risks, strategies, and echelons in reviewed supply chain papers

| Reference | Type of Risk | | Strategy | | Echelons |
|---|---|---|---|---|---|
| | Complete | Partial | Proactive | Reactive | |
| (Ivanov 2017a) | x | | F & I | | All |
| (Namdar et al. 2017) | | S | Tech, MS | BS & A | S-P |
| (Jabbarzadeh et al 2018a) | | P & S | | Cp & BS | All |
| (Ivanov 2018) | | DC | | BS, Cd, A | S-DC-C |
| (Ye et al. 2018) | | D | I | A | All |
| (Sabouhi et al. 2018) | x | | MS, I & F | A | All |
| (Jabbarzadeh et al 2018b) | x | | MF | A | All |
| (Aguila et al. 2019) | x | | MF | | All |
| (Nooraie et al. 2019) | | S & D | Tech | Cp | All |
| (You et al. 2019) | | P & D | | Cp, A | All |
| (Hosseini and Ivanov 2019) | | S | MS | | All |
| (Hosseini et al. 2019) | | S | MS | BS, Cs, A | All |
| (Diabat et al. 2019) | | DC & T | MF | BT | All |
| (Sato et al. 2020) | | D & T | | A | S-P |
| (Sabouhi et al. 2020) | x | | MS & MT | Cp & Cd, A | All |
| (El Baz and Ruel 2020) | x | | Tech | Cp & Cd | All |
| (Bahzadi et al. 2020) | | T | | BT, A | All |
| (Singh et al. 2020) | x | | | BF & A | D-C |
| (Dolgui et al. 2020) | x | | Tech & I | A | All |
| (Ivanov 2020a) | x | | I | Cp, A | All |
| (Fattahi et al. 2020) | | D & C | I | Cd, A | DC-C |
| (Tolooie et al. 2020) | | P | F | A | S-DC-C |
| (Ivanov et al. 2020b) | x | | | BS, Cp, Cd | All |
| (ElMaraghy et al. 2021) | x | | I | Cp | All |
| (Alinezhad et al. 2021) | | S | MS | Cp, Cd | All |

*S: Supplier, P: Producer, D: Demand, T: Transportation, DC: Distribution center, C: Customer
*F: Fortification, MS: Multiple supplier, MF: Multiple facility, Tech: Technological investment, I: Inventory safety stock, MT: Multiple transport routes, BS: Backup supplier, BT: Backup transport, Cp: Capacity buffer at P, Cd: Capacity at D, A: Alternative scenarios, BF: Backup facility

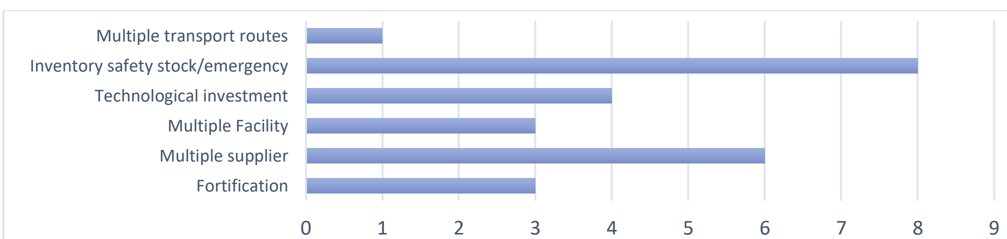



Figure 2. Frequency of proactive strategies

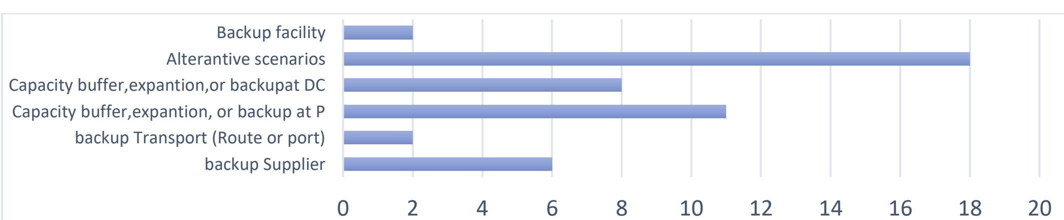



Figure 0. Frequency of reactive strategies

The majority of the decision variables addressed in reviewed supply chain papers were related to design parameters of the supply chain. Around 43% of the papers considered multi-stage models owing to the ripple effect of disruption, in which the decision variables are divided according to stages or disruptions phases. Facility location was the addressed in (You et al. 2019) and (Sabouhi et al. 2020) as a first stage decision variable for the model combined with the capacity of each manufacturing facility. However, the second stage variable is different in each model, (Sabouhi et al. 2020) concentrated on deciding the appropriate suppliers, the transportation route, and the flow of materials between each chain node, whereas the model of (You et al. 2019) concentrated on the schedule, procurement, and transportation of products. Ye et al. (2018) addressed the quantity of manufacturing goods as the only decision variable. However (Nooraie et al. 2019) coupled it with the purchasing quantity per supplier. In general, as seen in Figure 4, transportation variables are least studied and the procurement and product flow are the most common.

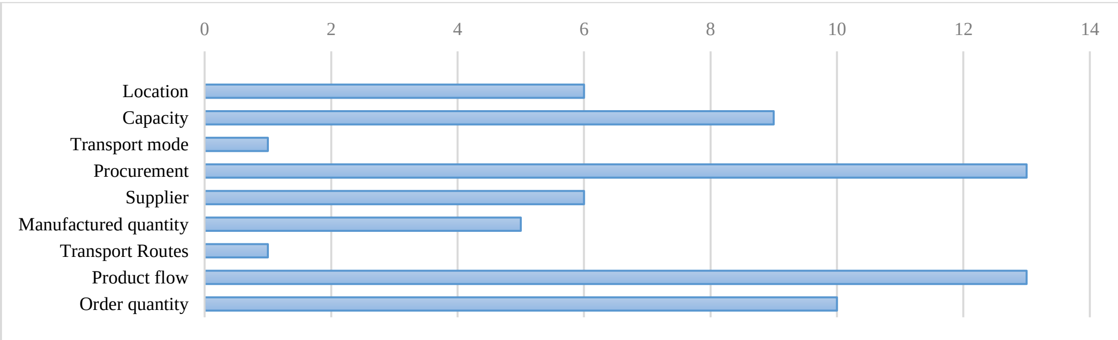



Figure 4. Frequency of each decision variable in supply chain papers

The objective of any model is naturally to maximize the performance. Objectives can be categorized as shown in table 2 according to their purpose into financial, customer-oriented, sustainability, and resilience objectives. The financial objective is naturally always present except for 1 paper which considered resilience alone, most of the time it is coupled with another type of objective to better achieve the model's goal. The customer objective is measured using the service level, lead time, lost sales or responsiveness, where the latter is the least measured in the reviewed papers. Resilience was measured using different methods, in which it was either measured by integration of the impact of disruption on the plant's functions from the start of disruption to the time when recovery is complete (Emenike and Falcone 2020) or as the ratio between the integration of supply chain performance in normal circumstances and during disruption (You et al. 2019). Also (Hosseini and Ivanov 2019) measured resilience as the ratio of the recoverability and vulnerability values. In (Hosseinia et al. 2019) work, they measured the loss of resilience by summing up lost capacity and the cost of recovery suppliers. While in (Bahzadi at al. 2020) they measured the time to recovery and lost profit during disruption.

Table 2. Objective of each reviewed supply chain paper

| Reference | Objective | | | |
|---|---|---|---|---|
| | Financial | Customer | Sustainability | Resilience |
| (Ivanov 2017a) | | SL & LT | s | |
| (Namdar et al. 2017) | C | | | |
| (Govindan et al. 2017) | P | LT | | |
| (Ye et al. 2018) | P | | | |
| (Jabbarzadeh et al. 2018a) | C | | E & s | |
| (Sabouhi et al. 2018) | C | | | |
| (Jabbarzadeh et al. 2018b) | C | LS | | |
| (Diabat et al. 2019) | C | LT | | |
| (Nooraie et al. 2019) | C | Rs | | |
| (You et al. 2019) | C | | | R |
| (Hosseini and Ivanov 2019) | | | | R |
| (Hosseini et al. 2019) | C | | | |
| (Aguila et al. 2019) | C | | | R |
| (Singh et al. 2020) | C | LT & SL | | |

| Reference | Objective | | | |
|---|---|---|---|---|
| | Financial | Customer | Sustainability | Resilience |
| (Bahzadi et al. 2020) | P | LS | | |
| (Ivanov 2020a) | C | | | |
| (Fattahi et al. 2020) | C | | | |
| (Tolooie et al. 2020) | C | | | |
| (Ivanov et al. 2020b) | Rv, P | SL & LT | | |
| (Sabouhi et al. 2020) | C | SL | | |
| (ElMaraghy et al. 2021) | C, P | SL & LS | | |
| (Alinezhad et al. 2021) | P & C | Rs | E | |
| *P: Profit, C: Costs, Rv: Revenue, LS: Lost Sales, SL: Service level, Rs: Responsiveness, LT: Lead Time, E: Environmental sustainability, s: Social sustainability, R: Resilience | | | | |

Resilience is a lot of times connected to supply chain sustainability, due to the influence the chain has on the economic topics like employment rates and natural resource consumption. Calleja et al. (2017) and (Chong et al. 2020) called for studying sustainability and resilience together. The review shows that sustainability is measured in only 7% of the reviewed papers. Sustainability is the interactions between the echelons of the chain that aids environmental and/or social pillars to the chain (Jabbarzadeh et al. 2018a). The environmental sustainability is concerned with how to properly use the resources with minimum impact on the environment, whereas social sustainability is considering the consumers and the employees while planning of supply chains (Emenike and Falcone 2020). To achieve a resilient design to mitigate the ripple effect of disruption and analyzing the spread of disruption while considering of sustainability factors (Ivanov 2017b) used different scenarios for policies of single sourcing, facility fortification and inventory placement. Selecting a single source was considered a social factor as it increases the employment rate and relationships at this firm and builds long term trust between entities and thus increases visibility which is an important factor in resilience.

## 4.2 Resilience in agro food supply chain

A number of strategies were not studied in the agro food supply chain research papers (as seen in table 3), such as having multiple facilities or a backup facility. That is probably due to the fact that the critical parts of the agro food chains are the supply or demand parts while the processing facility is less affected by disruption and also it needs to be close to the farms so the location cannot be easily changed. The proactive strategy is mostly studied as seen in Figure 5. Li et al. (2020) optimized inventory safety stock for a multi-echelon grapes supply chain in India where demand is uncertain and service level is maintained. Zanjani et al. (2021) researched how investing in technological infrastructure can increase the collaboration across the chain and maintain the profit when disruptions occur at the producer or the distribution center. Whereas 33% of the reviewed research implemented the reactive strategy and mostly a backup supplier is considered which is because suppliers for agro food are vastly affected by disruptions. Behzadi et al. (2017) proved that having a dynamic transshipment model including flexible rerouting and intermediate locations of distribution centers can hedge against disruptions in the demand and provide profit under market changes.

Table 3. Risks, strategies, and echelons in reviewed ASC papers

| Reference | Type of Risk | | Strategy | | Echelons |
|---|---|---|---|---|---|
| | Complete | Partial | Proactive | Reactive | |
| (Behzadi et al. 2017) | | D | | BT | All |
| (Ravulakollu et al.2018) | x | | Tech | | S-D |
| (Bottani et al. 2019) | | S & D | MS | | All |
| (Li et al. 2020) | | D | I | | All |
| (Zanjani et al. 2020) | x | | | BS, Cp, Cd & A | P-D |
| (Zanjani et al. 2021) | | D & P | Tech & MS | BS & Cp | P-D-C |
| *S: Supplier, P: Producer, D: Demand, T: Transportation, DC: Distribution center, C: Customer *MS: Multiple supplier, Tech: Technological investment, I: Inventory safety stock, BS: Backup Supplier, BT: Backup Transport, Cp: Capacity buffer at P, Cd: Capacity at D, A: Alternative scenarios | | | | | |

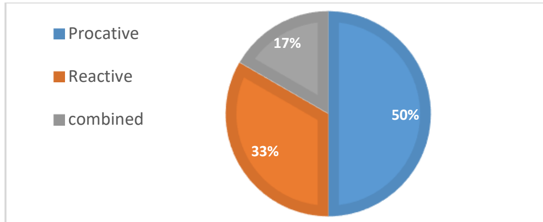
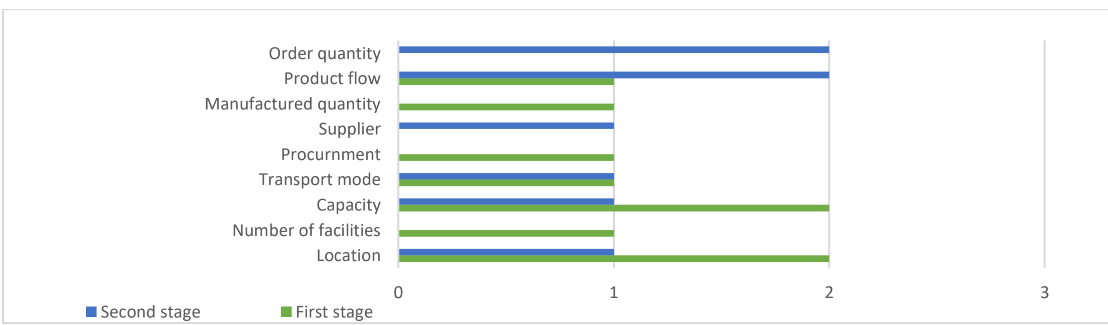



Figure 5. Percentage of ASC papers considering each strategy

Research on agro food supply chains concentrated mostly on the strategic decision variables. When other variables are addressed, there is always a strategic variable present with them except for (Li et al. 2020) in which the decision variable was the transportation mode selected and the lead time was set as a decision variable rather than a performance measure or an objective for that matter. The location of the facilities is widely discussed (figure 6) because of the product's nature. It is critical to have a facility close to the farm while at the same time close to the market or a transportation hub to deliver the products with minimum lead time. Product flow is one of the commonly researched variable due to the geographical distribution together with the vast volume of trade. Half of the reviewed ASC papers considered multi staged models. **Error! Reference source not found.**6 shows the frequency of decision variables addressed. Strategic variables are considered in the first stage and the operational ones are in the second stage. Whereas the tactical variables are considered in both stages owing to the time frame of each decision variable. A number of papers consider multiple variables from each category. Zanjani et al. (2021) suggested scenario-based location-inventory model subjected to disruptions in demand and capacity at their facilities. The first stage decision variables were quantity of products produced, allocation quantities, and the capacity at distribution facility. While the second stage variables included the inventory level and safety stock. Research sometimes considers variables from all levels at once in a single stage model, as the case of (Bottani et al. 2019) where a resilient tomato supply chain is studied. The decision variables considered were the capacity of processing facilities, supplier selection, and allocation quantities.




**Error! Reference source not found.**6. Frequency of each decision variable in ASC papers

The performance of a supply chain is the objective of any firm, a financial objective is logically always the first objective usually combined with another objective according to the preference of the organization. Most of the research puts in consideration customer-oriented objectives and only one paper measured resilience as an objective in an indirect way. The objective of the model was to maximize profit while minimizing risk for a multi-period model that analyses market demand disruption effects in a kiwi supply chains (Behzadi et al. 2017). Risk was measured by minimizing perishability (the risk of delivering products that are not fresh or reducing waste), which was minimized by introducing intermediary nodes that produces a transshipment model to support flexible rerouting.

When it comes to agro food chains, sustainability is essential owing to challenges from the growing population affecting the demand for food, yield problems due to climate change and environmental degradation that leads to resource constraints, food waste (*nearly half of all fruit & vegetables produced globally are wasted each year (*Andersen, 2022)), up to the limited wages of employees in farms which affects harvesting with all its social aspects (Mogale et al. 2019). Research in this area is scarce since out of the reviewed agro food supply chain papers only 15% considered sustainability. This shows that there is a prominent research avenue in this area.

### 4.3 Modelling and solution techniques

There are a number of research methods to undergo research. When reviewing the literature, it became clear that the highest percentage of methods were applied research (34%), followed by similar percentage (31%) for developing a framework which is a conceptual technique, owing to the fact that validation and application needs a lot of data and experimentation. Whereas the analytical models when a mathematical model is developed with real parameters from an existing chain are 21% of the papers and the empirical studies when the data collected is real and it is analyzed are 14%.

Developing a mathematical model for resilient supply chain can sometimes be stochastic (Jabbarzadeh et al. 2018a) and (Bahzadi et al. 2020) or deterministic (Nooraie et al. 2019). Stochastic programming models are scenario-based. Their parameters are characterized by discrete scenarios each having a different probability (Dolgui et al. 2017). For most stochastic programming models like (Ye et al. 2018) and (Sabouhi et al. 2020), demand is usually an uncertain parameter. Tolooie et al. (2020) considered the uncertainty in facility disruptions as well as the uncertainty in demand. Two-stage stochastic programing and mixed integer programming has been extensively applied (39%). Bahzadi et al. (2020) applied the latter for perishables supply chain to hedge against port disruptions with an objective of maximizing both profit and recovery level while minimizing time to recovery. 4% of the papers were modelled as quadratic mixed-integer programming model. Fattahi et al. (2020) developed a two-stage stochastic mixed integer non-linear programming model which was later reformulated as a conic quadratic mixed-integer program to protect against facility disruptions by investigating the effects of having a capacity buffer and alternative inventory configurations on the costs. Nooraie et al. (2019) used multi-objective integer programming modelling to study the effect of increasing responsiveness on reducing the total costs and increasing the resilience using capacity buffers and investing in technology. Aguila et al. (2019) formulated a single period integer programming model like 9% of the reviewed papers to minimize the risk score and costs when overall disruptions occur with the help of the proactive strategy. Another 9% of the papers developed an integer programming model like that of (Nooraie et al. 2019), the model was multi objective to balance the tradeoff between responsiveness, risk and costs.

Optimization is a solution technique that can be done heuristically or with the help of a software to solve a model that can withstand against disruptions with the help of technological innovations with the minimum cost (Emenike and Falcone 2020). The developed models were optimized either using a generic algorithm (Nooraie et al. 2019) or with the help of a software to get an exact solution (71%). Stochastic programming models can be solved using different algorithms such as Benders decomposition algorithm called multi-cut L-shaped method (Sabouhi et al. 2020). Simulation methods have proved to be an appropriate tool for the study of SCD as mentioned by (Ivanov 2017b) as it helps to mimic the performance of the supply chain. (Ivanov 2017a) used discrete event simulation on Logistix to introduce different scenarios using simulation to identify the best sourcing and inventory policy to increase SCR and decrease the ripple effect when there are disruptions along different parts of the chain. CPLEX is the most commonly used software (as seen in Figure 7). (Ivanov 2018) modelled a supply chain using a numerical example of products for four regional markets to mimic the effect of disruption of a distribution center in the recovery and post-disruption periods using CPLEX. Singh et al. (2020) used CPLEX to study the impact of COVID-19 on the transportation and distribution of grains in India.

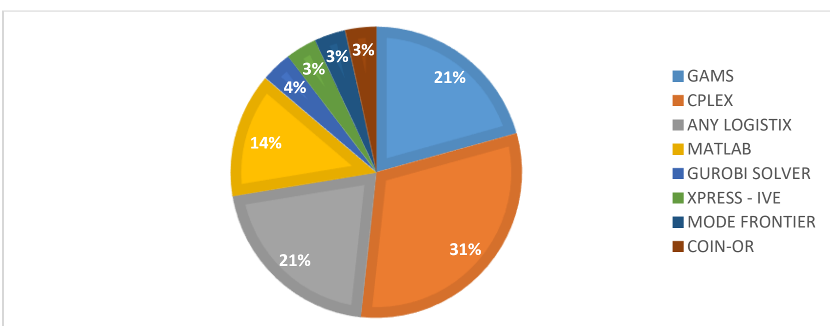



Figure 7. Percentage of using each software

### 4.4 Gap analysis

Noticeable gaps have been recognized from the reviewed literature which point to important future research ideas. A significant gap exists for applying models in different industries like agricultural and energy industries. Also the application of ASC research on a specific product is rarely mentioned. More research is needed to develop models with real data in order to validate the suggested research work. There should be more studies on the impact of digitalization and big data analytics on resilience. For an example, how to make use of available digital technology like simulation and digital twins to improve resilience. In addition, the following problems should be addressed:

- Risks: Develop revival policies for the post disruption period.
- Strategies: Design strategies that can be applied before disruption occurs. More research needs to be considered on having a backup facility to increase resilience.
- Decision variables: Models should take into considerations transportation modes and routes decisions as variables since they can drastically reduce risks and increase resilience. ASC research should study the number of facilities as a variable to increase resilience.
- Objectives: Develop appropriate measures to quantify resilience and sustainability.
- Sustainability: Study the three levels of sustainability with resilience to quantify their impact. To the researcher's knowledge, there is currently limited work on ASC that is extended from farm to customer and has sustainability and resilience as objectives.
- Modeling techniques: Extend the models to be multi-period, multi-objective models by using multi-stage modelling under uncertainty.

## 5. Conclusion

This study presents a review of supply chain resilience (SCR) to mitigate the effect of disruption in general and agro-food supply chains and to contribute to the call of several scholars (Esteso et al. 2018), (Bottani et al. 2019), (Hosseini and Ivanov 2019) and (Adbor 2020). Although the emphasis is on getting a deeper understanding of the concept of resilience, its strategies and the important aspects. This work also concentrates on how researchers introduced a resilient supply chain design, how their work was formulated and implemented, what decision variables were considered, how the work was solved to find the optimum configuration, and how far the sustainability measures were addressed with resilience.

SCR is a disruption driven notion that requires precise configurations, thus findings reveal that numerous strategies are efficient in the face of disruptions, like scenarios to choose between the strategies and combining proactive and reactive strategy is recommended. The reactive strategy that has the most positive influence on the chain is having a capacity buffer, whereas the proactive strategy is investing in technology to provide visibility. The review proved that the decision variable is always linked to the strategy, supplier and capacity decisions are critical for designing a resilient supply chain. The objective function is oriented towards the financial objective of cost minimization, and to a smaller extent, maximization of service level which is interrelated to the resilience. Sustainability was only addressed limited times with regard to resilience and mostly on the environmental pillar whether it is waste or air emissions.

Looking at the agro-food supply chain perspective, reviewed literature favored the same strategies like that for other supply chains as aforementioned above, the same goes for the decision variable but decisions concerning the product flow have been widely addressed and showed great improvements in performance of any ASC. Furthermore, this study show that having the objective of minimizing lead time has positive influence on the ASC's resilience, the most successful model for these type of chains mostly has a dual objective of financial and customer orientation. Sustainability was mentioned a little more often than with general supply chains but still scarce, this is probably owing to natural of the product which is perishable.

The highly successful models are the ones who dealt with the fact that disruption effect is gradual, consequently variables studied should be formulated into a two-stage linear programming model that will later be optimized with the help of a software. Finally, the findings provide that a stochastic model is most commonly formulated and solution is reached by solving it on CPLEX solver in the GAMS software.

## Acknowledgment

This work was supported by Academy of Scientific Research & Technology (ASRT) – Egypt, Prima program, project entitled "Innovation in By-Product Supply chain of citrus in Mediterranean area (Impulse)".

## References


Adbor, H. (2020). Supply chain resilience: an adaptive approach. *The International Journal of logistics management, 2*(19), 0957-4093.

Aguila, J. O. (2019). Impact of risk attitudes on the concurrent design of supply chains and product architectures. Procedia CIRP 81 52nd CIRP Conference on Manufacturing Systems.

Alinezhad, M. I., Mahdavi,I., Hematian, M. and Tirkolaee, E. (2021). A fuzzy multi-objective optimization model for sustainable closed-loop supply chain network design in food industries. *Environment, Development and Sustainability*.

Andersen, I. (2022). *UN enviroment programme.* Retrieved augest 17, 2021, from https://www.unep.org/thinkeatsave/get-informed/worldwide-food-waste

Bahzadi, G., O'sullivan, M., and Olsen, T., L. (2020). On Metrics of Supply Chain Reselience. *European Journal of Operations Research, 287*(2020), 145-158.

Behzadi, G., O'Sullivan, M., J., Olsen, T., L., and Zhang, A. (2017). Allocation flexibility for agribusiness supply chains under market demand disruption . *International Journal of Production research*.

Bottani, E. M., Murino, T., Schiavo, M. and Akkerman, R. (2019). Resilient food supply chain design: Modelling framework and metaheuristic solution approach. *computers and industrial engineering: an international journal, 2*.

Chong, L. N., Duong, K., and Josephine (2020). Supply chain collaboration in the presence of disruptions: a literature review. *International Journal of Production Research*.

Datta, P. (2017). Supply network resilience: a systematic literature review and future research. *The international journal of logistics management*.

Denyer, D. and Tranfield, D. (2009). Producing a systematic review. In D. A. (Eds.) (Ed.), *The Sage handbook of organizational research methods* (pp. 671-689). Sage Publications Ltd.

Diabat, A. J., Jabbarzadeh, A., and Khosrojerdi, A. (2019). A perishable product supply chain network problem with reliability and disruption . *International Journal of Production Economics*.

Dolgui, A., Ivanov, D., and Sokolov, B. (2017). Ripple effect in the supply chain: an analysis and recent literature. *International Journal of Production Research*.

Dolgui, Ivanov, D. and Alexandre (2020). A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0. *Production Planning & control*.

El Baz, J., and Ruel, S. (2020). Can supply chain risk management practices mitigate the disruption impacts on supply chains' resilience and robustness? Evidence from an empirical survey in a covid-19 outbreak era. *International Journal of Production Economics, II*(11), 50-101.

ElMaraghy, Olivares-Aguila, J., and Waguih (2020). System dynamics modelling for supply chain disruptions. *International journal of production research*.

ElMaraghy, Olivares-Aguila, J., and Waguih (2021). System dynamics modelling for supply chain. *International Journal of Production Research*.

Emenike, S. E, and Falcone, G. (2020). A review on energy supply chain resilience through optimization. *Renewable and Sustainable Energy Reviews, 1*(134), 1364-0321.

Esteso, A., Díaz, A. M., and Bas, Á. (2018). Conceptual framework for designing agri-food supply chains under uncertainty by mathematical programming models. *International Journal of Production Research, 56*(13).

Fattahi, M., Govindan, K., and Maihami, R. (2020). Stochastic optimization of disruption driven supply chain network design with a new resilience metric. *International Journal of Production Economics*.

G.Calleja, Corominas, A., Matrinez-costa, C., and De la torre, R. (2017). methodological approaches to supply chain design. *International Journal of Production Research*.

Govindan, K. M., Fattahi, M., and Keyvanshokooh, E. (2017). Supply chain network design under uncertainty: A comprehensive review and future research directions. *European Journal of Operational Research, 263*, 108-141.

Li, H., Li, D., and Jiang, D. (2020). Optimising the configuration of food supply chains. *International Journal of Production Research*.

Hosseini, S. N., Morshedlou, Nazanin, Ivanov, Dmitry, Sarder, M. D., Barker, Kash, Khaled, and Abdullah, A. (2019). Resilient supplier selection and optimal order allocation under disruption risks. *International journal of production economics, 213*, 124–137.

Hosseini, S., and Ivanov, D. (2019). A new resilience measure for supply networks with the ripple effect considerations: a Bayesian network approach . *Annals of Operations Research*.

Hosseinia, S. M., Ivanov, D., and Dolgui, A. (2019). Review of quantitative methods for supply chain resilience analysis. *Transportation Research, E*(125), 285-307.

Ivanov, D. (2017a). Revealing interfaces of supply chain resilience and sustainability: a simulation study. *International Journal of Production Research*.

Ivanov, D. (2018). Disruption tails and revival policies: A simulation analysis of supply chain design and production-ordering systems in the recovery and post-disruption periods. *Computers & Industrial Engineering* .

Ivanov, D. (2020a). Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case. *Transportation Research Part E: Logistics and Transportation Review, 136*.

Ivanov, D. (2020b). Viable supply chain model integrating agility, resilince and sustainability presepectives- lessons from and thinking beyond the covid 19 pandemic. *Annals of Operations Research*.

Ivanov, D., Dolgui, A., Sokolov, B., and Ivanova, M. (2017b). Literature review on disruption recovery in the supply chain. *International Journal of Production Research, 2017*(2), 1436–1441.

Jabbarzadeh, A. B., Fahimia, B. and Sabouhi, F. (2018a). Resilient and sustainable supply chain design: sustainability analysis under disruption risks. *International Journal of Production engineering, 2*(2018), 150-175.

Jabbarzadeh, A., Haghton, M. and Khorojedi, A. (2018b). Closed-loop supply chain network design under disruption risks: A robust approach with real world application. *Computers & Industrial Engineering*.

Linkov, I., Carluccio, S., Pritchard, O., and Bhreasail, A. (2020). The case for value chain resilience. *Management Research Review*, pp. 2040-8269.

Meindle, S. C. (2007). *Supply chain management : Strategy, Planning, and Operation* (third ed.). New Jersy: Pearson Prentice Hall.

Mogale, D. G., Cheikhrouhou, Naoufel ,Tiwari, K., and Manoj (2019). Modelling of sustainable food grain supply chain distribution system: a bi-objective approach. *International Journal of Production Research, 58*(18).

Namdar, J., Li,X., Sawhney, R., and Pradhan, N. (2017). Supply chain resilience for single and multiple sourcing in the presence of disruption risks. *International Journal of Production Research*.

Nooraie, V., Fathi,M., Narenji,M., Mellat-Parast, M., Pardalos, P., M.,& Stanfield, P., M. (2019). A multi-objective model for risk mitigating in supply chain design. *International Journal of Production Research*.

Pressman, A. L. (2020). *Fortune 2000*. Retrieved December 10, 2020, from https://fortune.com/2020/02/21/fortune-1000-coronavirus-china-supply-chainimpact

Rahimifard, J., Stone, J,. and Shahin. (2018). Resilience in agri-food supply chains: a critical analysis of the literature and synthesis of a novel framework. *Supply Chain Management: An International Journal, 3*(23), 207-238.

Ravulakollu, A., Urciuoli, L., Rukanova, B., Tan, Y., and Hakvoort, R., A. (2018). Risk based framework for assessing resilience in a complex multiactor supply chain domain. *Supply Chain Forum: An International Journal, 19*(4), 266 - 281.

Sabouhi, F., Jabalameli, M., S., Jabbarzadeh, A., and Fahimnia, B. (2020). A multi-cut L-shaped method for resilient and responsive supply chain network design. *International Journal of Production Research*.

Sabouhi, F., Pishvaee, S., M., and Jabalameli, S., M. (2018). Resilient Supply Chain Design under Operational and Disruption Risks Considering Quantity Discount: A Case Study of Pharmaceutical Supply chain. *Computers & Industrial Engineering*.

Saikia, C. P. (2020). Assessing the vulnerability and resiliency of indian agriculture: A Covid-19 percpective. *International Journal of Management, 11*(10), 1198-1209.

Sato, Y., Tse, Y., K., and Tan., K., H. (2020). Managers risk perception of SC uncertainties. *Industrial management and data systems*.

Scott, P. (2020). *KPMG*. Retrieved January 9, 2021, from https://home.kpmg/au/en/home/insights/2020/07/agrifood-supply-chain-resilience.html

Sharma, R., Shishodia, A., Kamble, S., and Gunasekaran, A. (2020). Agriculture supply chain risks and COVID-19: mitigation strategies and implications for the practitioners. *International Journal of Logistics Research and applications*.

Singh, S., Kumar, R., Panchal, R., and Tiwari, M., K. (2020). Impact of COVID-19 on logistics systems and disruptions in food supply chain. *International Journal of Production Research*.

Tolooie, A., Maity, M., and Sinha, A., K. (2020). A two-stage stochastic mixed-integer program for reliable supply chain network design under uncertain disruptions and demand. *Computers & Industrial Engineering: an international journal, 148*.

Tranfield, D., Denyer, D., and Smart, P. (2003). Towards a Methodology for Developing Evidence Informed Management Knowledge by Means of Systematic Review. *British Journal of management, 14*(3), 207-222.

Ye, F. G., Li, Y. and Fu, S. (2018, Augest 15). Managing bioethanol supply chain resiliency: a risksharing model to mitigate yield uncertainty risk. *Industrial Management & Data systems*, pp. 0263-5577.

You, S., Zhao, S., and Fengqi. (2019). Resilient Supply Chain Design and Operations with Decision Dependent Uncertainty Using a Data-Driven Robust Optimization. *AIChE Journal, 65*(3), 1006-1021.

Zanjani, S., Jabalameli, M., and Walid. (2021). A robust location-inventory model for food supply chains operating under disruptions with ripple effects. *International Journal of Production Research, 59*(1), 301-324.

Zanjani, S. M., Klibi, W., Jabalameli,M., S., and Mir (2020). The design of resilient food supply chain networks prone to epidemic disruptions. *International Journal of production economics*.

Zhao, G., Liu, S., Lopez,C., Chen,H., Lu, H., and Sachin (2020). Risk analysis of the agri-food supply chain: A multi-method approach. *International Journal of Production Research*.

## Biography

**Sherin Beshara** is a Ph.D student in Industrial Engineering at Alexandria University. She is an assistant Lecturer in the Industrial systems engineering at October University for Modern Sciences and Arts. Beshara received a BS and MS degrees in Industrial and Management Engineering Department, Arab Academy for Science, Technology & Maritime Transport. Her research interests include supply chain, simulation, optimization and agri-food supply chains.

**Hadi Fors** is an Assistant Professor in Industrial Engineering at Alexandria University and former Visiting Professor of Industrial Engineering at Arab Academy for Science, Technology, and Maritime Transport. He earned a BSc. degree in Production Engineering from Alexandria University and both MSc. and PhD degrees in Industrial Engineering from Alexandria University, Egypt. His research interests include modelling and optimization, manufacturing systems, supply chain, and service systems.

**Nermine A. Harraz** is professor of industrial engineering at Alexandria University. She is skilled in analytical Skills, Data Analysis, Supply chain and logistics, Engineering, and Technology Management and has more than 50 publications and two book chapters in these fields. Professor Harraz supervised more than 20 thesis. As a principal investigator she got grants for a number of research and institutional support funded projects.

**Hamdy Elwany** is professor of industrial engineering at Alexandria University. He is Founder and Member in the Egyptian Operations Research Applications Society, Cairo, Founder Member of Alexandria Operations Research and Scientific Management Society, Member in the Operations Research Society of America [ORSA], Senior Member in the Institute of Industrial Engineering [IIE], USA, Senior Member in The Society of Manufacturing Engineering, and registered professional engineer [PE], USA. Published six books and 100 technical papers and reports in industrial engineering, computer applications, and operations research.