Modelling supply chain viability during COVID-19 disruption: A case of an Indian automobile manufacturing supply chain

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Abstract

In recent years, supply chains seem to be moving more towards reconfiguring their networks to become more profitable. In the times of COVID-19, where the whole supply chains have been disrupted, suppliers are unable to supply, and manufacturers are unable to manufacture because of lockdowns in the various regions around the world. This pandemic can be compared to past earthquakes and tsunamis, as the coronavirus is also a natural disaster. Due to these past disruptions, organizations have taken many precautions and developed risk mitigation strategies to manage them. Because the COVID-19 outbreak shows the importance of new business perspectives like repurposing a viability strategy, that comes with sustainability and reconfigurability. Where reconfiguration focuses on adaptation, which directly means changes in resources and capabilities and repurposing focuses on a quick response solution to address the shortage. In this paper, a study has been done in two phases to model viability in an automobile supply chain during the COVID-19 times. In the first phase, a hybrid Multi-criteria Decision Making (MCDM) approach is used to get the best criteria and alternatives with sustainability and reconfigurability under consideration. The multi-objective mixed-integer linear programming (MOMILP) model has been developed in the second phase. Suppliers' weight that is obtained will be used to get the optimal order and allocation. This model will help develop supply chain strategies to cope with situations that hinder the firm's competitiveness. A case study of an Indian automobile manufacturer has been taken to show the applicability and effectiveness of the proposed methodology using GAMS/CPLEX solver.

Keywords Supply Chain · Supply Chain Reconfiguration · Repurposing · Viability · Disruption · Survive · Supplier selection · MCDM · COVID-19 · ANP · Fuzzy TOPSIS

1 Introduction

COVID-19 has shocked the whole world. The question is, how will the supply chain (SC) survive? This outbreak shows the importance of a new perspective like viability. Viability is a concept in biology illustrated by Aubin (1991) (Bene et al. 2001), who has studied how to multiplex

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network is connected to individual sub-networks. Viability simply means the ability to survive in changing environment. It adds new characteristics to SC behavior and its performance (Ivanov and Dogui 2020a). The SC's resistance to disruptions shows SC's viability to avoid collapse in the market and supply goods and services. It helps SC to maintain itself and survive this type of disaster. Given the development time and manufacturing requirements of new products, repurposing existing systems may also be a solution to the outbreak (Soldatos et al. 2021). Like Ford, did repurposing of manufacturing structures and SC networks at the time of the World war -II and COVID-19 outbreak. In World War II automakers transformed factories to provide armies, tanks, and planes. Now, during an outbreak, automakers, withinside the span of some weeks, converted their production centers to ramp up the manufacturing of vital medical supplies (Ivanov 2021).

Supply chain reconfigurability is a firm's ability to change its SC network (SCN) and processes to achieve its goals and profits. It replaces a fixed SC structure as the firm's objective is to reduce cost with maximum functionality (Osman and Demirli 2010). Making reconfiguration decisions includes manufacturing tasks, supplier selection, SC configurations, and risks (Jafarian and Bashiri 2014; Lemoine and Skjoett-Larsen 2004; Tian and Guo 2019). Another main criterion is reconfiguration that will achieve viability in a supply chain. According to Charu and Grabis (2009a), supply chain reconfiguration (SCR) is a chain of independent stages that possess the flexibility of changing its structure using minimum resources and maximum customer expectation. According to Talluri and Baker (2002), SCR has three phases. The first phase considers the identification and evaluation of SC units, the second phase deals with establishing SCR. In the third phase, tactical planning is carried out for SCR. Kelepouris et al. (2006) has found five dimensions responsible for the rearrangement of SC that will result in SCR, and these five dimensions are *Modularity*, *Integrability*, *Convertibility*, *Diagnosability*, *Customization* (Zidi et al. 2021b). One needs to consider these five factors while selecting a supplier that will enable SCR capabilities in an SC. The supplier selection from a sustainability viewpoint is a strategic and crucial decision. Sustainability involves economic, social, and environmental criteria. So for supplier selection, critical sub-criteria under economic, social, and environmental should be identified to advance criteria clusters. For a supplier in an SC, viability is a vital risk minimization measure. It calculates risk and finds whether the supplier can supply the materials or products correctly and timely (Linsley 2019). Viability is the property of a system that is behavior-driven. The system evolves whenever disruption occurs, depending on the disruption reaction balance (Ivanov 2020b). The SC which can survive the disruption could be called a viable SC. And, repurposing is one of the adaption strategies that firms are using to maintain SC viability in times of COVID-19 outbreak (Ivanov 2021). With repurposing the facilities, organizations are operating via alternative sourcing approaches. Identifying distinct SC situations and comparing operational influences is vital given the increasing SC risks.

Disruption has gotten increasing consideration over a recent couple of years. The explanation is without a doubt that, with longer ways and more limited time, there are more chances for disruption (Kleindorfer and Saad 2005). Many events were disruptive in the past, like the 9/11 terror attacks, the 2008 great recession, Ebola virus health scars 2013–16, and SARS 2002–3. They affected the supply chain significantly. But no country or person thought about the disruption like this. COVID-19 shook the world because COVID-19 (Cayuz 2022) firms have shortages of raw materials, parts, or products. Firms didn't think they had to face this kind of risk where countries are going total lockdown and prefer work from home strategy. This disruption significantly affects the firm economically, environmentally, and socially. Thus Viability in SC comes with the perspective of sustainability and reconfigurability.

Demirtas and Ustun (2008, 2009) proposed a combination of MCDM and MOMILP techniques for selecting the best supplier and determining order allocations. Then Jolai et al. (2011) used goal programming for purchasing while considering multi-period and multi product model. But none has considered the reconfigurability and sustainability into consideration. Numerous studies have been performed on sustainability in SC (Amindoust et al. 2012; Luthra et al. 2017; Li et al. 2019) and very few in the field of reconfigurability(Zidi et al. 2021a; Zidi et al. 2022). To the best of our knowledge, none of the studies has considered reconfigurability and sustainability in SC simultaneously for repurposing the SC. Our study will help fill this void, as in the time of COVID- 19 there is a need to repurpose the supply chain. The primary focus is the selection of suppliers with sustainability and reconfigurability under consideration and optimal order allocation.

The objectives of this study are given as follows: Development of an MCDM approach for supplier selection with sustainability and reconfigurability under consideration; Development of a MOMILP that considers viability while designing a SC during disruption. We used a hybrid MCDM approach, i.e., Analytic Network Process (ANP) and Technique For Order Preference By Similarity to Ideal Solution (TOPSIS) methods, to get the sustainable reconfigurable supplier for our viable SC per their rank calculated. This rank will be further used as an input for our MOMILP model to get the optimal order of suppliers in the SC.

This paper has six sections: "1" shows how the supplier is to be selected, criteria and subcriteria for the selection, and what methods have been used. "2" describes the impact of COVID-19 on the SC. The "4" exhibits the developed model. The "5" shows the result and discussions, and the paper is concluded in the "6".

2 Literature review

Here we will discuss the SC aspects concerning viability as there is no such paper on supply chain viability. Viability and reconfigurability is not new to the world. With the recent incident and SC issues, these ideas came forward. As the economy is not making it easy to find the supplier, companies are trying to reconfigure their SC to be viable enough to handle incidents like COVID-19.

2.1 Repurposing the manufacturing systems and Supply chain operations

COVID-19 pandemics impact manufacturing systems and supply chain operations. So the repurposing (Liu et al. 2021) is a quick response solution to address the global shortage of COVID19 essential items that can save lives by using unused production capacity. It is a temporary strategy that can be expensive and challenging, which explains the limited results. Different levels of repurposing are required to manufacture COVID-19 critical items, depending on the items' level of complexity. The development of rapid repurposing roadmaps, which reflect national priorities and contexts, can provide a logical and integrated framework to support effective policy responses as they are important in helping manufacturers meet repurposing (Soldatos et al. 2021) challenges and facilitate the transition to the new "normal" after COVID-19.

COVID-19 impact on the supply chain means the firm should respond quickly to reconfigure its supply chain. It is a test of corporate values and purpose. It tells how critical supply chains are on a humanitarian level. As the humane disaster (Accenture 2020) unfolds, supply chain leaders should ensure sustainable supply chain. The repurposing aims to help societies manage the COVID-19 crisis while building a more reconfigured and more purpose-driven supply chain for the future.

2.2 Viability in supply chain

Viability is an ability of a system to survive in the changing environment. It is the concept of biology (Aubin 1991) and cybernetics (Beer 1985). It is the analysis for SC reactions to disturbances. This disturbance is zanalyzed in the form of stability (fundamental property for SC, Demirel et al. 2019), robustness (performance in the analysis, Ivanov and Sokolov 2013), resilience (Zhao et al. 2019). Viability in an SC means the ability to cope with the change, like reacting smoothly to positive changes, being resilient enough to recover from disruptions and negative events, and surviving for the longer term, significant disruptions. It will be done by changing allocations in demand and by utilizing capacities. Viable SC is an open system that has contact with the environment and changes according to it. According to Ashby (1956), variety should be equitable with the response variety of handler. It can be taken as a pillar of viable SC to develop a decentralized system that will understand varieties. Beer's Model helps us to know how complex operations communicate with the environment (Beer 1985). Beer made an analogy with the human, i.e., survival-oriented system.

2.3 Attributes of sustainable supplier

Manufacturers, society, and environmentalists are under pressure to meet the customer demand. So for the new product manufacturing, each stage of SC should be sustainable. Krishnan and Ulrich (2001) tell sustainability as a changing market occasion. For a few years, attributes i.e., economical, social, and environmental have gained significant attention from the researchers. Here social criteria show the impact of processes, systems, firm activities on human life (Balaman 2019). Economic criteria refer to practices that support long-term economic growth without negatively impacting the community's social, environmental, and cultural aspects (Kates 2001). Environmental factor refers to natural resources (Goodland 1995). These three attributes should be considered whenever we talk about sustainability.

2.4 Attributes of supply chain reconfigurability

As we discussed, SCR is a firm's capability that enables it to change its SCN. According to Kelepouris et al. (2006), SCR has five attributes. They are: 1) *Modularity*- It means how much modular firms equipment's, resources, processes, and products are. 2) *Integrability*- It means integrating existing processes and resources within an SC. 3) *Convertibility*- Ability of firm to adapt to future products from old ones. 4) *Diagnosability*- It is the finding of problems and where they started from, reducing firm's effectiveness. 5) *Customization*- It is the flexibility of firm to adapt a change in SC. Attributes considered will be taken as input for ANP to understand the priorities for SC in a firm(Zidi et al. 2021b).

2.5 Designing for supply chain viability

SC viability is an actively adjustable and variable value-added network (Ivanov 2020b). It is comprised of SC (four stages), reconfiguration component, sustainability component i.e., environmental, social, and economical. SC should be considered viable if it can adjust itself when a disturbance occurs, utilize capacity and adjust allocation. Viable SC integrates all aspects and offers interaction with the ecosystem at the extent of profitability, resistance to disturbance, and survivability.

Various authors suggested various methods or models. Demirtas and Ustun (2008, 2009) combined the MCDM techniques and made MOMILP model for finding order allocation. Then Jolai et al. (2011) has considered multi product model and integrated MCDM techniques with multi period goal programming for buying. A bilinear goal programming model is developed to achieve the firm's objectives. The modified vendor decomposition method is successfully used to handle a bilinear goal planning model in which complex binary variables affect the value of the deviational variable to achieve the goal (Osman and Demirli 2010). Optimal SC

networks is designed with a combination of strategic and tactical level optimizations and validate of supply chain operations is done using comsyang puter simulation models based on system dynamics (Kristianto et al. 2012). The optimization model was developed to minimize the total cost of the supply chain network, taking into account manufacturing operations and reconfiguration costs and solved using graph-based model is proposed (Guo et al. 2018). In the SC network problem where the resource input is limited by the performance target for the reconfigured distribution system and to solve this reconfiguration problem, simulated annealing (SA) is used (Ross 2000). A conventional blended whole number program (MIP) and then an elective model that relates two-fold choice factors is proposed to accomplish the main goal (Wilhelm 2013). A reconfigurable model of supply chain is proposed where adaptive methods are grouped, and a basic list of systems is characterized (Oh et al. 2013). Chandra and Grabis (2009a, b) have taken a multi-criteria supplier selection problem from SCR where mathematical modelling is done to make final supplier selection. Assessing reconfigurability according to characteristics using fuzzy logic for this purpose, a quantitative evaluation of reconfigurability is proposed. A case study is used to evaluate the degree of reconfigurability after supply chain restructuring to validate the assessment model (Zidi et al. 2021a). The assumed model explored the optimum tactical and operational SCM decisions. The model's ability was assessed, and the result showed that the choice of various response strategies and new product production influenced supply chain configuration (Sabzevari et al. 2020). Reconfigurability is modeled in the SC using interpretive structural modeling (ISM) (Biswas 2017) and ISM based roadmap is developed to identify key enablers for SC performance (Dev et al. 2014). Park et al. (2018) used a case study to solve a two-stage supplier selection problem. The first stage considered social and economic factors, and the second stage presented a MOMILP model for economic and environmental goals.

MCDM is an active field of study and has produced many theoretical and applied articles and books. (Roy 2005). The MCDM method was developed to find preferred alternatives, categorize alternatives into a small number of categories, and rank alternatives by subjective priority. Various studies are there that applied MCDM methods and approaches in SCM, quality control, production control, and manufacturing systems. These areas contain several specific sub-areas, which use MCDM technology and approaches that include several publications in the field of supply chain management; supplier performance (Kang and Lee 2010), supplier selection (Bruno et al. 2012; Huang et al. 2011), supplier quality (Ho et al. 2012), sustainable supply chain management (Büyüközkan and Berkol 2011). According to Mardani et al. (2015a, b), AHP is the most widely used technique and very easy to solve and after AHP hybrid MCDM techniques are used to rank the criteria or alternatives (Mardani et al. 2015a, b).

As the supply chain is a long term strategic decision, firms are quite resisting to employ reconfiguration (Dev et al. 2016) to their supply chain. Because it can affect the existing supply chain and SCR Costs. Also, they do not have much knowledge or training about the reconfiguration techniques. Decades ago, firms did not have taken the sustainability factor of how much it affects the economy, natural resources, environment, etc. There may be uncertainty in demand volume because the supply chain can not hold its structure for a longer time. The SCR problem is complex, so multiple models are necessary for the evaluation to tackle the same. This paper proposes a methodology to model SC viability by adapting repurposing strategy and incorporating sustainability in developing SC for reconfigurability.

3 Supplier ranking

SCM and the supplier selection process have gotten extensively considerable in the business management on long-term connections, a firm's supply chain makes one of the strongest barriers to passage for contenders (Chen et al. 2006). Supplier selection (Ayhan 2013) is one of the crucial components of the firm. In a firm, manufacturers spend over 6O% of total sales on bought items. So proper supplier selection reduces purchasing costs and more customer satisfaction. It is also critical for the firm's competitiveness. Where we decide which supplier will help in getting your business up. In this paper, we are using Hybrid MCDM techniques to rank suppliers based on the criteria selected.

3.1 A case of automobile supply chain

A case of an automobile manufacturer 'X' in INDIA is taken to elaborate the proposed methodology. The case organization is a prominent commercial vehicle manufacturer in India. It manufactures trucks and buses. And here, supplier selection is one of the most sensitive issues as it sources 70% of the components. So their relation with the supplier is quite important and should be viable as it minimizes the risk. Supplier viability plan is to find the risk that a supplier may not deliver the product whereas repurposing aim is to speed up the delivery process. They select suppliers based on criteria like Quality, Cost, Logistics, Delivery, and past relationships. Their supplier management process includes engagement of suppliers and exchanging real-time information with them. Supplier viability in an SC is important in providing service to the market like delivering the raw materials, equipment, premises, intellectual property, funding, workforce, etc.(Lisnley 2019). As COVID-19 has affected the whole world, the countries have gone complete

lockdown to minimize the effect. But due to lockdown, their business has plunged. Their production plants became dysfunctional as they could not handle the disruption caused to SC, their manufacturing stopped, and the supplier was unable to supply. The Un-availability of work force had incredibly affected their SC. There comes the concept of reconfigurability where the manufacturer selects multiple suppliers for the parts or raw materials according to some criteria if one is in the south region, then another one will be in the north region. Because of this, if one supplier falls into the containment zone, then another supplier will be supplying the same. But the capacity has to be adjusted; when the pandemic was not there, they were providing approximately 15,000–20,000 vehicles with chassis, but demand also has fallen. So the alternative supplier can manage the demand of the firm. Also, if demand is high, like the firm is demanding 10,000 supply and the supplier has only 5000 capacity, the supplier will break the demand into 5000–5000 or lead time to fulfill the demand can also be increased. The supplier that is being selected is critical. The case of both falling in the containment zone is not yet happened. Because of the pandemic, the manufacturing of parts at the supplier side has also been stopped. So right now, the case of both falling in the containment zone is not yet happened. Alternative suppliers can cope up with the company and fulfill the demand.

3.2 Supplier ranking

In this study fuzzy (Chen et al. 2006) Analytic Network Process (ANP) and fuzzy Technique For Order Preference By Similarity to Ideal Solution (TOPSIS) has been used where fuzzy AHP (Saaty 1980, Dyer 1990) is used to rank criteria, fuzzy TOPSIS is used to rank the suppliers. ANP and TOPSIS methods are easy to use programmable and simple processes. ANP is used to calculate intangibles using the judgement of humans. AHP is a starting point of ANP (Forman and Glass 2001). Here ANP is preferred over AHP because it allows for complex interrelationships among different criteria and attributes (Yuksel and Dagdeviren 2007). It does not require interdependence on criteria and alternatives. They both are preferred because they can give complete ranking results. They are suitable to be combined with stochastic analysis, use of weights that is calculated and objective data to provide the relative distance, the smoothing trade-offs with non-linear relationships. ANP reduces the complexity of decision making, it supports both single, and group decision-makers, and also specialist is not required. Whereas TOPSIS (Wang et al. 2020) calculates the ranking of alternatives to find the optimal one nearest the positive ideal solution and afar from the negative ideal solution. As both methods are based on the technical characteristics required to properly solve the supplier selection problem. The following factors were considered when choosing these two MCDM

methods: Appropriateness for alternatives or criteria; Agility in the decision-making process; Computational complexity; adequacy to support group decisions; Number of criteria or alternative; Uncertainty modeling (Lima et al. 2014).

3.3 Finding the priorities of criteria by using ANP

AHP is a method to solve complex decisions based on the data. AHP was developed by Saaty (2008). It adds opinion and evaluation scores of experts into a hierarchy system. Yahya and Kingsman (1999) are the researchers that realized and utilized AHP to decide needs in choosing suppliers. Economic, social, environmental, and reconfiguration criteria are the main criteria. And for each main criteria, a sub-criteria have been found from literature (26 in total). These criteria are important to find the best sustainable- reconfigurable supplier. A questionnaire and interview have been taken to find important criteria and sub-criteria to get the quantitative values. Table 1 shows the criteria for evaluation or selection of suppliers. Steps to find the criteria weights. In first step pairwise comparison of main criteria is to be done. In second step pairwise comparison of each sub-criterion is to be done. Hence final priority of criteria will be obtained.

3.4 Fuzzy ANP approach

ANP is an MCDM technique, a more general form of AHP (Saaty 1980). It is used to find priorities criteria/sub-criteria from individual judgement. These judgment shows relative influence, by a pairwise comparison. It uses the network without specifying levels. It provides an answer from a fundamental scale of AHP as it is a starting point for ANP (Gorener 2012). The priority vector is found by doing pairwise comparison of matrices and entered in some columns of supermatrix (Kheybari et al. 2020). All the elements can interact and do not require interdependence (Promentilla et al. 2008). Here fuzzy AHP is first used to get the priority weight of different criteria. In Fuzzy AHP, a pairwise comparison of criteria is done using linguistic variables (Chan and Kumar 2007). A triangular matrix is used to assign fuzzy numbers to the matrix. So to get the pairwise comparison matrix a questionnaire is developed to communicate the relevancy of the criteria selected. This questionnaire is sent to seven (Engineers) industrial and five academic (Lecturer) experts. Where four industrial and two academic experts has responded. We then used influence values from AHP as the base for the super matrix for determining ANP weights (Yang et al. 2008). Then supermatrix and a limiting super matrix is generated. Steps to perform Fuzzy AHP are:

Step1- Pairwise comparison of criteria is to be done,

Step2- Geometric mean of fuzzy comparison matrix is to be calculated, $r_i = (\prod_{j=1}^{n} d_{ij})^{1/n}, (i) = 1, 2, \ldots n$ where n is no of criteria and {r}_{i} still represents triangular number. (i)

Table 1 Main criteria and their sub-criteria with symbols

Main Criteria	Sub-criteria	Reference	Sub-criteria symbol
Economic(C1)	Cost of production	Awasthi et al. (2018), Chan et al. (2008)	SC1
	SC flexibility	Awasthi et al. (2018), Chan et al. (2008)	SC 2
	Shelf life of product	Chan and Kumar (2008), Levary (2008)	SC 3
	Cost of Design	Chan and Kumar (2008), Levary (2008)	SC 4
	Cost of Resources	Awasthi et al. (2018), Chan et al. (2008)	SC 5
	Automation	Scott et al (2013), Dou and Sarkis (2010)	SC 6
	Cost of return	Scott et al (2013), Dou and Sarkis (2010)	SC 7
	SC cost	GRI (2013), Kuo and Lin (2012)	SC 8
Environmental(C2)	Recognition of market variations	Genovese et al. (2013)	SC 9
	Partnership	Chan and Kumar (2008), Levary (2008)	SC 10
	Integration of process	Scott et al. (2013), Dou and Sarkis (2010)	SC 11
	Pollution	Chan et al. (2008), Levary (2008)	SC 12
	Work Environment's dangerous factors	Scott et al. (2013), Dou and Sarkis (2010)	SC 13
Social(C3)	Human rights	Awasthi et al. (2018), Chan et al. (2008)	SC 14
	Culture and technology development	Awasthi et al. (2018), Chan et al. (2008)	SC 15
	Improvement of quality	Scott et al (2013), Dou and Sarkis (2010)	SC 16
	Delivery timing	Chan et al. (2008), Levary (2008)	SC 17
	Status of customer	Genovese et al. (2013)	SC 18
	Marketing performance	Scott et al. (2013), Dou and Sarkis (2010)	SC 19
	Trust B/w buyer and supplier	Genovese et al. (2013)	SC 20
	Delivery and packaging	GRI (2013)	SC 21
Reconfiguration(C4)	Diagnosability	Kelepouris et al. (2006)	SC 22
	Integrability	Chandra and Grabis (2009a, b)	SC 23
	Convertibility	Chandra and Grabis (2009a, b)	SC 24
	Modularity	Kelepouris et al. (2006)	SC 25
	Customization	Chandra and Grabis (2009a, b)	SC26

Step-3- Finding the fuzzy weight of criteria i (w_i), multiply with reverse vector (r_i)

$$* r_i = w_i * \left(r_1 * r_2 * \ldots . r_n \right)^{-1} (ii)$$

Step4- Relative non-fuzzy weight of each criterion (M_i) is calculated by taking an average of fuzzy numbers.

Step5- Normalize weight

$$N_i = M_i / \sum_{i=1}^{n} M_i (iii)$$

Step6- Consistency Ratio (CR)

CR = CI/RI, where CI is consistency index, and RI is random consistency index. (iv).

CI = (λmax-n)/(n-1), where λmax is eigenvalue, and n is no. of criteria. (v)

An inconsistency of 10% or less implies that the adjustment is small compared to the eigenvector entries' actual values.

We can use M_i or N_i as a priority vector to form a supermatrix.

So, according to previous steps, the main criteria priority has been identified using the respondents' responses, as shown in Fig. 1. The inconsistency ratio came as 0.0518, which is less than 0.1, which means the matrix is consistent and can be trusted.

3.4.1 Sub criteria priotization

In this step, sub-criteria will be prioritized, and its consistency will be checked. Priority of Economic, Environmental, social, and reconfiguration sub-criteria will be done followed by checking the consistency.

3.4.2 Economic sub criteria

There are eight sub-criteria under reconfiguration, so there will be a need for 28 paired comparisons. The consistency ratio came as 0.0666, which is less than 0.1, so the paired comparisons are consistent. Priorities can be seen in Fig. 2. The first three

Fig. 1 Weights obtained after prioritizing the main criteria
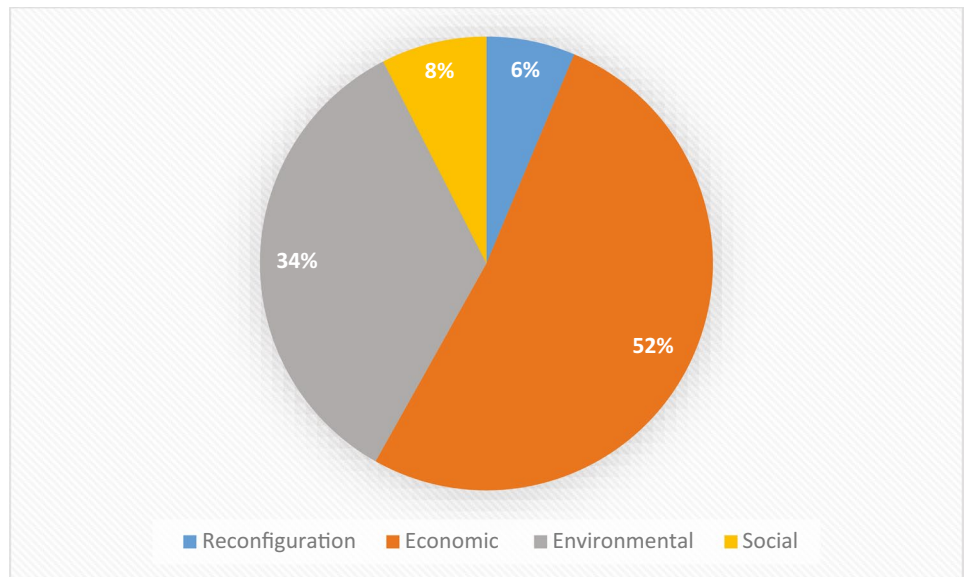
sub-criteria are a cost of resources, automation, SC cost. All the sub-criteria will be arranged according to the weights obtained.

3.4.3 Environmental sub-criteria

As there are five sub-criteria under reconfiguration, so there will be a need for ten paired comparisons. After doing so, the consistency ratio came as 0.0296, which is less than 0.1, so the paired comparisons are consistent. Priorities can be seen from Fig. 3 and can be arranged according to their weights.

3.4.4 Social sub-criteria

There are eight sub-criteria under reconfiguration, so there will be a need for 28 paired comparisons. After doing so, the consistency ratio came as 0.0412, which is less than 0.1, so the paired comparisons are consistent. The distribution of weights can be seen from Fig. 4.

3.4.5 Reconfiguration sub-criteria

There are five sub-criteria under reconfiguration, so there will be a needfor ten paired comparisons. After doing so,

the consistency ratio came as 0.0925, which is less than 0.1, so the paired comparisons are consistent. The distribution of weights can be seen, and priorities can be set from Figs. 5. This means the first sub criteria will be Modularity, the second will be diagnosability, the third will be convertibility, customization, and the last integrability.

### 3.4.6 Priorities obtained by applying FANP

A super matrix has been generated to find the ranking of sub-criteria, and from that limiting super matrix is obtained by using software *GNU octave*. The ranking of sub-criteria can be seen from the table, and their weights and normalized weight also can be seen. So the sub-criteria at first rank is integration of process and at second is partnership list goes on by their rankings.

3.4.7 Selection of supplier using fuzzy TOPSIS

To prioritize the supplier, fuzzy TOPSIS is used. It was developed by Hwang and Yoon (1981). In TOPSIS, the alternative that is being chosen should be at the shortest distance from the positive ideal solution and maximum distance from the negative ideal solution.

Fig. 2 Economic sub-criteria

Fig. 3 Environmental sub-criteria
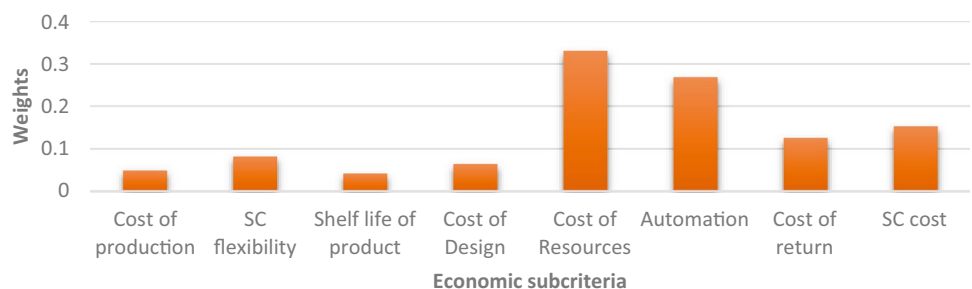
Fig. 4 Social sub-criteria
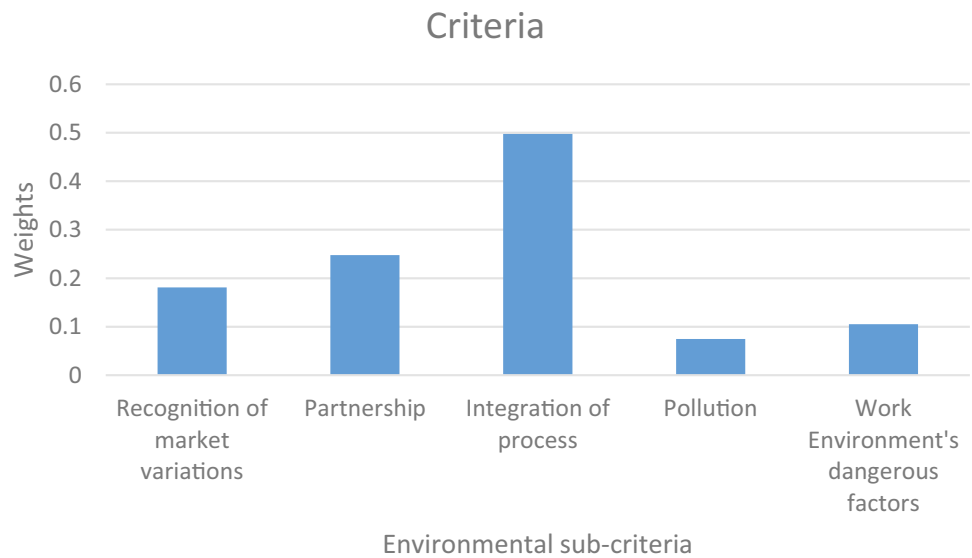
Many researchers have enhanced the working of TOPSIS by using fuzzy numbers. Chen and Hwang (1992) used fuzzy variables to get fuzzy TOPSIS (Kannan et al. 2014). Triantaphyllou and Lin (1996) found fuzzy TOPSIS where closeness for each alternative is calculated according to fuzzy arithmetic operations. Chu (2002) and Chu and Lin (2002) improved the method that has found by Chen (2000). We can see the ranking of suppliers from Table 2.

3.4.8 Fuzzy TOPSIS approach

It is used for ranking, where we get ideal solution among similar options. Because of limitations i.e., inability to capture vagueness in the decision making process, Fuzzy concept came into picture. In fuzzy TOPSIS, the weight is shown by linguistic numbers. It is to find positive and negative ideal solutions and after that calculate the distance of the alternatives from the ideal solutions based on which ranking will be decided. A positive ideal arrangement expands the benefit criteria and limits the cost criteria, and in negative ideal arrangement expands the cost criteria and limits the benefit criteria. Steps to be taken in getting ranking:
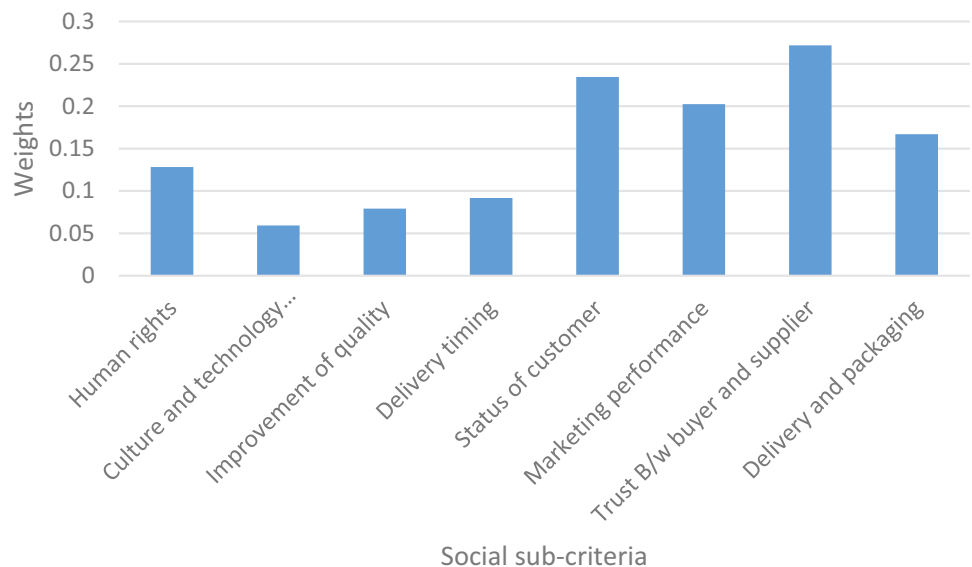
Step1- Defining decision matrix $X_{ij} = \left(X_{ij} \right)_{mn}$

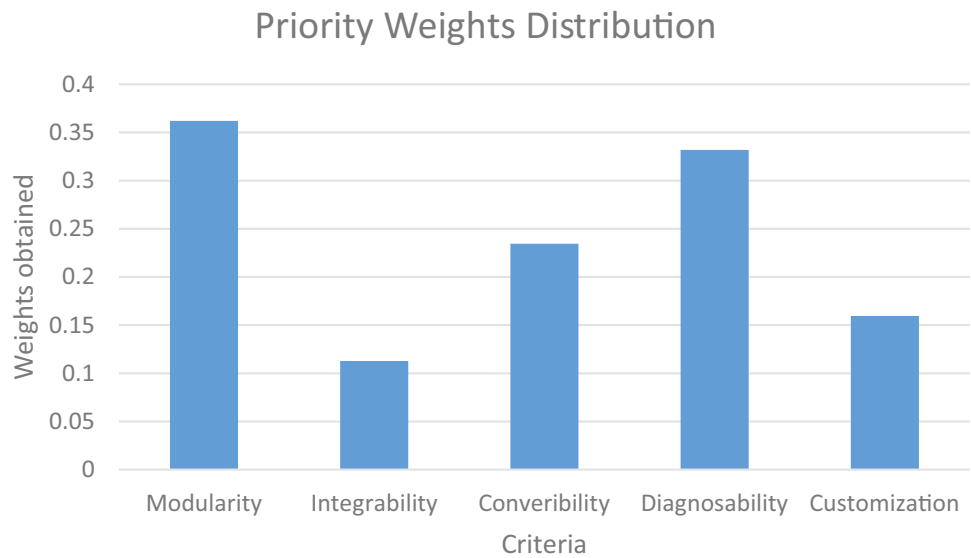Step2- Construct the normalised decision matrix $S_{ij} = \left(S_{ij} \right)_{mn}$

Where $s_{ij} = r_{ij} / \left(\sum_{i=1}^{m} r_{ij}^2 \right)^{\wedge} (1/2)$

Step3- Construct the weighted normalised decision matrix

Fig. 5 Reconfiguration sub-criteria

Priority Weights Distribution

$$V_{ij} = s_{ij} * W_j \qquad (1)$$

Step 4- Determine the ideal solutions.

$$A^+ = (v_1, v_2, \dots \dots v_n) \qquad (2)$$

$$A^- = v_1, v_2, \dots \dots v_n \qquad (3)$$

Step5- Calculate the distance of each alternatives.

$$d^+ = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^*)^2} \qquad (4)$$

$$d^- = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - v_j^*\right)^2} \qquad (5)$$

Step6- Calculate the closeness coefficient.

$$CC = \frac{d^-}{d^- + d^+} \qquad (6)$$

Step7 – Alternatives are ranked according to their CC.

After the criteria have been ranked using the fuzzy ANP approach, fuzzy TOPSIS is used to find the rank of suppliers. It can be seen from Table 2 that supplier 6 got the first rank and supplier 3 ranked seventh. And the normalized weight we got will be used as an input for the MOMILP model to get the optimized value.

4 Development of model for viable supplier selection

Model is developed for the SC network mentioned earlier according to the problem definition. Model assumptions are: three products and four periods are considered for a model, wholesalers location are fixed, deterministic model, the capacity of each facility is limited. Mixed integer and multi-objective are used in many areas, some applications are vehicle routing, job scheduling, lot sizing, SC planning and logistics (Sulogtra 2002; Antunes et al. 2004; Wandel and Ruijgrok 1993). This model aims to devise a reconfigurable SC network to satisfy customer demand by finding the optimal order for the best supplier. The SC here has four levels, i.e., T2 supplier, T1 supplier (machined part), central warehouse, and wholesalers level can be seen in Fig. 6. Here T2 supplier is raw component supplier, T1 supplier is machined part supplier. The procurement process starts from the firm that sends the demand forecast to the central warehouse, then it will be sent to the T1 supplier and at last to the T2 supplier. The state company is in minimizes the distribution cost that is failing in distributing the products.

The aim here is to find the size of order and central warehouse allocation for viable SC so that the wholesalers' demand of products at different time periods is satisfied with a minimum lost sales, ordering, and inventory holding cost. By finding the optimal value, we can say that the X

Table 2 Ranking of sub-criteria

Sub-criteria	Symbol	Weight	Normalized Weight	Ranking
Cost of production	SC1	0.0033	0.0027	25
SC flexibility	SC 2	0.0055	0.0045	23
Shelf life of product	SC 3	0.0029	0.0023	26
Cost of Design	SC 4	0.0043	0.0035	24
Cost of Resources	SC 5	0.0223	0.0181	15
Automation	SC 6	0.0181	0.0147	18
Cost of return	SC 7	0.0085	0.0069	22
SC cost	SC 8	0.0103	0.0084	20
Recognition of market variations	SC 9	0.0998	0.0810	3
Partnership	SC 10	0.1367	0.1108	2
Integration of process	SC 11	0.2744	0.2225	1
Pollution	SC 12	0.0411	0.0334	10
Work Environment's dangerous factors	SC 13	0.0581	0.0471	8
Human rights	SC 14	0.0469	0.0380	9
Culture and technology development	SC 15	0.0217	0.0176	16
Improvement of quality	SC 16	0.0290	0.0235	13
Delivery timing	SC 17	0.0336	0.0272	11
Status of customer	SC 18	0.0857	0.0695	5
Marketing performance	SC 19	0.0740	0.0600	6
Trust B/w buyer and supplier	SC 20	0.0994	0.0806	4
Delivery and packaging	SC 21	0.0610	0.0495	7
Modularity	SC 22	0.0290	0.0236	12
Integrability	SC 23	0.0090	0.0073	21
Converibility	SC 24	0.0188	0.0153	17
Diagnosability	SC 25	0.0266	0.0216	14
Customization	SC 26	0.0128	0.0104	19

automobile manufacturer will be able to survive disruptions caused and will be able to reconfigure as per the situation.

Sets and indices.

I Supplier.

J Product.

K Wholesaler.

T Time period.

i Supplier index($i = 1,2,3….M$).

j Product index($j = 1,2,3….PR$).

k Wholesaler index($k = 1,2,3….KR$).

t Time period index($1,2,3….PE$).

Variable.

XK_{kjt} Product amount dispatched by central warehouse to wholesaler.

D_{jt} Central warehouse demand.

X_{ijt} Product amount that is ordered to supplier.

I_{jt} Amount of inventory.

X'_{ijt} Excess amount ordered.

Lo_{jt} Amount of Lost sales at a supplier level.

LO'_{jt} Amount of Lost sales at wholesaler level.

Ox_t Temporary warehouse established.

Y_{ijt} Binary variable, 1 when a supplier is supplying otherwise zero.

X_{iijjt} Amount of raw component r and machined part ii shipped from T1 to the company.

Parameters.

Xr_{jjkkt} Amount of raw component r and machined part ii shipped from T2 to T1 supplier.

U Temporary warehouse maximum number at each period.

W_j Weight normalized.

C_{ijt} Capacity.

SC_{jt} Central warehouse maximum capacity.

SO_j Temporary warehouse maximum capacity.

PO Cost of establishing a temporary warehouse.

P_{ij} Unit purchasing price of ith supplier for jth product.

CE_{ij} Emergency purchasing cost.

St_{ij} time for setting up jth product at an ith supplier that includes production and delivery time.

LT_{jt} Lead time for delivery.

O_{ij} cost of ordering.
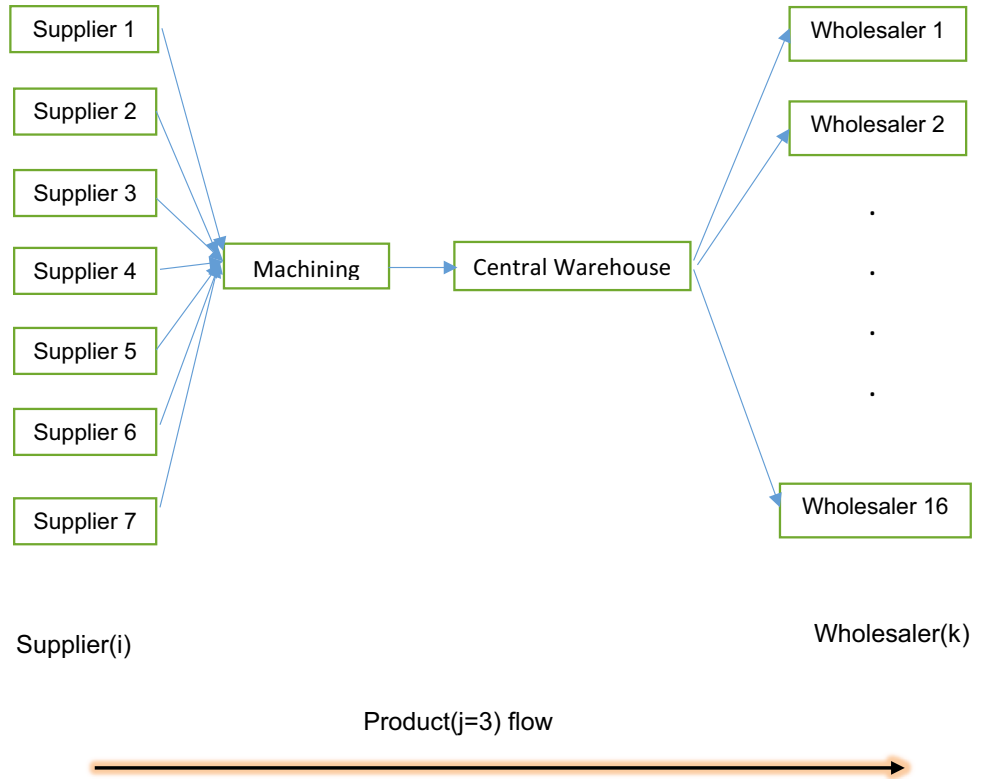
Do_k unit transportation cost.

DK_{kjt} Wholesaler Demand.

h_j Unit holding cost.

LS_j Unit lost sale at supplier level.

LW_j Unit lost sale at wholesaler level.

Fig. 6 Supply chain stages

Supplier(i)

Wholesaler(k)

Product(j=3) flow

qa_i Avg. defect rate.
Qa_j Max. defect rate acceptable.
L_{max} Maximum Lost sale level.
Bm Big number.
The MOMILP model is given as follows.

$$
\begin{aligned}
Z_i = &\left(\sum_{j=1}^{PR} \sum_{t=1}^{M} CEij X'ijt\right) \\
&+ \left(\sum_{j=1}^{PR} \sum_{t=1}^{M} \sum_{t=1}^{PE} P_{ij}X_{ijt}\right) + \sum_{j=1}^{PR} \sum_{t=1}^{PE} h_j I_{jt} \\
&+ \sum_{i=1}^{M} \sum_{j=1}^{PR} \sum_{t=1}^{PE} O_{ij}Y_{ijt} + \sum_{j=1}^{PR} \sum_{t=1}^{PE} LS_j LO_{jt} + \sum_{j=1}^{PR} \sum_{t=1}^{PE} LW_j LO'_{jt} \\
&+ \sum_{k=1}^{KR} \sum_{j=1}^{PR} \sum_{t=1}^{PE} DO_k XK_{kjt} + \sum_{t=1}^{PE} PO.OX'_t
\end{aligned}
\tag{7}
$$

Maximize $\quad Z_2 = \sum_{i=1}^{M} \sum_{j=1}^{PE} \sum_{t=1}^{PE} W_i X_{ijt}$ (8)

Subjected to.

$\sum_{i=1}^{M} X_{ijt} + I_{jt-1} + LO_{jt} - \sum_{k=1}^{KR} XK_{kjt} = I_{jt}$ (9)

$D_{jt} = \sum_{k=1}^{KR} DK_{kjt}.B_{kjt}$ (10)

$LO_{jt} \leq Bm(1 - B_{kjt})$ (11)

$LO_{jt} \leq D_{jt}$ (12)

$\sum_{i=1}^{M} X_{ijt}.qa_i \leq Qa_j.D_{jt}$ (13)

$X_{ijt} \leq C_{ijt}$ (14)

$\sum_{i=1}^{M} st_{ij}.Y_{ijt} \leq LT_{jt}$ (15)

$\sum_{i=1}^{M} X_{ijt} + I_{jt-1} = SC_{jt} + SO_j.OX_t$ (16)

$LO'_{jt} + XK_{kjt} = DK_{kjt}$ (17)

$\sum_{j=1}^{PR} \sum_{t=1}^{PE} LO_{jt} \leq L_{max} \sum_{j=1}^{PR} \sum_{t=1}^{PE} D_{jt}$ (18)

$OX_t \leq UR$ (19)

$X_{ijt} \leq BMY_{ijt}$ (20)

Equation 1, i.e., first objective function minimizes the SC total cost. It includes seven terms, i.e., cost of purchasing, cost of ordering of product, cost of holding the product, lost sales at supplier and wholesaler level, cost of transporting the product, and cost of the temporary warehouse. Equation 2,

Table 3 Supplier Selection

Supplier	S*(+)	S*(−)	Ci (Closeness Coeff.)	Normalized Weight	Rank
1	0.0307	0.0705	0.696	0.174	3
2	0.0507	0.0465	0.478	0.119	6
3	0.0699	0.0287	0.291	0.073	7
4	0.0275	0.0728	0.726	0.181	2
5	0.0453	0.0511	0.530	0.132	5
6	0.0246	0.0747	0.752	0.188	1
7	0.0409	0.0473	0.536	0.134	4

Table 4 Product ordered to suppliers (X_{ijt})

Supplier-product combination	1	2	3	4
Supplier1.Product1	18.64	24.27	0	20.49
Supplier1.Product2	32.55	18.87	32.73	34.5
Supplier1.Product3	67.2	69.99	84.3	59.34
Supplier7.Product1	0	0	17.36	0

i.e., the second objective function, maximizes the product purchased from the supplier with their weighted value. Equation 3 to 14 shows constraints, where Eq. 3 shows the concept of balancing the inventory. Equation 4 is showing product demand at each period. Equation 5 has binary variable for satisfying the wholesaler demand. Equation 6 shows lost sales maximum level. Equation 4 shows defect percent that will not exceed from limiting value. Equation 5 shows total product ordered from the supplier should be less than or equal to its capacity. Equation 6 product will be available in the given lead time. Equation 10 shows whether a temporary warehouse is formed or not. Equation 11 showed that products transported to wholesalers and lost sales should equal the demand of wholesalers. Equation 12 shows lost maximum sales level at supplier level should not exceed a specific value. Equation 9 no of the temporary warehouse should not be greater than allowable no. of warehouse, and Eq. 10 shows the relation between quantities ordered and order allocated.

The problem was solved in GAMS using a PC with 4 GB RAM, 2 GB Radeon graphics, 750 GB Hard Disk, and 64-bit i7 processor. The solver uses the branch and cuts method to solve the multi-objective multi-integer programming. After solving the problem in GAMS we get the following result.

It can be seen from Table 3 that product 1, 2, 3 is ordered from supplier 1 where product 2 and 3 is ordered at all the four periods whereas product 1 is ordered at period 1, 2 and 4. And supplier 7 is getting order for only product 1 at period 3 only. Wholesaler and central warehouse demand also can be seen from Tables 4 and 5.

5 Results and discussion

To tackle or survive a disruption, SC should be viable such that we can reconfigure it. We are studying a 'X' manufacturer where suppliers are selected based on the sustainability (21 criteria) and reconfigurability (five criteria) factor. A hybrid approach is used to get the best supplier ranking. For the ranking of criteria, fuzzy ANP technique is used, and it can be seen from Fig. 1 that the automobile manufacturer's

most important main criteria is 'Economic'. And its most important sub-criteria is 'Integration of processes'. In large industries, manufacturers are interlinked with each other, and partnership should be present there. Hence 'Partnership' sub-criteria holds the second position, ranking can be seen in Table 6. After ranking criteria, the ranking of suppliers is done using the fuzzy TOPSIS approach. These two hybrid MCDM methods were used to find the best supplier for a manufacturer. And also, if one supplier cannot provide material, there are alternatives present to procure the raw material. Then weight obtained from fuzzy TOPSIS has been used to design the MOMILP model to find the optimal size of orders and its allocation. And to decide the number of orders shipped to the wholesalers and the needs of the central warehouse in a planning horizon. It can also be seen from the result that the product was ordered only from supplier 1 and supplier 7, where all three products are ordered from supplier 1 and only one product is ordered from supplier 7. The result can be seen for wholesalers, and central warehouse demand also can be seen.

As we know, automobile manufacturers have shifted from vertical integration towards smaller and leaner operations (HUallacháin and Wasserman 1999; Kaiser and Obermaier 2020). Firms have downsized and started focusing on core things to increase their competency by leveraging their suppliers' capabilities. So the firms depend on suppliers and conditions around them and develop cooperative and mutually beneficial relationships. They have exploited suppliers' capabilities by improving their parts, raw material, or product qualities and faster integration of technologies. The firm selects multiple suppliers based on the criteria to avoid disruptions. As in the case of the COVID-19 pandemic, measures like keeping inventory are only for a short time we can only avoid disruption at the beginning. Subcontracting will also be less efficient because of the lockdowns. Repurposing the SC will ramp up the production line to reach a daily demand in the time of an outbreak. The viability in the SC can shift focus from proactive measures to real-time situations, and it will be more effective. Demirtas and Ustun (2008, 2009) combined the MCDM and MOMILP techniques for selecting the best supplier and determining order allocations. Then Jolai et al. (2011) used goal programming for purchasing while considering multi-period and multi product model. In these times of COVID 19 reconfigurability and sustainability plays a very important role while

Table 5 Product sent to wholesalers(XK_{ijt})

Supply chain entity		Period			
		PD1	PD2	PD3	PD4
Wholesaler1	Product 1	0	0	0.8	0
Wholesaler1	Product 2	0.8	1.5	0	0
Wholesaler1	Product 3	0	3.3	3.30	0
Wholesaler 2	Product 1	2.6	0	0	0
Wholesaler 2	Product 2	2.5	0	0	2.5
Wholesaler 2	Product 3	0	2.5	2.40	3.7
Wholesaler 3	Product 1	2.6	0.8	0.90	0.8
Wholesaler 3	Product 2	2.0.5	0	0	2.50
Wholesaler 3	Product 3	1.8	3.3	2.80	3.30
Wholesaler4	Product 1	2	1.8	1.50	1.50
Wholesaler4	Product 2	2	1	1.00	2.08
Wholesaler4	Product 3	2	1	1.00	2.08
Wholesaler 5	Product 1	0.8	1.50	1.92	1.92
Wholesaler 5	Product 2	2.5	1.9	1.92	1.92
Wholesaler 5	Product 3	2	0.8	0.90	0.90
Wholesaler 6	Product 1	1.8	2.5	2.40	2.30
Wholesaler 6	Product 2	1.8	3.3	3.30	2.20
Wholesaler 6	Product 3	0	2.6	2.60	2.00
Wholesaler 7	Product 1	2.5	0	0	0
Wholesaler 7	Product 2	0.8	0.8	2.40	2.30
Wholesaler 7	Product 3	0	0.9	0.90	0.90
Wholesaler 8	Product 1	0.8	0	0.90	0
Wholesaler 8	Product 2	3.3	1	0	0.90
Wholesaler 8	Product 3	1.8	3.3	1.10	3.30
Wholesaler 9	Product 1	1.7	0.9	0.90	1.77
Wholesaler 9	Product 2	0	1.70	0	1.70
Wholesaler 9	Product 3	0	0	1.10	0
Wholesaler 10	Product 1	0	2.60	1.77	0
Wholesaler 10	Product 2	2.1	1.70	1.70	0
Wholesaler 10	Product 3	0	1.10	2.20	1.10
Wholesaler 11	Product 1	1.69	0.90	0	0
Wholesaler 11	Product 2	1.77	2.40	2.40	1.70
Wholesaler 11	Product 3	0	2.20	2.20	1.10
Wholesaler 12	Product 1	2.5	2.60	1.77	0
Wholesaler 12	Product 2	2.1	1.70	2.40	2.50
Wholesaler 12	Product 3	2.6	1.10	1.10	0.200
Wholesaler 13	Product 1	0	2.60	0.90	2.60
Wholesaler 13	Product 2	2.1	0	0	0
Wholesaler 13	Product 3	2.6	1.10	0	2.10
Wholesaler 14	Product 1	0	0.90	2.60	2.70
Wholesaler 14	Product 2	0	0	2.40	0
Wholesaler 14	Product 3	2.6	3.30	2.20	0
Wholesaler 15	Product 1	0.8	0.90	1.80	2.50
Wholesaler 15	Product 2	2.1	0	0.90	0.90
Wholesaler 15	Product 3	0	3.3	1.0	2.1
Wholesaler 16	Product 1	0	0.90	0	0
Wholesaler 16	Product 2	0	0	1.70	0.90
Wholesaler 16	Product 3	0	0	3.30	0

Table 6 Central warehouse demand

Product	Warehouse			
	1	2	3	4
Product1	18.64	24.27	17.36	2.049
Product2	21.70	12.58	21.82	2.300
Product3	22.40	23.33	28.10	1.978

shown the world how disastrous (Ivanov 2020a) it is for SC. Its impact on the supply chain means the firm should respond quickly to reconfigure its sustainable supply chain. Repurposing will help SC to dynamically adapts to rapid structural changes by reorganizing and reassigning or modifying its components to rapidly adapt the supply. Repurposing is useful when SC is not understood as a robust physical system with fixed and static allocation of some processes to some companies, but various physical companies deliver, manufacture, logistics, etc. and provide sales services, dynamic allocation of processes and dynamic SC structure. So this study is repurposing the SC such that SC will be more viable with respect to reconfigurability and sustainability. We considered the reconfiguration metrics: Modularity, Convertibility, Integrability, Diagnosability, and Customization indicators to measure reconfigurability. Hybrid MCDM techniques are used, where fuzzy AHP (Saaty 1980, Dyer 1990) is used to rank criteria, fuzzy TOPSIS is used to rank the suppliers. If we talk about reconfigurability criteria modularity holds the first position and it simply means how modular manufacturers' equipment, resources, processes, and products are then diagnosability, convertibility, customization, and integrability are at the second, third, fourth, and fifth positions. Where diagnosability means finding the problems and where they started. Convertibility means the ability of the manufacturer to adapt to future products. Customization means the flexibility of the manufacturer to adopt a change. And integrability means integrating existing processes into SC. Firms are now focusing more on multiple suppliers as the COVID-19 situation has arisen as if one of the suppliers falls into the containment zone, other suppliers will be able to supply the same.

The suggested approach bestows a company with a combined methods for assessing alternative suppliers and selecting the best, and allocating orders to each. The data needed for supplier selection are mostly qualitative, They are determined based on the supplier's history and the decision maker's judgments (s). As a result, the decision-maker(s) should assess each supplier's overall performance against each criterion. They can include their concerns and personal judgments about each supplier by considering appropriate criteria in the first phase of the approach.The risks realated with buying processes increase as the business environment becomes more uncertain. One of the major concerns in today's purchasing decisions is the risk of supply disruption,

selecting a supplier. Reconfigurability (Zidi et al. 2021a, 2022) and sustainability (Amindoust et al. 2012; Luthra et al. 2017; Li et al. 2019) have been studied separately. But COVID-19 has

which, if it occurs, can bring a company's entire operation to a halt. As a result, this concern is taken into account in the design of the proposed approach. Specifically, by ordering from suppliers and purchasing risk can be considerably reduced by evaluating each supplier against a set of essential qualitative and quantitative criteria.Many mathematical models developed for selection of supplier and order allocation issues can result in few and ineffective order quantities. This paper addressed this issue as well by incorporating constraints into the MOMILP model. It is also possible to add, remove, or change some or all criteria for the supplier selection by taking the choice decision makers. So our approach has flexibility to customize different criteria as per decision makers viewpoint.

Sharing accurate data between buyer and supplier should be there to improve raw material supply. Here data analytics and blockchain can be engaged to improve SC visibility. So that they can enhance collaborations with SC partners. It can be included in future work to get a more viable and visible SC.

6 Conclusion

COVID-19 had brought disaster to the world, whether with a person's life or business. It had created a significant impact on SC. It was an ultimatum for the manufacturers with high demand and essential products. There may be a sudden increase in product demand substantially and the supply of raw materials can suddenly decrease. These disturbances make the planning phase more difficult. Thus the SC should be viable so that it can cope up with the disruptions caused and can be able to modify it as and when required. Viability may require up-gradation or modifications of the existing SC network. The research work done will help in tackle with these situations. In this paper, reconfiguration criteria is incorporated, and SC is designed having four stages (Fig. 6), i.e., Tier 2 supplier, Tier 1 supplier, warehouse, and wholesaler. The developed model facilitated getting the best supplier with optimal order and allocation at the wholesaler level. We have considered emergency sourcing. A hybrid MCDM (fuzzy ANP and TOPSIS) approach was used to find the best supplier. The supplier selection problem was formulated with two objective functions: finding optimal order and allocation, The second was to get suppliers based on their weighted value, maximization function. So by developing the model and solving it in GAMS we found the demand of wholesalers, products ordered from a supplier, products sent to wholesalers and the central warehouse demand.

Our idea integrated the factors of sustainability and reconfigurability into one model of supplier selection. Furthermore, this paper provides a methodology to deal with or understand SC's viability more clearly. To show the application of the proposed model an automobile manufacturer SC was investigated includes seven suppliers, three products, and four periods. Our study has some limitations, like the values taken are deterministic. Fuzzy MCDM methods are computationally demanding with respect to crisp MCDM methods but it can be solved by selecting properly configured computer. It is limited to some of the vehicle manufacturing companies and is primarily focused on inbound SC. So we can research in the future using stochastic programming and by using different algorithms, we can find values. The firm can see the relationship between the criteria and the dependent variable and primary variable by using the DEMATEL technique. According to these approaches, they can more thoroughly sort the criteria as per their situation. Also they can integrate ISM and DEMATEL approaches to get better results, as they have already been applied in different fields such as ecotourism, new product support, etc. Then to find optimal order, MOMILP modeling can be done to get the desirable results. Future research can also explore digital technologies like blockchain, real-time visibility, artificial intelligence, etc. as we are moving towards a more technological era, it should be included to get more competitive. Develop techniques to repurpose existing alternative SC that are currently underutilized. The repurposing of production facilities is likely to meet demand, but the immediate need because of the outbreak has resulted in diverse and dispersed workforce mobilization. SC viability and SC repurposing concept are relatively new concerning the COVID-19 outbreak, so we can focus more on this research area and should be studied in depth so that more techniques could be generated to deal with the disruptions on a long term basis. And to repurpose and reconfigure supply chains for the future such that they will be more viable, business leaders are required to act quickly to protect and support their workers and sustain the operations that are vital lifelines for their customers and communities.

Declarations

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