IMPACT OF COVID-19 ON SUSTAINABILITY ENABLERS AND EVALUATION OF PERFORMANCE INDEX

A Thesis Submitted

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Master of Technology

In

Production Engineering

SUBMITTED BY

DIMPY
(2K19/PIE/18)

UNDER THE GUIDANCE OF

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CANDIDATE'S DECLARATION

I, DIMPY, hereby certify that the work which is being presented in this thesis entitled "Impact of COVID-19 on Sustainability Enablers and Evaluation of Performance Index" being submitted by me is an authentic record of my own work carried out under the supervision of Dr. Saurabh Agrawal, Delhi school of Management and Professor Qasim Murtaza, Department of Mechanical Engineering, Delhi Technological University, Delhi.

The matter presented in this thesis has not been submitted in any other University/Institute for the award of M.Tech Degree.

14/07/2021

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CERTIFICATE

We hereby certify that the major project entitled "Impact of COVID-19 on Sustainability Enablers and Evaluation of Performance Index", in partial fulfilment of the requirements for the award of the Degree of Master of Technology in Production Engineering and submitted to the Department of Mechanical, Production and Industrial Engineering of Delhi Technological University has been an authentic record work of Ms. Dimpy (2K19/PIE/18) carried out under our supervision.

It is to further certify that the matter embodied in this report has not been submitted to any other university or institution by her for the award of any other Degree/Certificate and the declaration made by her is correct to the best of our knowledge and belief.

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ABSTRACT

The definition of sustainability in any kind of manufacturing organization deals with the impact of various production processes and products on the economy, environment, and society. Due to the outburst of deadly COVID-19, sustainability which has three dimensions i.e., economy, environment, and social have been severely afflicted. Logistics has been stopped due to the spread of COVID-19 by which disruption in supply and demand takes place. This paper involves the study of sustainability enablers in the COVID-19 times and their sub-attributes that influences these sustainability enablers with the help of the Graph-theoretic approach (GTA) and then to measure the performance index pre and during COVID-19. With the help of the graph-theoretic approach (GTA), the inter-relationship between the sustainability enablers pre and during COVID-19 has been studied thereby quantitatively measure the extent to which COVID -19 has an impact on sustainability enablers. The objective of this study is to identify a performance index by analyzing different sub-attributes of sustainability enablers. Also, digraphs are shown for the whole system and sub-systems representing inter-relationships and dependencies between various enablers and attributes to interpret the performance of the sustainability enablers before and during the time of COVID-19. This paper provides the impacts of COVID -19 on these three factors and provides the framework how to identify the performance index pre and during COVID-19.

Keywords: Sustainability enablers, COVID-19, graph-theoretic approach, performance index.

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CHAPTER 1. INTRODUCTION

The novel coronavirus caused infectious disease 2019 (COVID-19) first emerged in December 2019 in China and spread worldwide in such a way that the World Health Organization (WHO) announced it as a pandemic in March 2020 (WHO, 2020a). As of January 25, 2021, a total number of 98, 794, 942 confirmed cases of COVID-19, including 2,124,193 deaths in 235 countries, areas, and territories, has been recorded by the WHO (WHO, 2021). The crisis's magnitude has marked the COVID-19 pandemic as the most severe health catastrophe of this century (Maity, 2020). The COVID-19 crisis has imposed immense pressure on the global economy and business activities with significant adverse financial consequences, increased GDP loss by countries, and raised poverty and hunger across the world (Jude-Iwuoha,2020). As a result, the global health crisis caused by this pandemic tremendously slows the international community's progress towards sustainability (Lee et al., 2020). COVID-19 is a significant threat to implementing sustainable development by reducing the SDGs' priority (Leal Filho et al., 2020). Hence, while significant global efforts are being put into controlling this pandemic, sustainability in the post-COVID-19 era should not be neglected (Lambert et al., 2020). As a matter of fact, sustainability and achieving the SDGs are even more critical now than before (Leal Filho et al., 2020). We all suffer from complex situations in 2020 because of the spread of the fatal Corona Virus Disease COVID-19. Also due to lockdown in many countries supply and demand have been severely afflicted. Supply chain is a system that involves organization, person, details, and materials that help to move end product from supplier to customer. Basically, supply chain is a chain that includes manufacturers, suppliers, transporter, warehouses, retailers, wholesalers, and also

customers (Paulra, 2004). Representation of supply chain through the flow diagram is shown below:-

Figure 1. Flow of supply chain

Supply chain management is defined as managing of goods and services from starting point i.e., supplier till the end user in most efficient way. This is quite complex process which depends upon many factors (Ellram et al., 1998). The flow of money, product and information is taken place in any kind of supply chain.

Within the chart, we will see the flow of products, resources, and knowledge from the producer to customers. The statistic indicates the flow of a commodity from supplier to the manufacture, who forward it to the shipping dealer. The dealer then send the products to different retailers or shops from where costumers may easily purchase the items.

Typical supply chain includes a number of phases, i.e.

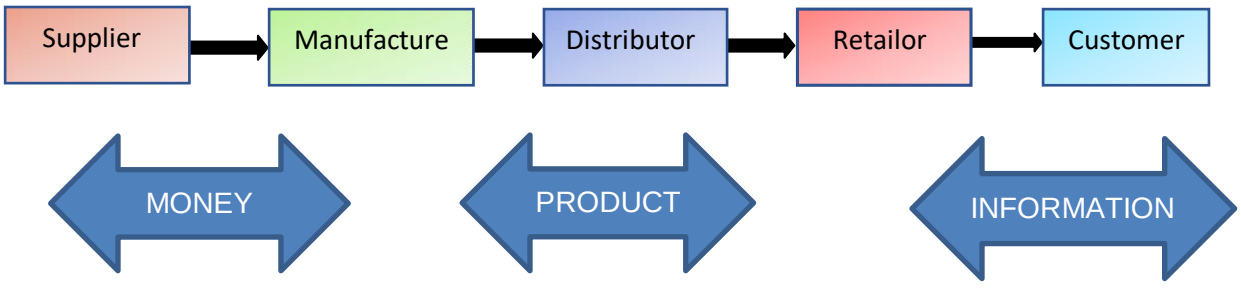


Figure 2. Flow of supply chain management

❖ Customers

❖ Retailers

❖ Distributors

❖ Manufacturers

❖ Raw material supplier

1.1 KEY BENEFITS OF SUPPLY CHAIN

The key benefits of supply chain management are as follows: -

❖ Improve of service and customer relationship.

❖ With the minimum delay of product and service create a delivery mechanism.

❖ Increase productivity and maintain business facilities.

❖ Optimize transportation and warehouse cost.

❖ Optimize all cost i.e., direct and indirect cost.

❖ Operate best by shipping of defect free products at right time to the right place.

❖ Enhance management of inventory.

1.2 SUPPLY CHAIN GOAL

Every firm aims to match demand with supply promptly with optimize utilization of resources. Some one of main goals of every supply chain are:

❖ In the supply chain, people work together to attain maximum utilization of resources, build standardized processes, and decrease the level of safety stock requirement.

❖ Reducing spending on the supply chain is very significant, particularly as there is economic instability in businesses over their ability to retain resources.

❖ Supply chain's managers need to focus on creating value for their customers. The best way to satisfy customer's expectations is to exceed them regularly.

❖ Increased consumer demands for greater product range, personalized products, off-season inventory quality and fast shipping at comparable cost will be balanced with in-store offering.

1.3 SUPPLY CHAIN PROCESS

Supply chain process is very important in many industries, in case of fast moving consumer goods company, whole reputation of the company depends on its supply chain. These companies invest a lot on their supply chain process to make it work smoothly. The main stages of supply chain are:

❖ Plan

❖ Develop

❖ Return

❖ Deliver

❖ Make

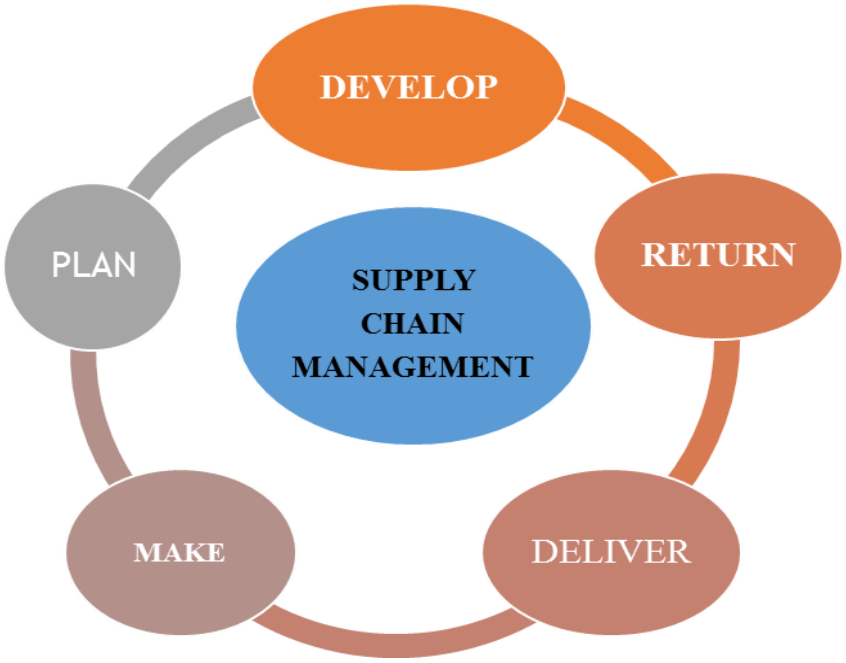


Figure 3. Basic components of supply chain management

1.3.1 Plan

Planning stage is the first stage in supply chain process. To know, how goods and services will fill the customer requirements and also to know who all are targeted customer, there is requirement of proper a plan or strategy. In this stage, maximizing the profits is the core point that need to be focus while making a strategy. The organization also need to design the plan for optimum utilization of resources. Planning and develop a set of metrics is the main area that is focused in supply chain management.

1.3.2 Develop

After planning, developing or sourcing is the second stage in supply chain management. Developing a good bond with suppliers of raw materials required for production is the focus area of this stage. This stage looks at various methods of planning related to shipping, delivery, and payment of the product along with identifying dependable suppliers.

1.3.3 Make

The process of making the products as per customer requirement is third stage of supply chain management. In this stage products are assembled as per specifications, quality of products are checked and further packed to synchronize for delivery. Here agenda is to timetable all the activities of the process by the supply chain manager. This stage is most significant stage of the supply chain as it helps the organization to check quality and productive.

1.3.4 Deliver

The delivery stage is the fourth stage in the supply chain process. In this stage, the customer received the product at final location by the supplier. This stage mainly focuses on logistic part, where customer orders are accepted and planning is done to deliver the goods. This stage is said to be logistics, where organizations combine for the receipt of purchased orders from customers and builds a link with warehouses and set up an invoicing system to receive payments.

1.3.5 Return

The final stage of supply chain management is referred to as the return. The defective products are sent back to the supplier by the customer. Hence,customer queries and responses to their complaints are responded by the company as quickly as possible. This stage is the most problematic section of the supply chain as in this stage there is need to develop another network for accepting and storing the damaged products and make sure that customer don't face any trouble.

1.4 TYPE OF SUPPLY CHAIN MANAGEMENT

There are three types of supply chain management:

1.4.1 Material Flow

Material flow includes a quick and steady movement of an item from the supplier to the customer. It can be raw material, in product inventory, or finish product. This is usually done at different stages of supply chain that includes supplier, distributors, dealers, and retailers. The main challenges which needs to consider in this are that the material move rapidly without any hurdle through all stages in the chain. The quickly it flows, the more it minimizes the cash cycle.

1.4.2 Information Flow

In this information or data is flow from customers to supplier's end which includes quotation request, purchase order,schedules, engineering change request, quality complaints, and reports on suppliers. There is vice versa flow of information as well i.e. from producer's side to the consumer's side. The information that flows from producer side to customer side which includes presentation of the company, offer, confirmation of purchase order, invoices, etc.

1.4.3 Money Flow

Once the invoice is raised by the producer, the order is examined by the client to verify whether he or she has received the correct order or not. On receiving the correct order, the client makes the payment to the respective producer. Debit notes are another form of the flow of money that travels from the producer side to the client. To efficiently and effectively run the supply chain, the key requirement is to manage all the three flows with minimal efforts.

1.5 DRIVERS OF SUPPPLY CHAIN PERFORMANCE

Responsiveness and efficiency area a key factor of the supply chain management. To have a smooth working of the supply chain there should be a balance between these two key factors. The communication between all drivers is very important to develop the balance between responsiveness and efficiency which ultimately affects the performance of supply chain The main drivers of supply chain performance are: facilities, inventory, transportation, information, sourcing, and pricing. Any organization's aim is to arrange the drivers to obtain the optimal degree of flexibility at the lowest practicable expense by enhancing the supply chain and the financial efficiency of the company. The various drivers of supply chain performance are:

1.5.1 Facilities

Facilities are the real sites where the commodity is processed, packaged, or produced in the supply chain network. The two main buildings are processing sites and distribution areas. The performance of supply chain depends totally on region, flexibility, size, and role of facility.

1.5.2 Inventory

Inventory refers to the safety stock that firms keep in order to fulfil the customer demands. Raw materials, work in process, and finished goods are the part of the inventory in the supply chain management.

1.5.3 Transportation

Transportation involves moving inventory in the supply chain, from the end to another end. Transportation can be conducted in any ways or by the combinations of ways, each with characteristics of its own performance. The responsiveness and efficiency of the supply chain mainly depend on transport choices.

1.5.4 Information

Data consists of details and information across the supply chain about equipment, products, distribution, rates, sales, and consumer. Knowledge is theoretically the increasing output variable in the supply chain because it impacts each other driver directly.

1.5.5 Sourcing

In-Sourcing we particular choose the activities are done in the supply chain and who will perform a particular activity in the supply chain. The main activities are manufacturing, storage and movement of goods, or the management of information. These decisions regarding which functions are performed with the company and which functions are outsources is very important for company development.

1.5.6 Pricing

The amount that the company charges for the goods and services that they provide to the customer are the pricing of that product or services in the supply chain. Demand and supply chain performance is also get affected by the pricing as it ultimately affects the behaviour of the buyer. For examples there may be people who are more concerned about the price rather than quality.

CHAPTER 2. LITERATURE REVIEW

A large number of studies have been done on supply chain network design under disruptions in a variety of domains, such as supplier selection and order allocation (Prasanna Venkatesan, 2016), biofuel supply chain (Govindan, 2018), reverse supply chain (Hosseini-Motlagh et al., 2019), blood supply chain (Hamdan and Diabat,2020), fashion supply chain (Zhao et al., 2020), etc. by means of mathematical programming tools. In this regard, some studies have even touched upon the impacts of epidemic outbreaks on supply chains (Choi, 2020). In the following, Section 2.1 discusses the COVID-19 literature. Section 2.2 discusses the studies undertaken in sustainable supply chain management. Section 2.3 is dedicated to the factors that has impact on sustainability during covid-19.

2.1 COVID-19

Epidemic outbreaks are specifically considered among supply chain disruptions. Further, they denote a particular variety of threat in the supply chain, which is recognized by the three following components: (1) the presence of long-term and unexpected scaling disruption, (2) disruption propagation in the supply chain and epidemic outbreak propagation in the population, and (3) disruptions in the infrastructure of logistics, demand, and supply. In contrast to most disruption threats and risks, epidemic outbreaks are minor at the outset, but they develop and spread over various geographic areas very quickly (Liu, 2015). The latest pertinent examples include MERS, SARS, Swine flu, Ebola, and the newest one, coronavirus. The COVID-19 outbreak started in Wuhan, China and quickly affected the Chinese economy as a result, supplies in worldwide supply chains were considerably diminished. Accordingly, (Araz et al. 2020) has asserted that the outbreak of this viral disease is one of the most critical disruptions to occur in recent decades and, thereby, it is ravaging a large portion of supply chains across the world.

To investigate epidemic outbreaks that struck before that of COVID-19, one will find limited information in connection with supply chain measures. For example, (Johanis,2007) analyzed a pandemic response plan that was designed at Toronto's Pearson International Airport after undergoing the harmful effects of SARS epidemic outbreak in 2002–2003. This virus terribly influenced the global airline industry; in fact, airlines in Taiwan suspended about 30% of international flights (Chou et al., 2004). However, the spread rate of the SARS virus and China's role in the critical situation of SARS totally differed from that of the current COVID-19 virus; accordingly, SARS had lower adverse effects on the SCs. Similarly, the spread of the Ebola virus badly affected worldwide logistics (BSI, 2014). In this regard, (Büyüktahtakın et al., 2018), (Calnan et al., 2018) shed some light on the valuable experiences obtained while Ebola virus was dominant. They called for the development of a decision-support framework through which epidemic outbreaks might be predicted and their effects on the supply chains could be facilitated. With such a framework, required measures and logistic policies could be adopted during and following the disaster.

(Ivanov,2020) studied the impact of epidemic outbreaks on supply chain networks. He specifically considered the propagation of the COVID-19 virus on global networks using characteristics of the uncertainty type. As for the methodology, Any logic software was used to predict and simulate both short- and long-term impacts. Experiments show that closing and opening dates of facilities are the most impactful factors in the propagation. The results could help decision makers to mitigate the uncertainties and to curb or decelerate propagation While this crisis provides sustainability opportunities, it could also result in disappointment. The two most popular views are John Elkington's triple bottom line profits, people, planet and the multi-generational philosophy born of the Brundtland Report meeting the needs of

the present without compromising the ability of future generations to meet their own needs. The research in sustainable supply chains especially the greening focus has found a permanent foothold in the supply chain discipline.

Our discipline should be proud that our community leads corporate and business sustainability research (Hallinger, 2020). Manufacturers are using Industry 4.0 technologies cyber-physical systems (CPS), internet of things (IoT), cloud computing and cognitive computing that can complement human decisions with technologies that can decentralize decision-making. These technologies may take on important long-term roles in response to COVID-19 activities (Kumar et al., 2020a). A likely major change is data-driven awareness-based collective action (Scharmer, 2020). This action means addressing situations collaboratively, and then adjusting behavior in response to the COVID-19 crisis. As systems begin to fail, especially market and governmental regulatory systems, organizations need behavior adjustment. Similar behavioral adjustments can benefit sustainability. Organizations and their supply chains require more and timely data during and after the crisis; they will internalize decision-making, develop new initiatives and programs in response to the crisis. This issue became evident in the financial crisis of 2008, as organizations tended to delay or discard some of their short-term and tactical plans to address the immediate crisis (DesJardine et al., 2019). This organizational capacity can enhance sustainability thinking – environmental and social crises will occur but with uncertain timing and levels.

Having the necessary data-driven systems such as big data can help organizations to respond quickly to crises, especially environmental and social crises. Collaborative technologies such as blockchain technology allow for sharing of information transparently, reasonably quickly, accurately and widely. Integrating these systems with IoT and artificial intelligence (AI) can alter how supply chain managers make

decisions and subsequently operate (Saberi et al., 2019),(van Hoek, 2019). Knowing the supply chain capabilities and capacities is critical for building resilience. Effectively identifying supply chain environmental and social vulnerabilities can be completed using blockchain transparency and traceability, paired with big data predictive analytics tools helping to build the needed capabilities and capacities. This crisis provides evidence that localized systems are more likely to be robust and resilient than global supply chains (Nandi et al., 2021),(Handfield et al., 2020). Localization is also important to environmental supply chain sustainability (Gutowski, IJOPM 2017).

Local production can mean rapid response to local needs, but with low energy and resources consumption. For example, in the COVID-19 pandemic, many "hot-spots" emerged. Ensuring critical equipment and materials through more agile production and rapid delivery logistics to hot spots can equate to saving more lives or slowing the spread of positive cases a social sustainability concern. Flexible manufacturing system technologies such as additive manufacturing and robotics can localize production capabilities. Local additive manufacturing of parts for ventilators or masks were important solutions during the pandemic. In northern Italy, a hospital required replacement valves for its ventilators but could not locate any through its local supply chain. Smart factories with distributed information, additive manufacturing and integrated Industry 4.0 technology is one solution for building supply chain resilience and robustness through localization (Gutowski, 2017). Localized production capability can support sustainable supply chains by producing only what is needed. Less waste, less transportation and less need for inventory storage due to shorter supply chains; each has sustainable supply chain implications. There are sustainability concerns with some recommended solutions to building resilience in supply chains.

Agility in supply networks will likely mean building redundant capacity and capabilities. Redundancy results in wasted resources and energy. Social distancing, remote work and reduced business travel during the COVID-19 crisis offer sustainable supply chain lessons. Reduced employee commuting and business travel contribute to reduced organizational carbon footprints. Virtual meetings and virtual reality acceptance are likely to increase and become the norm (Sarkis et al., 2020a). In an interview with a machine parts distributing company, they informed us that they will likely require fewer physical supplier location visits due to greater distance communication acceptance. Unintended negative environmental sustainability concerns may occur. Working from home may not be as sustainable as initially thought. For example, UK researchers have found work from home environmental impact was higher in the winter due to heating individual worker homes versus centralized office buildings (Turits,2020). Thus, research on the overall lifecycle environmental impact of operational behavioral changes will be needed. COVID social distancing lessons can provide lessons for future health and safety operational concerns, e.g. when working with hazardous materials.

Virtual reality and linked CPS technologies that can help manage operations at a distance. These practices reduce travel to and from locations, resulting in reduced energy resource usage and emissions. A burst of demand for IoT and e-commerce consumer goods and groceries occurred during the crisis (Wang et al., 2020). Shelter in place and social distancing mandates forced consumers to turn to online sources of goods and services. This behavior had been increasing incrementally over the past two decades – it is likely to become an even more dominant form of consumerism. This event required farmers and local retail outlets to pivot to e-commerce delivery. Shopify, a Canadian e-commerce platform, stepped in to address this need and provided cloud and supply chains (Behrouz Alavi et al.,2020) presented a decision

support system for demand management health care supply chains considering the epidemic outbreaks: case study of corona virus disease-2019 (COVID-19) which develops a practical decision support system based on physician's knowledge and fuzzy inference system(FIS) in order to help with the demand management in the healthcare supply chain, to reduce stress in the community,to break down the COVID-19 propagation chain, and, generally, to mitigate the epidemic outbreaks for health care supply chain disruptions. (Lucie K. Ozanne et al.,2020) presented a paper on a transformative supply chain response to COVID-19 which employs a transformative service lens to examine the role of the supply chain ecosystem in ensuring the health and safety of employees and customers as a well-being outcome during the coronavirus disease of 2019(COVID-19) pandemic. (Babaee Tirkolaee et al.,2020) presented a paper on Evaluating of Green and Sustainable Supply Chain Management Using Application of Structural Equation Modelling: A systematic review of the state of the art literature and recommendations for future research for the purpose to present the comprehensive review study about the application of the Structural Equation Modelling (SEM) in the assessment of sustainable and green supply chain management (SCM). (Shahin Sarowar e al.,2020) presented a paper on COVID-19 and the environment: A critical review and research agenda by providing identified four underlying research clusters based on a systematic content analysis of the studies.(Cao, L et al.,2020) presented a paper on association between short-term exposure to air pollution and COVID-19 infection by exploring the relationship between ambient air pollutants and the infection caused by the novel coronavirus by applying a generalized additive model to investigate the associations of six air pollutants ($PM_{2.5}$, PM_{10}, SO_2, CO, NO_2 and O_3) with COVID-19 confirmed cases. (Joseph

Sarkis,2020) presented a paper on Supply chain sustainability: learning from the COVID-19 pandemic by publishing literature, personal research experience, insights from virtual open forums and practitioner interviews. (Anil Kumar et al.,2020) presented a paper on developing a framework for enhancing survivability of sustainable supply chains during and post-COVID-19 pandemic by developing a framework for enhancing survivability of SSCs to survive in and post COVID-19 pandemic. The study has utilised Stepwise Weight Assessment Ratio Analysis (SWARA) method for identifying the significant factors for enhancing survivability of SSCs to be focused in pandemic situation and is helpful for firms, suppliers, and other stakeholders to focus on the identified factors for healthier future.(Samuel Fosso Wamba et al.,2020) presented a paper on Impacts of epidemic outbreaks on supply chains: mapping a research agenda amid the COVID-19 pandemic through a structured literature review by presenting a systematic analysis of the impacts of epidemic outbreaks on SCs guided by a structured literature review that collated a unique set of publications.(Esteban koberg,2019) presented a systematic review of sustainable supply chain management in global supply chains which aims to provide a synthesis of the key elements of sustainable supply chain management in global supply chains.

(Bikram Bahinipati et al.,2019) presented a sustainable supply chain management a review of literature and implications for future research in which attempts to map the various theories in the SSCM literature from the perspectives of economic performance, environmental dimensions, and social values and ethics has been discussed. (Ming K Lim et al.,2019) presented a paper on sustainable supply chain modeling and analysis past debate, present problems and future challenges.(Sojin Jung et al., 2016) presented a paper on a review on sustainable supply chain management contracts in reverse logistics

aim to review in this paper the recent state of the art literature (2006-2016) on supply chain contracts with a focus on reverse logistics systems. (Qasim Murtaza et al.,2015) presented a paper on a literature review and perspectives in reverse logistics study which attempts to fill the existing gap through literature review on reverse logistics issues, and outline the future directions for research based on research gap analysis by analysing four steps such as material collection, descriptive analysis, category selection, and material evaluation.

2.2 Definitions from the sustainability literature

The most well-adopted and most often quoted definition of sustainability is that of the Brundtland Commission (World Commission on Environment and Development, 1987,p. 8): "development that meets the needs of the present without compromising the ability of future generations to meet their needs." Included within this broad rubric of sustainability are such issues as understanding the environmental impact of economic activity in both developing and industrialized economies (Erlich, 1991); ensuring worldwide food security (Lal et al., 2002); ensuring that basic human needs are met (Weber, 2006); and assuring the conservation of non-renewable resources (Cooper, 2000). Unfortunately, the macro-economic, societal definition of sustainability is difficult for organizations to apply and provides little guidance regarding how organizations might identify future versus present needs, determine the technologies and resources required to meet those needs, and understand how to effectively balance organizational responsibilities to multiple stakeholders such as shareholders, employees, other organizations in the supply chain, and broader stakeholders including society and the natural environment (Hart, 1995); (Rands,1995). In addition, because the Brundtland Commission's definition is so far reaching, organizations often find it difficult to determine their individual roles within this broader, macro-economic perspective (Shrivastava, 1995a);(Stead, 1996)."Supply chain sustainability" means managing environmental, social

and economic impacts by encouraging best practices in life cycles of goods and services.

The objective of supply chain sustainability is to create, protect and grow long term environmental, social and economic value for all stakeholders involved in bringing products and services to market. Sustainable Supply Chain Management (SSCM) is a set of managerial practices which comprises of :-

- Environmental impacts
- Examining of all stages
- A multi-disciplinary perspective involving the entire product life cycle.

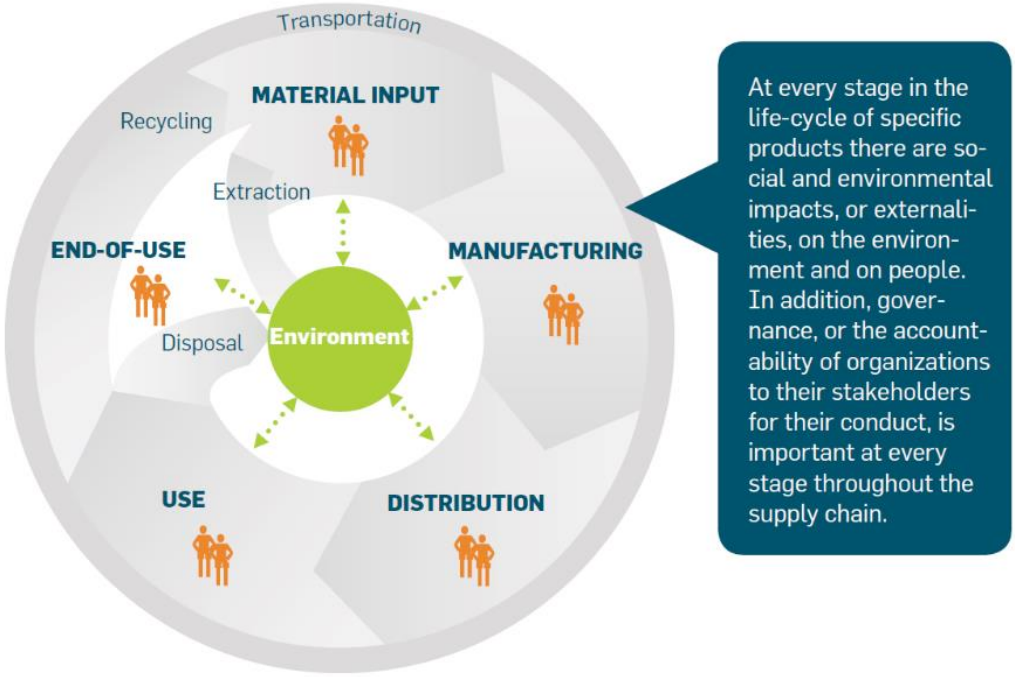


Figure 4. Environmental, Social and Economic Impacts Exist Throughout Every Stage of Supply Chains

The organizations should be aware of environmental impacts of their activities as an crucial part to make decision rather than rule imposed by government or any other social pressure to be "green".The Brundtland Commission (World Commission on Environment and Development,1987) gave the definition of sustainability

as “development that meets the needs of the present without compromising the ability of future generations to meet their needs.” The organizations unfortunately can’t apply this macro-economic and societal definition of sustainability as it is complex for organizations to understand regarding how organizations identify future versus present needs. In the existing organization the sustainability focuses on ecological balance i.e., the natural environment with impact of social and economic.Sustainability is defined as the tendency to reduce long term risks that encourages decrease in natural resources, costs, related to energy, pollution and waste management.The literature review tells that sustainability consists of three dimensions i.e., the natural environment, society, and economic performance at a broader level. Figure 5 depicts a representation of these three components. The figure examine the idea of the triple bottom line, a concept developed by (Elkington,1998) which considers the simultaneous balance of economic, environmental and social from a microeconomic point.

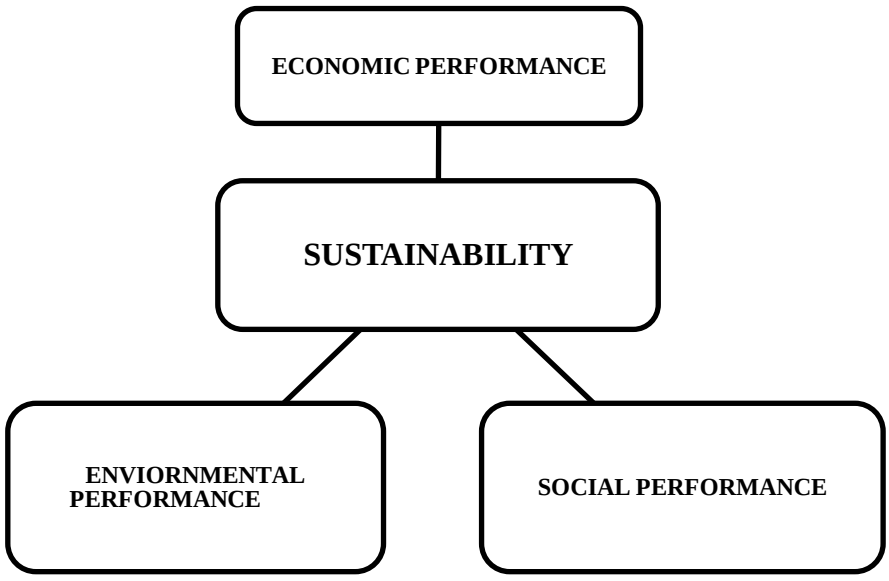


Figure 5. Sustainable supply chain

Thus, the triple bottom line encompasses that at the intersection of the three dimensions of sustainability i.e., social, environmental, and economic practices, there are certain activities in which organization can indulge which will give positive impacts and can also develops long-term economic benefits and advantage for the firm.

2.3 FACTORS

Any natural disaster or natural calamities destroys well-being. The breakout of the deathly Corona Virus Disease COVID 19 leads to losses in jobs, losses in lives, losses in production, and business. The manufacturing, and logistics has been stopped due to lockdown by which supply and demand has been severely afflicted. The definition of sustainable supply chain management means managing of activities within the supply chain considering environmental, economic and social impacts. Sustainability has three dimensions that is economic, environment and social.

Economy

From the economic perspective, lockdown is shown in most part of the world but it's not the right solution when a greater number of populations is dependent on regular emolument in job loss during lockdown phase (Melinda C.Mills .2020). According to ILO it was estimated that 25 million jobs was lost and further it can go to 40 million worldwide(ILO,2020). According to CII's report, in India after lockdown phase CEOs told that employees will lose their job around 30–40%(CII,2020). It was reported that global GDP from 2.2 to 4.8% in September 2019 by WHO and World bank due to pandemic impacts (GPMB,2019).15% of GDP in India come from agricultural activities because around 500 million people depend upon agriculture (A.Islam,2020).

During lockdown phase in and within the country because of laborers unavailability and trucks the FDS and MSME is severely afflicted (Manoj Kumar Tiwari ,2019).All manufacturing activities has been stopped and 111million people indulge work in 63.2 million units in India.The MSME is the foundation of country's economy as it contributes to the GDP and job creation and it is backup by supply chain and logistics (Teresa Taurino,2018). To reduce the spread of covid-19 all flights including national as well as international has been cancelled worldwide and planes were kept grounded with 50 million people has been affected by which aviation sector has been afflicted also 25% shrinkage has been estimated that impact 50 million employees (KPMG. 2020). Food supply has been also disturbed during lockdown phase because demand of various food items has been changed because of the change in nature and discrepancy in the industries.

Environment

In lockdown social and economic activities has been banned by which quality of air has been improved in many parts of the world. There's increase in use of face masks, hand gloves with their haphazard disposal damages environment also huge waste through hospital creates negative environmental effects. The positive and negative environmental impacts of COVID-19 are described below:-

Positive Environmental Effects

As there's fall in GHGs because all manufacturing industries has been shut down and it was calculated that N_2O and CO is reduced about 50% due to the close down of industries**.** It's known that NO_2 emission is key indicator of global economic activities.The NO_2 is releases from the burning of fossil fuels which comes from vehicle exhaust about 80%, also acid rain is caused by NO_2 with mixture of O_2 and H_2O and humans suffered breathing problems. Levels of NO_2 and $PM_{2.5}$ lowered

around 70% in Delhi, the capital of India (USEPA,2016). It was reported in India that 46% and 50% reduction of $PM_{2.5}$ and PM_{10} during lockdown(IEP.2020). Transportation and aviation contribute 72% and 11% emission that comes from transport sectors,Aviation sector suffer drastic impacts because of strict measures that has been made to mitigate the spread of virus globally also, all national and international flights has been stopped by aircraft companies because of low number of passengers(Henriques M. Will,2020). Because of shrinkage in industrial pollution there's reduction in environment pollution there's restriction in import export business, movement of ship and thus, decreases marine pollution. Noise pollution has been reduced 50% in Delhi during lockdown and noise level of Govindpuri metro station is reduced about 50-60Db(SK Sharma,2020).

Negative Environmental Effects

The generation of medical waste is increased globally due to the breakout of deathly virus that damage not only human health but also environment. In hospitals, the manage of used needles, gloves, masks etc. should be done properly to lower the infection. Also, disposal of the protective equipment i.e., hand gloves, face masks etc. creates infectious diseases, people due to lack of knowledge dump these wastes in open areas and thus destroys environment, this haphazard disposal of equipment block canal and thus affects environment pollution (Mamun M.A et al.,2020). The protective equipment that has been used to cure the virus is the main source for microplastic fiber and N-95 mask is made up of polypropylene and gloves, face shields, are made of Tyvek that releases harmful compound named dioxin that harms the environment(Okoffo E.D,2020). Thus, it is suggested to dispose off the hazardous medical waste properly if not done can increases the risk of disease transmission and exposure to the virus of waste workers. To reduce the pollution, it is necessary to save energy and conservation of natural resources.

Other Effects on the Environment

In pandemic, disinfectants is used on roads to reduce the level of COVID-19 by which species which are beneficial to natural environment has been affected thus creates ecological balance (Bhuiyan M.A.H,2016). By using chlorine virus can be prevented at utmost level.

Social

COVID-19 has not only affected economy and environment but has also attacked societies at a tremendous level. Outburst of COVID-19 destroys all kinds of population i.e., poor people, people with disabilities, older people, youth. Also, people who are homeless are more prone to virus. People not having access to running water, refugees, migrants, are also more prone to virus due to less employment due to movement restriction. Proper policies have been adopted to create equality, inclusion and global employment such as by giving social protection system to vanish social impacts.

CHAPTER 3. RESEARCH METHODOLOGY

For the methods used in any research work, the literature review is the best and appropriate way to understand and analyse the conceptual framework. In this report, I've analysed the concept of the supply chain through material collection and supply chain actions.

3.1 Material Selection

In material selection methodology, all the data which are related to the specific issue or research are collected through searching, collecting, and reading data referring to various literature reviews from many research papers and then sorting and sequencing them according to the user's need. In this method, we try to focus on that literature review that is to be collected for analyses of the specific issue that are well adequate and relevant to the topic.

3.2 Supply chain actions

The spread of the COVID-19 has disturbed the working of the complete supply chain, that actually provides less opportunities to explore in this area for researchers.

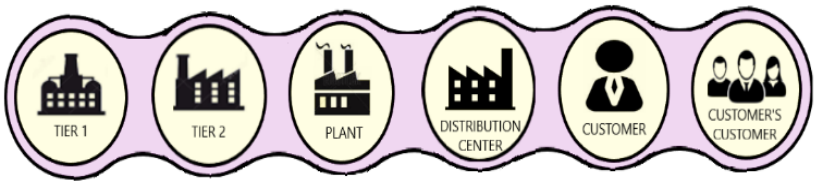


Figure 6. Supply chain recovery in corona times

STEP 1 (SUPPLIER T1 AND T2)

Creation of transparency:

First, find out complex points and beginning of supply. Search for risk interruption areas in tier 2 supplier. Alternative solutions are to be find out if suppliers are in

acutely affected areas. After finding of complex points, assessing of risk interruption from tier-2 supplier and further supplier can be done. In this step we can directly ask the questions from tier-1 firm like who are they and where their supplier are and thus creates information to know the disruptions in firms. To know the lead times and to analyse interruption risk manufacturers should involve with all suppliers of all tiers and form agreements and make plan for recovery.

STEP 2 (PLANT AND DISTRIBUTION CENTRE)

Optimization:

In this step calculate influence on performance and available resource capacity mainly workforce. Focus on safety and transparent communication with employees. According to available inventory schedule planning and analyse influence on performance of operations. Optimization of limited production according to human health, mankind, resources and opportunity cost or penalty.

STEP 3(Customer and Customer's customer)

Customer demand:

To know the required supply, work with sales and operations planning to get demand. Support direct to consumer channels of communication. By using internal databases estimate customer's customer.

PROJECT: IMPACT OF COVID-19 ON SUSTAINABILITY ENABLERS AND EVALUATION OF PERFORMANCE INDEX

GTA is a mathematical and systematic approach that has a hierarchical structure, maintains inter-relationship and interdependencies among attributes. Also, the advancement in graphs helps in the modelling and analysis of systems(Qasim Murtaza et al.,2016).Graph theory is a mathematical methodology which consist of digraph representation, matrix representation and permanent function. The permanent function is obtained in a as we obtain determinant except the fact that in a determinant a negative sign is present whereas in evaluating permanent function only positive sign is present. It has a set of objects i.e., V {v1, v2, …} called vertices, and other set E {e1, e2, …} and elements are called edges thus edge e_k is identified with an unordered pair (vi, vj) of vertices. We can represent graph by means of diagram in which the vertices are represented as points and each edge as a line segment joining its end vertices.

Digraph representation

A digraph is direction assigned graph used to represent the factors and their interdependencies in term of nodes and edges. The SCM digraph represents the Sustainability through its Nodes and edges. In proposed study, the graph-theoretic approach (GTA) is used to find out the performance index pre and during COVID-19 by considering attributes and sub-attributes. GTA is also used in the Indian mining industry to identify, classify, and ranked the barriers to the green supply chain. This approach is used to evaluate supply chain sustainability for small and medium-scale industries. Diagraph is the representation of vertices connected with edges. As nodes depict selection attributes. The Selection attribute is defined

as a factor that influences the best alternative selection decision. Conversion of diagraph into a square matrix called a relative importance, the off-diagonal elements depict the relative importance of one attribute over other and the diagonal elements depict the individual importance of attributes to the system or inheritance. The diagraph with respective matrix changes with change in number of attributes, a standard form of matrix function which is known as permanent functions is evaluated rather than the determinant of the matrix. Researchers preferred to evaluate the permanent function of a matrix rather than the determinant function of a matrix because some information may be lost due to the presence of negative signs in case of determinant of a matrix so in order to provide the complete information without any loss permanent function is evaluated (Rao and Padmanabhan, 2006).In general, evaluation of the permanent function of a M × M matrix A with attributes a_{ij} is performed as follows:-

$$Per(A) = \sum_{p} \prod_{i=1}^{N} a_i, P(i)$$

P(i) where the sum is overall permutations P. To calculate the permanent function value, a computer program for M × M matrix was written in C++ language. This program takes few minutes to run the program and computes the value of permanent function.

Application of GTA

- Supplier development program (Routroy et al., 2016)
- Supply chain network design problems (Pishvaee and Rabbani, 2011)
- Collaboration in between manufacturers (Anand and Bahinipati, 2012)

- Retailers of Indian apparel retail industry (Anand and Bahinipati, 2012)
- Selection of suitable supply chain strategy (Faisal et al., 2006)

GTA has been used in total quality management (Franceschini et al, 2006), total productive maintenance (Attri et al., 2014), machining (Jangra et al., 2011), remanufacturing (Sabharwal and Garg, 2013), process routing (Kato, 1995) and robotics (Rao and Padmanabhan, 2006). The GTA involves step by step methodology to find out the last result.

The detailed methodology of proposed method is illustrated below: -

Step: 1 Identify Attributes.

Step: 2 Identify the sub-attributes of each selected attribute. SBSC is to be used to select attributes and sub-attributes. SBSC is sustainable balanced scorecard used to measure system performance by selecting attributes and sub-attributes with triple bottom line aspects of sustainability.

Step: 3 Make the digraph representing attributes and then convert the graph into the matrix.

Table 1. Attributes and sub-attributes for the proposed study

Attributes	Sub-attributes	References
ECONOMIC(E)	i. Transportation(T)	IBEF, 2020a
	ii. Unemployment (UE)	Gopinath,2020
	iii. Education(E)	Nidhi singh et al., 2021
	iv. Labour(L)	ILO,2020
	v. Food Supply Chain (FSC)	Currie et al., 2020
	vi. Agriculture(A)	Shrestha et al., 2020
ENVIRONMENT(EN)	i. Increase in Medical Waste (MW)	Calma,2020
	ii. PPE disposal (PD)	Rahman et al., 2020
	iii. Less recycling waste (LRW)	Somani et al., 2020
	iv. Human loss (HL)	WHO,2020
	v. Increase Municipal Waste (IMW)	Van Doremalen et al., 2020
	vi. Air, water and soil pollution (AWS)	Yunus et al., 2020
SOCIAL(S)	i. Self-isolation (SI)	UN,2020
	ii. Older person (OP)	O'Neill N, et al..2020
	iii. The person with a disability (PWD)	Pai M,2020
	iv. Youth (Y)	Balvir singh tomar et al.,2020
	v. Sports (S)	Patrick shu hang yung et al.,2020
	vi. Researchers (R)	D. Bagli et al.,2020

Step: 4 For the weights of interrelationship or relative importance among attributes take views from experts using sustainable balanced scorecard (SBSC) taking suitable scale shown in table 3 and they represent off-diagonal elements of the matrix.

Table 2. The relative importance of attributes

Description	a_{ij}	$a_{ji} = 1 - a_{ij}$
Two attributes are equally important	0.5	0.5
One attribute (i) is slightly more important than the other (j)	0.6	0.4
One attribute (i) is strongly more important than the other (j)	0.7	0.3
One attribute (i) is very strongly important over the other (j)	0.8	0.2
One attribute is extremely important over the other	0.9	0.1
One attribute is exceptionally more important than the other	1	0

Table 3. Disposition option selection attribute

A qualitative measure of attributes	The assigned value of Di
Exceptionally low	0.0
Extremely low	0.1
Very low	0.2
Low	0.3
Below average	0.4
Average	0.5
Above average	0.6
High	0.7
Very high	0.8
Extremely high	0.9
Exceptionally high	1.0

Step: 5 Obtain diagonal elements or inheritance for the matrix as follows:

i. Each attribute is to be selected one by one and identify respective sub-attributes. Like, there are three attributes of sustainability in the proposed research, each attribute has six sub-attributes.

ii. Make a digraph for all the identified sub-attributes then convert the digraph into the matrix where off-diagonal elements represent the inter-relationship among sub-attributes.

iii. Take responses for weights of inheritance i.e., diagonal elements from a selected scale from the experts. In the proposed study, the scale present in Table 3 is used for the inter-relationship, and Table 4 is used for the inheritance.

iv. After taking the values of inheritance and interrelationship put the values in the matrix and compute the permanent function for the first attribute by using expression per(A). C++ Program can be used for computing the permanent function of the attributes.

v. Repeat the steps from 1 to 4 to compute the permanent function for all other two attributes.

Step: 6 Put the values of inheritance in the matrix and compute the permanent function of the selected scenario by using the expression per(A) or C++ program.

Step: 7 Compute the permanent function for each of the scenarios by repeating step 3 to step 6. This permanent function is referred to as the performance Index.

Step: 8 Select the most impacted scenario based on the sustainability performance Index of all the scenarios.

CHAPTER 4. CASE ILLUSTRATION

This section illustrates the step-by-step methodology as described to find out the performance index in the context of Indian business for pre and during COVID-19. Experts were selected who are involved in the area of environmental management and sustainability. As COVID-19 distorts the sustainability factors, in this study the three attributes i.e., economy, environment, and social with each of them having six sub-attributes have been taken with the expert's opinion. The calculation is performed to find out the performance index before and during the COVID-19. In the proposed research there are two scenarios, the first case deals with the impacts on sustainability factors before COVID-19, and the second case deals with the impacts on sustainability factors during COVID-19. Based on the expert's opinion, the selection has been performed.

Step:1 Selection of attributes i.e., Sustainability has three attributes which are economy, environment and social as shown in Table 2.
Step:2 Selection of sub-attributes for each selected attribute as shown in Table 2.
Step:3 Plotting of digraph depicting selected attributes and convert digraph into the matrix as shown in figure 7 the three attributes of sustainability.

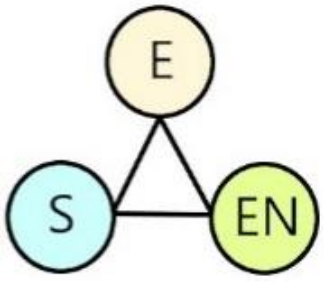


Figure 7. Diagraph of Sustainability Attributes

Step:4 Take the expert's opinion to put the values to off-diagonal elements by taking a suitable scale as shown in table 3. Here, the diagonal elements, inheritance is not written. These values are the permanent function that is to be calculated from sub-attributes matrices of each attribute.

SCENARIO 1 (Performance Index Matrix for pre covid)：

The matrix A is generated for the evaluation of permanent function for pre-covid-19 situation and off diagonal elements are taken from the table 3.

$$A = \begin{bmatrix} & E & EN & S \\ E & D_{11} & 0.7 & 0.4 \\ EN & 0.3 & D_{12} & 0.8 \\ S & 0.6 & 0.2 & D_{13} \end{bmatrix}$$

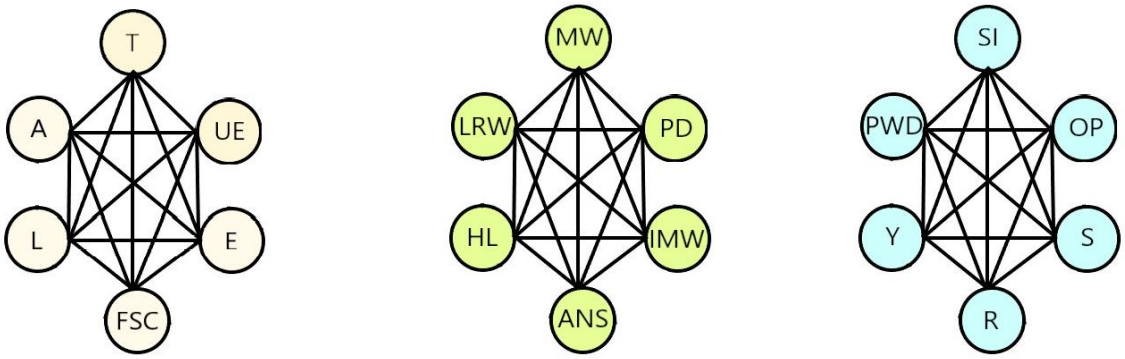
SCENARIO 2 (Performance Index Matrix for during covid):

The matrix B is generated for evaluation of performance index during covid-19 situation and off diagonal elements are taken from table 3.

$$B = \begin{bmatrix} & E & EN & S \\ E & D_{21} & 0.7 & 0.4 \\ EN & 0.3 & D_{22} & 0.8 \\ S & 0.6 & 0.2 & D_{23} \end{bmatrix}$$

Step:5 Compute the value of diagonal elements for scenario 1 and scenario 2 matrices by evaluating the permanent function of the sub-attributes matrices of each attribute by following sub-steps of step 5. Make a digraph for the sub-attributes representing six sub-attributes for each attribute, it contains six nodes corresponding to the six sub-attributes of each respective attribute as shown in figure 8. Also, inter-relationship among sub-attributes is shown by the directed edges. Then these diagraphs are converted into respective matrices. The off-diagonal elements values are taken from Table

3 based on experts' opinions. The diagonal element values for respective scenarios are taken from Table 5. The values shown in Table 5 are based on the group of expert's opinions, selected from Table 4. The matrices are shown in the following steps along with computation of permanent function for all three perspectives with two scenarios. For two scenarios computation of permanent function of sub-attributes of three attributes has been shown in the following matrices.



a) **b)** **c)**

Figure 8. Diagraph for sub-attributes i.e for all three attributes a) Economy b) Environment c) Social

Table 4 Values of diagonal elements of respective sub-attributes

Attributes	Sub-attributes	PRE COVID	DURING COVID
1. ECONOMIC(E)	i. Transportation(T)	0.7	0.4
	ii. Unemployment (UE)	0.5	0.9
	iii. Education(E)	0.4	0.9
	iv. Labour(L)	0.6	0.8
	v. Food Supply Chain (FSC)	0.8	0.6
	vi. Agriculture(A)	0.9	0.5
2. ENVIRONMENT(EN)	i. Increase in Medical waste (MW)	0.6	0.3
	ii. PPE disposal (PD)	0.5	1.0
	iii. Less recycling waste (LRW)	0.4	0.6
	iv. Human loss (HL)	0.8	0.6
	v. Increase Municipal Waste (IMW)	0.7	0.5
	vi. Air, water and soil pollution (AWS)	0.9	0.6
3. SOCIAL(S)	i. Self-isolation (SI)	0.2	0.8
	ii. Older person (OP)	0.4	0.5
	iii. Person with disability (PWD)	0.5	0.6
	iv. Youth (Y)	0.7	0.9
	v. Sports (S)	0.8	0.4
	vi. Researchers (R)	0.8	0.5

CHAPTER 5. RESULT AND DISCUSSION

The step 5 , from the economic perspective, the following matrix is obtained as follows for scenario 1 i.e., impact on Indian business for pre covid-19 situation here the values of the diagonal elements are taken from table 5 i.e., 0.7,0.5,0.4,0.6,0.8, and 0.9. The value after evaluating the permanent function of the matrix comes out is 9.35404 and is D_{11} for scenario 1 matrix as shown.

MATRIX FOR ECONOMIC PERSPECTIVE (FOR PRE COVID)

$$\begin{bmatrix} \_ & T & UE & E & L & FSC & A \\ T & & 0.3 & 0.6 & 0.4 & 0.7 & 0.4 \\ UE & 0.7 & & 0.8 & 0.6 & 1 & 0.7 \\ E & 0.4 & 0.2 & & 0.3 & 0.6 & 0.3 \\ L & 0.6 & 0.4 & 0.7 & & 0.8 & 0.6 \\ FSC & 0.3 & 0 & 0.4 & 0.2 & & 0.3 \\ A & 0.6 & 0.3 & 0.7 & 0.6 & 0.7 & \end{bmatrix} = 9.35404$$

From the environment perspective, the following matrix is obtained as follows for scenario 1 i.e., impact on Indian business for pre covid-19 situation, here the values of the diagonal elements are taken from table 4 i.e.,0.6,0.5,0.4,0.8,0.7 and 0.9. The value after evaluating permanent function of the matrix comes out is 10.0162 and it is D_{12} in the scenario 1 matrix as shown.

MATRIX FOR ENVIRONMENT PERSPECTIVE (FOR PRE-COVID)

$$\begin{bmatrix} \_ & MW & PD & LRW & HL & IMW & ANS \\ MW & & 0.3 & 0.4 & 0 & 0.3 & 0.4 \\ PD & 0.7 & & 0.6 & 0.3 & 0.4 & 0.2 \\ LRW & 0.6 & 0.4 & & 0.2 & 0.3 & 0.3 \\ HL & 1 & 0.7 & 0.8 & & 0.6 & 0.5 \\ IMW & 0.7 & 0.6 & 0.7 & 0.4 & & 0.5 \\ ANS & 0.6 & 0.8 & 0.7 & 0.5 & 0.5 & \end{bmatrix} = 10.0162$$

From the social perspective, the following matrix is obtained as follows for scenario 1 i.e., impact on Indian business for pre covid-19 situation, similarly the values of the diagonal elements are taken from table 4. The value after evaluating permanent function of the matrix comes out is 7.00126 and is D_{13} in the scenario 1 matrix.

MATRIX FOR SOCIAL PERSPECTIVE (FOR PRE-COVID)

$$\begin{bmatrix} & SI & OP & PWD & Y & S & R \\ SI & & 0.4 & 0.3 & 0.7 & 0.5 & 0.7 \\ OP & 0.6 & & 0.4 & 0.8 & 0.7 & 0.8 \\ PWD & 0.7 & 0.6 & & 0.8 & 0.7 & 1 \\ Y & 0.3 & 0.2 & 0.2 & & 0.4 & 0.6 \\ S & 0.5 & 0.3 & 0.3 & 0.6 & & 0.7 \\ R & 0.3 & 0.2 & 0 & 0.4 & 0.3 & \end{bmatrix} = 7.00126$$

Hence, for scenario 1, the values obtained by calculating the permanent function of sub-attributes matrices are as follows D_{11}=9.35404, D_{12}=10.0162, D_{13}=7.00126

For scenario 2, the similarly same procedure is to be followed by taking diagonal element values from table 4.

Now, the matrix for scenario 2 has been shown as follows.

From the economic perspective, the following matrix is obtained as follows for scenario 2 i.e., impact on Indian business during covid-19 situation, here the values of the diagonal elements are taken from table 4 i.e., 0.4,0.9,0.9,0.8,0.6, and 0.5. The value after evaluating the permanent function of the matrix comes out is 10.3878 and is D_{21} for scenario 2 matrix as shown.

MATRIX FOR ECONOMIC PERSPECTIVE (DURING COVID)

$$\begin{bmatrix} \_ & T & UE & E & L & FSC & A \\ T & & 0.3 & 0.6 & 0.4 & 0.7 & 0.4 \\ UE & 0.7 & & 0.8 & 0.6 & 1 & 0.7 \\ E & 0.4 & 0.2 & & 0.3 & 0.6 & 0.3 \\ L & 0.6 & 0.4 & 0.7 & & 0.8 & 0.6 \\ FSC & 0.3 & 0 & 0.4 & 0.2 & & 0.3 \\ A & 0.6 & 0.3 & 0.7 & 0.6 & 0.7 & \end{bmatrix} = 10.3878$$

From the environment perspective, the following matrix is obtained as follows for scenario 2 i.e., impact on Indian business during covid-19 situation, here the values of the diagonal elements are taken from table 4 i.e., 0.3,1.0,1.6,0.6,0.5, and 0.6. The value after evaluating the permanent function of the matrix comes out is 11.2526and is D_{22} for scenario 2 matrix as shown.

MATRIX FOR ENVIRONMENT PERSPECTIVE (DURING COVID)

$$\begin{bmatrix} \_ & MW & PD & LRW & HL & IMW & ANS \\ MW & & 0.3 & 0.4 & 0 & 0.3 & 0.4 \\ PD & 0.7 & & 0.6 & 0.3 & 0.4 & 0.2 \\ LRW & 0.6 & 0.4 & & 0.2 & 0.3 & 0.3 \\ HL & 1 & 0.7 & 0.8 & & 0.6 & 0.5 \\ IMW & 0.7 & 0.6 & 0.7 & 0.4 & & 0.5 \\ ANS & 0.6 & 0.8 & 0.7 & 0.5 & 0.5 & \end{bmatrix} = 11.2526$$

From the social perspective, the following matrix is obtained as follows for scenario 2 i.e., impact on Indian business during covid-19 situation, here the values of the diagonal elements are taken from table 4 i.e., 0.8,0.5,0.6,0.9,0.4, and 0.5. The value after evaluating the permanent function of the matrix comes out is 7.68257 and is D_{23} for scenario 2 matrix as shown.

MATRIX FOR SOCIAL PERSPECTIVE (DURING COVID)

$$\begin{bmatrix} \_ & SI & OP & PWD & Y & S & R \\ SI & & 0.4 & 0.3 & 0.7 & 0.5 & 0.7 \\ OP & 0.6 & & 0.4 & 0.8 & 0.7 & 0.8 \\ PWD & 0.7 & 0.6 & & 0.8 & 0.7 & 1 \\ Y & 0.3 & 0.2 & 0.2 & & 0.4 & 0.6 \\ S & 0.5 & 0.3 & 0.3 & 0.6 & & 0.7 \\ R & 0.3 & 0.2 & 0 & 0.4 & 0.3 & \end{bmatrix} = 7.68257$$

Hence, for scenario 2, the values obtained by calculating the permanent function of sub-attributes matrices are as follows D_{21}=10.3878, D_{22}=11.2526, D_{23}=7.68257.

STEP 6 and 7: Evaluation of performance index

Now put these diagonal elements for both the scenarios named as D_{11}, D_{12} and D_{13} AND D_{21}, D_{22} and D_{23}values which are calculated in step 5 by finding the permanent

function of the sub-attribute's matrix of each attribute matrix for both the scenarios into the attribute matrix of both scenarios mentioned in step 4, and compute the permanent function to get the values of the performance index for both the scenarios.

$$A = \begin{bmatrix} & \text{E} & \text{EN} & \text{S} \\ \text{E} & 9.35404 & 0.7 & 0.4 \\ \text{EN} & 0.3 & 10.0162 & 0.8 \\ \text{S} & 0.6 & 0.2 & 7.00126 \end{bmatrix}$$

$$A = 661.692$$

$$B = \begin{bmatrix} & E & EN & S \\ E & 10.3878 & 0.7 & 0.4 \\ EN & 0.3 & 11.2526 & 0.8 \\ S & 0.6 & 0.2 & 7.68257 \end{bmatrix}$$

$$B = 904.35$$

The value of the performance index for scenario 1 (pre-covid-19) is 661.692 and the value for scenario 2 (during covid-19) is 904.35.

The radar chart representing all values for both scenarios. The environment is highly impacted by COVID-19.

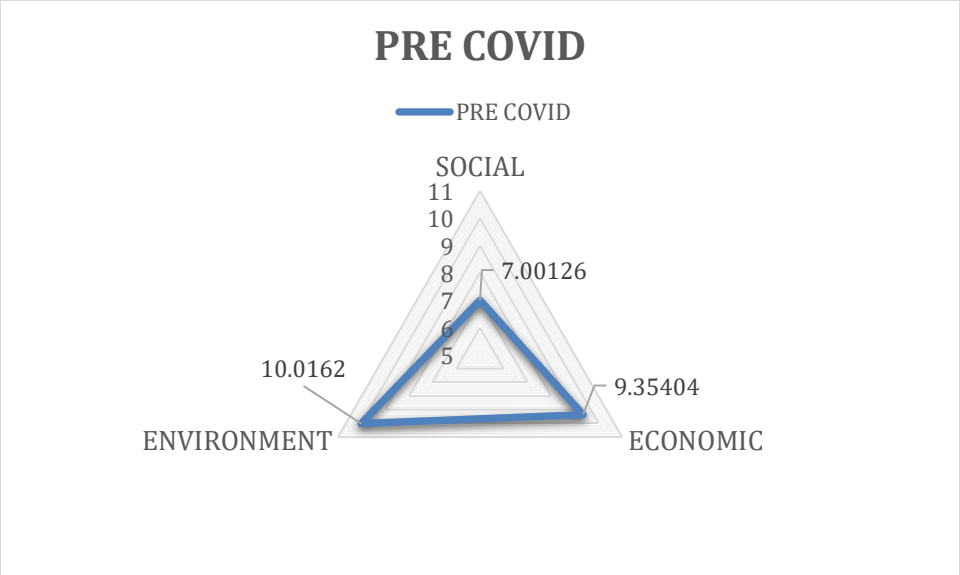


Figure 9 Radar chart showing pre covid attributes

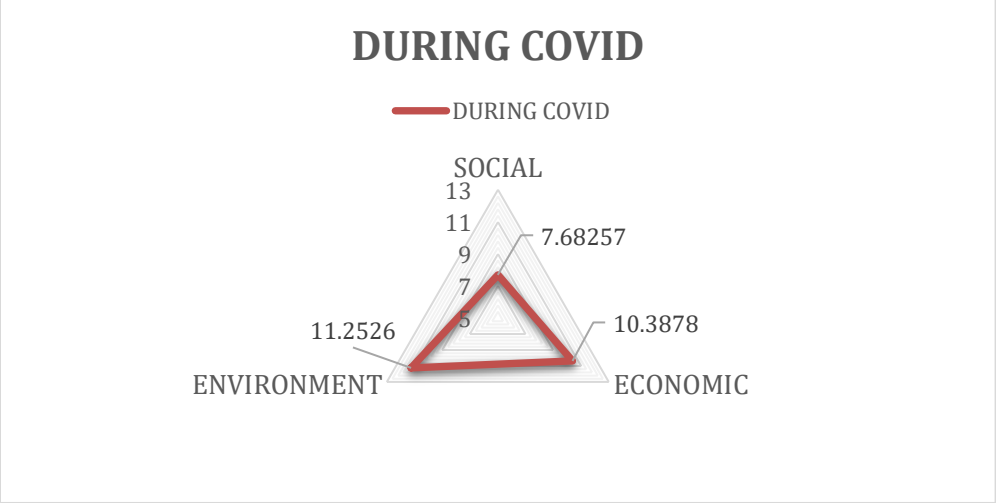


Figure 10 Radar chart showing during covid

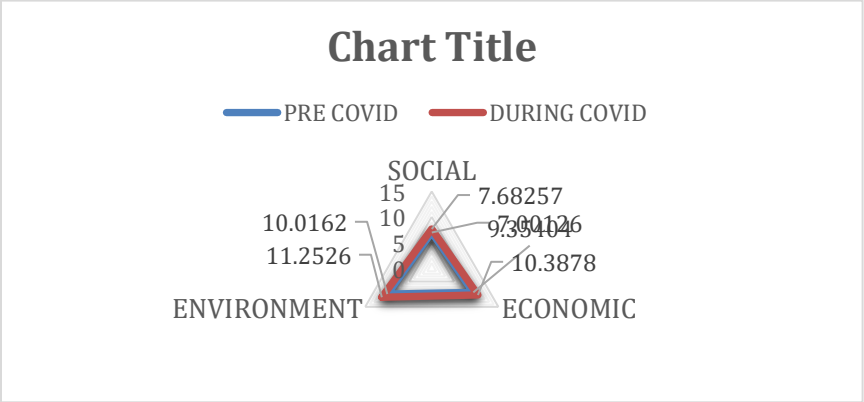


Figure 11 Radar chart showing all three attributes

Step:8 Selection of scenarios

Based on the performance index determined above, during COVID-19 the impact is more on sustainability enablers as compared to pre-COVID-19. We can conclude that during COVID-19 the impact on sustainability enablers i.e., economy, environment and social perspectives on Indian buisnesses is more as compared with pre COVID-19.

Hence, Scenario 2 > Scenario 1 in order of impact of COVID-19 on sustainability enablers.

CONCLUSION

Pandemic leads to disturbance of sustainable supply chain as it brings insubstantiality and improper functionality in every area. Therefore, it becomes important to study the impact of COVID-19 on sustainable supply chain enablers i.e., economic, environmental and social. In chapter 1 discusses the covid-19 disturbances and supply chain. Chapter 2 discusses the literature reviews of covid-19, definition of sustainable supply chain, and factors that impacts covid-19. study provides the analyses of economic, environmental and social parameters affecting sustainability. Chapter 3 discusses the research methodology which involves the introduction of graph theory and comparison based on the impact of COVID-19(pre and during) on sustainability enablers with the help of GTA for the analysis, taking economic, environmental and social as attribute following their respective sub-attributes. Chapter 4 involves the case illustration in which the attributes matrices are generated according to scenarios using graph theory i.e., pre and during covid-19. Chapter 5 involves calculations based on preferences and weightage to each attribute and the sub-attribute that are provided with the help of experts and literature reviews thus result and discussions has been performed. The framework was developed using two scenarios that are pre-covid and during covid, attributes that are economic, environmental and social, and these attributes were followed by their respective sub-attributes. The permanent function to find out the performance index was evaluated with the help of the C++ program. If we consider the pre-covid scenario then the attribute environment was affecting the sustainable supply chain and in the during-covid scenario, the attribute that was affecting the sustainable supply chain is the environment only as calculated from GTA. This thesis provides economic, environmental, and social impacts in context of Indian business that occurred pre and during COVID-19.

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