

# Enhancing Pharmaceutical Supply Chain Resilience: A Study of Pharmaceutical Companies in Multiple Geographies

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## ABSTRACT

**Background:** Pharmaceutical businesses had enormous difficulties in product distribution during COVID-19, and the solution to this perpetual issue is a resilient supply chain. **Aim:** The study aims to understand the vulnerabilities to which it subjected the pharmaceutical product distribution supply chains during the COVID-19 pandemic and further develop an adaptive model through which the pharmaceutical product supply chain can enhance its resilience capabilities. **Materials and Methods:** The conceptual model is developed for the supply chain of pharmaceutical companies based on the literature survey, and then the conceptual model is explored through factor analysis. Researchers have developed a validated model after a statistical analysis using Cronbach's alpha. Subjective analysis has concluded that the pharmaceutical supply chain's resilience is driven by factors such as "trade cost," which comprises transport cost, business practices, and raw material sourcing cost; "shock propagation," which comprises country-specific shocks, production shocks, and policy changes; and "technological infrastructure bottleneck," which relates to the availability of cold chain storage warehouses and refrigerated transport vehicle facilities. **Results:** An empirical model pertaining to supply chain resilience may be further studied with different geographies, like Pune, Hyderabad, and Delhi NCR, for the purpose of generalizing the study. **Conclusion:** The identified major factors were trade cost, shock propagation, and technological infrastructure bottlenecks. The sensitivity of the issue under investigation required a personal touch to the survey, as the COVID-19 pandemic had left these respondents emotionally vulnerable. As COVID-19 is the recent catastrophe that has hit humanity, it has made the pharmaceutical product distribution channel vulnerable during the pandemic. This difficult time of pandemic has really tested the pharmaceutical products' supply chain capabilities as well.

**Keywords:** Supply Chain Resilience, Trade cost, Shock propagation, Technological infrastructure bottleneck.

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## INTRODUCTION

The COVID-19 pandemic has hit the world since 2019, which has affected not only the normal lives of people worldwide but also the economies of the countries. To recover from this pandemic, many pharmaceutical companies concentrated their research and development efforts towards the development of vaccines, and some companies achieved success in developing the COVID-19 vaccine. Although the greater challenges the companies faced were to first produce the needed medicines in large quantities and then supply the medicines safely to the end user under COVID-19 restrictions, The newer facets of challenges to which the supply

chain has been subjected have been as complex as political diplomacy, lockdown restrictions, raw material availability, getting cold storage and cold transport technologies, as well as finding a workforce to work during the tough time.

Thus, the study focuses on understanding the vulnerabilities in the pharmaceutical product distribution network and aims to develop an adaptive model through which the pharmaceutical product supply chain can enhance its resilience capabilities.

## Literature review

Shortage of medicine supplies is a major issue. Companies can expect and predict the shortages through demand forecasting, but challenges lie in avoiding shortages of medical supplies. Resilient supply chain has certain answers to it, such as sourcing the medicine from several suppliers and maintaining buffer inventory, but this state of resilience in supply chain can be



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achieved through shared responsibilities by value chain partners and with effective control of supply chain activities.<sup>1</sup>

Though the above is true for managing usual medicine supplies, certainly managing the medicine supply chain during the COVID-19 phase has been much more challenging. Some challenges pointed out in the research studies are the risks associated with channel partners, regulatory interventions, political tumult, and disputes amongst channel partners, government guidelines, and financial uncertainty.<sup>2</sup>

Supply chain resilience can be defined as an inherent operational efficiency that helps the supply chain absorb the impact of disruption and get back into its healthy shape. The research also states that the key to achieving supply chain resilience is through the synchronization of channel partners and the capability of the supply chain to identify and mitigate the risks.<sup>3</sup>

The sudden emergence of the COVID-19 virus has affected almost all supply chains adversely. In such an adverse scenario, coming up with vaccines as new products or supplying emergency medicines and establishing supply chains for the same has been a risky situation, with the risk of huge monetary investments in research and development activities, the efficacy of vaccines, acceptance by regulatory authorities, acceptance by various countries' governments, political diplomacy, finding supply chain partners, finding correct labour, newer technologies, customer acceptance, and balancing demand and supply among the challenges faced by the vaccine supply chains. In transportation, LTL (less than truckload) problems have been identified as commerce has been restricted during the pandemic and fuel prices in India have been high. Time-bound delivery dates have led to an increase in trade costs but have also created a technological infrastructural bottleneck, which is understandable with the example of COVID-19 vaccines, as stringent temperature-controlled vehicles and cold storages are required for the movement of vaccines.

The outbreak of COVID-19 and related lockdowns have adversely affected interdependent global supply chains. Which shows that the government's policy decision regarding restriction of interdependent global supply chains. which shows that the government's policy decision regarding restriction of men's and material's movement has been a shock to medicine production units.<sup>4</sup> The COVID-19 pandemic had curtailed the movement of people and goods and the manufacturing activities.<sup>5</sup> During the early phase of the pandemic, when India entered the state of lockdown on March 24<sup>th</sup>, ventilator and hydroxychloroquine and hand sanitizers were included in a prohibited list for export. Only exports on humanitarian grounds are conducted and supervised by the Ministry of External Affairs.<sup>6</sup> Although India imports approximately 80% of its bulk drug requirements from China, this drug is then converted into consumable formulations in the form of tablets, capsules, syrups, and injections. Indian

pharmaceutical companies face fierce competition from the Chinese pharmaceutical sector. Thus, it is required to provide a viable environment to small and medium-scale pharmaceutical companies in India by formulating industry-supportive government policies, manufacturing clusters, economic incentives, cold storage infrastructure, subsidies on refrigerated vehicles, subsidies on air transportation of medicines, and the revival of public sector pharmaceutical companies. The above measures may help to close the demand and supply gap in medicine supplies. Until there is a dependence on imports for approximately 80% of bulk drug requirements, the Indian pharmaceutical companies may remain under the influence of shock propagation.<sup>7</sup>

## Theoretical Background

### Trade cost

Pharmaceutical products are classified in the essential goods category. Pharmaceutical products are manufactured domestically as well as imported from other countries. The trade data from 68 countries revealed that the impact of COVID-19 has negatively impacted the trade. This is due to government policies that impacted trade group understandings, resulting in curbs on exports. Countries may have achieved resilience in pharmaceutical supply chains by introducing public spending programs. It has been noticeable that the government's attention has been shifted to the formulation of vaccines and pharmaceutical products. This has called for new drug development policies that may have helped reduce trade costs.<sup>8</sup>

Impact of COVID-19 on bilateral trade suggests that there has been a change in the way countries do business. The countries should try to become self-sufficient in terms of supplying the essential commodities through a local network of suppliers, which invariably will reduce the imports. Another way to reduce trade costs is through economic negotiation with supplying countries as well as reducing taxes on imports of goods that fall under the "essential" category. The pandemic has led to a drop in exports, a crash in share markets, and a negative impact on foreign direct investment, which has made trade costs more challenging for supply chains to bear. Researchers advocated that the sudden decrease in the country's GDP, currency exchange rate, and political changes across the globe were amplified severely due to the pandemic. The study uncovered that COVID-19 led to underutilization of capital, a decline in manufacturing output, a rise in production costs, and inflation in export-import trade costs.<sup>9</sup>

During the pandemic, there has been enormous loss of human life, which has impacted social, economic, and political disruptions. The COVID-19 pandemic has severely impacted economies, and the study revealed that there is a negative association between the COVID-19 pandemic and trade. The role played by governments

of different countries regarding vaccination has been a crucial decision to mitigate the risk of a pandemic.<sup>10</sup>

A preliminary assessment reported that globally, governments were trying to contain the spread of the COVID-19 pandemic. The preventive actions taken by the national governments globally had a significant impact and immediate repercussions on national as well as world economies. Previous experiences with similar pandemic situations have shown a significant increase in human costs. The pandemic has also led to a reduction in the levels of foreign direct investment as, during the uncertain phases, companies have been deferring investments. The synchronization of companies' value chains and coordination have been crucial to reducing the rising trade costs during the pandemic.<sup>11</sup>

Through the COVID-19 pandemic, the prices of perishable goods with a short shelf life have been severely impacted and the common consumer's landed up to pay more as a result. Perishable goods producers also found difficulties in reaching their customers and were left with no choice other than to dump their respective produce. Online delivery businesses flourished during the time of the pandemic and tried to provide goods to customers in a cost-effective way.<sup>12</sup>

In the duration of the pandemic, consumers postponed their plans to purchase durable goods, and companies differed their investment plans due to a high level of uncertainty. The manufacturing firms had also reduced their inventory levels in fear of falling demand. The trade cost had been rising during the COVID-19 pandemic due to travel and export restrictions for pharmaceutical products, and medical equipment that had been augmented in different sectors.<sup>13</sup>

To gain further insights regarding trade costs during the pandemic, the following parameters have been studied.

### **Wage Difference**

The pandemic had pushed humanity into very uncertain situations where businesses were struggling to survive. Work from home was not possible in those kinds of businesses, the employees lost their jobs or had to face a severe pay cut. Invariably, the logistics and supply chain sector are called the backbone of the economy of any nation. The businesses related to logistics and supply chain sectors were essential to be kept open. The challenges that were faced were that employees were refusing to go to work, and some of the employees resigned and took a career break. These scenarios lead to incremental risk have impacted both the availability of the workforce as well as the rise in the salaries of the employees. To restrict the spread of virus, employees were asked to work from home during the pandemic, but not many of them were in occupations that could be supported by working from home. The workforce who had to report to the office during the pandemic, as they were involved in product supply chain activities such as transportation, land

container depot operations, and custom bonded warehouse operations, were seeing an incremental increase in their wages.<sup>14</sup>

Lockdown curbs have impacted wage distribution, which has led to inequality in the payment of wages. The disparity mainly continued in the workforce, which is made up of members of lower income groups subjected to poverty. The qualified workforce with a higher education level has also been affected, but in a different way. In some professions people cannot be continued from home had to live up to their savings, those who can operate from home continued to earn, and those who had to visit the company to run essential services, seeing the risk involved, started earning higher sums. The researchers also pinpointed that education has been a key dimension in determining an employee's vulnerability to the pandemic.<sup>15</sup>

### **Transportation cost**

Restrictions on domestic and international travel were the initial worldwide response to the pandemic, which had an immediate effect on trade in goods. The limitations have an effect on the increase in transportation expenses. Additionally, during this time, the worldwide air cargo capacity fell by 26%, which also contributed to an increase in transportation costs. Governments all throughout the world have provided some assistance for the trade of vaccinations, medications, and related goods, but by offering incentives to labour throughout the epidemic, community health workers were also got assistance. The supply chain businesses, who were in charge of distributing drugs and medical supplies, might have done the same thing. The cost of pharmaceutical labour has undoubtedly grown because of the compensation given to the employees.<sup>16</sup>

### **Raw materials sourcing cost**

Market conditions are the driving forces of the prices of commodities. Recently, due to stringent global demand, oil prices have gained upward trends since November 2020. The upward trend contributes to 58% of the rise in oil prices. Shortages of shipping containers have been seen globally, which has led to shortages of supplies. The non-tariff costs due to special arrangements made during the pandemic period have added to the cost of the imported raw materials. The cost of commodities like industrial metals is rising sharply. Production losses are impacting the production of polymers. Shipping costs have also increased four times compared to previous costs. So has the packaging cost.<sup>17</sup>

### **Shock propagation**

#### **Country specific shocks**

The COVID-19 pandemic has adversely impacted the pharmaceutical sector. The pharmaceutical sector has also taken a hit in terms of required chemical raw materials, packaging, and shipping costs. The short-term impact on the pharmaceutical

sector includes changes in demand, shortages of supplies, regulatory changes, a shift in the way of communicating, and higher research and development costs. Long-term impacts will include delays in approval and a national self-sustaining pharmaceutical movement.

### **Production shocks**

Just before COVID-19 breakout, two major shocks had hit the international trade operations: The first shock was the trade war between China and the US., and the second shock was that the trade market had been tumbling. The COVID-19 pandemic has led to the pairing of centrally located trading collaborators. The governments introduced additional tariffs, which have made manufacturing, distribution, offshore, and cross-border operations come to a halt. The trade war and curbs on exports of medicines and food commodities have challenged cross-border trade. The trade competition between countries has impacted the rise of tariffs relevant to global trade. The damaging impact of COVID-19 lockdown and the increase in tariff rates call for a resilient supply chain eco system for pharmaceutical supply chains.<sup>18</sup>

The COVID-19 outbreak and lockdown have seriously impacted normal operations and manufacturing activities. The financial markets were also subjected to massive shocks. The research also indicates that manufacturing firms with flexible operations had better stock performance than those with rigid operations. The severity of COVID-19 was less for the organizations that had more fixed assets. The research also indicates that those firms that operate with production flexibility have suffered less negative impact from COVID-19 breakout and subsequent lockdown.<sup>19</sup>

Just in time, manufacturing strategies were followed by the manufacturing firms to optimize their supply chain by keeping the lowest possible inventory in their production system. These low levels of inventories have helped the production firms to cut their operating costs. This reduction of manufacturing cost leads to potential savings, which helps to attain profitability. The "just in time" concept has been very fruitful during normal times. Due to this approach, today's supply chain does not have backup supply chains, but it was not suitable during the pandemic times, as this has led to major product shortages. Supply chains in the pandemic scenarios are either too fragile or too rigid.<sup>20</sup>

To achieve healthcare goals, local production of pharmaceutical products has been a priority in developing economies. The governments are providing favorable conditions manufacturing of pharmaceutical products locally. But the challenge for local manufacturers is to become cost-effective pharmaceutical manufacturers. Support for setting up factories helps boost pharmaceutical production. Moreover, if the right conditions and support are provided, the developing countries will be able

to have a healthy pharmaceutical manufacturing sector that will not only fulfil the nation's demand but will also contribute to exports.<sup>21</sup>

Travel restrictions and lockdown during the COVID-19 pandemic had led to disruption of transportation, which has severely impacted the supply chains. The products that were outsourced and used as raw materials for production were finding it difficult as well as towards the dispatch of finished products. Similar production shocks have been suffered by pharmaceutical manufacturers, as many pharmaceutical companies rely on countries like China for their supplies. An Indian company's sources estimate that it imports about 60 percent of its active pharmaceutical ingredients from China for formulations' production.

Pandemic has uncovered such dependence on the pharmaceutical sector for raw material supplies. The pharmaceutical production shocks are caused by supply shortages, export restrictions, lockdowns, non-utilization of available production capacity, and human resource shortages.<sup>22</sup>

### **Policy changes**

The COVID-19 pandemic has been a challenging phase as the healthcare sector and pharmaceutical companies have been struggling to provide health care services to the patients. The COVID-19 has not only led to revisit of government policy but has also tested the strength of the country's healthcare infrastructure.<sup>23</sup> The government was forced to permit the essential category of work to continue. Differentiating between essential and non-essential activities has severely impacted the income gain of the individuals. The lockdown has been a temporary cause of disruption in supply chain.<sup>24</sup>

### **Technological Infrastructure Bottleneck**

#### ***Cold storage warehouses and b. Refrigerated transport vehicles***

The vaccination campaigns demanded the movement of COVID-19 vaccines under temperature control, which led to the requirement for the development of cold storage and material movement infrastructure. Pandemic led to an increase in storage capacity requirements at national and subnational levels to support the COVID-19 immunization program.<sup>25</sup>

The last mile of vaccine delivery has been challenging. Micro-level solar-powered cold storages were developed, which helped with the last-mile delivery of vaccines.<sup>26</sup> There has been an increase in the number of refrigerated vehicles during the pandemic. The challenges were to control the transportation cost of reefers as fuel consumption has been very high. Hybrid diesel-solar trucks and electric vehicles were used with installed refrigeration technology.<sup>27</sup>



**Table 1: Variable under Study.**

Factor	Number of Method	Nature of Questions
Rising Trade Costs	5	Wage difference, transport cost, Raw Material Sourcing Cost
Information Shock Propagation	12	Country specific Shocks, Production Shocks, Policy Changes
Technological Infrastructure bottleneck	7	Cold Chain Storage Warehouses, Refrigerated Transportation vehicles, Intellectual property rights and know- how

The distribution of vaccines has been possible because of the willingness of the supply chain companies to adopt new refrigeration technologies.<sup>28</sup>

### Intellectual property rights

Pandemic had led governments across the world to adopt ad hoc intellectual property rules haphazardly. The authors endorse the idea that humanity should learn from the pandemic and prepare more stringent and resilient systems for safeguarding intellectual property rights.<sup>29</sup>

Governments across the world should follow a cooperative strategy and share intellectual property with each other to overcome situations like pandemics.<sup>30,31</sup>

### Supply chain resilience

Supply chain resilience essentially means creating a flexible and shockproof supply chain that is immune to internal and external shocks. During COVID-19, companies tried to achieve supply chain resilience by trying to eradicate hurdles in transportation and managing the supply chain by trying to establish supply chain command centers.<sup>32</sup>

Healthcare product supply chains have been tested to the breaking point during pandemic restrictions. Risk managers had very limited information regarding how to tackle a pandemic scenario. The supply chains have suffered from demand shocks, stockouts, and bullwhip effects; this has highlighted the importance of supply chain resilience in health care-related product supply chains.<sup>33</sup>

## MATERIALS AND METHODS

Researchers have used primary and secondary methods of data collection in this study. The major aim of this study is to find out the factors that affect the supply chain vulnerability of pharmaceutical companies. The researchers have designed a questionnaire to identify the factors influencing the supply chain

of pharmaceutical companies based in Pune, Hyderabad, and Delhi NCR. From the period of October 2020 to May 2021, a face-to-face survey of 210 companies was conducted. The paper recognizes that there are a varied range of causal factors that affect the supply chain resilience of pharmaceutical companies, and this paper primarily focuses on the readiness of the supply chain of pharmaceutical companies in the pandemic scenario, where each company is under pressure to supply the medicines and vaccines in a shorter span of time.

The researchers deemed it essential to conduct face-to-face interviews considering the non-responsiveness of emails, as 49% of the pharmaceutical companies' respondents were not tech savvy. The researchers recognized that the sensitivity of the issue under investigation required a personal touch to the survey, as the COVID-19 pandemic had left these respondents emotionally vulnerable.

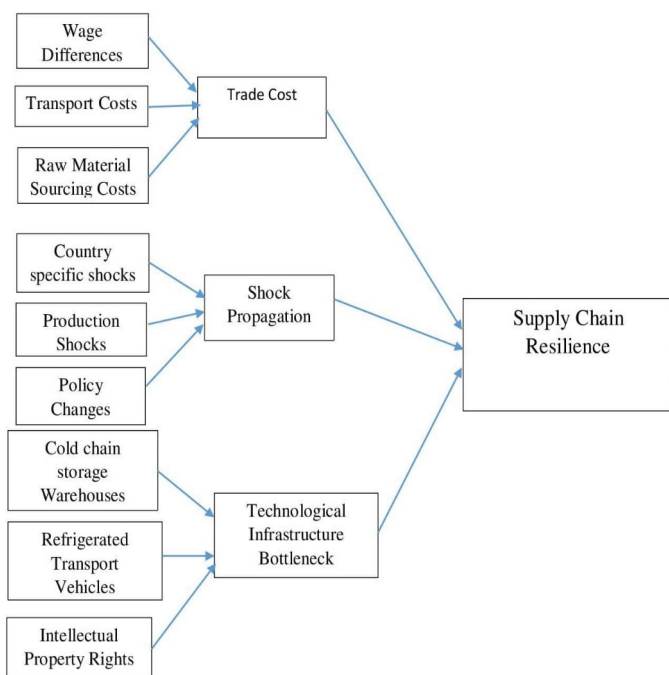
### Rationale of the Study

This paper is an attempt to identify the loopholes or factors that are affecting the supply chain of pharmaceutical companies. Further, after identification, researchers have put forth validated measures to make the supply chain more resilient.

The researchers designed a questionnaire to identify the variables that are important for the supply chain vulnerability of pharmaceutical companies. These included trade-related cost factors, the shocks encountered by the supply chain during the pandemic, and shortcomings in the technological infrastructure of our country. The detailed description of the factors is given in Table 1.

Convenience and purposive sampling are used to collect the samples. The researchers have targeted pharmaceutical companies in the Pune, Hyderabad, and Delhi-NCR regions for assessing the real-time difficulties faced by these companies. Through an extensive literature survey, researchers have conceptualized a model, which is substantiated by a field survey of 210 companies and a focus interview of selected respondents from Pune, Hyderabad, and Delhi NCR companies (Figure 1). Researchers have presented the validated model, which is much more foolproof as the model is validated both quantitatively and qualitatively. First, the quantitative validation is done by factor and reliability analysis; personal observations of a few selected employees are considered a mark of qualitative validation.

After studying the local geographical factors, input from the pharmaceutical associations, insights from the research papers, and local news articles, the researchers decided on the target companies within the city. The researchers acknowledged that the supply chain of pharmaceutical companies has a lot of strain points, and the situation changes from a small-scale company to a large-scale company. Thus, the survey may not represent the entirety of national or international pharmaceutical companies.



**Figure 1:** Conceptual Model.

It provides valuable cross-sectional insights into the crisis and pressures facing pharmaceutical companies in order to be agile and resilient during and after pandemic situations.

### Empirical Model

After considering the actual hard-core facts of pharmaceutical companies, the issues faced could be categorized as inputs like i) rising trade costs. ii) shocks faced by supply chain companies; iii) technological infrastructure bottlenecks; and consequently, pictured here as an output of the models are: (i) diversification of networks regarding suppliers and clients; (ii) supply chain visibility; and (iii) order fulfilment within time.

The researchers have conceptualized a supply chain resilience model based on the literature review and the reports of the pharmaceutical companies in three geographical locations, as shown in Figure 1.

### Research Design

The design of this research is of an exploratory nature since the researchers are trying to find out the variables associated with the supply chain resilience of pharmaceutical companies.

### Objectives

To analyze the supply chain resilience of pharmaceutical companies in the Pune region with the following three input parameters: Rising trade costs, shock propagation, and technological infrastructural bottlenecks.

To develop a validated model after substantiating the factors identified through factor and reliability analysis.

### Data Collection

The researchers have used both primary and secondary methods of data collection. Researchers have collected primary data through a survey of 210 companies, and for secondary data, they have considered the research papers published up to the last 5 years with a high level of quality and more citations. The 210 pharmaceutical companies were contacted and a questionnaire was administered face-to-face. The respondent's details are given in Table 2.

As the aim of this study is to analyse the supply chain resilience of pharmaceutical companies, researchers have tried to contact more senior-level employees because they are the ones who strategize the supply chain to combat the risk and try to make it more vulnerable. The conceptual model considered here in this research comprises the three broad factors, which are again subdivided into three categories.

### RESULTS

The collected data of 210 pharmaceutical companies from different areas of Pune, Hyderabad, and Delhi NCR was analyzed with the help of SPSS. The respondents have considered three different geographies, viz., Pune, Hyderabad, and Delhi NCR, to make it a more generalized study. The researchers have conducted an exploratory factor analysis (EFA) to check which factors are associated with the supply chain resilience of Pune pharmaceutical companies. The principal component analysis with oblique rotation method is applied to the data of 210 pharmaceutical companies. After running the factor analysis, the Kaiser-Meyer-Olkin (KMO) value achieved here is 0.75, which shows that the sample size taken in the study is adequate to do the statistical test. The cutoff value of Cronbach's alpha (0.52 and above) is considered a measure of construct validity, and the corrected item-total correlation score is used to delete the factors that are not associated with supply chain resilience.

The method of Principal Component Analysis (PCA) is used. Factors assessing economic conditions and social wellbeing of domestic workers are grouped accordingly.

The factor analysis of supply chain resilience resulted in 3 factors being extracted with an eigenvalue greater than 1. These factors were namely Trade cost (comprises trade cost = 0.773 and material scarcity = 0.787), shock propagation (comprises country-specific shocks = 0.913, production shocks = 0.860 and policy changes = 0.570), technological infrastructure bottleneck (comprises cold chain storage = 0.919, refrigerated transport vehicles = 0.570). These results show that the 3 factors explain 78% of variance in the sample, showing a significant impact on the supply chain resilience of pharmaceutical companies. The corrected item-total correlation score given here in Table 4.

**Table 2: Respondent's Profile.**

Designation	Frequency	Percentage (%)	Geographical Locations of Pharmaceutical Companies
Senior Manager	80	38	Pune-50, Hyderabad-20, Delhi NCR-10
Manager	70	33	Pune-40, Hyderabad-15, Delhi NCR-15
Executives	60	29	Pune-30, Hyderabad-10, Delhi NCR-20
TOTAL	210	100	210

**Table 3: Supply Chain Resilience Factor Analysis.**

Rotated Component Matrix <sup>a</sup>			
Factors	Component		
	1	2	3
Wage difference	0.087	0.792	-0.075
Transport Cost	0.773	-0.075	-0.202
Material Scarcity	0.787	-0.115	-0.180
Country Specific Shocks	0.913	0.201	0.013
Production Shocks	0.860	0.305	0.172
Policy Changes	0.570	0.575	0.459
Cold Chain Storage	0.919	0.231	0.093
Refrigerated Transport Vehicles	0.570	0.575	0.459
Intellectual Property Rights	-0.167	-0.168	0.823
Technical Know How	-0.025	0.881	-0.107
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.			

a. Rotation converged in 5 iterations.

To measure the construct validity, reliability analysis performed and through which Cronbach's alpha value (0.91) and corrected item-total correlation score.

Hence, the authors have generated this model to represent the factors which influence overall supply chain resilience of pharmaceutical companies (Figure 2).

The researchers have also done qualitative analysis to substantiate the factors and the validated model developed here in this study.

### Some quotes from the respondents

**Respondent 1:** "Transportation cost has been a genuine worry, as there has been a hike in fuel prices and restricted movement of trucks during the COVID-19 lockdown."

**Respondent 2:** "It has been very challenging to get the workforce to work in industry because of the permissions required from authorities." Also, we have to follow lots of precautions.

**Respondent 3:** "For vaccine distribution, the greatest challenge was the availability of cold storage and refrigerated vehicles."

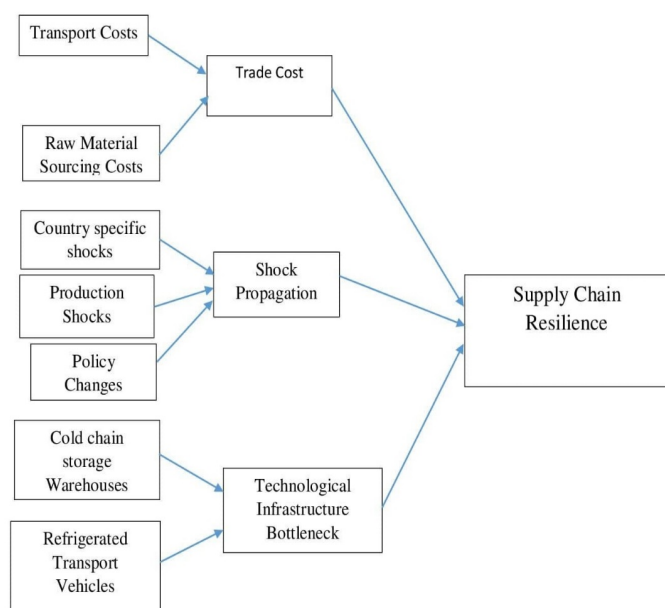
**Respondent 4:** "Following the master production schedule has been an enormous challenge as they face disturbances in the availability of raw materials."

## DISCUSSION

The final pharmaceutical product model has the following factors: trade cost (transport cost and raw material sourcing cost was the finalized sub-factors); shock propagation (country-specific shocks, production shocks, and policy changes); and technical infrastructure bottleneck (availability of cold chain storage warehouse, availability of refrigerated transport vehicle, and technical know-how).

Based on the above reactions of the respondents, supply chain resilience can be built in the pharmaceutical supply chains by focusing on the critical factors. These are end-to-end transparency, meaning visibility of business practices adopted by the suppliers; bankruptcy of the transportation provider could shut down the entire supply chain; and time-to-time assessments of the threats posed by the uncertainty of the key players involved in the pharmaceutical supply chains.

The outcome resulted from a resilient supply chain as a result of a diversified network of suppliers and clients, supply chain visibility (end-to-end transparency), and reassessments of the supply chain through simulations to understand the production shutdowns and shutdowns at the suppliers, which will give sufficient time to the pharmaceutical companies to strategize accordingly. The prepared model will help pharmaceutical product supply chains



**Figure 2:** Validated Model.

**Table 4:** Corrected Item Total Correlation for Supply Chain Resilience.

Item-Total Statistics		
	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Transport Cost	0.567	0.914
Material Scarcity	0.567	0.914
Country Specific Shocks	0.869	0.885
Production Shocks	0.879	0.880
Policy Changes	0.707	0.898
Cold Chain Storage	0.899	0.878
Refrigerated Transport Vehicles	0.707	0.898

achieve an enhanced level of operational resilience. The supply chain's resilience can be enhanced by focusing on localization strategies at both the procurement and distribution ends. The agility and collaborative efforts through the digital supply chain are in high demand at the present time.

## CONCLUSION

In the first step of the study, a literature review was conducted to identify preliminary factors that may have a certain impact on the state of resilience of the pharmaceutical product supply chain under the purview of the COVID-19 pandemic. The identified major factors were trade cost, shock propagation, and technological infrastructure bottlenecks. These major factors have been further subdivided into sub factors, such as "trade cost," where the identified sub factors were wage difference, transport cost, and raw material sourcing cost; "shock propagation," where the identified

sub factors were country-specific shocks, production shocks, and policy changes; and "technological infrastructure bottlenecks," where the identified sub factors were availability of cold chain storage warehouses, availability of refrigerated transport vehicles, intellectual property rights, and technical know-how. Based on the above factors, a preliminary supply chain resilience model has been planned for pharmaceutical products. Researchers have tested the model with the help of primary data collected from 210 companies, subjecting the data to exploratory factor analysis and reliability studies. This has helped to reduce the factors from the study that didn't seem to be prominent in the model.

The future perspective of supply chain resilience for pharmaceutical companies are from linear to networked ecosystem. The pharmaceutical supply chain companies are working hard to make it resilient, by adopting smart localization strategies, incorporating E2E supply chain visibility and transparency, local finished goods stock and E2E localization for packaging.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

## ABBREVIATIONS

SC: Supply Chain; SC-Resilience: Supply Chain Resilience; LTL: Less than truck load; U.S.: United States.

## SUMMARY

The study has helped generate an empirical model pertaining to supply chain resilience and has been further studied with different geographies, like Pune, Hyderabad, and Delhi NCR, for the purpose of generalizing the study.

It is one of its kind, as the factors identified and substantiated by reliability tests would help the supply chain managers configure the supply chains to make them more vulnerable in adverse times.

Scope for Further ResearchThe study can be replicated to study the supply chains of products other than pharmaceutical products. The researcher can test the current models by considering two or more countries for the study.

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