Examining the Effect of COVID-19 on rail freight volume and revenue using the ARIMA forecasting model and assessing the resilience of Indian railways during the pandemic

Aditya Saxena1 · Ankit Kumar Yadav2

Received: 19 April 2022 / Accepted: 9 September 2022 / Published online: 5 October 2022
© Springer Nature Switzerland AG 2022

Abstract
India implemented a nationwide lockdown on 22 March 2020 to prevent Coronavirus (COVID-19) from spreading throughout the nation. Only the most critical services were running during this period. As a result of the pandemic, several organizations, including the travel industry, put a moratorium in place. This included the Indian Railways. In spite of the lockdown, the freight services were operational and carrying out essential duties, but the volume of freight and revenue generated was adversely affected. Railways contribute around 1% to the overall GDP of India and a significant part of India's economy is freight transport by rail. This necessitates an analysis of rail freight volume and corresponding revenue loss due to COVID-19. The present study is an attempt to estimate these losses. Based on the monthly historical data the present study employed the ARIMA forecasting model to develop a scenario and measure freight volume without COVID-19. Under the first scenario, month-wise actual historical freight volumes were considered for the period from April 2012 to November 2021. On the other hand, in the second scenario, the monthly historical data from April 2012 to March 2020 and from October 2020 to November 2021 were used as-is, while from April 2020 to September 2020, ARIMA modelling was used to forecast freight volume without the effect of COVID-19, since the first lockdown occurred in the latter days of March 2020. Further, in order to predict revenue loss, we developed a linear regression model based on the temporal data (April 2012–November 2021) for freight volume and revenue generated by Indian Railways. Based on the ARIMA modelling, the total loss of freight volume and revenue was estimated at 149.08 million tonnes and INR 16712.68 crores, respectively. Furthermore, the present study also discusses the resilience shown by the Indian railways during the outbreak of COVID-19.

Keywords Rail freight volume · Rail freight revenue · COVID-19 · ARIMA modelling

Introduction
Traditionally, the Indian Railways were referred to as ‘imperium in imperio’, which means its scale and size are enormous. The Indian Railways is a national asset. In addition to connecting and integrating the country, it allows for balanced regional development [1]. The Indian Railways is a state-owned and state-operated railway owned and operated by the Government of India [2]. It operates as the fourth-largest rail network in the world, after the U.S., China, and Russia and is considered as the world’s largest government-owned monopoly, with a very high freight volume and passenger numbers that exceed the population of the entire planet. India’s railway is a giant in terms of finances and its revenues account for about 1% of the country’s GDP [3]. India’s railways is a vertically integrated travel, logistics, and transport organization with the following business divisions in place: Freight Services, Passenger Railways, Parcel Carriers, Catering & Tourism Services, Parking-lot Operations, and Ancillary Services [4]. With nearly 19,000 trains, the Indian railway network is one of the world’s largest transportation and logistics networks. Approximately, 3 million tonnes of freight are transported each day on more than 7000
freight trains. The rail network of 65,000 route kilometres equals one and a half times the circumference of the earth [1]. There are almost 8500 Indian Railways stations across the country, making Indian Railways the nation’s national carrier. The Railways immensely contributes to the economic growth of the country by offering affordable and reliable transportation services, especially for bulk commodities [3].

The demand for rail freight is an important aspect of rail operations. It is vital to have an empirical understanding of rail transport demand in order to plan and manage it effectively. As with many other inputs that are needed, such as labour, energy, etc., such demands are derived from nature. The need for freight transport is usually governed by the demand for goods spatially differentiated from the locations where goods are produced. Mobilizing freight on a macro-level is crucial for a country’s competitiveness, economic growth, and regional connectivity. Having a well-developed transport system facilitates smooth freight movements from origin to destination in an efficient manner [5]. The Indian Railways have been increasingly challenged by other transportation modes, such as roads and air, which provide cheaper and faster networks, resulting in fewer revenues, still it is considered as the backbone of the nation [3]. Over the course of 64 years (1950–2014), freight loading at Indian Railways increased by 1344% [1]. The freight volume is therefore a critical component of revenue generation. In light of this, it is imperative to pay more attention to rail freight operations in India, and this necessitates studying the effect of COVID-19 on the probable loss in rail freight volume and corresponding revenue.

### Rail operations in India during COVID-19

Due to COVID-19, the transport industry in India was badly impacted [6, 7]. On 25 March 2020, all of India was put on lockdown due to COVID-19. The lockdown affected all transportation operations, including the Indian Railways, and only essential services and medical facilities were permitted to operate. Cargo trains, however, were prohibited from operating after 31 May 2020. Moreover, to continue the supply chain for essential items, Indian Railways offered parcel van services for quick e-commerce deliveries during the lockdown. A summary of Indian Railways operations is presented in Table 1 [8].

COVID-19 has been evidently affecting the rail sector in India from March 2020 to September 2020, as shown in Fig. 1. As per the data released by Indian Ministry of Railways, in this period, freight volume averaged 89.6 tonnes per month, but from April 2012 to November 2021, it rose to 97 tonnes per month, even after accounting for decadal population increase, which grew freight volume at an increased rate.

### Global effect of COVID-19 on rail system

In the current COVID-19 epidemic, policy interventions have focused on addressing the issue of public transportation as a facilitator of infectious diseases [9]. A drastic decline in rail transit demand around the world has been witnessed as a result of the outbreak of COVID-19 in 2020 [10]. Due to this hypothesis, few researchers have focussed on assessing the impact of rail system on increment in COVID cases. It is because of this hypothesis that few researchers have focused

### Table 1  Rail operations during pandemic

| Lockdown period | Railway operations |
|-----------------|--------------------|
| Lockdown 1.0    | I. In response to the Corona virus outbreak, all railway operations were suspended in March 2020. Passenger trains were not permitted to run until 30 June 2020  
II. The Indian Railways announced on 29 March 2020 that they will operate parcel trains for the transport of essential goods in addition to their already existing parcel trains |
| Lockdown 2.0    | I. In order to ensure essential supplies in different parts of the country, and that movement of freight and parcel trains continues, the national transporter allowed all freight trains to operate |
| Lockdown 3.0    | I. Indian Railways have extended the restrictions on passenger service until 17 May 2020 and only a few special trains have begun operating starting on May 12  
II. Approximately, 300 trains were operated daily as ‘Shramik Specials’ to accommodate those stranded in various areas of the country, such as migrants, pilgrims, tourists, students, and others |
| Lockdown 4.0    | I. Train bookings began on 21 May 2020 |
| Unlock 1.0 & 2.0| I. In operation were only shramik special trains, 15 pairs of special Rajdhani express trains, and 100 pairs of special timetabled trains |
| Unlock 3.0      | I. Train services on the suburban line and regular mail/express remain suspended  
II. During the first five months of the lockdown, 17.80 million confirmed train tickets were cancelled |
| Unlock 4.0      | I. Additional 80 passenger trains which were suspended due to COVID-19 have begun running from September 2020  
II. However, Express and suburban train services remain suspended |
on assessing the impact of public transportation on increment in COVID cases. Pengyu and Yuqing 2021 [9] examined how air and rail connections with Wuhan and the suspension of these connections affected the development of the epidemic in China. In the case of high-speed rail (HSR) and air connectivity with Wuhan, the average daily number of new confirmed cases increased by 25.4% and 21.2%, respectively. However, plenty of the researchers have focussed on the contrary part of this hypothesis and analysed the impact of COVID-19 on rail systems. Using varied timelines of the pandemic outbreak, Mengwei et al., 2021 [10] examined the impact of COVID-19 on daily ridership on Urban Rail Systems in 22 cities in Asia, Europe, and the United States. In another study, it found that ridership declined in most Chinese cities by about 90%, with some variations while the decline was slightly smaller in Singapore and Seoul. Another study performed in Tehran examined the effects of the pandemic on rail passengers’ travel behaviour by using data from crowd perception (before and after the spread of the pandemic) [11]. The study found that crowding levels increased, low comfort scores were observed where occupants occupied seats, and standee density was high. In a similar manner, another research study was conducted in Israel by Elias and Zatmeh-Kanj 2021 [12] that evaluated attitudes and beliefs about train use as well as risk perceptions of flu-type contamination, as well as more traditional factors that affect decisions whether or not to continue using the train. In constructing the study, structural equation modelling was used based on two surveys conducted approximately seven months apart. It was found in their study that perceptions of infection risk and decisions to continue train travel were inextricably linked. Grechi and Ceron 2021 [13] performed a study in Italy to analyse the effect of COVID-19 on ridership and load factor of railway system and found that pandemic resulted in 40–60% reduced demand of travel in regular commuters and occasional travellers. Based on media reports, Abreu and Conway 2021 [14] evaluated the impact of COVID on the multimodal transport system in New York City (NYC), including rail, taxis, personal vehicles, cycling, and micro-mobility, and emphasized that both public and private sectors should be prepared to respond to changing market needs with innovative services and partnerships. This can serve as a model for future operations and institutional arrangements that can adapt to rapid market change.

However, few studies have been conducted in India to assess the impact of Coronavirus on the rail network and describe its role during the outbreak. Velmurugan et al. [8] examined the effect of COVID-19 on various modes of transportation in India, including the railway system. According to their study, there were 13,500 trains halted in India for almost eight months as a result of the pandemic, and only a few cargo trains operated to deliver necessary goods. Due to the lockdown, the monthly freight volume decreased to as low as 65.3 million tonnes in April 2020. The importance of freight rail services in India was highlighted in another study [15]. In the course of the pandemic, ‘Jai Kisan’ special freight trains brought farm products and food supplies to all parts of the country quickly. As part of this new concept, two trains were combined, totalling 84 covered wagons that move 5200 tons of food grains to different destinations.

![Temporal variation in freight volume](image-url)
as a single train. The ‘Doodh Duronto’ special trains were introduced as a means of transporting milk in the national interest. The tanks held up to 42,000 L of milk each [16].

Global effect of COVID-19 on freight operations

The transportation sector has been important during the COVID-19 pandemic, and like many other sectors, it has been sharply affected [17]. Tardivo et al. [18] from their study suggested that a new representative paradigm of mobility is needed for future health emergencies that meet environmental demands. The development of green new mobility will be essential to stemming the rebound effect of GHG emissions. Globally, only several researchers have studied the effect of COVID-19 on freight operations. Dimitris et al. [19] and Nektarios et al. [20] analysed the impact of COVID-19 on global shipping market by employing linear regression models and found that the pandemic outbreak has negatively affected the dry bulk and the dirty tanker segments. Shan-Ju et al. [21] evaluated the effect of COVID-19 on freight transportation in China, using monthly data from 13 Chinese cities from December 2019 to August 2020, and interestingly, found that COVID-19 had a positive impact on the road freight transport turnover even under the higher numbers of COVID-19 confirmed cases. He attributed his results to increased demand for basic amenities and sharp declines in the price of crude oil. However, in another study conducted by Yanling et al. [22] utilizing confirmatory factor analysis (CFA) and structural equation modelling (SEM), the results were contradictory as COVID-19 was found to have a negative, significant impact on air, land, and ocean freight. Another study performed in China by Xiang and Qiong Tong [17] examined the economic implications of traffic consumption during the COVID-19 pandemic and found that logistic and freight systems were adversely affected. In the transport sector, the road sector registered the largest drop in output (10.17%), followed by railways (1.76%) and aviation (1.53%). Dominic 2020 [23] analysed the change in freight volume on 15,715 routes in the time frame from 23.03.2020 to 30.04.2020 and determined that the increase in freight volume for dry products in retail logistics is not dependent on the duration of the COVID-19 epidemic, but rather on the intensity as measured by the number of new infections per day.

In 2020, the worst economic factor is likely to be the Coronavirus pandemic, which quickly spread from Asia to Europe. Various literatures have focussed on event studies and macroeconomic studies to assess the effect of COVID-19; however, very few attempts have yet been made to study how external shocks, such as COVID-19 outbreaks, may affect the rail logistics sector [19]. Similarly, in the Indian context, several studies have been conducted on revenue management and forecasting of future finances in order to evaluate the performance of transportation systems [5, 24–27]. Rail systems have been extensively studied for their economic and social benefits by several researchers [1, 3, 25, 27, 28]. However, the impact of COVID-19 on Indian railways is an imperative subject to be addressed but has been neglected until now. Using ARIMA Modelling, this study attempts to bridge the gap by forecasting the rail freight volume without the effect of COVID-19. Two objectives are addressed in this study: (i) to identify losses caused by COVID-19 in terms of freight volume and (ii) to estimate losses in revenue due to lost freight volumes.

Method

As shown in Fig. 2, the present study follows a systematic methodology for estimating the effect of COVID-19 on Rail Freight Volume and Revenue. Using the Google search engine, the secondary data on freight volume and freight revenue were obtained by typing and searching ‘Indian Railway Monthly data’. Data on freight volumes and freight revenue were obtained from the official website of the Indian Railways [29]. Microsoft Excel was used to filter, sort and tabulate the data; then, SPSS (Statistical Software) was used to analyse it. Further, two scenarios were developed; (i) a business as usual scenario with the effect of COVID, monthly data for freight volume were adopted from April 2012–November 2021, (ii) to evaluate the effect of COVID, monthly data for freight volume were bifurcated into three periods: April 2012–March 2020 (business as usual), April 2020–September 2020 (forecasted data using ARIMA model) and from October 2020–November 2021 (business as usual). After obtaining the monthly values of freight volume from both the scenarios, the difference in freight volume was obtained which was referred to as ‘loss in freight volume due to COVID-19’. For evaluating the loss in freight revenue, the present study considered following assumptions:

- According to historical patterns of growth, if COVID-19 outbreaks had not occurred, freight volume growth would have increased.
- Statistical relationship between revenue and freight volume would have remained the same during the period of COVID-19.

Based on the historical data obtained for month-by-month freight volume and freight revenue from April 2012 to November 2021, a linear regression model using SPSS was developed to estimate the loss in freight revenue. According to the linear regression model, freight volume and freight revenue exhibit a significant and strong relationship. Using the equation obtained from the linear regression model, the
'loss in freight revenue' was estimated by substituting the value of 'loss in freight volume'.

**ARIMA modelling**

An ARIMA model is an exploratory data-driven approach with the flexibility to fit an appropriate model based on data structure. Using autocorrelation functions and partial autocorrelation functions, the stochastic nature of time series can be approximated, allowing us to detect trend, random variations, periodic components, cyclic patterns, and serial correlations. In this way, it is possible to make accurate forecasts of the series' future values [30]. In the scientific literature, the Box–Jenkins Autoregressive Integrated Moving Average (ARIMA) methodology has gained widespread popularity. For determining the suitability of a proposed model, it is necessary to go through an iterative three-stage process, i.e. model identification, parameter estimation, and diagnostic check [30]. The following steps were performed in order to run an ARIMA model [31].

The ARIMA $(p,d,q)$ is the combination of the Autoregressive AR $(p)$, Moving Average MA $(q)$, and the Mixed ARIMA $(p,q)$ in these three cases. Non-seasonal ARIMA models are generally denoted ARIMA $(p,d,q)$ where parameters $p$, $d$, and $q$ are nonnegative integers, $p$ is the order (number of time lags) of the autoregressive model [32].

As given in Eq. 1, in the first case, the AR $(p)$ model is as follows:

$$y_t = c + \alpha_2 y_{t-2} + \cdots + \alpha_p y_{t-p} + \varepsilon_t$$  

(1)

As depicted on Eq. 2, the second, the MA $(q)$ model is represented as:

$$y_t = c + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \ldots + \theta_q \varepsilon_{t-q}$$  

(2)

The third ARIMA $(p,q)$ model corresponds to Eq. 3:
where both $\alpha$ and $\theta$ are the parameters to be estimated and $L$ is the lag operator.

**ARIMA modelling in transport planning**

ARIMA Forecasting Model has been extensively used in urban transportation planning by a number of researchers [33, 34]. Multiple studies have used ARIMA and other time series forecasting models to predict short-term traffic flow characteristics [35-37], while few researchers have used ARIMA models to predict travel time and travel speed of a road network [38-41]. A number of studies have also used ARIMA Models to predict the freight volume and ridership of public transit modes [31, 32, 42-45].

**Table 2** Rail freight volume during lockdown

| Month      | Year | Date       | Freight Volume (2020) in million tonnes |
|------------|------|------------|----------------------------------------|
| April 2020 | 2020 | 01–04–2020 | 65.3                                    |
| May 2020   | 2020 | 01–05–2020 | 82.5                                    |
| June 2020  | 2020 | 01–06–2020 | 93.5                                    |
| July 2020  | 2020 | 01–07–2020 | 99.9                                    |
| August 2020| 2020 | 01–08–2020 | 94.5                                    |
| September 2020 | 2020 | 01–09–2020 | 102.1                                   |

**Fig. 3** Variation in freight volume (April 2012 to November 2021)

**Calculations**

Data used for this study are from April 2012 to November 2021, for Indian railway freight volumes. In order to estimate the loss in freight volume and freight revenue due to the pandemic, two scenarios were developed. The developed scenarios are as follows:

**Scenario 1: Business as usual (freight volume with the effect of COVID-19)**

The rail operations from March to September of 2020 were severely affected by the pandemic, as all transport modes were shut down during this time. As shown in Table 2, during this period the freight volume averaged 89.6 tonnes per month; however from April 2012 to November 2021, freight volume was recorded as 97 tonnes per month on an average, even after accounting for decadal population increase, which grew freight volume at an increased rate.

As shown in Fig. 3, the variation in monthly freight volume from April 2012 to November 2021 is represented using a line diagram.

**Scenario 2: Estimation of rail freight volume without the effect of COVID-19**

According to this scenario, to evaluate the impact of COVID, monthly data for freight volume were broken down into three periods: April 2012–March 2020 (business as usual), April 2020–September 2020 (forecast using the ARIMA model) and October 2020–November 2020 (business as usual).
The ARIMA model is performed in four steps: Identification, Estimation, Diagnostic Testing and Forecasting. As shown in Fig. 4, the Trend was observed to be non-stationary indicating a fit for ARIMA Modelling.

Furthermore, using the ‘Expert Modeller’ option in SPSS, it was validated that ARIMA model will be a good fit for dataset. After Model Identification, Autocorrelation and Partial Autocorrelation in the dataset were performed in SPSS at first difference and a correlogram was obtained, as shown in Figs. 5 and 6. From correlogram $P$ and $Q$ values are obtained, wherein $P$ is the order for autoregressive while $Q$ is the order for moving average.

For determining $P$ value, correlogram obtained from Partial Autocorrelation is used while for determining the value of $Q$, correlogram for autocorrelation function is used. Using the ‘Expert Modeller’ function in SPSS the value for ARIMA model was obtained as ARIMA (0,1,2).

The results obtained from the ARIMA model are depicted in Table 3. According to the result, the R-square value was found to be around 0.7, indicating a good fit.

The obtained forecasted values of freight volume from April 2020 to September 2020 are shown in Table 4. As per the forecasted data, the average freight volume would have remained around 114 million tonnes, while the average of lower and upper forecasted values would have reached at 99.24 and 129.72 million tonnes, respectively, if pandemic would have not occurred (Table 5).

The growth trend for Freight volume if COVID-19 would have not occurred is depicted through a line diagram as shown in Fig. 6.

![Fig. 4 Correlogram for autocorrelation function](image1)

![Fig. 5 Correlogram for partial autocorrelation Function](image2)
Loss in freight volume and freight revenue due to COVID-19

In order to analyse the effect of COVID-19 on Rail Freight Volume, two scenarios were developed (Scenario 1: With the effect of COVID-19 or Business as usual; Scenario 2: Without the Effect of COVID-19), as shown in Sect. 3.1 and 3.2. From the developed scenarios, the difference in freight volume was estimated as follows (Fig. 7).

Furthermore, in order to estimate the loss in freight revenue, a linear regression model was developed between freight volume and freight revenue based on temporal data from April 2012 to November 2021 [46].

\[ y_i = b_0 + b_1 x_i \]  

(4)

where \( y_i \) is dependent variable, \( b_0 \) is constant, \( b_1 \) indicates slope of the equation and \( x_i \) is dependent variable. Under the context of present study, in order to estimate the relation between freight volume and freight revenue, Freight revenue and Freight volume is considered as dependent and independent variables, respectively. Using SPSS, regression model was performed. The obtained results from the model are depicted in Tables 6, 7, 8 and 9.

As shown in Table 6, as per the descriptive statistics the mean value for freight revenue was around INR 9504.2 crores, while the mean value for freight volume was found to be 97 million tonnes per month.

From the Pearson correlation test, it was analysed that freight volume and freight revenue was highly correlated (Pearson correlation coefficient: 0.86) and significant, as shown in Table 7.
Table 8 depicts the model summary for the performed linear regression model. The obtained results from the regression model shows an R square value of above 0.7, indicating good fit for the data [46]. The obtained model coefficients from the linear regression model are shown in Table 9. As per the table, freight volume had a positive relationship with freight revenue. Using Table 9, Eq. 5 was developed to estimate the loss in freight revenue.

\[ \text{Revenue(inINR Crores)} = -3949.8 + 138.6 \times \text{Freight Volume(in Million Tonnes)} \]  

(5)

![Fig. 7 Temporal variation in freight volume in million tonnes based on two scenarios](image)

Table 6 Descriptive statistics obtained through linear regression model

|                          | Mean  | Std. Deviation |
|--------------------------|-------|----------------|
| Freight revenue in INR (Cr.) | 9504.23 | 1734.74 |
| Freight volume (million tonnes) | 97.05  | 10.79 |

Table 7 Pearson correlation test

| Pearson Correlation | Freight revenue in INR (Cr.) | Freight volume (million tonnes) |
|---------------------|------------------------------|---------------------------------|
| Sig. (1-tailed)     | 0.86                         | 1.00                            |
| Freight revenue in INR (Cr.) | 1.00 | 1.00 |
| Freight volume (million tonnes) | 0.00 | 0.00 |

Table 8 Linear regression model summary

| Model | R     | R square | Adjusted R square | Std. Error of the estimate |
|-------|-------|----------|-------------------|----------------------------|
| 1     | 0.863 | 0.745    | 0.742             | 880.3                      |

Table 9 Coefficients obtained from regression model

|                          | B       | Std. Error | Sig      | 95% Confidence interval: Lower bound | 95% Confidence interval: Upper bound |
|--------------------------|---------|------------|----------|-------------------------------------|-------------------------------------|
| (Constant)               | - 3949.9| 742.3      | 0.000    | - 5420.3                           | - 2479.5                           |
| Freight Volume (Million Tonnes) | 138.6  | 7.6        | 0.000    | 123.6                              | 153.7                              |
Substituting the values of loss in freight volume, the loss in freight revenue is obtained as follows:

\[
\text{Loss in freight revenue (in INR Crores)} = 16712.68
\]

**Resilience of Indian railways against COVID-19 outbreak**

In the wake of the COVID-19 pandemic, the economy and the transportation system have been hit by cascading effects never experienced before [47]. The COVID-19 outbreak caused hefty monetary losses to the Indian railways in both the terms: freight/logistics and passenger demand. The analysis from the present study found that a total loss of freight volume and revenue was estimated at 149.08 million tonnes and INR 16,712.68 crores, respectively. A resilient transport system is capable of preparing for shocks, absorbing them, adjusting to them, and recovering from their consequences in a timely and efficient manner. From Fig. 3, it can also be assessed that a strong resilience was shown by the Indian railways against COVID-19 outbreak since the demand again hiked from September 2021.

An exploration of this aspect was considered under the premise of the present study based on the existing literature, and discussion with stakeholders (railway officials, Rail India Technical and Economic Services (RITES) officials, private e-commerce players). It was found that the major factor in the success of Indian railway was diversifying freight basket it in a big way by reaching out to customers and bringing in new commodities like industrial salt, onions, automobiles, cotton, and others. Indian Railways weaned itself off the road sector by selling salt, sugar, onions, sand, and automobiles. A further strategy used by the rail authorities was increasing freight train speeds from 22–24 km/h earlier to 45 km/h in order to increase capacity and ensure that goods were delivered in a timely manner. Additionally, Indian Railways also operated special parcel trains after the lockdown; several courier services and e-commerce companies used scheduled parcel trains and container trains to transport goods. During COVID, Indian railways also ran 'Anaconda' trains that were three times the regular length, and introduced 'SETU'—a one-stop helpline for parcel trade—to overcome supply chain gaps. Another strategic move made by the railways was to fully utilize and optimize its CAPEX allocation for infrastructure projects during COVID times. This also led to increase in employment opportunities. The railway took advantage of the availability of traffic blocks as a result of reduced train operations during the shutdown period to perform over 350 vital and long-pending significant bridge and track improvements. These improvements have a substantial impact on safety and operating efficiency.

Prior to Covid-19, Indian supply chain players emphasized interconnected and lean supply chains to alleviate the gaps by increasing efficiency. The pandemic, however, made Indian firms vulnerable to supply chain disruptions (SCD) resulting from undiscovered supply chain vulnerabilities. The private logistics players shared that since the railways were the first type of public transport that became operational during COVID-19, its orders for new rolling stock were not significantly affected. The stakeholder was very well prepared for the second wave in terms of operating practices and isolation mechanisms. All the employees from private players even including contract labour were vaccinated with at least one dose of vaccine. The Global consumer behaviour was significantly altered by the COVID-19 pandemic, affecting the timing, breadth, and volume of purchases. Thus, distribution channels played a crucial role in the interaction between producers and consumers. The slowdown in industrial output also posed significant challenges for rail freight. During that time necessary measures to prevent the disappearance of operators and capacity in the short term, were adopted with the aid from the Indian government [18, 48]. Increase in public private partnership and use of technology is another factor which helped Indian railways to recover against COVID.

**Supply chain disruptions in post-COVID-19**

The COVID-19 epidemic has infected a large number of people worldwide. Due to the worldwide lockdown, major production facilities have been shuttered, causing significant supply chain disruption (SCD) in all manufacturing sectors. SCDs are unexpected and unanticipated occurrences that disrupt the flow of products and services across the supply chain. The worldwide costs of raw materials and intermediate suppliers have risen as a result of the production slowdown and transit interruption. Border restrictions have temporarily halted human mobility and transportation activities, putting unprecedented strain on marine and road freights and creating significant barriers to international trade. Transportation disruptions have caused significant disruptions in real goods movements, and product mobility, and have impacted the whole supply chain [49].

A responsive supply chain and transportation flexibility can help deliver items to clients more efficiently. A multitude of causes and sub-factors contributed to transportation disruptions in supply networks, for example, bad weather disrupted transportation and negatively impacted supply chains. However, a disruption like the COVID-19 epidemic poses a significant risk to transportation in the supply chain and
has created meta-uncertainty. The COVID-19 has hindered transportation supply chains, albeit in varied ways across the air, rail, road, and maritime sectors. As a result, there are numerous potential ramifications for the supply chain as a result of transportation disruptions, necessitating the identification of potential threats induced by transportation disruptions via creative SCM methods and effective mitigation strategies via supply chain risk [50]. The SCDs caused in various different sectors in India are as follows:

Maritime transport

In recent years, India's maritime transport generated approximately 95% and 70% of commercial volume and value, respectively. India has 12 large ports and 205 minor and intermediate ports. Throughout the lockdown period, cargo capacity at key ports in India remained unused. Major ports handled more than half of India's maritime transport, which fell 10.5% to 414 million tonnes (MT) between April and November 2020 compared to the previous year. Cargo volume at non-major ports fell 10.8% to 310 MT between April and October 2020. During the national lockdown period of April–May 2020, cargo traffic at both major and minor ports declined sharply, followed by a gradual rise in cargo flow since June 2020 due to an increase in economic activity and commerce [51].

Air Cargo

Transport mobility has been severely hampered by the lockdown measures brought on by COVID-19, which has also limited foreign trade and fuelled the fire in the logistics industry. The mobility of goods has been significantly slowed down by restrictions on transport freight. Lockdown regulations initially completely stopped first- and last-mile delivery and intermodal movement of goods before being relaxed. These limitations have significantly affected both domestic and international trade by causing a dramatic decline in vessel capacity and equipment shortages. Major air cargo carriers had to halt their services, including empty sailings to and from India and the Middle East, Europe, and the Mediterranean, due to a sharp fall in freight volumes. The volume of air cargo handled in India has expanded significantly, from 703,000 tonnes in FY2000 to 3,328,296 tonnes in FY2020. Domestic and international airfreight traffic accounted for 39.8 and 60.2% of total traffic in FY2020, respectively. However, because of the lockout limits, aviation freight flow has dropped dramatically to 0.99 MT from April to September 2020 [51].

Conclusion

The COVID-19 crisis is projected to be worse than the Great Depression of 1930. Due to the pandemic Indian economy has severely suffered [52]. There has been an adverse impact of the pandemic on India's public transport system. On 25 March 2020, all of India was put on lockdown due to COVID-19 including the transport system [8]. The Indian railways contribute about 1% to the country's economy [3]. This makes it imperative to assess the effect of the pandemic on rail system in India. In the Indian context, most of the studies have assessed the effect of coronavirus on rail commuters travel behaviour; however, none of the studies have measured the impact of COVID-19 on Indian railway freight transport systems [19, 53]. This necessitates the relevance of the present study. Under the scope of present study, a scenario based approach was utilized to assess the effect of COVID-19 on rail freight volume and rail freight revenue in India. Based on the results obtained from the analysis, it was found that due to the pandemic, the rail freight volume and rail freight revenue suffered a loss of 149.08 million tonnes and INR 16,712.6 crores. Future studies can utilize the approach used in the present study when estimating the loss in the rail freight sector due to a pandemic. In addition, the present study can aid stakeholders in estimating the loss and reclaiming the same after the pandemic is dealt with.

In a post-COVID-19 economic recovery scenario, enterprises must mix short- and long-term risk mitigation methods with flexible and inventive use of available resources to smooth and secure the supply chain across the industry. Furthermore, the following recommendations should be considered for flexible resource use in post-COVID-19 supply chain recovery: shifting ocean cargo to air, converting empty passenger aircraft to passenger-freighters by including belly cargo, freight consolidation, warehousing close to point-of-origin or destination, converting stores into distribution and fulfilment hubs, and strategically using ocean freight as floating storage through careful timing. In the future, it may happen that demand may become unpredictable, and the transport and logistics sector will be under a lot of pressure to function efficiently by making creative and flexible resource utilization to deliver a high-performing logistics system. For a better reaction through an autonomous plan, it is necessary to identify planning gaps and the necessary internal and external resources.
Limitation and future scope

Various researchers have advocated that employing forecasting models such as ARIMA can be helpful in predicting the future; however, predicting the future is unrealistic and impossible. Further, the study hypothesized the reduced number of freight volume as the loss in freight volume; however, present study does not consider any model to forecast the freight volume after September 2020. It might have been the case that in order to bridge the demand and supply gap occurred during the pandemic would have been sufficed in the later months.

In future such studies can also be considered for forecasting the impact of pandemics on other transport systems like passenger railways, air freight and air passenger ridership, bus passenger ridership, etc. Additionally, in future, a detailed study on the viewpoint of the supply chain stakeholders (intermodal carriers, equipment manufacturers, car leasing companies, shippers, and e-commerce players to characterize) is also needed for in-depth understanding of the effect of COVID-19 on freight and railways.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participations or animals performed by any of the authors. If require for a minor portion.

Informed consent For this type of study formal consent is not required.

References

1. Ministry of Railways (2015) Indian railways lifeline of the nation (A White Paper), no. February, pp 1–66, 2015, [Online]. Available: www.indianrailways.gov.in/railwayboard/uploads/.../White_paper-_English.pdf
2. Gunaki P, Devaraj S (2020) Value chain model for Indian Railway Sanitary System. Mater Today Proc 45:236–239. https://doi.org/10.1016/j.matpr.2020.10.429
3. Roy SS, Kulshrestha M (2021) Performance assessment study of indian railways—Case of low efficiencies in large government monopoly. Transp Res Rec 2675(11):1272–1284. https://doi.org/10.1177/036119812111025516
4. Dutta M (2021) Organisational restructuring of Indian Railways. Case Stud Transp Policy. https://doi.org/10.1016/j.cspol.2021.11.005
5. Khan MZ, Khan FN (2020) Estimating the demand for rail freight transport in Pakistan: a time series analysis. J Rail Transp Plan Manag 14:100176. https://doi.org/10.1016/j.jrptpm.2019.100176
6. Pawar DS, Yadav AK, Akolekar N, Velaga NR (2020) Impact of physical distancing due to novel coronavirus (SARS-CoV-2) on daily travel for work during transition to lockdown. Transp Res Interdiscip Perspect 7:100203. https://doi.org/10.1016/j.trip.2020.100203
7. Pawar DS, Yadav AK, Choudhary P, Velaga NR (2021) Modeling work- and non-work-based trip patterns during transition to lockdown period of COVID-19 pandemic in India. Travel Behav Soc 24:46–56. https://doi.org/10.1016/j.tbs.2021.02.002
8. Velmurgan S, Advani M, Padma S (2020) Impacts of COVID-19 on the transport sector and measures as well as recommendations of policies and future research: Report on India. SSRN Electron J. https://doi.org/10.2139/ssrn.3700377
9. Zhu P, Guo Y (2021) The role of high-speed rail and air travel in the spread of COVID-19 in China. Travel Med Infect Dis 42:102097. https://doi.org/10.1016/j.tmid.2021.102097
10. Xin M, Shalaby A, Feng S, Zhao H (2021) Impacts of COVID-19 on urban rail transit ridership using the Synthetic Control Method. Transp Policy 111(July):1–16. https://doi.org/10.1016/j.tranpol.2021.07.006
11. Aghabaky K, Esmaipour J, Shiawakoti N (2021) Effects of COVID-19 on rail passengers’ crowding perceptions. Transp Res Part A Policy Pract 154:186–202. https://doi.org/10.1016/j.tra.2021.10.011
12. Elias W, Zatmeh-Kanj S (2021) Extent to which COVID-19 will affect future use of the train in Israel. Transp Policy 110:215–224. https://doi.org/10.1016/j.tranpol.2021.06.008
13. Grechi D, Ceron M (2021) Covid-19 lightening the load factor in railway transport: performance analysis in the north-west area of Milan. Res Transp Bus Manag. https://doi.org/10.1016/j.ribm.2021.100739
14. L. Abreu and A. Conway, “A Qualitative Assessment of the Multimodal Passenger Transportation System Response to COVID-19 in New York City,” Transp. Res. Rec. J. Transp. Res. Board, p. 036119812110271, 2021, https://doi.org/10.1177/03611981211027149.
15. Rao A, Shailashri VT (2020) An Insight into the Indian Railways COVID-19 Combat. Int J Manag Technol Soci Sci 5(2):389–399. https://doi.org/10.47992/ijmts.2581.6012.0126
16. S. Narayanan and S. Saha (2020) “One Step Behind: The Government of India and Agricultural Policy During the Covid-19 Lockdown,” THEJ vol. 10, no. 1, pp. 111–127, 2020, doi: https://doi.org/10.22004/ag.econ.308103.
17. Zhang Q, Tong Q (2021) The economic impacts of traffic consumption during the COVID-19 pandemic in China: a CGE analysis. Transp Policy 114:330–357. https://doi.org/10.1016/j.tranpol.2021.10.018
18. Tardivo A, Zanuy AC, Martin CS (2021) Covid-19 impact on rail passengers’ crowding perceptions. Transp Res Rec 2675(5):367–378. https://doi.org/10.1177/03611981211027149.
19. Gavalas D, Syriopoulos T, Tsatsaronis M (2022) COVID–19 impact on urban rail transit ridership using the Synthetic Control Method. Transp Policy Part A Policy Pract 154:186–202. https://doi.org/10.1016/j.tranpol.2021.07.006
20. Michail NA, Melas KD (2020) Shipping markets in turmoil: An inter-disciplinary approach. Transp Policy 116:157–164. https://doi.org/10.1016/j.tranpol.2021.11.016
21. Ho SJ, Xing W, Wu W, Lee CC (2021) The impact of COVID-19 on rail passenger ridership in the area of Milan. Res Transp Bus Manag. https://doi.org/10.1016/j.ribm.2021.100739
22. Xu Y, Li JP, Chu CC, Dinca G (2021) Impact of COVID-19 on urban rail transit ridership using the Synthetic Control Method. Transp Policy Part A Policy Pract 154:186–202. https://doi.org/10.1016/j.tranpol.2021.11.016
23. Loske D (2020) The impact of COVID-19 on transport volume and freight capacity dynamics: An empirical analysis in German food retail logistics. Transp Res Intercdiscip Perspect 6:100165. https://doi.org/10.1016/j.trip.2020.100165

© Springer
24. Brons M, Pels E, Nijkamp P, Rietveld P (2002) Price elasticities of demand for passenger air travel: a meta-analysis. J Air Transp Manag 8:10. https://doi.org/10.10432/9781315850177-4

25. Gopalan RS, Ravibabu M, Sahu S (2020) Alternative approach to costing on Indian Railways: Linking outputs and expenses to activity centres. Asian Transp Stud 6:100001. https://doi.org/10.1016/j.eaast.2020.100001

26. Bhattacharya S and Sharma S (2021) Expense based performance analysis and resource rationalization: Case of Indian Railways. Socioeco Plann Sci 76(2020):100975. https://doi.org/10.1016/j.seps.2020.100975

27. Bharill R, Rangaraj N (2008) Revenue management in railway operations: A study of the Rajdhani Express, Indian Railways. Transp Res Part A Policy Pract 42(9):1195–1207. https://doi.org/10.1016/j.tra.2008.03.007

28. Zhang X (2021) Does high-speed railway strengthen the ties among nearby regions? Evidence from China. Asian Transp Stud 7:100039. https://doi.org/10.1016/j.eaast.2021.100039

29. Autoridad Nacional del Servicio Civil (2021) Monthly Data: Indian Railways. Indian Railways

30. Ho SL, Xie M (1998) The use of ARIMA models for reliability forecasting and analysis. Comput Ind Eng 35(1–2):213–216. https://doi.org/10.1006/ciea.1998.0066-7

31. Tang X, Deng G (2016) Prediction of civil aviation passenger transportation based on ARIMA model. Open J Stat 06(05):824–834. https://doi.org/10.4236/ojs.2016.65068

32. Zhao J, Cai J, Zheng W (2018) Research on railway freight volume prediction based on ARIMA model. In: CICTP 2018 Intel1. Connect. Mobil. - Proc. 18th COTA Int. Conf. Transp. Prof., pp 428–437. https://doi.org/10.1061/978078441523.043

33. Shrirai Reyna OS, Flores de la Mota I, Rodríguez Vázquez K (2021) Complex networks analysis: Mexico’s city metro system during the pandemic of COVID-19. Case Stud Transp Policy 9(4):1459–1466. https://doi.org/10.1016/j.cstp.2021.07.003

34. Ratanavaraha V, Jomnonkwa S (2015) Trends in Thailand CO2 emissions in the transportation sector and Policy Mitigation. Transp Policy 41:136–146. https://doi.org/10.1016/j.tranpol.2015.01.007

35. Gao H, Wang Z, Yan Z, Yu Z, Luo W, Yuan L (2021) Synchronized entry-traffic flow prediction for regional expressway system based on multidimensional tensor. Transp Res Rec 2675(10):291–302. https://doi.org/10.1177/03611981211011169

36. Williams BM, Durvasula PK, Brown DE (1998) Urban freeway traffic flow prediction application of seasonal autoregressive integrated. Transp Res Rec 1644(98):132–141

37. Chikaraishi M et al (2020) On the possibility of short-term traffic prediction during disaster with machine learning approaches: an exploratory analysis. Transp Policy 98(May):91–104. https://doi.org/10.1016/j.tranpol.2020.05.023

38. Wang H, Liu L, Qian Z, Wei H, Dong S (2014) Empirical mode decomposition-autoregressive integrated moving average: hybrid short-term traffic speed prediction model. Transp Res Rec 2460(1):66–76. https://doi.org/10.3141/2460-08

39. Zhang Y, Haghani A, Sun R (2014) Stochastic volatility modeling approach that accounts for uncertainties in travel time reliability forecasting. Transp Res Rec 2442:62–70. https://doi.org/10.3141/2442-08

40. Zahid Reza RM, Pulugurtha SS (2019) Forecasting short-term relative changes in travel time on a freeway. Case Stud Transp Policy 7(2):205–217. https://doi.org/10.1016/j.cstp.2019.03.008

41. Suardo MN, Kamaruddin I (2009) Arima models for bus travel time prediction. J Inst Eng 71(2):49

42. Dhingra SL, Munjumdar PP, Gajjar RH (1993) Application of time series techniques for forecasting truck traffic attracted by the Bombay metropolitan region. J Adv Transp 27(3):227–249. https://doi.org/10.1002/atr.5670270303

43. Miller JW (2018) ARIMA time series models for full truckload transportation prices. Forecasting 1(1):121–134. https://doi.org/10.3390/forecast1010009

44. Tsioumas V, Papadimitriou S, Smirlis Y, Zahran SZ (2017) A novel approach to forecasting the bulk freight market. Asian J Ship Logist 33(1):33–41. https://doi.org/10.1016/j.ajsl.2017.03.005

45. Xie Y, Zhang P, Chen Y (2021) A fuzzy ARIMA correction model for transport volume forecast. Math Probl Eng. https://doi.org/10.1155/2021/6655102

46. Koncny V, Bridzikova M, Marienka P (2021) Research of bus transport demand and its factors using multicriteria regression analysis. Transp Res Procedia 55(2019):180–187. https://doi.org/10.1016/j.trpro.2021.06.020

47. Jenelius E (2020) Rail transport resilience to demand shocks and COVID-19. KTH R. Inst. Technol. Jenelius@kth.se Abstract, no. August, 2020. [Online]. Available: https://www.researchgate.net/publication/343600990_Rail_Transport_Resilience_to_Demand_Shocks_and_COVID-19

48. Chandra Kant Patel DKS, Kamatchi Selvam V (2019) Railway anaesthesiologists and Indian railway COVID-19 management system. Indian J Anaesth 49(4):257–262. https://doi.org/10.4103/ija.IJA

49. Sudan T, Taggar R (2021) Recovering supply chain disruptions in post-COVID-19 pandemic through transport intelligence and logistics systems: India’s Experiences and Policy Options. Front Futur Transp. https://doi.org/10.3389/ffutr.2021.660116

50. Zhen X, Li Y, Cai G, Shi D (2016) Transportation disruption risk for transport volume forecast. Math Probl Eng. https://doi.org/10.1155/2021/6655102

51. Shrirai Reyna OS, Flores de la Mota I, Rodríguez Vázquez K (2021) Complex networks analysis: Mexico’s city metro system during the pandemic of COVID-19. Case Stud Transp Policy 9(4):1459–1466. https://doi.org/10.1016/j.cstp.2021.07.003

52. Williams BM, Durvasula PK, Brown DE (1998) Urban freeway traffic flow prediction application of seasonal autoregressive integrated. Transp Res Rec 1644(98):132–141

53. Williams BM, Durvasula PK, Brown DE (1998) Urban freeway traffic flow prediction application of seasonal autoregressive integrated. Transp Res Rec 1644(98):132–141

54. Chikaraishi M et al (2020) On the possibility of short-term traffic prediction during disaster with machine learning approaches: an exploratory analysis. Transp Policy 98(May):91–104. https://doi.org/10.1016/j.tranpol.2020.05.023

55. Wang H, Liu L, Qian Z, Wei H, Dong S (2014) Empirical mode decomposition-autoregressive integrated moving average: hybrid short-term traffic speed prediction model. Transp Res Rec 2460(1):66–76. https://doi.org/10.3141/2460-08

56. Zhang Y, Haghani A, Sun R (2014) Stochastic volatility modeling approach that accounts for uncertainties in travel time reliability forecasting. Transp Res Rec 2442:62–70. https://doi.org/10.3141/2442-08