

Covid-19 Impact on Rail and Air Modes: a SARIMA Model of Duration and Severity (Case Study: Iran)

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Abstract

People's outdoor activities changed significantly as a result of the spread of the COVID-19 pandemic. People's travel behavior was greatly affected by the change in their activities, and as a result, the demand for public transportation systems such as rail and air was dramatically reduced. Despite the existence of numerous studies relating to the impact of COVID-19 on rail and air travel demand, the extent of the impact of the pandemic on non-high-speed railway (HSR) and air travel is still unknown in developing countries in terms of intensity and duration. In this research, two SARIMA models have been calibrated to forecast travel demand for rail and air modes. This is done using monthly data on the number of passengers carried up to the date before COVID-19 outbreak. The forecasts from the mentioned models are assumed to represent travel demand in the absence of pandemic. According to the results, the demand for rail transportation has decreased by 46%, resulting in a reduction of 31.924 million passengers, while the demand for air travel has decreased by 34%, resulting in a reduction of 9.588 million passengers. Also, rail transportation reached normal conditions eight months later than air transportation (lack of pandemic impact on demand). This study is important to identify the behavior of non-HSR and air transportation modes in the face of future crises similar to COVID-19, which can lead to the optimal distribution of limited resources of developing countries in future crises.

Keywords: Railway passenger demand, Air passenger demand, COVID-19, Time series

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1. Introduction

A pneumonia-like illness of unknown cause was reported in Wuhan on the last day of 2019 [World Health Organization, n.d.]. The World Health Organization declared it a pandemic in March 2020 after it spread rapidly across several countries in Asia, Europe, and the United States [World Health Organization, n.d.]. The disease spread rapidly throughout the world and affected many aspects of human life. Thus, restrictions were imposed on various modes of transportation around the world [Abu-Rayash & Dincer, 2020]. The first suspected COVID-19 case was identified in Iran on February 19, 2020 [Abdi, 2020]. Due to international sanctions, Iran faced many and complex challenges with pandemic. Various fields, including public transportation, faced these challenges [Takian et al., 2020]. A severe impact of COVID-19 was experienced by the rail and air modes of transportation, as well as other modes of transportation [Rothengatter et al., 2021]. The effectiveness of these travel modes has been determined in many regions of the world. Based on past research, rail travel demand has decreased less than air demand [Mahpour & Kazemi Naeini, 2021; Rothengatter et al., 2021]. In most past researches, when comparing rail and air modes, high-speed railway (HSR) is considered. This is despite the fact that many countries in the world, such as Iran, do not have HSRs. The results of these studies cannot be used in the presence of non-HSRs. On the other hand, developing countries have special conditions. These countries have wider and more complex problems, and this may cause different travel behavior in dealing with the pandemic. The extent of decline in rail and air travel demand has been examined in previous research and by numerous international statistical institutions, denoted by the disparity between travel demand during the pandemic and the pre-pandemic years [Rothengatter et al., 2021; Eurostat, 2021; Mahpour & Kazemi Naeini, 2021].

Comparing travel demand between the pandemic year and the year prior to the pandemic does not yield precise results, as demand during the pandemic year should ideally be compared with travel demand during non-pandemic conditions of the same period. Assessing the impact of the pandemic on travel demand can be achieved through forecasting. For this purpose, the travel demand during COVID-19 outbreak is compared with the forecasted travel demand. According to our findings, previous research has not examined the duration of the impact of COVID-19 on rail and air travel demand. This research answers to: (1) How did pandemic affect rail and air travel demand in Iran during different months? (2) For how long has the pandemic affected rail and air travel demand? (3) In comparison to air travel demand, how much and for how long has rail travel demand been affected?

To answer the above questions, the seasonal autoregressive integrated moving average (SARIMA) model is used. As a result of using the forecast generated by this model, it has been possible to predict how much travel demand will be generated for rail and air in the absence of COVID-19. In this study, the amount of travel demand reduction and the duration of demand return to normal conditions were analyzed by comparing the actual demand with the forecast results. Iran is a developing country without a HSR network. As a result, the answers to the above questions provide results that have not been covered in previous research. Therefore, in summary, the innovation of this research in three different categories includes: (1) the method of investigating the impact of COVID-19 on the demand for rail and air travel, (2) the investigation and comparison of the duration of the impact of COVID-19 on the demand for rail and air travel, and (3) the comparison between regular and air trains in the absence of HSR. There are six sections in this study. In the second section, a literature review is conducted and gaps in research are identified. The third section discusses the research

methodology, including introduction of data, selection of a model, and method of analysis. The fourth and fifth sections present models and their results for rail and air travel, respectively. Lastly, a conclusion is presented in the sixth section.

2. Literature Review

Due to the spread of the COVID-19, the demand for rail and air transportation has significantly decreased. In such a way that the total number of air passengers carried worldwide in 2020 decreased by 60.1% compared to 2019 [ICAO, 2020]. The Middle East, accounting for 8.6% of the total global air traffic, experienced a 67.7% decrease in air travel demand in 2020 compared to 2019 [ICAO, 2020]. Additionally, according to the statistical yearbook of Iran's air transportation, domestic air passenger traffic in Iran decreased by 52%, and the country's air traffic decreased by 67% in 2020 compared to 2019. A study has compared the impact of COVID-19 on rail transportation in Iran and 10 European countries. According to this research, in 2020, rail demand decreased by 72% in Iran, 44% in Switzerland, 66% in the Netherlands, 80% in Ireland, and 51% in Poland (M. A. Emami, 2021). Various aspects of the conditions of transportation systems during the outbreak of COVID-19 have been identified through past research. Various modes of transportation have been studied in order to gain a better understanding of the conditions of the transportation system during the pandemic crisis. The mass movement of passengers through rail and air travel modes to remote areas has resulted in an increased spread of COVID-19. Also, travel demand is a derived demand and is related to people's activities. As a result of the spread of COVID-19 and subsequent quarantine, people reduced their outdoor activities. As people's activities changed, the demand for public transportation such as rail and air decreased. Thus, transportation systems have a two-way impact, on the one hand, they contribute to the spread of COVID-19, and on

the other hand, they have lost travel demand as a result of the pandemic.

Different studies exist on the impact of the rail transportation system on the spread of pandemics. In a study, the impact of HSR on the spread of the pandemic from Wuhan to other cities in China was examined using gravity models [Pang et al., 2023]. According to the results of this study, HSR have the greatest impact on the spread of COVID-19 compared to regular rail transportation and air transportation. Another study investigated the impact of the presence of HSR infrastructure on the spread of the pandemic in the absence of government intervention in Wuhan [Wan & Wan, 2022]. According to the results of this study, the presence of HSR infrastructure increases the number of COVID-19 patients by 0.029 per 10,000 people. In another study, the HSR transportation network was used to evaluate and predict the regional spread of COVID-19 based on a probabilistic risk model [T. Li et al., 2021]. According to the results of this study, high-risk areas for the spread of COVID-19 are distributed along the southern half of the Beijing-Hong Kong HSR. Studies in the air transportation also examine the impact of air travel on the spread of the pandemic. A study examined the role of the air and HSR transport systems in the spread of COVID-19 using random-effects panel data models and a Difference-in-Differences in Reverse (DDR) model [Zhu & Guo, 2021]. According to the results of this study, the air and HSR transport systems have led to a 21.2% and 25.4% increase, respectively, in the average number of newly confirmed cases daily in Wuhan. Another study investigated the impact of air transportation on the spread of COVID-19 in the United States, showing that air travel significantly contributes to the spread of COVID-19 [Atalan & Atalan, 2022].

In the section on the impact of the pandemic on rail travel demand, several studies have been conducted. A study examined the effect of the COVID-19 pandemic on rail passenger demand

in Iran using ARIMA time series models and linear regression [Emami & Khadem Sameni, 2023]. According to the results of this study, rail travel demand in Iran had a 73.12% decrease in the first year of the pandemic. Another study examined the impact of the pandemic on rail transport in Slovakia, showing a 40% decrease in the performance of Slovak rail transport in 2020 and 2021 due to the pandemic and related measures [Fabianová et al., 2023]. In addition to the passenger sector, the freight sector of the rail transport system has also been affected by the pandemic. According to the results of a study using ARIMA time series models, India's rail transport system lost 149.08 million tons of freight [Saxena & Yadav, 2022]. In the air transportation section, research has also been conducted on the impact of COVID-19 on air travel demand. A study examined the impact of the pandemic on air travel demand using forecasting methods in France, showing that Air France–KLM lost 40.3% of its passengers during the pandemic [X. Li et al., 2023]. An interesting point in this study is the differentiation between demand and supply. Based on their results, 57.4% of the mentioned amount is attributed to a decrease in demand, while 42.6% is attributed to supply. Another study examined the impact of COVID-19 on air passenger demand and CO₂ emissions in Brazil using structural Bayesian time series models, showing a 68% reduction in air travel demand and a 63% reduction in total CO₂ emissions compared to what would have occurred without the pandemic [Bazzo Vieira et al., 2022].

The research results discussed above do not address all the needs of policy making and specifying the dimensions of changing travel behavior during the pandemic. Therefore, some research studies change travel behavior during this period [Tan & Ma, 2021; Vichiensan et al., 2021]. In this regard, Tan and Ma's study investigated whether passengers opt for rail transit during pandemics. Their study found that occupation, walking distance to the subway, infection risk perceptions, and vehicle type

significantly impact rail transit choice. In this context, some research has explored the impact of COVID-19 from the perspective of passengers. For instance, Pereira et al. have studied how COVID-19 affects the satisfaction of airline passengers [Pereira et al., 2023]. Their study reveals that passenger dissatisfaction existed pre-pandemic, worsening post-COVID-19. Staff behavior significantly impacts passenger satisfaction.

It is important to note that the studies mentioned are often conducted in countries with HSR systems, and their findings cannot be generalized to other countries lacking such infrastructure, such as Iran. In addition, the impact of pandemic on transportation systems has been examined less than the impact of transportation systems on the spread of the disease. It will be possible to determine the behavior of different types of transportation systems in the face of crises such as COVID-19 by examining their effectiveness in comparison with each other. A more targeted allocation of resources and adoption of transportation policies is made in this situation. In analyzing the effects of pandemic on a transportation system, it is possible to consider factors such as the amount of reduction in travel demand, the duration of the pandemic's impact on travel demand, and the associated costs. The amount of travel demand reduction and its costs have been examined in previous studies [Saxena & Yadav, 2022]. However, based on our findings, the duration of the impact of COVID-19 on transportation systems has not been investigated.

This study examines the impact of COVID-19 on non-HSR and air transportation demand in Iran. Research on HSR and air transportation should be compared with the results of this study. Unlike earlier studies, these results provide a clear picture of rail and air demand in developing countries without HSR during the outbreak of COVID-19. In addition, in this study, the impact of pandemic has been measured based on the amount of travel demand

reduction and the duration of the travel demand reduction. The present study examines how COVID-19 has affected rail and air modes and for how long.

3. Methodology

The purpose of this study is to assess the severity and duration of the impact of COVID-19 on rail and air travel demand in Iran. The amount of travel demand for the two modes of transportation in the absence of pandemic should be compared with the amount of travel demand during the pandemic. Travel demand is not available in the absence of COVID-19, and therefore must be calculated. Due to this, forecasting models for transportation planning can be used to estimate travel demand. It is possible to categorize forecasting models in transportation planning into two categories: qualitative and quantitative [Profillidis & Botzoris, 2019b]. The focus of this study is on quantitative models. A quantitative model can be divided into four subcategories: time series models, econometric models, artificial neural networks, and fuzzy models [Profillidis & Botzoris, 2019b]. In this study, the univariate time series model was chosen based on the purpose and the type of data available. In various fields of science, time series models are widely used. In general, these applications can be divided into three categories: prediction, estimation of transfer functions, and design of discrete control systems [Box & Jenkins, 1970]. It is possible to model time series data as a univariate or multivariate model. Univariate equations or functions consist of only one variable. It should be noted that in univariate time series, time is an implicit variable.

There are a number of time series processes that can be considered, including white noise, random walks, autoregressive moving averages, autoregressive integrated moving averages, and seasonal autoregressive integrated moving averages [Profillidis & Botzoris, 2019a]. A white noise process is a univariate time series with zero mean and constant variance, which is

random in nature and has no correlation between its values. In a random walk time series, the value of a variable in a certain period is equal to the sum of three terms of the value of the previous period, white noise and a constant term. According to the autoregressive process, the value of the dependent variable at time t is the sum of three parts: the weighted average of p 's previous value, a random factor such as white noise, and a fixed value (Equation 1) [Profillidis & Botzoris, 2019a].

$$Y_t = c + \phi_1 \cdot Y_{t-1} + \phi_2 \cdot Y_{t-2} + \dots + \phi_p \cdot Y_{t-p} + \varepsilon_t \quad (1)$$

Where Y_t is the time series value at time t and $\phi_1, \phi_2, \dots, \phi_p$ are model parameters that are calculated by computer software. c represents the constant term and μ is the average of the time series. Also, ε_t is a random factor like white noise. The constant term is related to the average of the time series and the model parameters (Equation 2) [Profillidis & Botzoris, 2019a].

$$\mu = \frac{c}{1 - \phi_1 - \phi_2 - \dots - \phi_p} \quad (2)$$

The moving average process is another time series process in which the value of the dependent variable at time t is obtained as a linear function of the current and q past values of a random process such as white noise (Equation 3) [Profillidis & Botzoris, 2019a].

$$Y_t = \mu + \varepsilon_t - \theta_1 \cdot \varepsilon_{t-1} - \theta_2 \cdot \varepsilon_{t-2} - \dots - \theta_q \cdot \varepsilon_{t-q} \quad (3)$$

$\theta_1, \theta_2, \dots, \theta_q$ are model parameters that are calculated by computer software. Other symbols remain the same. The autoregressive moving average process, denoted as ARMA(p, q), is a combination of the two previous models that have the properties of both (Equation 4) [Profillidis & Botzoris, 2019a]:

$$Y_t = c + \phi_1 \cdot Y_{t-1} + \phi_2 \cdot Y_{t-2} + \dots + \phi_p \cdot Y_{t-p} + \varepsilon_t - \theta_1 \cdot \varepsilon_{t-1} - \theta_2 \cdot \varepsilon_{t-2} - \dots - \theta_q \cdot \varepsilon_{t-q} \quad (4)$$

Time series must be stationary before modeling an autoregressive moving average process

when there is no stationary time series. This is accomplished by differentiating using different orders. In most cases, first and second order differences cause stationary time series [Profillidis & Botzoris, 2019a]. By performing the differences, the autoregressive integrated moving average process is obtained, in the form of ARIMA (p,d,q). d denotes the number of differences required for the AR(p) term to become stationary. The last process is the seasonal autoregressive integrated moving average process. This process is shown as SARIMA(p, d, q)(P, D, Q)_m. The added part is related to the seasonal characteristics of the time series, where m represents the number of periods in each season. In this model, the seasonal autoregressive process and the seasonal moving average process are calculated as Equations 5 and 6, respectively [Profillidis & Botzoris, 2019a].

$$\text{SAR}(P): \quad y_t = \sum_{i=1}^P \Phi_i \cdot y_{t-s,P} + \varepsilon_t \quad (5)$$

$$\text{SMA}(Q): \quad y_t = \varepsilon_t - \sum_{i=1}^Q \theta_i \cdot y_{t-s,Q} \quad (6)$$

In this study, rail and air demand data were collected from the Statistical Yearbook of the Islamic Republic of Iran Railways and the Statistical Yearbook of Air Transport of Iran, respectively. In rail section, Based on monthly data on the number of domestic passengers carried from April 2013 to February 2020 (82 months prior to the outbreak of COVID-19 in Iran), A SARIMA model was calibrated using Minitab 16 software to determine the severity and duration of the impact of the pandemic on Iran's rail travel demand. After checking the accuracy of the model based on various criteria (MAPE, MAD, MSE and RMSE), the demand for rail travel in the year of the pandemic has been forecasted in the absence of COVID-19. The severity and duration of COVID-19's impact on rail travel demand has been determined by comparing the model forecast with the amount of actual rail travel demand. A

SARIMA model has also been calibrated using monthly data on domestic passenger carriers in the air transportation sector between April 2011 and February 2020 (106 months prior to the outbreak of COVID-19 in Iran). Similarly, to rail transportation, the calculations are made by comparing the forecasted and actual demand. For developing countries without HSRs, the comparison of impact of pandemic on the mentioned modes over different months yields useful results. As a result, the behavior of rail and air modes during crises such as COVID-19 is determined by both the severity and duration of the reduction in passenger demand. These items can be useful in allocating the limited resources available to developing countries.

4. Model Calibration

In this study, the SARIMA model was used to evaluate the severity and duration of the impact of COVID-19 on rail and air travel demand in Iran. For this purpose, a separate model has been calibrated for each mode of transportation. In order to calculate the impact of pandemic, the forecast results were compared to the actual demand.

4.1. Rail Transportation

In order to calibrate the SARIMA model, it is necessary to confirm the stationary of the time series in terms of variance and mean before calibrating the model. For this purpose, the stationary of the variance of the time series is examined prior to the stationary of the mean. In this study, the Cox-Box method was applied to evaluate the stationary of variance, and according to its result ($\lambda=1$), no transformation is needed (Fig.1). The Cox-Box method is a statistical technique used for transforming time series data to stabilize variance. It is particularly useful when dealing with non-constant variance, also known as heteroscedasticity, commonly encountered in time series analysis. The Box-Cox transformation is power transformation that is defined by Y^λ , where Y represents the data and λ is the "power" to

which each data value is raised. Some common values of λ are in Table 1 (Osborne, 2019):

Table1. λ values and the Box-Cox Transformation

λ	Transformation
1.00	no transformation needed
0.50	square root transformation
0.33	cube root transformation
0.25	fourth root transformation
0.00	natural log transformation
-0.05	reciprocal square root transformation
-1.00	reciprocal (inverse) transformation

In addition, the mean stationary was determined based on the time series plot. Mean stationary specifically implies that the mean of the series remains constant over time. This can be observed in a time series plot where the series fluctuates around a constant horizontal line, indicating that the mean remains the same throughout the observed period. In the current research on the railway time series, the aforementioned conditions existed, and the time series was stationary. Based on the stationary variance and mean, the time series pattern was determined using the autocorrelation function (ACF) and partial autocorrelation function (PACF). ACF shows the overall correlation structure of a time series, while PACF highlights direct correlations between observations and their lagged values. Both ACF and PACF plots are useful for identifying the order of autoregressive (AR) and moving average (MA) terms in time series models. After constructing various models, Based on the Akaike criterion (ACI) and the significance of the model parameters at the five percent level, the SARIMA(1,1,1)(0,0,2)₁₂ model was selected. Taking into account the monthly consideration for the modeling period, the number of periods was set to 12.

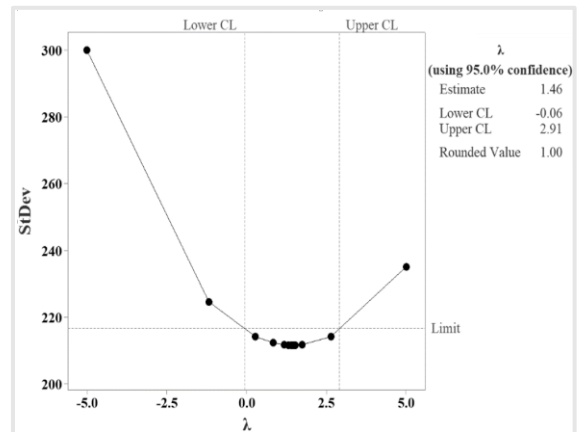


Figure 1. Box-Cox plot of Iran's rail travel demand time series

To check the validity of Iran's rail travel demand model forecasting results, statistical tests are conducted. It is possible to verify residual normality numerically or graphically. In this study, a graphic method is used. The figs 2 and 3 illustrate the normal probability plot and histogram of model residuals, respectively. In a normal probability plot, the points follow an approximately linear pattern and the histogram is normally distributed. As can be seen from these two figures, the residuals of the model are normally distributed.

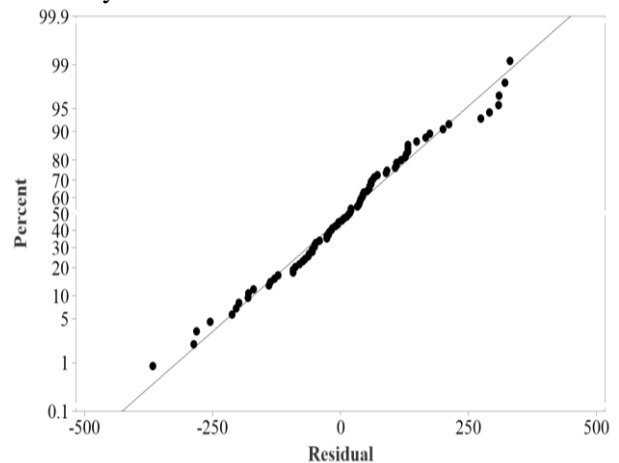


Figure 2. Probability plot of residuals of SARIMA model of rail travel demand in Iran

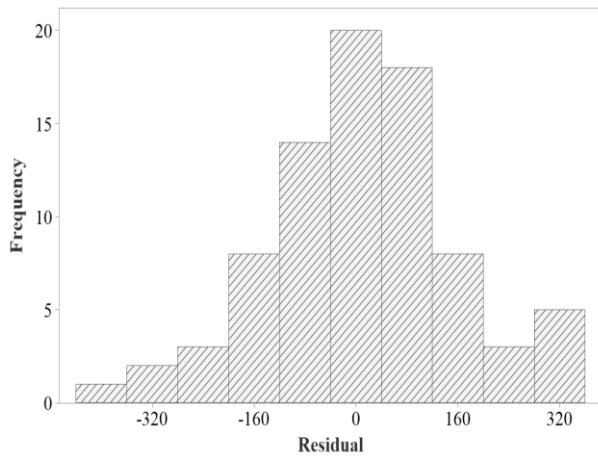


Figure 3. Histogram of residuals of SARIMA model of rail travel demand in Iran

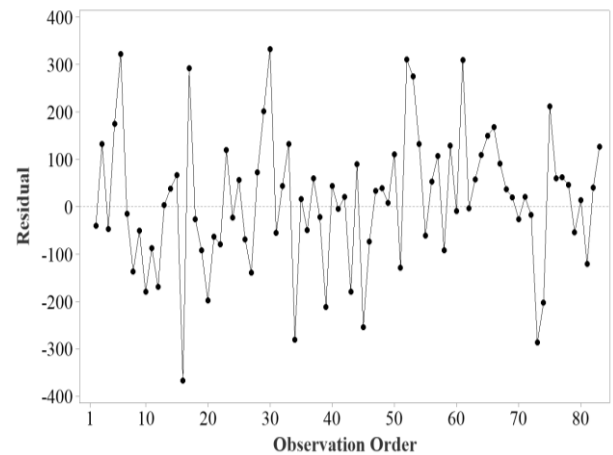


Figure 5. Residuals of the SARIMA model of Iran's rail travel demand against time

A plot of the residuals against the fitted values is used to determine the homoscedasticity of the residuals. In the absence of a regular pattern in the plot, homoscedasticity is not rejected [Chatterjee & Simonoff, 2013]. As illustrated in Fig.4, no specific pattern can be observed in the residuals when plotted against the fitted values. Additionally, Fig.5 shows the residuals of the model plotted against time, but no specific pattern can be observed in the plot. As a result, the residuals of the model behave like a completely random process, indicating the appropriateness of the model.

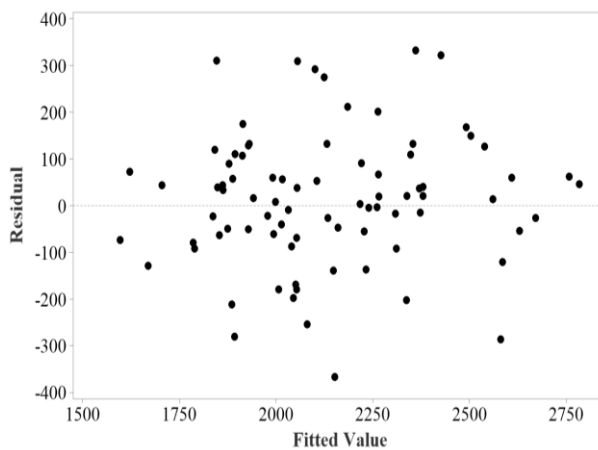


Figure 4. Residuals against the fitted values of the SARIMA model of Iran's rail travel demand

Using quantitative criteria and graphical comparisons of real demand and the model forecast, it is possible to determine the error rate of Iran's rail travel demand time series model. Four quantitative criteria are used in this study (Table 2): MAPE, MAD, MSE, and RMSE. The MAPE is a scale-free measure and values are acceptable if they are less than 20 [Lewis, 1982]. As a result, the time series model of Iran's rail travel demand has a small error (MAPE = 5.12). A comparison of forecasted and actual demand is shown in Fig.6. It can be seen from this figure that the model has been fitted correctly to the actual rail travel demand data. Rail travel demand has decreased significantly as a result of the spread of COVID-19.

Table 2. Error criteria of SARIMA time series model of Iran's rail travel demand

RMSE	MSE	MAD	MAPE	Model
141.45	20009.43	107.86	5.12	Railway Travel Demand

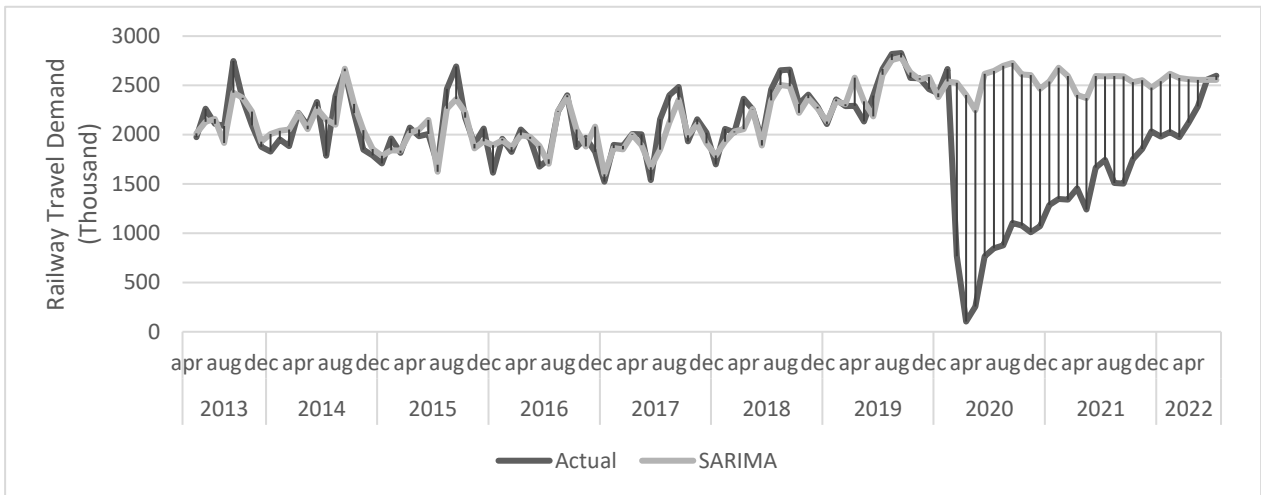


Figure 6. Performance plot of SARIMA model in fitting to actual Iran’s rail travel demand data and the change in rail travel demand due to the spread of COVID-19

4.2. Air Transportation

Prior to calibrating the air travel demand model, it is necessary to determine the stationary variance and mean of the time series. The Cox-Box plot of air travel demand is shown in Fig.7. As can be seen, there is no need for any transformation ($\lambda = 1$). According to the time series plot, the mean stationary was also determined. Then, using ACF and PACF, the time series pattern of air travel demand was determined. Based on the Akaike criterion (ACI), SARIMA(0,1,1)(1,0,0)₁₂ model for forecasting Iran’s air travel demand is introduced among the calibrated models. The calibrated models have significant parameters and serial non-correlations have been verified.

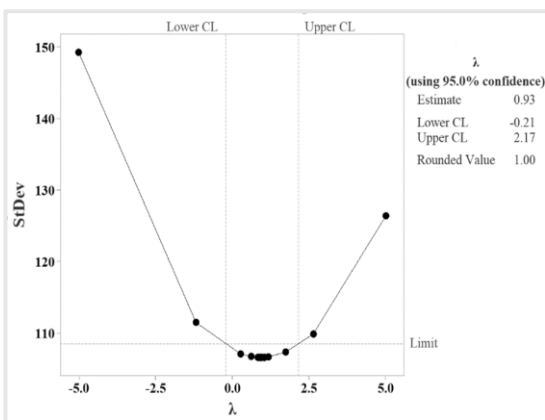
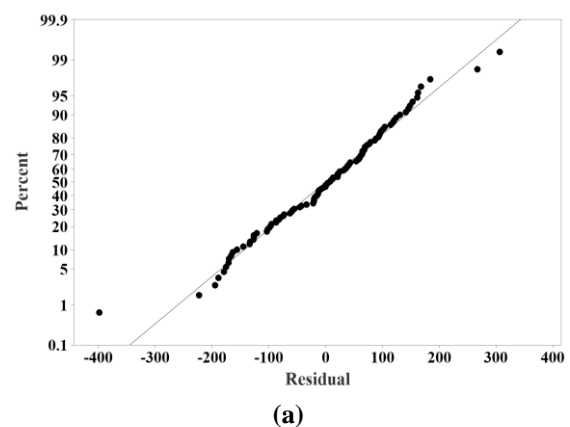


Figure 7. Box-Cox plot of Iran’s air travel demand time series

The residuals of the air travel demand time series model were tested for normality, homoscedasticity, and randomness in order to determine the validity of the forecasting results. In Fig.8; the probability plot (a) are shown, the points have an approximate linear pattern, and their histograms (b) have a normal distribution. Therefore, the residuals of the time series model have a normal distribution. Additionally, the residuals do not exhibit any specific pattern when plotted against the fitted values (c), which supports the assumption that the residuals are homoscedastic. Moreover, when plotting the residuals of the model against time (d), no specific pattern can be observed, indicating that the model is appropriate.



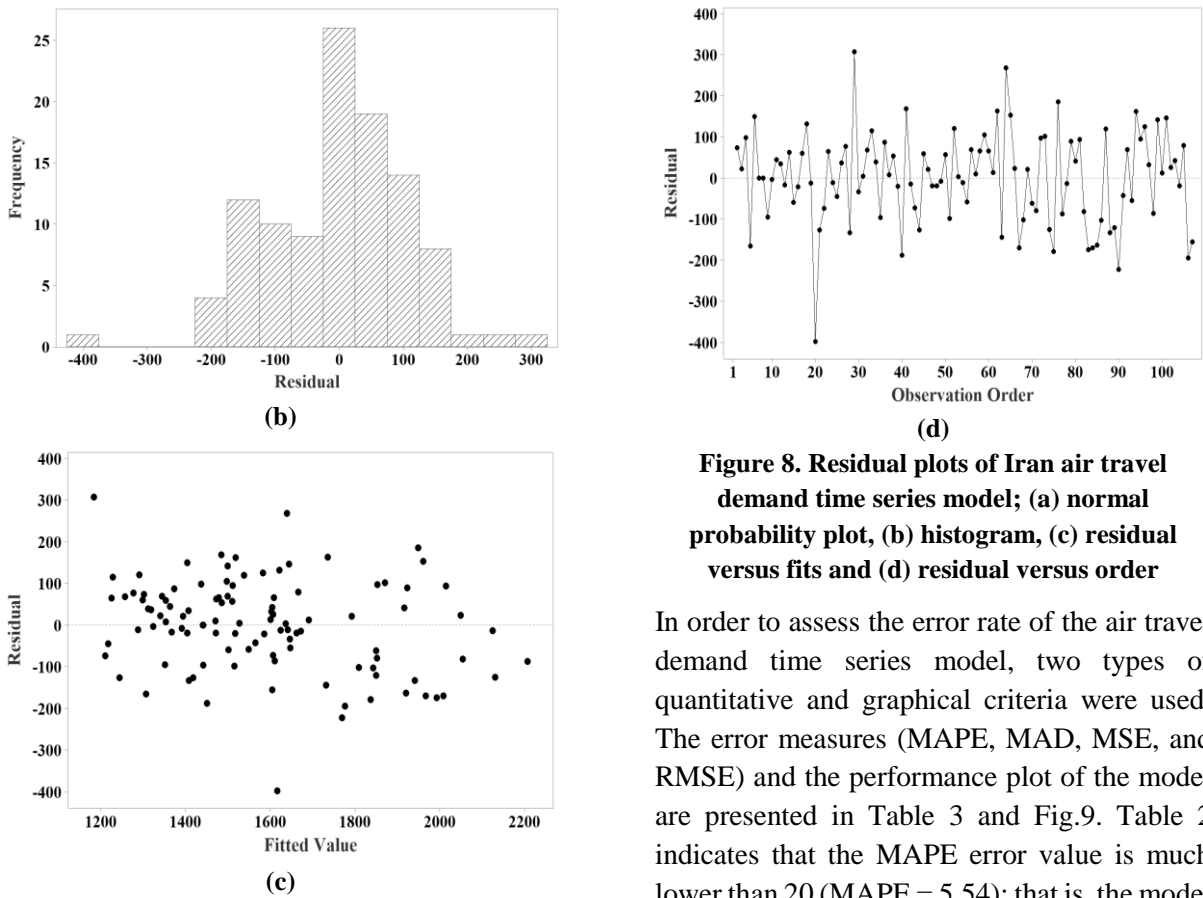


Figure 8. Residual plots of Iran air travel demand time series model; (a) normal probability plot, (b) histogram, (c) residual versus fits and (d) residual versus order

In order to assess the error rate of the air travel demand time series model, two types of quantitative and graphical criteria were used. The error measures (MAPE, MAD, MSE, and RMSE) and the performance plot of the model are presented in Table 3 and Fig.9. Table 2 indicates that the MAPE error value is much lower than 20 (MAPE = 5.54); that is, the model has a small error when fitting the real data. Additionally, according to Fig. 9, the demand for air travel has decreased sharply since March 2020 due to the spread of COVID-19, but it has returned to its normal trend after a few months.

Table 3. Error criteria of SARIMA time series model of Iran’s air travel demand

RMSE	MSE	MAD	MAPE	Model
110.58	12228.57	86.59	5.54	Air Travel Demand

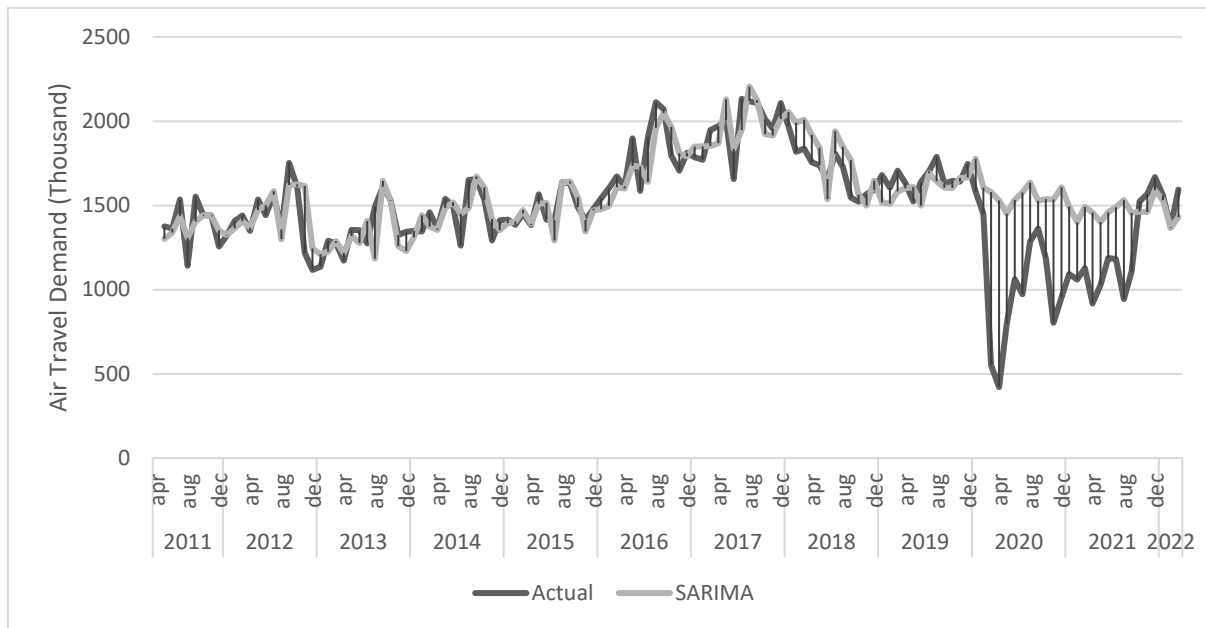


Figure 9. Performance plot of SARIMA model in fitting to Iran’s air travel demand data and the change in air travel demand due to the spread of COVID-19

5. Results and Discussion

It is assumed in this study that the results of two rail and air travel demand forecasting models during the pandemic are equivalent to the amount of travel demand during this time period in the absence of COVID-19. Also, it is assumed that once the forecasted demand and actual demand are equal, the period of impact of pandemic on the travel demand of both modes will come to an end. Furthermore, this study assumes that the sole reason for the decrease in demand for rail and air travel is COVID-19. As shown in Table 4, Iran’s actual and forecasted travel demand by rail and air is presented. In addition, the Change (%) in demand for each mode of travel is calculated for each month. As a result of the COVID-19 pandemic, Iran's demand for rail and air travel decreased by 31.924 million and 9.588 million passengers, respectively. This means that Iran’s railway has been affected 3.3 times more than air transport in domestic passenger transport. It is possible to make a better comparison by utilizing a percentage expression. The demand for rail and air transportation has decreased by 46% and 34%, respectively. Based on Table 4, rail and air travel experienced the highest decreases in

demand in April 2020, with reductions of 96% and 72% respectively.

COVID-19 has affected air transportation for a shorter period of time than rail transportation. In October 2021, COVID-19’s impact on air transportation ended. The duration of COVID-19’s effect on rail transport demand ended with an 8-month delay in June 2022. The COVID-19 pandemic has not affected rail and air travel demand after these dates. As can be seen in fig.10, the Change (%) in travel demand during the pandemic is shown. There has been a similar reduction in rail and air travel demand since the beginning of the COVID-19 pandemic (70% and 65%, respectively). A drastic difference in performance is observed over time. Rail transport demand has returned to normal more slowly than air transport demand. However, it is worth noting that in April 2021 and August 2021, the reduction in travel demand for both rail and air travel modes was very close to each other in terms of percentage. However, after August 2021, air transportation returned to normal more rapidly compared to rail transportation. In order to deal with future crises, it is necessary to investigate the reasons and come up with different solutions.

Table 4. Forecasted & actual rail and air travel demand by month for COVID-19 period (Mar 2020 to April 2022)

year	month	Railway Travel Demand (Thousand)			Air Travel Demand (Thousand)			
		Actual	Forecast	Change (%)	Actual	Forecast	Change (%)	
2020	Mar.	766	2526	-70	551	1580	-65	
	Apr.	104	2404	-96	422	1530	-72	
	May.	256	2247	-89	798	1452	-45	
	Jun.	766	2616	-71	1063	1534	-31	
	Jul.	846	2648	-68	972	1577	-38	
	Aug.	878	2699	-67	1287	1637	-21	
	Sep.	1103	2728	-60	1363	1527	-11	
	Oct.	1078	2610	-59	1188	1538	-23	
	Nov.	1009	2606	-61	803	1535	-48	
	Dec.	1072	2466	-57	953	1607	-41	
	2021	Jan.	1284	2539	-49	1092	1493	-27
		Feb.	1347	2678	-50	1060	1401	-24
Mar.		1342	2593	-48	1130	1492	-24	
Apr.		1455	2403	-39	918	1457	-37	
May.		1239	2370	-48	1028	1403	-27	
Jun.		1667	2594	-36	1188	1460	-19	
Jul.		1743	2591	-33	1181	1490	-21	
Aug.		1509	2596	-42	945	1531	-38	
Sep.		1502	2592	-42	1107	1455	-24	
Oct.		1752	2533	-31	1524	1462	4	
Nov.		1853	2551	-27	-	-	-	
Dec.		2033	2477	-18	-	-	-	
2022	Jan.	1980	2541	-22	-	-	-	
	Feb.	2025	2617	-23	-	-	-	
	Mar.	1973	2575	-23	-	-	-	
	Apr.	2121	2561	-17	-	-	-	
	May.	2285	2556	-11	-	-	-	
	Jun.	2560	2555	0	-	-	-	

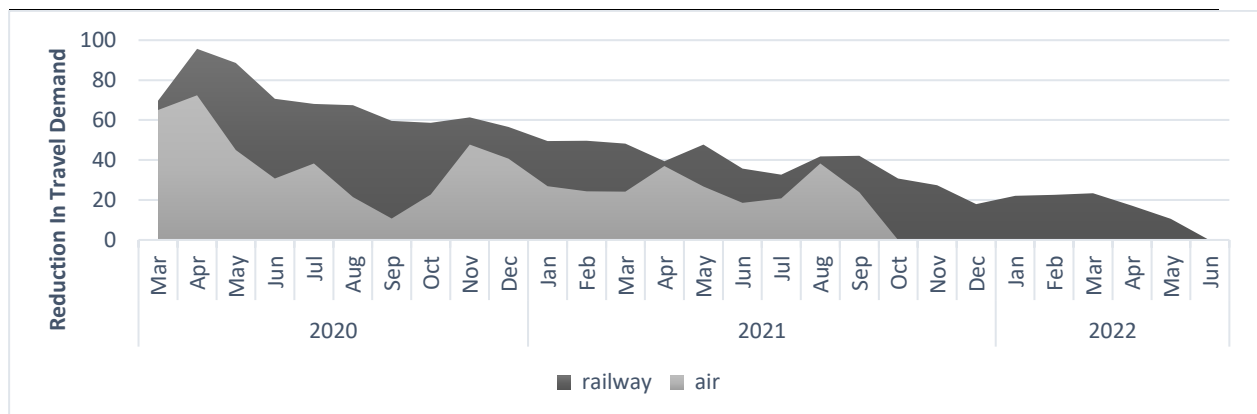


Figure 10. changes (%) in the travel demand of rail and air modes during the period of the COVID-19 pandemic

6. Conclusion

This study has improved the method used by some researchers and international statistical institutions to calculate the impact of pandemic on Iran's rail and air travel demand in terms of severity and duration. Therefore, rather than comparing the travel demand during the period of COVID-19 with that in the year before the pandemic, two SARIMA time series models were used to forecast the rail and air travel demand during this period. It is assumed that the model results show the amount of travel demand in the absence of the spread of COVID-19. The pandemic effect on travel demand reduction has ended if the forecast plot and the actual demand are in agreement. Forecast results and actual demand during the pandemic were compared to determine the severity and duration of the pandemic effect. This research was conducted in a developing country without HSRs, and its results are contrary to other studies comparing HSR and air transportation in developed countries. According to previous studies, COVID-19 had a smaller impact on rail transportation than on air transportation. Our findings indicate that there has been no investigation of the extent of the impact of COVID-19 on the demand for non-HSR and air travel in a developing country, and this study fills that research gap.

During the COVID-19 pandemic, both rail and air transportation faced significant reductions in demand. However, the demand for rail transportation decreased more compared to air transportation. Furthermore, rail transportation remained affected by the COVID-19 virus for a longer period compared to air transportation. Initially, both rail and air transportation experienced similar declines in demand at the onset of the virus outbreak. However, over time, the effects of COVID-19 on demand for air transportation diminished at a faster rate.

In this study, certain assumptions and simplifications have been made. The number of passengers carried is considered as travel

demand, and supply constraints have not been investigated. This implies that people have not traveled by rail and air modes solely due to the COVID-19 pandemic, and there was sufficient supply for these two modes of travel. Additionally, it is assumed that the forecast results of the models are equivalent to the travel demand in non-pandemic conditions, and the intersection point of the prediction chart and the actual demand chart indicates the endpoint of the pandemic's effect on each mode of travel. Moreover, modal shift has not been considered in this article. In addition to these points, there were numerous limitations in obtaining the required data, so there will still be many questions. Future research should investigate the reasons for the greater impact of COVID-19 on rail travel demand in terms of severity and duration. By identifying the reasons, policies can be proposed to maintain rail mode efficiency in future crises. This requires the use of other variables in calibrating the model. Considering the difference between the results of this study and those of comparative studies between HSR and air transportation, it is suggested that it be investigated in other countries with similar conditions. A rule can be developed for how developing countries without HSR can deal with future crises if similar results are obtained in those studies. This study has only investigated the severity and duration of the impact of COVID-19 on the demand for rail and air travel. Future researchers may investigate this issue from the perspective of passengers and utilize tools such as questionnaires to investigate behavior variables such as latent variables to determine the causes of the difference in the impact of pandemic on rail and air modes. Based on this study, the only reason for the decrease in travel demand is assumed to be the spread of COVID-19. By testing this assumption, the accuracy of the results may be enhanced.

7. Declaration of Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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