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Impact of Padma Bridge on transportation system: a case study for Barisal Division

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Abstract

This study aims to identify Padma Bridge's impact on Barisal Division's transportation system. Through an extensive literature analysis, a total of 19 impact factors have been identified. A questionnaire was formed to evaluate public perception by rating these 19 factors using a Likert scale from 1 (very poor) to 5 (very good). A total of 614 responses were collected from the users of different transportation modes like buses, passenger ferries, and aeroplanes. A structural equation (SE) model was developed to evaluate the impact of the Padma Bridge on the transportation system. The relative importance index (RII) technique was also used to verify the SE model by establishing the weights given to each factor. According to the SEM path coefficient value, the impact factors are divided into three zones: red, yellow, and green, based on their significance. Among 19 factors, nine are in the red zone, three are in the yellow zone, and seven factors fall into the green zone. Due to the Padma Bridge, there has been a radical change in the bus sector. Destinations are being reached in less time, new buses are connected, daily bus trips have increased, and goods are transported in less time. On the contrary, passenger ferries are experiencing a sharp decline in passenger numbers, daily trips are reducing, and staff members are losing their jobs. The outcome of this study will help the authorities and stakeholders to establish a sustainable transportation system in Barisal Division.

Keywords: Padma Bridge, Barisal Division, Transportation system, Structural equation modeling, Relative importance index

Introduction

Padma Bridge has emerged to be the longest bridge in Bangladesh, having a 6.15-km length and the deepest bridge construction in the world installed a 127-m-long pile into the river flowing with a strong current Padma. According to Ali et al. (2020) [1], Padma is a steel pallet bridge with two levels designed to facilitate the transportation of a four-way highway on the upper level and a distinct railway track on the lower level. Padma Bridge is a blessing for the transportation system connecting the Barisal division to Dhaka city.

Transportation scenario before Padma Bridge

The transportation connectivity between the Barisal Division and the capital Dhaka mainly depended on inland waterways prior to the inauguration of the Padma multipurpose bridge. The Southern region was linked to Dhaka through two inland waterways, Mawa-Kathabaria and Paturia-Goalundo [1]. Almost one million vehicles and 21 million passengers cross the Padma River each year at the Paturia-Goalundo and Mawa-Charjanajat crossings. Just over 58,000 people were recorded crossing the river daily by vehicle or Passenger ferry, locally known as launch [2]. The Paturia location used to employ a fleet of 22 ferries that operated continuously for 24 h across five River Terminals. In contrast, the Goalundo site featured three River Terminals [1].

The vehicle ferry fleet in Bangladesh is categorized into two variants, considering the service and vessel types. The first type comprises ferries utilized for river crossings, specifically designed to transport cars and trucks, and are under the jurisdiction of the Inland River Authority. The second type of ferry is utilized for longer distances, departing from Dhaka to reach the islands and delta communities [3]. Longer waiting times, delays due to bad weather, and safety issues are behind the ineffective contribution of vehicle ferries to the Transportation system of the Barisal Division. On average, buses and light vehicles wait around one hour before crossing Paturia-Daulatdia or Mawa-Charjanajat, while trucks wait about 2.5 h. Consequently, maximum utilization of resources was not possible prior to the Padma Bridge construction, negatively impacting the country's economy. Moreover, the Bangladesh Inland Water Transport Authority (BIWTA) had to spend significant money on dredging the river yearly to ensure navigability for regular ferry movement [4].

The road networking system was not as developed as now, so the passenger ferry service was considered the most convenient and accessible to all socioeconomic groups. People from the southern districts of Barisal, Bhola, Patuakhali, Jhalokathi, Borguna, and Pirozpur used to rely on passenger ferry services for their communication. Eventually, the rapid population growth increased the demand for transportation facilities in the southern region, resulting in congestion in the waters. In contrast, the waterways were not expanding [5]. Over the years, the rate of accidents has been a significant concern about the IWT system. BIWTA stated, that between 1977 to 2000, 248 motor passenger ferry accidents resulted in 2309 fatalities, 374 injuries, and 208 missing individuals [6].

For the next two decades, the death tolls continued. According to Rahman and Degiuli (2015) [7], waterway accidents commonly occur due to multiple causes, including collision, grounding, fatigue, overloading, and adverse weather. The biggest challenge of the inland water transport system is to find a proper navigation route as the length of the waterway decreases in the dry season. Moreover, the alluvial deposition is also an obstruction to the water transport movement in the rivers of the southern region [8]. Lack of waste management, proper sanitation, and uncontrolled discharge of petroleum from ships and passenger ferries massively contribute to river pollution [9]. There is an Airport in Barisal Division. Due to comparably high fares, only a few people can afford to have aviation facilities.

Transportation scenario after Padma Bridge

The transport scenario of the Barisal Division has undergone significant transformation subsequent to the completion of the Padma Bridge project. Following the inauguration of the Padma Bridge, there has been a discernible decline in reliance on waterways for transportation, accompanied by a notable surge in road traffic. The accessibility study conducted by the Japan International Cooperation Agency (JICA) predicts that after the completion of the Padma Bridge, the daily traffic volume will reach 21,300 vehicles and 41,600 vehicles per day by 2025 [10]. Waterway transportation facilities like vehicle ferries and passenger ferries in southern regions are declining as passengers find crossing Padma Bridge is the most convenient option rather than waiting hours after hours for vehicle ferries or passenger ferries. Many passenger ferry operators take off their services from the Dhaka-Barisal route, and ferry movement is reduced in Paturia- Dawlatdia ghat, resulting in a significant loss of BIWTC.

The Padma Bridge, on the other hand, was viewed as a blessing by bus operator owners due to the decline in the use of car ferries, the shorter travel time between stops, and the convenient distance. Consequently, there has been a notable increase in the number of buses allocated to the Dhaka-Barisal routes compared to the past [10]. As predicted by Jalil and Mia (2021) and Ali et al. (2022), travel time savings is about 2 h for cars and buses and 10 h for trucks, saving 681,600 l of fuel within a day [1, 11]. Padma Bridge seems to have all the potential to mitigate the limitations of the waterways transport system. Waterway transportation facilities like vehicle ferries and passenger ferries in southern regions are facing a declining trend as passengers find crossing Padma Bridge is the most convenient option rather than waiting hours after hours for vehicle ferries or passenger ferries. Many passenger ferry operators take off their services from Dhaka-Barisal route and ferry movement is reduced in Paturia-Dawlatdia ghat resulting in a significant loss of BIWTC. The passenger survey in this study also shows that more than 65% of the air transport users are willing to switch to road or rail transport from aviation once the Padma Bridge is entirely constructed [12].

This study aims to analyze the impact of the Padma multipurpose bridge on the Overall transportation system and communication development in the Barisal Division. The aided transportation system by the Padma Bridge may facilitate the nation's economy by boosting annual GDP. The Padma Multipurpose Bridge is estimated to boost the country's annual GDP by 1.23% [1]. The results are conspicuous in the toll collection as a total of Tk 6.6 billion was earned in the ten months since the Padma Bridge was opened to traffic. Improved transportation systems can extensively help the long-overlooked southern region tourism and the peripheral areas' health care facilities.

Many previous studies described the structural complexity and economic and environmental impact of the Padma Bridge. Still, no study focused on the overall transportation system's implications because of the Padma Bridge construction. This paper focuses solely on the factors influencing the comprehensive transportation system of the Barisal Division after the construction of the Padma Bridge.

Methods

We initially analyzed previous studies to determine the effect of the Padma Bridge on the transportation system. Then, in order to assess the impact of the Padma Bridge, we discussed with professionals and staff connected to Bangladesh's transportation industries [13]. Then, we developed a questionnaire to carry out a more detailed examination of the effect factors. Nineteen observed variables were selected as impact *factors*. Then, using an online questionnaire survey, we gathered user responses [14]. The research steps are presented in Fig. 1 as a flow chart.

A detailed literature analysis and pilot survey have identified 19 potential factors impacting the transportation system of the southwestern region of Bangladesh. The factors were classified into three latent groups, with related factors being put together under one leading group:

1. Passenger ferry
2. Bus
3. Aeroplane

In a questionnaire form, the factors were tallied. To assess the questionnaire's substance, the draft was made and then discussed with various experts in these three means of transportation systems. After a brief discussion with experts, effective changes and modifications have been introduced to the questionnaire. The passengers and the authorities associated with these transportation modes in the Barisal division are the target population. The questionnaire was sent out to collect the responses from the users. A total of 614 responses were collected to assess the impact of Padma Bridge on the transportation system. Among the 614 answers, 42.7% are male, and 57.3% are female, which indicates almost equal participation of men and women in the survey.

To identify the impacts of Padma Bridge on the transportation system, we have examined the hypothesis through two consecutive approaches: structural equation modeling and relative importance index. Figure 2 shows the classifications of nineteen variables into three latent variables.

Structural equation modeling

Estimating the structural equation model is a recurrent method that ultimately generates the best-fitted model, which justifies the hypothesis [15]. The estimation of structural

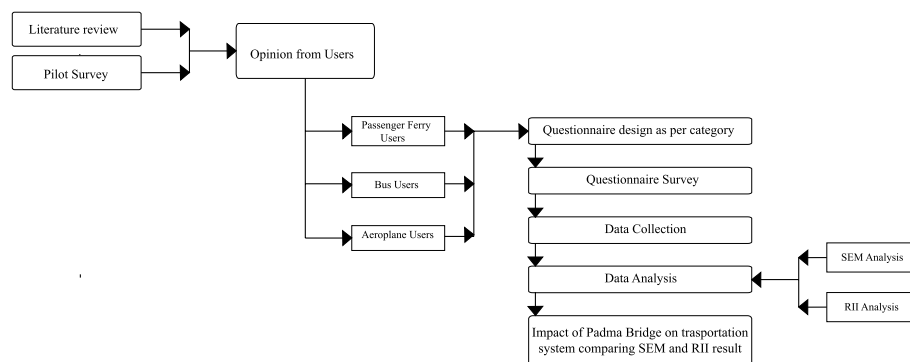


Fig. 1 Flowchart of the procedure used in carrying out the research

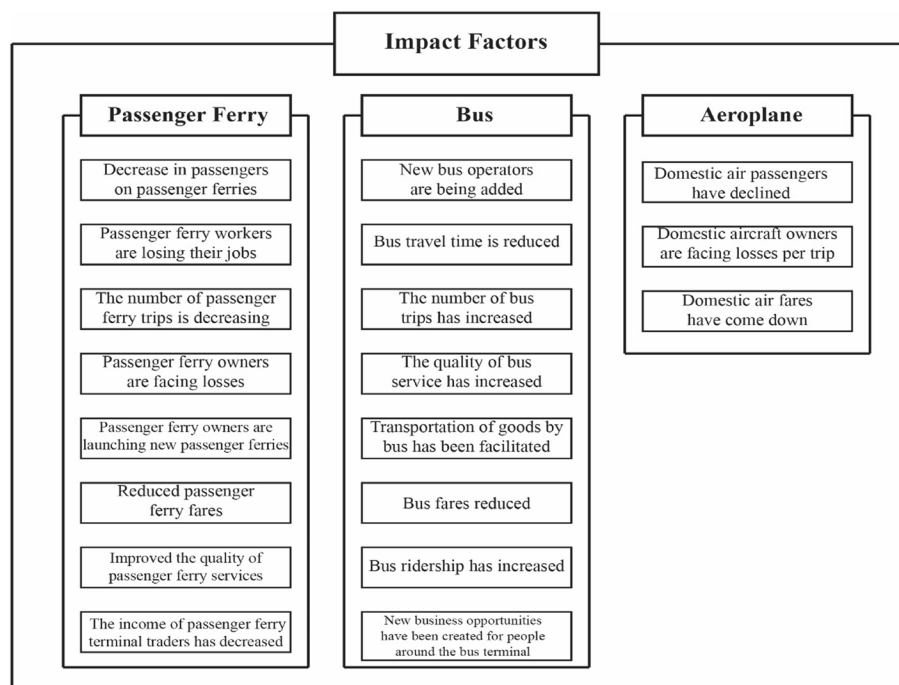


Fig. 2 Classifications of impact factors

equation models can be done using a variety of techniques, such as maximum likelihood (ML), generalized least squares (GLS), and weighted least squares (WLS). Among these three methods, ML is the most popular [16]. The selection of the best SEM depends on parameters like various probability distribution assumptions, the SEM's complexity, the parameters' scale properties, and the sample size [17]. The relationships between two categories of variables, namely observable (directly measured) and latent (not directly measured), can be characterized using SEM [18]. A measuring component and a structural component are the two methods that make up the SEM method [19]. The measurement component describes the relationship between latent variables and observable variables. Relationships between the latent variables are expressed via the structural component [20]. SEM model specifying the impact of Padma Bridge on the transportation system is shown in Fig. 3.

Model development

The correlation coefficient and expert views were used to develop the SEM research model, as illustrated in Figs. 3, 4, and 5. Figure 3 presents the basic structural equation model for justifying the impact of the Padma Bridge on the transportation system. This model denotes a basic proposition where all three latent groups have significance denoting the current condition of the transportation system after the inauguration of the mighty Padma Bridge. Additionally, the substructural equation models depicted in Figs. 4, 5 and 6 indicate the case in which a single component selectively has a

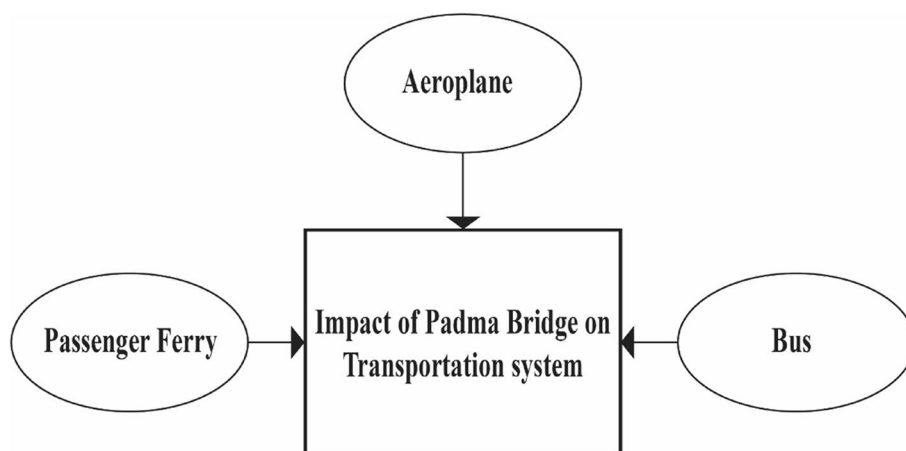


Fig. 3 Main structural equation model of impact factor

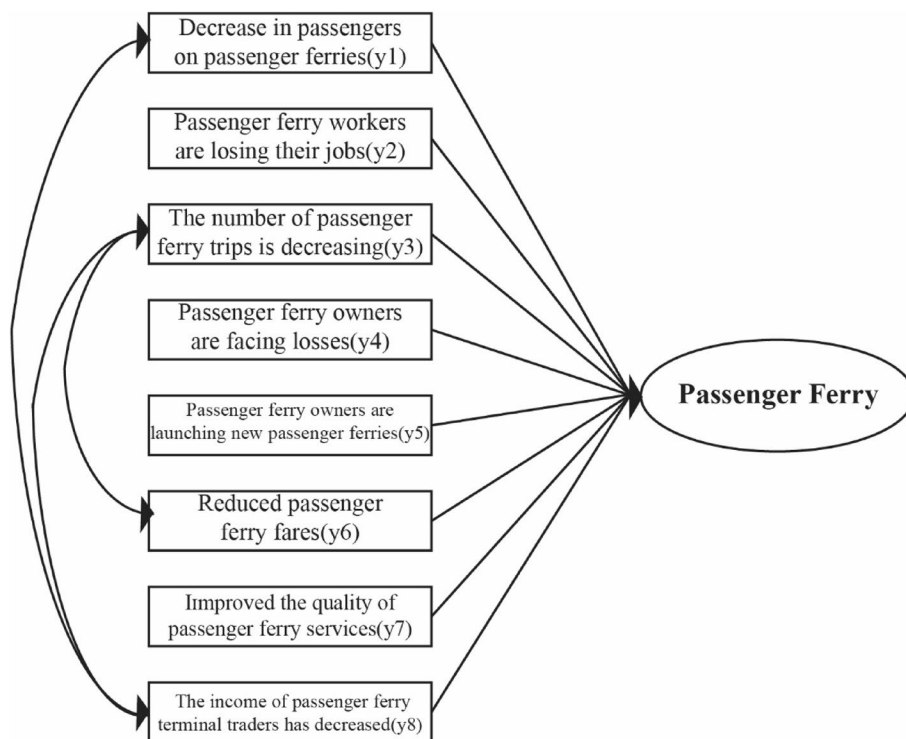


Fig. 4 Sub-structural equation model: passenger ferry latent variable

considerable impact on other factors in each class while also having a solid connection with a latent variable (Fig. 6).

Consequently, the developed SEM model is a framework for examining the relationships between studied factors. Several hypotheses that express informal modeling were produced to evaluate the fundamental proportions in this study. For example, the decrease in passengers on passenger ferries in Fig. 4 strongly connects with

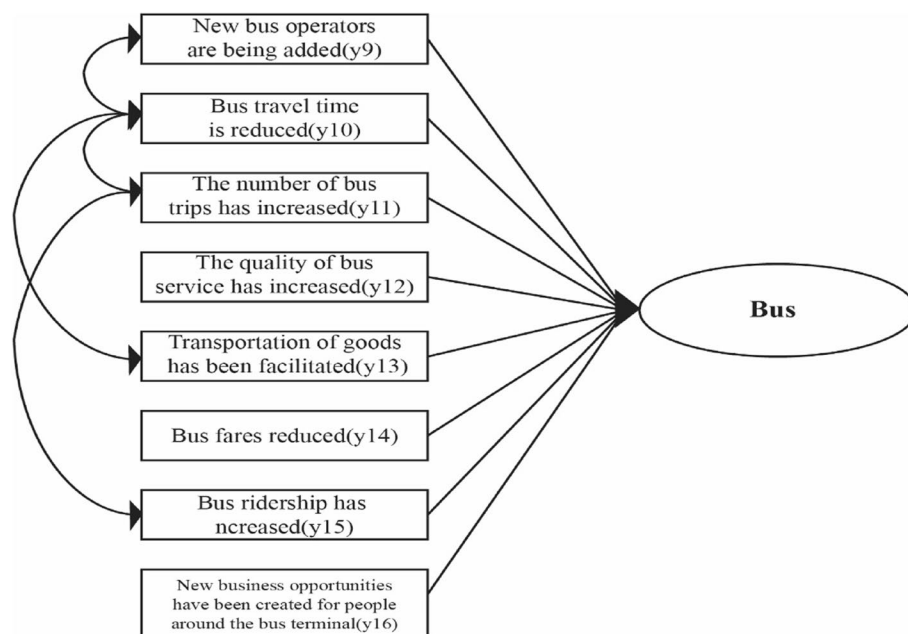


Fig. 5 Sub-structural equation model: bus

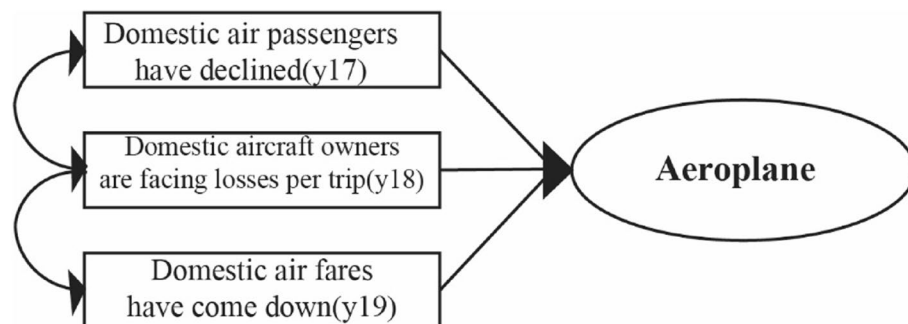


Fig. 6 Sub-structural equation model: aeroplane

the “passenger ferry” latent group. The constructed SEM model in Fig. 7 provides a framework for exploring the link between study factors.

Model specification and assessment

The SEM model was developed by SPSS Amos computer software. An initial model was developed in light of the rotate component matrix analysis by SPSS Statistics. Several iterations were made to improve the model and continued until it achieved the required goodness of fit. The best model is shown in Fig. 7. There are several latent variables, each showing its influence on different factors and its degree of connection to the impact class.

The goodness of fit indices is a critical SEM tool for evaluating the fitness of generated models. The most important indices to justify model fitness are the normal fit index (NFI), root mean squared error of approximation (RMSEA), and χ^2/df . According to Hooper et al. (2008) [21], the NFI value closer to 1.00, the RMSEA value between

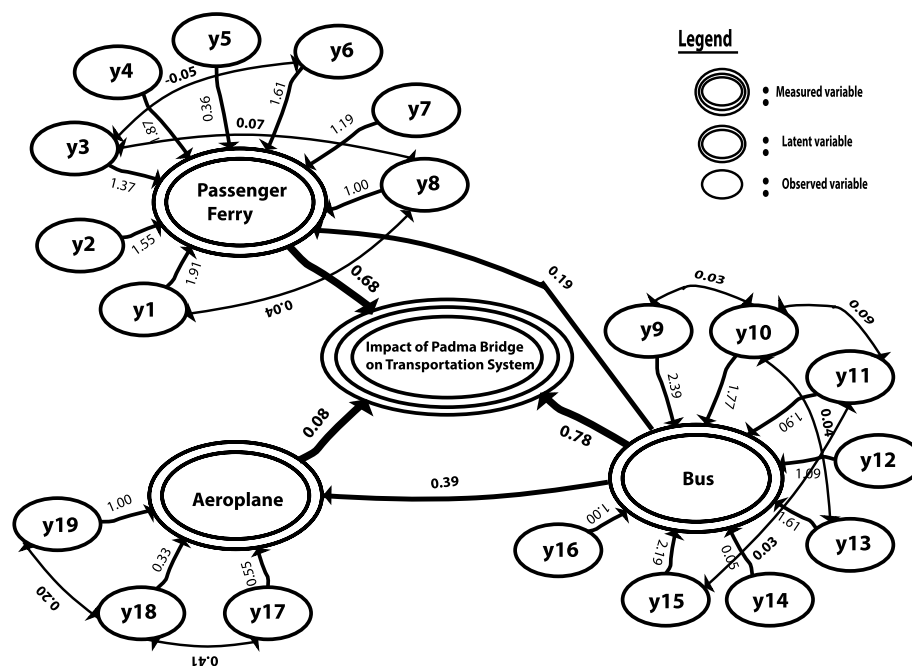


Fig. 7 Final structural equation modeling (SEM) model specification of impact factors

0.00 and 0.08, and the χ^2/df value below three (03) define the good fitness of the model. Model fitness defines each factor that has significant impacts. Our model meets the fitness criteria with the NFI value of 0.834, RMSEA value of 0.03, and χ^2/df value of 2.35. Consequently, the model's significance is increased because it is significant at probability $p < 0.005$.

Relative importance index

According to several studies, to evaluate the overall rank, the mean and standard deviation of each item are inadequate because they do not consider the relationship between the factors [22–24]. The RII approach classifies the variables according to priority and prioritizes the factors that have been discovered [25, 26].

$$\text{RII} = \frac{\sum W}{A \times N} \quad (1)$$

where,

W = weighting of each factor given by respondents.

A = maximum weight.

N = total number of respondents.

Results and discussions

Structural equation modeling

Our SEM model, in Fig. 7, is calibrated with three latent groups and nineteen impact factors. With a 95% confidence level, all SEM model's measurement component coefficients are not zero. Among the three latent variables, "bus" with a layer coefficient of

Table 1 Estimated parameters value of different impact variables

Factor group	Factor name	Factor notation	Coefficient value
Passenger ferry	Decrease in passengers on passenger ferries	y1	1.91
	Passenger ferry workers are losing their jobs	y2	1.55
	The number of passenger ferry trips is decreasing	y3	1.37
	Passenger ferry owners are facing losses	y4	1.87
	Passenger ferry owners are launching new passenger ferries	y5	0.36
	Reduced passenger ferry fares	y6	1.61
	Improved the quality of passenger ferry services	y7	1.19
	The income of passenger ferry terminal traders has decreased	y8	1.00
Bus	New bus operators are being added	y9	2.39
	Bus travel time is reduced	y10	1.77
	The number of bus trips has increased	y11	1.90
	The quality of bus service has increased	y12	1.09
	Transportation of goods by bus has been facilitated	y13	1.61
	Bus fares reduced	y14	0.05
	Bus ridership has increased	y15	2.19
	New business opportunities have been created for people around the bus terminal	y16	1.00
Aeroplane	Domestic air passengers have declined	y17	0.55
	Domestic aircraft owners are facing losses per trip	y18	0.33
	Domestic airfares have come down	y19	1.00

Table 2 Scale used to identify factor's impact and probability of occurrence

Scale	Significance	Color zone
Coefficient > 1.50	Very high	Red
1.00 < coefficient < 1.50	High	Yellow
1.00 < coefficient	Normal	Green

y1: Decrease in passengers on passenger ferries y2: Passenger ferry workers are losing their jobs y4: Passenger ferry owners are facing losses y6: Reduced passenger ferry fares	y3: The number of passenger ferry trips is decreasing y7: Improved the quality of passenger ferry services	y5: Passenger ferry owners are launching new passenger ferries y8: The income of passenger ferry terminal traders has decreased
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Fig. 8 Risk zone for factors under the passenger ferry latent group

0.78 proved to be the most impacted sector. According to the responses, the “bus” sector is experiencing a significant transformation due to the Padma Bridge. Also, the impact on the bus is not to be ignored. Factors coefficient values are presented in Table 1.

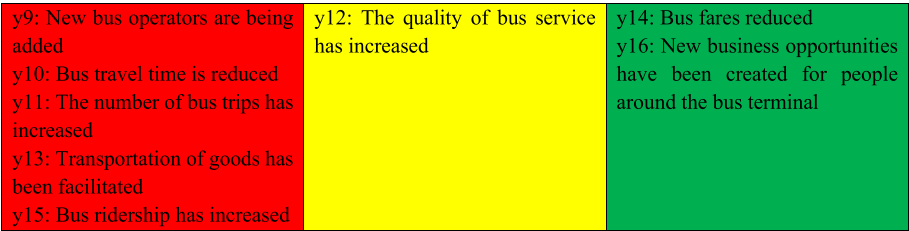


Fig. 9 Risk zone for factors under the bus latent group

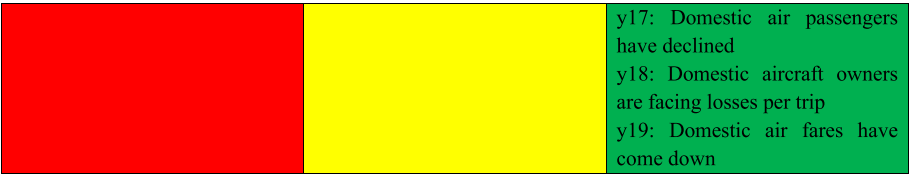


Fig. 10 Risk zone for factors under the aeroplane latent group

To determine the significance, each factor under latent groups is divided into three categories based on their coefficient as presented in a study by Mahamid in 2011 [27]. Table 2 shows the scale used to determine the impact of each latent group.

The red zone indicates the most significant impacts on those factor groups due to the Padma Bridge. And it has also made an enormous change in that particular transportation mode factor. The yellow zone defines a moderately significant impact. The green zone denotes the impacts of Padma Bridge are less likely than others.

Passenger ferry latent group

Under this group, eight factors are there. Among them, four factors are in the red zone: two are in the yellow zone and two are in the green zone, as shown in Fig. 8.

Due to the Padma Bridge, the passenger ferry sector is experiencing a substantial negative impact. People can travel within a short time via Padma Bridge. Now, they do not need to wait until night to reach their destination. As a result, the passenger ferry service is experiencing a scarcity of passengers. The number of passenger ferries is decreasing, and the staff associated with this are losing their jobs. Due to the higher fuel price, the passenger ferry owner can't reduce fares to attract passengers.

Bus latent group

This group also consists of eight factors. Among them, five factors are in the red zone: one is in the yellow zone and two are in the green zone, as shown in Fig. 9.

Padma Bridge has arrived as a blessing for the passengers traveling by bus. Before Padma Bridge, the duration from Barisal to Dhaka was more than the passenger ferry service. Buses have to cross the mighty Padma River by vehicle ferry service. Buses have to wait a long time to board the vehicle ferry. It would cost them almost 3 to 4 h. Due to Padma Bridge, passengers and goods carriers can reach their destinations

Table 3 Risk matrix

Factors	Latent groups	Significance	Color zone
y1: Decrease in passengers on passenger ferries	Passenger ferry	Very high	Red
y2: Passenger ferry workers are losing their jobs	Passenger ferry	Very high	Red
y4: Passenger ferry owners are facing losses	Passenger ferry	Very high	Red
y6: Reduced passenger ferry fares	Passenger ferry	Very high	Red
y9: New bus operators are being added	Bus	Very high	Red
y10: Bus travel time is reduced	Bus	Very high	Red
y11: The number of bus trips has increased	Bus	Very high	Red
y13: Transportation of goods has been facilitated	Bus	Very high	Red
y15: Bus ridership has increased	Bus	Very high	Red

Table 4 RII analysis result and variable ranking

Factor group	Factor name	Factor notation	RII value	Rank
Passenger ferry	Decrease in passengers on passenger ferries	y1	0.351	1
	Passenger ferry workers are losing their jobs	y2	0.434	4
	The number of passenger ferry trips is decreasing	y3	0.382	2
	Passenger ferry owners are facing losses	y4	0.446	5
	Passenger ferry owners are launching new passenger ferries	y5	0.694	8
	Reduced passenger ferry fares	y6	0.493	6
	Improved the quality of passenger ferry services	y7	0.586	7
	The income of passenger ferry terminal traders has decreased	y8	0.398	3
Bus	New bus operators are being added	y9	0.336	2
	Bus travel time is reduced	y10	0.309	1
	The number of bus trips has increased	y11	0.309	1
	The quality of bus service has increased	y12	0.499	6
	Transportation of goods has been facilitated	y13	0.341	3
	Bus fares reduced	y14	0.677	7
	Bus ridership has increased	y15	0.349	4
	New business opportunities have been created for people around the bus terminal	y16	0.368	5
Aeroplane	Domestic air passengers have declined	y17	0.510	1
	Domestic aircraft owners are facing losses per trip	y18	0.570	2
	Domestic airfares have come down	y19	0.610	3

within 3 to 4 h. Due to this time reduction, most passengers prefer the bus service over the passenger ferry service. And the bus owners are also taking this advantage. They are operating extra trips and launching new buses to provide comfort and convenience.

Aeroplane latent group

This group consists of three factors. All of them are in the green zone, as shown in Fig. 10.

Domestic aeroplane service charges high fares compared to passenger ferry and bus operators. And the users of this service are also the higher class people. Padma Bridge also impacts this service, but a negligible one.

Top affecting factors

Table 3 shows the top significant factors that impact the transportation system more due to the Padma Bridge. It can be seen that four factors are from the passenger ferry latent group, and five factors are from the bus latent group. Passenger ferry and bus services have experienced more impact due to Padma Bridge.

Relative importance index

The value of RII ranges from 0 to 1. The value of RII near 1 denotes the most significant factors [24, 25]. The RII analysis of the variables is given in Table 4.

Considering the top two highest-ranked factors from each latent group, due to Padma Bridge number of passengers using the ferry service and air service has decreased, and the authorities are operating less number of trips per day. But, the scenery of the bus is opposite. Bus travel time has been reduced, and operators are increasing their daily trips.

Conclusions

This study aims to identify the impact of Padma Bridge on the transportation system of Barisal Division. A total of 614 responses were collected through an online questionnaire survey. Nine of the factors—out of 19—are positioned in the red zone, three are in the yellow zone, and seven are in the green zone, according to the study, which discovered the factors using a questionnaire survey. The severe factors that are located in the red zone are:

- y1: Decrease in passengers on passenger ferries
- y2: Passenger ferry workers are losing their jobs
- y4: Passenger ferry owners are facing losses
- y6: Reduced passenger ferry fares
- y9: New bus operators are being added
- y10: Bus travel time is reduced
- y11: The number of bus trips has increased
- y13: Transportation of goods has been facilitated
- y15: Bus ridership has increased

It can be seen that most of the factors are under the “bus” related latent group. Because of the Padma Bridge, the bus services have been developed a lot, introducing new operators, extra trips, and less travel time. Before the Padma Bridge people traveling via bus had to spend a lot of time in Mawa or Paturia vehicle ferry ghat to cross the mighty Padma River. It almost took them around 3 or 4 h to cross it. Now, passengers can easily cross the river within seven to eight minutes. Moreover, the

transportation of goods has been accelerated. But, an opposite scenario is observed for passenger ferry service. Passengers are discouraged from traveling via passenger ferry as it takes longer time than the bus service. People traveling for official work, economic purposes, and social work can reach their destination in less time due to the Padma Bridge. They need not wait till the whole night or day to reach their destinations. Passenger ferry-related workers are losing their jobs as there are not enough daily trips, and the owner also faces losses by operating each trip. The daily trip requires many barrels of fuel which costs them huge money. The money collected from the passengers does not cover the fuel cost. Maximum seats and cabins remain vacant. This mode of transportation will eventually become inoperable if this trend continues. This study has the potential to enhance the transportation networking of the southwestern region of Bangladesh and actively contribute to the infrastructure development and management of the Padma Multipurpose Bridge. Moreover, this study can also pinpoint the sector that helps to regulate the revenue from Padma Bridge. In the future multiple perception, models can be introduced considering the factors of one specific transportation mode solely (i.e., bus services, train services). The following study might cover the topic of how to retain the passenger ferry as a mode of transport.

Abbreviations

BIWTA	Bangladesh Inland Water Transport Authority
BIWTC	Bangladesh Inland Water Transport Corporation
GDP	Gross domestic product
GLS	Generalized least squares
IWT	Inland water transport
JICA	Japan International Cooperation Agency
ML	Maximum likelihood
NFI	Normal fit index
RII	Relative importance index
RMSEA	Root mean squared error of approximation
SEM	Structural equation modeling
SE	Structural equation
SPSS	Statistical Package for Social Sciences
WLS	Weighted least squares

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Authors' contributions

MM prepared the questionnaire, collected data, and analyzed the data. MM has also contributed to writing and conceptualization. SA has also contributed to its conceptualization, data collection, writing, and reviewing. Questionnaire preparation, writing, and reviewing. MR contributed by providing valuable feedback, revising the manuscript, and approving the final version for submission. All authors read and approved the final manuscript.

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Availability of data and materials

Readers should contact the corresponding author for details.

Declarations

Competing interests

There are no competing interests connected with this publication. This research is self-studied and no one influences this research.

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