


# Assessing Travel Time Reliability of Public Transport in Kolkata: A Case Study



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**Abstract** Punctuality of a trip maker directly depends on the on-time performance of the whole transportation system and specifically on the travel time reliability of the preferred mode of transport. As a matter of this fact, daily commuters prefer a reliable mode of transport which adheres to its schedule and is frequently available. Thus, the present study aims to find only the travel time reliability of the different public transport modes in a particular route of Kolkata Metropolitan Area. The route from Banskroni Bazar Area to Park Street Area was chosen as the case study area. The in-vehicle travel time reliability of the state government bus, private bus and minibus were estimated using the method proposed by Liu and Sinha [15] and the results compared with that of the metro railway. The result of the analysis shows that the travel time reliability of all bus types ranges from 45 to 65% of the reliability of the metro railway. The parameters prescribed by FHWA, such as Buffer Time ( $T_B$ ), Buffer Index ( $B_i$ ), Planning Time ( $P_t$ ) and Planning Time Index ( $P_i$ ), were also estimated which provides valuable information about the reliability of the buses plying on the route under study. Delay parameters in transit contribute a lot to the travel time which was also observed to indicate the reliability of buses from delay perspective. The effects of some other relevant traffic parameters such as the congestion delay and waiting time delay on reliability have also been discussed as well.

**Keywords** Public transport · Reliability · Travel time · Buffer time · Buffer index · Planning time

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## 1 Introduction

Commuters all over the world try to minimise their overall journey time. This gives rise to the need for reliable services of transportation system, especially the public transport system. Reliability for various systems can be defined in various forms. Reliability can be defined as the operational consistency of a facility over an extended period of time. Ebeling [8] defined reliability as the probability that a system will perform a required function for a given period of time. In transportation engineering, reliability can be defined as the level of variability between the commuters' expectation and the actual experience. Kolkata is a densely populated city and according to a study by the Union Ministry of Urban Development in 2013, about 54% of daily commuters avails bus for any trips. Hence, reliability of the bus system in Kolkata is highly desirable. In a city where majority of the trip makers are of captive characteristic, the unreliable public bus system would force the commuters to either opt for para-transit system or shift towards personal vehicles. In most of the cases, the personal vehicles will be of motorised two wheelers and four wheelers and also the para-transit modes are mostly three-wheeled auto-rickshaws along with taxis and application-driven cabs such as Uber/Ola, etc. Increase of these smaller size modes of traffic in the same right of way along with the bigger size vehicles will not only cause increase in congestion but will also have a bad impact on environmental pollution. Therefore, it is necessary to operate the public transport system at desired level of reliability. The present study mainly focuses on the in-vehicle travel time reliability of the buses and the delays incurred during the bus trips in Kolkata. The objectives of the study can be stated as follows:

- To estimate the travel time reliability of the public transport modes plying along the specific study corridor.
- To compare the travel time reliability of different category of buses with that of the metro railway.
- To estimate the buffer time and planning time required for the trip makers choosing the public mode of transport system, especially buses as their mode of transport.
- To identify the delays in a trip and its effect on the travel time reliability.

The previous works and journals related to public transport reliability literature have been summarised in the next section.

## 2 Literature Review

The concept of reliability in travel time has been introduced in the late twentieth century, though in Indian context the applications have been in limited quantity. Some of the recent works have been studied, and the relevant points have been discussed here.

In 2013, Tony [17] identified the public transit priority features and the method to enhance the operational characteristics of public transit in Munich, Germany and

Zurich, Switzerland. Diab and El-Geneidy [6], in the same year, tried to understand the impacts of various improvement strategies on transit service reliability. Chien and Liu [5] measured the travel time variability and reliability with floating car data. Diana [7] showed that satisfaction measures of trip makers can be exploited to gain insights on the relationships between personal attitudes, transit use and urban context. Cantwell et al. [2] examined the level of stress caused by commuting into Dublin city centre. It revealed that the commuters who spend long time for waiting for public transport service tend to be more stressed. This occurs when the reliability of the bus service is poor. Route length, headway, distance from stop to original terminal and the use of exclusive bus lanes affect the service reliability as found by Chen et al. [4]. Lyman and Bertini [16] tried to improve regional transportation planning and operations using travel time reliability measures. Liu and Sinha [15] estimated some of the measures to assess reliability of an urban bus network using microsimulation model framework. It was observed that with increasing congestion and passenger demand, reliability is reduced. Reduction in per passenger boarding time proves to be an effective measure in improving reliability. Iseki et al. [11] studied the effects of out-of-vehicle time on travel behaviour, and the findings were used to improve the travel connectivity at the transit transfer points. Laura [13] and Lin et al. [14] used new techniques, such as AVL and APC techniques, to collect data and measured reliability, cause of unreliability and application of strategies to improve the service. During early twenty-first century, Kimpel [12] analysed transit service reliability and estimated passenger demand.

The reliability measure of a corridor is important for the operational efficiency of a road. In the Indian context, it is important to enhance and maintain accessible, reliable and affordable public transport services as mentioned by Badani and Haider [1] in their work. The travel time reliability of urban arterial corridor in Delhi road network was studied by Gopi et al. [10]. They used the reliability measures developed by Federal Highway Administration (FHWA Report 2006) [9] to measure the reliability of the arterial corridor at a different time of the day. Higher Planning Time Index (PTI) and Buffer Index (BI) values during the morning peak hour of non-working days as compared to morning peak hour of working days were obtained from their analysis. Chalumuri et al. [3] also used the FHWA measures for estimating reliability of an urban corridor and further used the microsimulation to determine the travel time reliability. They also found out the influence of the demand side factors (such as traffic flow, speed distribution vehicle composition, driver characteristics, etc.) and supply-side factors (such as reserved lane for bus, lane closure, etc.) on the reliability value (Reviewer 2).

In most of the previous literature, it is found that travel time reliability has been considered to be the key indicator for the performance and health of a region's transportation system. Thus, in this article, the performance of the public transport (especially buses) has been analysed using the methods of travel time reliability measures. In the following sections, the methodology and the case study area has been described. The reliability of the buses has been compared with that of the most reliable mode of public transport in the same route, i.e. metro railway.

### 3 Methodology

The metro railway is considered as the benchmark for the travel time reliability. The estimated travel time reliability for all the modes is compared with that of the metro railway. The comparison reveals the current situation of travel time reliability of all the modes with respect to the metro railway.

The data collected from the on-board survey (the process is described in ‘Data collection and Survey’ section later) was analysed in three categories. Initially, the travel time reliability was estimated for each of the modes considering the method used by Liu and Sinha [15]. They defined travel time reliability as the ratio of the mean travel time to the standard deviation. The formula can be written as follows:

$$RT = \frac{\mu}{\sigma} \quad (1)$$

where

- $\mu$  is the mean travel time and
- $\sigma$  is the standard deviation of travel time.

The data collection and the calculations are easy for this method and hence have been used in this study to estimate the reliability (Reviewer 1).

Second, the five standard measures developed by Federal Highway Administration (FHWA Report 2006) [9] to determine the travel time reliability are also used here. It is used in this study as it is a well-established method and has been used by many researchers for estimating the route reliability (Reviewer 1). The parameters are mentioned below.

**95th Percentile Travel Time ( $T_{95}$ ).** It denotes the travel time which is less than or equal to 95% of sample travel times. Higher  $T_{95}$  means the variation in travel time of the bus is high. This indicates less reliability.

**Buffer Time ( $T_B$ ).** The difference between the 95th percentile travel time and the mean travel time ( $\mu_t$ ) is called the buffer time. This represents the extra time needed to compensate for unexpected delays. The higher the buffer time for a passenger, the less reliable is the mode of travel for that passenger.

$$T_B = T_{95} - \mu_t \quad (2)$$

**Buffer Index ( $B_i$ ).** It is the ratio of buffer time to the mean travel time expressed in terms of percentage. This indicates the extra percentage of time a trip maker should add to his/her expected mean travel time to ensure on-time or earlier arrival to the destination. The more the buffer index, the lower is the reliability.

$$B_i = \frac{T_B}{\mu_t} \times 100\% \quad (3)$$

**Planning Time Index ( $P_i$ ).** It is the ratio of the 95th percentile travel time to the free-flow travel time expressed in terms of percentage. It compares the longest travel

time against a travel time incurred by free-flow traffic. The higher the  $P_i$ , the less reliable is the mode of travel. In the present study, free-flow travel time was obtained by observing the travel time taken by a car to reach the destination from the origin via the same route in the early morning hours. The free-flow speed is observed to be 1380 s for this present study.

$$P_i = \frac{T_{95}}{T_F} \times 100\% \quad (4)$$

**Planning Time ( $P_t$ ).** It is the summation of average/mean travel time and buffer time. The higher the buffer time, the more will be the planning time and lesser there liability of the mode.

$$P_t = \mu_t + T_B \quad (5)$$

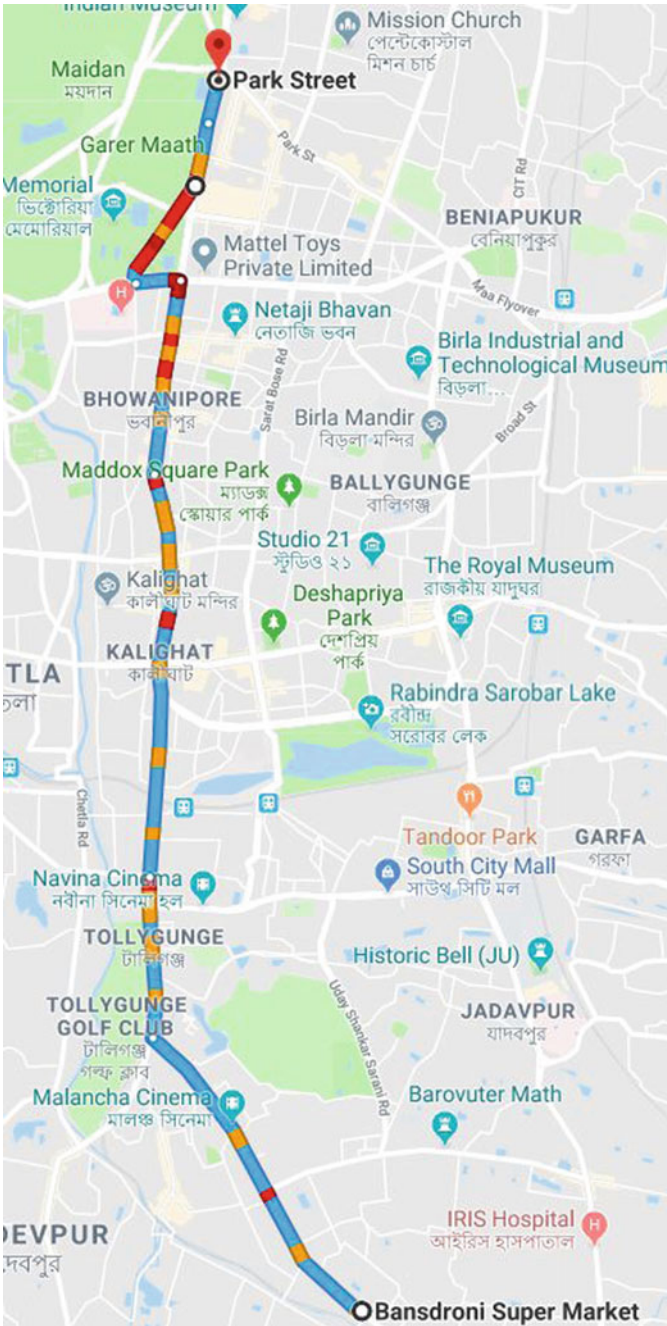
Finally, the reliability is also indicated with the help of the delay caused by travelling in public buses. The more the delay, the less is the reliability. The different types of delay focussed in this present study are as follows:

- **Signal Delay:** The vehicle stopping within a distance of 100 m from the 'stop' line under the influence of signal which incurs the delay in the travel time is termed as signal delay.
- **Bus Stop Delay:** These delays are attributed to boarding and alighting of individual passengers at specified bus stops only.
- **Waiting Delay:** This includes any extra delay occurred due to unnecessary halt at empty stoppages.
- **Congestion Delay:** Any delay caused by the congestion created due to the huge volume of traffic during the peak hours.

Since the bus routes are the same, the number of signalised intersection encountered in a single trip is the same for all modes. So, in addition to congestion delay, the travel time delay is dependent mostly on the bus stop delay and the waiting time delay which will negatively affect the travel time reliability. A sensitivity analysis is included in this study to understand and identify the delay that affects the travel time reliability of a public bus.

## 4 Study Area

Kolkata is the third largest metropolitan city in India and the capital city of West Bengal state. It has a huge population, mostly residing in the suburban regions. Bansdronei Bazaar area is one such region in the southern part of Kolkata that generates a significant amount of work trips to Park Street, a well-known commercial area in the central part of Kolkata. Out of the various corridors connecting Bansdronei Bazaar with Park Street, one corridor of about 10.5 km long is selected as the case study due to the presence of metro railway all along the corridor (Fig. 1) in addition to the



**Fig. 1** Map showing the case study route from Bansdrone Bazaar to Park Street. *Source* Google Map

**Table 1** Bus route characteristics under study

Bus route	Bus operator	Origin	Destination	Route segment under study
A	State Govt.	Garia bus stand	Howrah station	Bansdroni bazar to Park street
B	State Govt.	Garia bus stand	Howrah station	Bansdroni bazar to Park street
C	Private	Bansdroni bazar	Howrah station	Bansdroni bazar to Park street
D	Private (minibus)	Naktala bus stand	Howrah station	Bansdroni bazar to Park street

different public modes of transport. This corridor consists of four busiest roads of Kolkata. They are Netaji Subhash Chandra Bose Road, Shyama Prasad Mukherjee Road, Ashutosh Mukherjee Road and Jawaharlal Nehru Road. These roads are having all types of modes of transport plying on Kolkata streets, namely, regular private and government buses, private minibuses, three-wheeled auto-rickshaw, taxi/cabs and private cars and motorised two wheelers along with other non-motorised modes.

A number of bus routes of various characteristics and different routes are plying on the study corridor. Out of them, four bus routes have been considered for this study as these four bus routes have a common segment in their route from Bansdroni Bazar to Park Street. The other routes do not have such a long common route segment. Moreover, these four types of buses (i.e. Govt. AC, Govt. Non-AC, Ordinary Private Non-AC and Private Minibus) mostly ply in the urban streets of Kolkata and represents the public bus system of Kolkata (Reviewer 2).

A brief description of these bus routes is provided in Table 1. The survey procedure and the data collected for analysis are discussed in the next section.

## 5 Data Collection and Survey

In this study, two state government buses (Route A and Route B), one private bus (Route C), one mini private bus (Route D) and metro railway were selected. To calculate the reliability measures (as mentioned in the 'Methodology' section), the time taken by the buses of the aforesaid bus routes to travel from Bansdroni Bazar to Park Street along the route (mentioned in 'Study Area') was observed. This travel time is nothing but the running time of the buses between two consecutive bus stops whose summation gives the total running time. Along with the travel time, different delays such as signal delay, bus stop delay, waiting delay and congestion delay were also noted using a stopwatch. AVL data [14] was not available to obtain these data, hence, on-board technique was adopted. In this technique, an enumerator travelled from Bansdroni Bazar to Park Street in a bus of the study routes and the different

delay and travel time are noted down using a stopwatch. Since the study focuses on the reliability of buses for work trips only, the morning peak hour was selected for conducting the survey. Three buses of each bus route travelling between 9 and 10 am each day were randomly selected on any seven weekdays of a month. The same procedure was carried out for metro railway as well. Free-flow travel time was obtained by observing the time taken by a standard car to reach Park Street from Bansdroni Bazar via the same route at 6 am for three consecutive weekdays and the average is calculated. This is considered as the datum for free-flow travel time. There is difference in the operational characteristics of car and bus but the free-flow travel time cannot be extracted accurately from a bus because the drivers of the public buses drive according to their own will and may not drive at a free-flow speed even if a free-flow condition prevail in the road segment. Due to this reason mainly, free-flow travel time was obtained by observing the travel time taken by a car to travel the road segment under study during the early morning hours at a speed not more than 30 kmph to replicate the free-flow driving characteristics of a bus (Reviewer 2).

## 6 Results

### 6.1 *Travel Time Reliability (RT) and Comparison of Reliabilities of Bus with Metro Railway*

The travel time reliability of the different modes is estimated using the expression mentioned in Eq. 1. The expression indicated the variation of the travel time of public buses from the average travel time of the bus. The higher the variation, the less will be the RT value and vice versa. Thus in this context, the higher the RT value, the more reliable is the mode. The RT value of the metro railway service has been set as the benchmark and is compared with the other modes, i.e. the different buses under study. The comparison of the reliability of different modes with that of the metro railway is done by estimating the ratio of the RT of different modes to that of the metro railway expressed in percentage. The average travel time and its deviation from the average are also tabulated in Table 2 along with the RT values. This provides an overview of the present condition of the public buses of the Kolkata region.

Table 2 shows that the average travel time of state government buses ranges from 40 to 45 min with a deviation of 6 to 7 min, which is comparable to the private minibus (Route D) which has an average travel time of 47 min with a deviation of 9 min. But the travel time of private bus (Route C) is maximum with a mean of 64 min and a deviation of 12 min. These are compared with the metro railway which has an average travel time of 23 min and a deviation of just 2 min. It is a typical characteristic of the government-run buses that it will maintain the travel time with minimum deviation from the average travel time. This increases the RT value and makes it more reliable. On the other hand, private buses because of their operating characteristics have a tendency to maximise the revenue earned from the passenger.

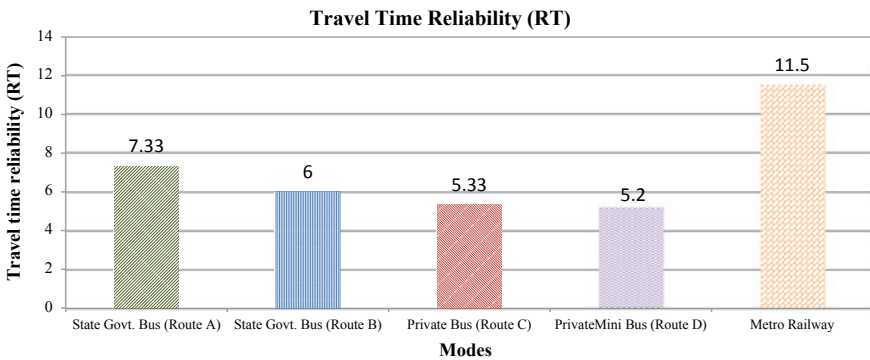


**Table 2** Comparison of travel time reliability of different buses with that of the metro railway

Bus route	Average travel time, $\mu$ (min) <sup>a</sup>	Standard deviation, $\sigma$ (min) <sup>a</sup>	Travel time reliability (RT)	Comparison of reliability of the studied bus routes w.r.t reliability of metro railway (in %)
Route A	44	6	7.33	63.8
Route B	42	7	6.00	52.2
Route C	64	12	5.33	46.4
Route D	47	9	5.20	45.4
Metro railway	23	2	11.50	100 <sup>b</sup>

<sup>a</sup>The values are rounded off to the next minute

<sup>b</sup>The RT value of metro railway is considered as benchmark and is assumed a value of 100%



**Fig. 2** Travel time reliability comparison among different modes

Due to this reason, the deviation from the average travel time is higher and the RT value decreases. Comparing the above results with the travel time reliability of the metro railway wherein it is found that the value of travel time reliability of Route A and Route B buses is more than 50% of the value of metro railway travel time reliability, whereas the same for Route C and Route D buses are less than 50%. The Travel Time Reliability (RT) values of the different modes have been demonstrated graphically in Fig. 2.

### 6.2 Travel Time Reliability Measure According to FHWA

The Federal Highway Administration developed some factors to measure the reliability of a particular mode in FHWA Report 2006. The results obtained by using Eqs. 2–5 are tabulated below. The 95th percentile travel time for each of the modes are obtained from cumulative frequency curves.

**Table 3** Measure of travel time reliability parameters of different modes (by FHWA)

Mode	95th percentile travel time, $T_{95\%}$ (min)	Buffer time, $T_B$ (min)	Buffer time index, $B_i$ (%)	Planning time index, $P_i$ (in %)	Planning time, $P_t$ (min)
Route A	52	9	20.45	226.1	52
Route B	49	7	16.66	213.04	49
Route C	81	17	26.56	352.17	81
Route D	60	13	27.66	260.87	60
Metro railway	24	2	8.70	104.35	24

\*Free-flow speed is observed to be 23 min

From Table 3, it is evident that the 95th percentile travel time of the government buses is around 50 min, whereas it is as high as 81 min for Route C which is the highest with respect to all other modes. The buffer time is the extra time which a commuter should include in his/her journey time so as to compensate any unexpected delay. A mode is said to be reliable if the buffer time is less. In this context, it is evident from Table 3 that the state government buses have a buffer time within 10 min, whereas the buffer time of 17 min for the Route C buses is quite high. The higher the value of planning time index indicates unreliable mode of transport, as a commuter has to include these extra time while planning their journey time. Once the journey time of passenger increases which finally forces the passengers to shift their mode, from this analysis, it is evident that buses of Route C are the most unreliable in nature and of Route B have the highest reliability.

### 6.3 Delay Measurement

Apart from these two types of measure of reliability, delay measurement can also be used to estimate the reliability. Deviations from the scheduled departure time and the delay in transit are the two broad categories in which the total delay can be classified. The in-transit delay can be classified as signal delay, bus stop delay, congestion delay and waiting delay. Referring to Table 4, it is clearly evident that the Route A has the maximum starting time delay which is followed by Route C. On the other hand, the delay in transit is maximum for Route C which is followed by the Route B. If the in-transit delay is compared to the total travel time of the different modes, it is observed that the transit delay of 29 and 15 min make up 30–45% of the total travel time for Route C, whereas the government buses have a transit delay within 20 min which comprises 25–40% of the total travel time.

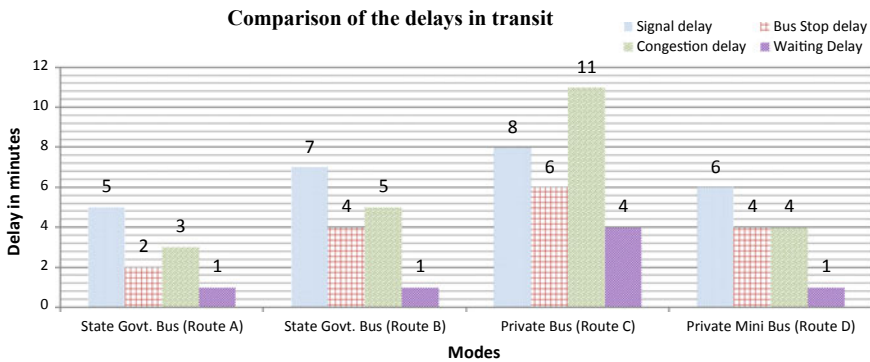
The delays in transit are separately shown in the bar chart which compares the different delays for the different buses. The figure is shown (Fig. 3).

Due to heavy traffic movement during the peak hours, congestion on the road network in Kolkata is a major issue that deviates the actual travel time from the

**Table 4** Comparison of the delays

Type of delays	Route A		Route B		Route C		Route D	
	min	%	min	%	min	%	min	%
Starting time delay from scheduled time	15	–	7	–	13	–	10	–
<i>Delay in transit</i>								
Signal delay	5	47	7	45	8	28	6	43
Bus stop delay	2	17	4	21	6	19	4	25
Congestion delay	3	28	5	28	11	39	4	26
Waiting delay	1	8	1	6	4	14	1	6
<b>Total delay in transit and its share in total transit time</b>	<b>11</b>	<b>25</b>	<b>17</b>	<b>41</b>	<b>29</b>	<b>45</b>	<b>15</b>	<b>32</b>

scheduled travel time. These congestions sometimes are created by the bus drivers himself due to unnecessarily waiting for the passengers not only at the scheduled stoppages but also in between the scheduled stoppages and sometimes the bus drivers willingly get on the congested side of the road. This driving behaviour is persistent in private buses of Route C more than the other buses. These influence the travel time to a great extent. The graph in Fig. 3 shows that all the delays for buses of Route A are less than all other buses in that route. On the other hand, buses of Route C have the maximum delays in transit among all the modes. Among all the types of delay, signal delay has the maximum share in all the modes which is followed by congestion delay. Observing all the results, it can be clearly stated that private buses of Route C have the least reliability among all the modes. The state government buses show better reliability among the buses.



**Fig. 3** Comparison of the delays in transit

## 6.4 Sensitivity Analysis

The analysis shows that the most reliable mode of public transport in this route is the metro railways. The buses have a very low reliability as compared to that of the metro railways. As metro railway has a separate right of way, the in-transit delay is negligible, whereas the buses face delay during the transit as it travels through a heterogeneous traffic stream. A sensitivity analysis was carried out to determine the effect of congestion delay and the waiting delay of the buses on its travel time reliability. Table 5 shows the RT using modified average travel time and standard deviation of buses if there was no congestion or waiting delay, i.e. zero minutes of congestion delay and waiting delay. The RT is compared with that of the metro railway.

Table 5 shows that the reliability of buses can be improved if the congestion and waiting delay can be minimised. The modified RT value of state government buses (RT of buses of Route A: 9.75 and RT of buses of Route B: 7.60) increased by one-third of the actual value. Buses of Route C have the maximum improvement of 66% which may be attributed to the fact that the delay of buses of Route C mostly comprises congestion delay and waiting delay and has a high impact on the overall travel time reliability. In case of Route D buses, the modified value increased to 6.83 which shows an improvement of 31% from the actual RT. In comparison to the metro railway, the RT of buses of Route B and Route C increased by almost 15%. On the other hand, buses of Route A increased by 21% and the maximum improvement of 30% occurred in buses of Route C.

**Table 5** Effect of congestion and waiting delay on RT

Mode	Modified average travel time, $\mu$ (min)	Modified standard deviation, $\sigma$ (min)	Travel time reliability (RT)			Comparison of RT of all the different modes under study with RT of metro railway (in %)		
			Actual	Modified	Improvement (%)	Actual	Modified	Improvement (%)
Route A	39	4	7.33	<b>9.75</b>	33	63.8	<b>84.8</b>	21
Route B	38	5	6.00	<b>7.60</b>	27	52.2	<b>66</b>	13.8
Route C	53	6	5.33	<b>8.83</b>	66	46.4	<b>76.8</b>	30.4
Route D	41	6	5.20	<b>6.83</b>	31	45.4	<b>60</b>	14.6
Metro railway			11.50			-		

## 7 Conclusion and Discussion

The present study is focused on the travel time reliability of public transport in Kolkata. The public transports included in this study are two state government buses, private bus, private minibus and metro railway all running along the same route. The reliability of all these modes is estimated using the method proposed by Liu and Sinha [15]. As per Liu and Sinha, the higher the RT value, the more reliable is the mode. The analysis showed that the RT value ranges from 5 to 7.5 which is low as compared to the RT of metro railway (11.50) as mentioned in Table 2.

The parameters developed by FHWA in the FHWA Report 2006 to measure the reliability were also used here to determine important reliability parameters like buffer time, buffer time index, planning time index and planning time (Table 3). A buffer time of more than 14 min was estimated for private bus and minibus and below 10 min for state government buses are quite high as compared to 2 min buffer time of metro railway. All these results showed that the public buses, especially the private bus (Route C), are having the least reliable service.

Finally, the delay measurement shows that the buses face a high signal and congestion delay during the peak hour. Figure 3 reveals the comparison of delay in transit for all the buses under study. From the figure, it is shown that all the types of delay are high for private bus (Route C). Sometimes, these delays are incurred intentionally by some bus drivers which is a common behaviour of many of the bus drivers. This delay increases the travel time of the buses which ultimately reveals the poor service reliability of the buses in Kolkata. The high unreliability of buses, in terms of travel time, is pushing commuters to choose private vehicles as their mode of transport which increases traffic volume and congestion on the road.

The sensitivity analysis shows that if the in-transit delay can be minimised when the reliability of the buses improves by more than 30% on an average with the private bus (Route C) having the maximum improvement (Table 5). It is of utmost importance to improve the reliability of the buses in order to restrict the shift of the mode choice to private vehicles. This will not only minimise the environmental degradation but also help to control and manage the traffic flow on the roadway networks more efficiently.

In this study, the main focus is on the public buses, but the metro railway is set as benchmark for comparison. Further research can be done by including other modes of transport like para-transit, etc. Moreover, only one route is selected as the case study route. This may be applied to other significant routes of Kolkata as well and compared with the present study.

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