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Development of a Performance Measurement Framework on Bus Transport Reliability at Bus Stops

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Abstract: The purpose of this study is to develop a performance measurement framework for measuring bus transport reliability at bus stops. For this, time keepers' records at bus stop level have been collected. They consist of four factors, i.e. scheduled arrival, actual arrival, scheduled departure and actual departure. From these data, scheduled headway and actual headway were calculated. A measure on perceived waiting time (PWT) was developed as the difference between actual headway and a half of the average schedule headway for the particular time period. The performance measure was validated for 3 bus stops. Earliness index was developed as the number of observations, which was where the PWT was lesser than half of the average schedule headway. This Earliness index was validated for 3 bus stop records, and it was observed that along with the changes in the scheduled headway in time duration, the EI value is also changed. This measure helps for policy makers to decide on the reliability of public transport at bus stops.

Keywords: Perceived Waiting Time (PWT), Earliness Index (EI), Bus stops

Introduction

There are many passengers leaving public transport because of public transport not being reliable. Reliability of transit service has been recognized as a significant determinant of quality of service (Ma, Ferreira, and Mesbah 2013). Performance measures of reliability of bus transport at bus stops portray the level of existing condition of the service reliability. Policy makers can use these measures for better decision making towards optimal use of public transportation. These measures have not been developed in most of the developing countries for evaluating the bus transport service reliability at bus stops. Data is very vital for the development of performance measurements. Collection of useful data is very much important. The main drawback in performance measurements of the public transport systems in the developing countries is that data generation, recording and being saved in a systematic approach are not existing. Developing countries should go for the development of performance measurement frameworks for bus transport service reliability based on the relevant existing data mostly manually collected and not by using advanced technologies.

This main objective of this chapter is to develop an index for perceived waiting time (PWT) as a performance measure for bus transport reliability at bus stops in Sri Lanka using the existing secondary data.

Literature Review

The buffer time indicates extra travel time required to allow the passengers on time arrival. Generally, it is defined as the difference between xx percentile and the average travel time. The planning time is defined as the xx-percentile travel time. It indicates the total time that a passenger has to budget for the trip. Buffer time index is defined as the buffer time divided by the average travel time. Reliability buffer time, defined as the difference between the upper percentile xx, and an intermediate or lower percentile yy, is the additional time that would be required to be xx-percent sure of arriving at the destination on time. Excess reliability buffer time (ERBT) is defined as the difference between the actual levels of reliability experienced by passengers and what they should have experienced had everything gone according to plan. The ERBT indicator can be used to capture the incident-caused additional unreliability above that was caused by recurrent factors (Ma, Ferreira, and Mesbah 2013). Most importantly, the buffer time calculation depends entirely on the travel time distribution. Automatic Vehicle Location (AVL) is used to calculate travel time in this study. But in terms of Sri Lankan scenario, travel time calculation using AVL is impossible and origin to destination bus arrival data are not recorded by the timekeepers too for many of the bus routes. Hence this approach can't be applied for Sri Lankan context to model bus reliability patterns at bus stops.

Transit service reliability at the time point level has been analysed with many performance measures such as headway delay variability, departure delay variability, mean scheduled headway, boarding variability, unscheduled stop variability etc. Automatic data collections systems such as automatic vehicle location and computer aided dispatch have been used for data collection. (Kimpel 2001). The measures used here are of the same existing in the literature and they suffer from all the weakness of those. And huge data set has been collected because of the automatic collection systems which is impossible in Sri Lankan contexts at the moment and no methodology for performance evaluation has been proposed.

A probability-based headway regularity metric for bus service reliability at stops has been proposed with the view to estimate the probability the next bus would be arriving within the certain time period after the last bus had arrived. Headway between two consecutive buses at stop, previous bus travel time on link, current bus travel time on link, previous bus dwell time at stop, current bus dwell time at stop, passenger arrival rate at stop and passenger boarding process rate at stop had been used to develop this metric and they had been collected by AVL and APC (Ruan and Lin 2009). As passenger arrival counts also play an important role in this metric, this is impossible in Sri Lankan contexts since there is less possibility to find the best way to count the passenger arrivals to the stops. Passenger arrival counts at Sri Lankan bus stops are not recorded.

On-time performance measures how well actual departures and arrivals conform to scheduled departures and arrivals. This is often the case for passengers using low frequency routes. If a vehicle departs early, then it is not ''on-time'' from the perspective of passengers because that will mean that passengers must wait a full headway until the next vehicle arrives. On-time performance is often measured as a percentage of bus arrivals or departures at a given point within a predetermined range of time. A bus that departed no earlier than 30 and no later than 60 seconds compared to schedule departure time was set to be departing on-time (Firew, Weckström, and Mladenovic 2016). Even though delay and early arrival can be traced, this tolerance threshold is subjective and cannot be generalized for Sri Lankan context.

Headway is the time between two vehicles passing the same point traveling in the same direction on a given route. Headway adherence is a good measure of reliability for high frequency routes . Percentage

Regularity Deviation Mean is the average deviation from the scheduled headway as a percentage of the scheduled headway. Average headway deviation was taken as the difference between actual headway and scheduled headway and the coefficient of variance of headways was calculated (Firew, Weckström, and Mladenovic 2016).

Passenger perceived waiting time at bus stops was influenced by income, location, trip distance and purpose, and survey method whereas transit agencies considered reliability to be a priority, defining it in terms of OTP measures to achieve the objective of increasing customer satisfaction. They did not frequently report users' satisfaction regarding service reliability despite its perceived importance (Diab, Badami, and El-Geneidy 2015). To take the factors that affect the passengers perceived waiting times at bus stop in the article, one has to use AVL or any automatic systems and survey has to be conducted individually which is impossible in Sri Lankan contexts.

Excess wait time was measured as the difference between actual wait time and scheduled wait time. Actual wait time was the ratio between summation of square of actual headway and 2 times summation of actual headways. The same was applied for scheduled wait time. Standard deviation of difference between actual and scheduled headway was used as a measure of reliability at bus stops. This is suitable for a normally distributed data set . It does not differentiate the delay and earliness.

The Earliness Index (EI) is defined as the percentile rank of delay/headway deviation of zero. The percentile rank of a particular delay/headway deviation is the percentage of delay/headway deviations in its frequency distribution that are lower or equal to it. Let X denote the delay (for infrequent services) or headway deviation (for frequent services) and F(x) denote the cumulative distribution function of x as follows: $F(x) = P(X \leq x)$. Therefore, EI can be defined as F(x) when x=0: EI = F(0) (Saberi et al. 2013). This measure is significantly varying from others in terms of differentiating the delay versus early arrivals but predefined threshold for the waiting time is zero which is subjective to criticism as all the above measures have allowed a predefined threshold for waiting time.

In conclusion of the literature review, there are three main research gaps identified for the bus transport reliability measures for Sri Lankan bus stops. Firstly, measures need to focus both delay and early arrivals. Secondly, the data cannot be collected by AVL or APC. Hence, the researchers should look for secondary data. Third and important factor is the predefined amount of threshold to be allowed for passenger waiting time.

Methodology

According to theoretical aspects a bus service can be categorized under frequent or non-frequent according to their 'Scheduled Headway'. If the scheduled headway is 10 minutes or less than 10 minutes it can be considered as a frequent service. The buses which have a scheduled headway which is more than 10 minutes can be considered as non-frequent bus service. This methodology is applicable for frequent service buses only.

First the data is collected under four categories as scheduled arrival time, scheduled departure time, actual arrival time and actual departure time of buses. Scheduled Headway is measured from the difference between the scheduled arrival time of two consecutive buses at the stop and Actual Headway is measured from the difference between the actual arrival times of the two consecutive buses at the same stop. Headway deviation is found from the difference between actual and scheduled headways. After clustering the same scheduled headways together half of the particular clustered scheduled headway is taken as the tolerance. And the headway deviation is taken from deducting this value from the actual headway. This is identified as the perceived waiting time (PWT). For the particular cluster Earliness Index (EI) was found.

The EI (Earliness Index) is defined as the percentile rank of delay/headway deviation of half of averaged scheduled headway. The percentile rank of a particular delay/headway deviation is the percentage of delay/headway deviations in its frequency distribution that are lower or equal to it. (Saberi & Zockaie, 2013) The equation is modified by using the assumption of tolerance. As the assumptions were taken as the passengers are willing to wait ½ of the time of Scheduled headway for a bus the tolerance level is added to the formula.

The equation is: F(x) when x=Half of averaged scheduled headway: EI = F (1/2*Average scheduled headway); where F = Function, Average schedule Headway = percentile.

When we use the above equation in Microsoft XL it is applied as

=PERCENTRANK.INC (Headway Deviation Data range, 1/2* Average Schedule Headway)

It is how the index is calculated for the proposed method.

Here the Earliness Index being in a high value means the service reliability is high of that bus service.

To apply these following data was collected.The data is collected for three bus routes per bus time keeper records for consecutive ten days including both week days and weekends.

Table 3.1 Number of observations of buses

Bus Route Number and Stop	Week day (for 10 days)	Week end (for 10 days)
221 – At Nittabuwa stop (Giriulla-Nittabuwa)	726	162
174 – At Borella stop (Makumbura-Borella)	1045	263
192 – At Malibun Junction stop (Maharagama – Moratuwa)	426	105

Source : Developed by authors (2020)

Figure 3.1 Sample of Time Table
Source :By bus time keepers

Experimental Design

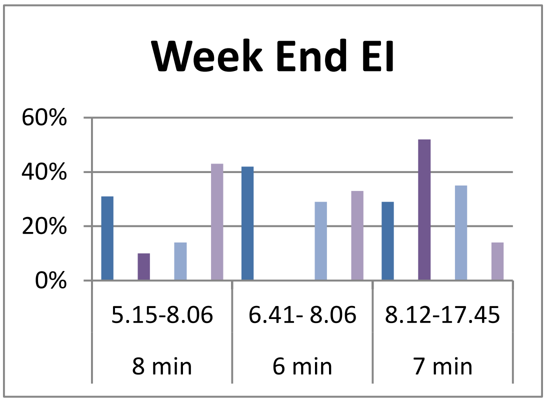

Figure 4.1 EI value for week end for 221 bus route
Source: Developed by Authors (2020)

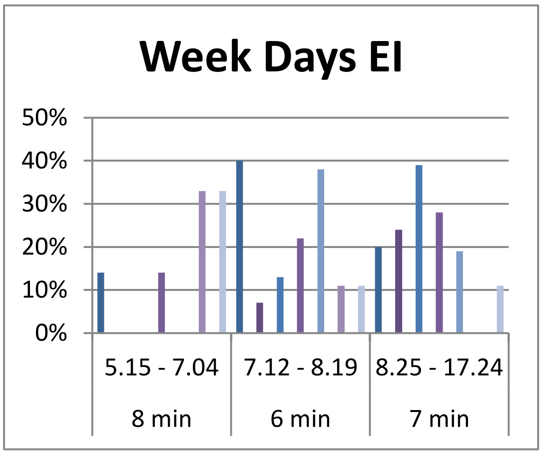

Figure 4.2 EI value for week days for 221 bus route
Source: Developed by Authors (2020)

Here shown in graphs, the 8 minuites, 6 minuites and 7 minuites are the scheduled headways for the time intervals of buses. Comparatively in the bus route 221 at Nittabuwa halt the EI values are comparatively high in weekends to week days. The highest EI values are recorded nearly to peak times and in both week end and week days in the time slot of 7.12 a.m. to 8.19 a.m. and when it comes to off peak hours it is getting less gradually. In weekends the time slot 8.12 a.m.to 17.45 p.m. where scheduled headway is 7 minutes shows the highest EI values with a busy schedule.

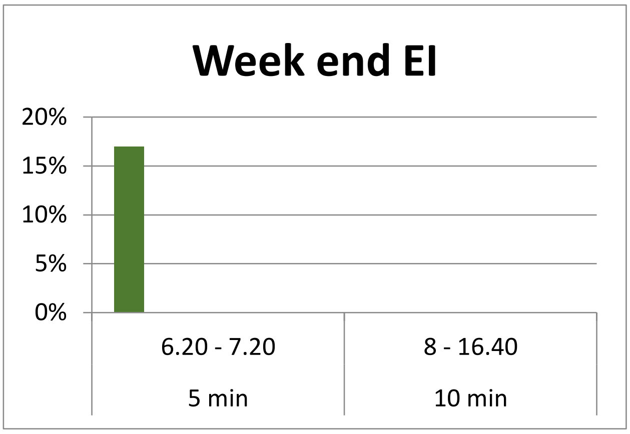

Figure 4.3 EI value for week end for 192 bus route
Source: Developed by Authors (2020)

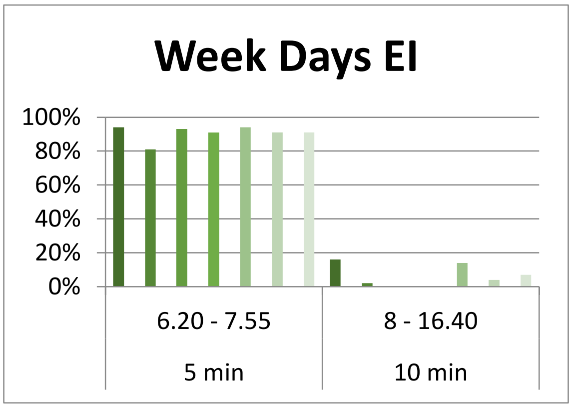

Figure 4.4 EI value for week days for 192 bus route
Source: Developed by Authors (2020)

The 5 minuites and 10 minuites shown in the graphs are the scheduled headways for the time intervals of buses at the stop. In the route number 192 at Malibun junction bus stop the week end EI values dosen't have a varitaion. For the time phase 6.20 – 7.20 a.m. the EI index is showing 17% of early arrivals or buses. And in week days also there's no busy schedule where varitaes among higher number of schedule headways. In the paek time from 6.20 to 7.55 where there's 5 minuites of schedule headway shows that buses are arriving early.

Figure 4.5 EI value for week end for 174 bus route
Source: Developed by Authors (2020)

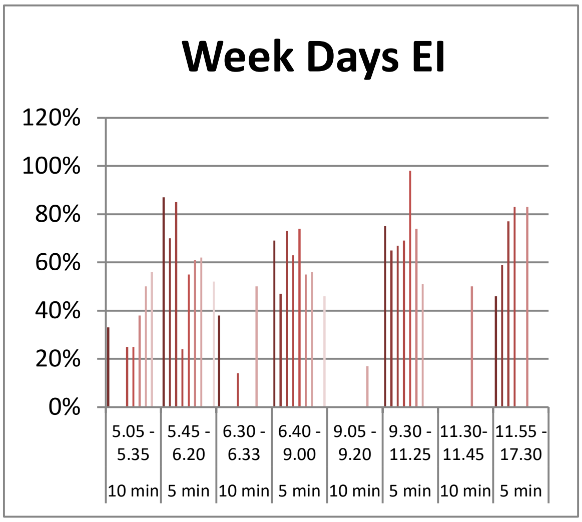

Figure 4.6 EI value for week day for 174 bus route
Source: Developed by Authors (2020)

Here the times shown as 10 minutes and 5 minutes are the scheduled headways for the time intervals of buses at the borella stop. Comparing the route number 174 at Borella bus stop week days are busier than weekends. Most of the EI variations are recorded high in the peak hours of the days. And comparatively can be seen getting less only in off peak hours. Most of highest EI values are recorded in 5 minutes of schedule headway time phases. For weekends the EI values are recording not too less but not in a busy schedule.

This analysis shows that by using the existing data the performances of the buses can be evaluated taking the proposed measures. The analysis shows that in the peak hours the buses are arriving to the stop early. This means passengers assume for waiting time for a bus is getting less in peak hours, especially in morning. This shows a positivity of service reliably as people are lesser waste their time for a bus at a stop concerning their tolerance time.

Discussion and Conclusion

According to the study, in Sri Lanka Reliability is not an index that taken into concern when developing service quality in public transportation of buses. Throughout the discussion the findings disclosed that there is availability of data that can be used to measure reliability and the findings can be combined with scheduling of buses and it will help to manage a reliable service in traffic blocks also.

As per the practical aspects followed in Sri Lanka reliability is out of concern when taking system evaluation decisions. Even for bus scheduling they use only the passenger demand. They demand is taken by doing a "survey" from taking times that people gets crowed in the specific routes. For high crowds and peak times they crate approximately 5 minutes headways and develop the timetables and for low crowds they expand the headways and develop the time tables. There are no schedule developments or adjustments are done through any measurements. There are more practices can be developed by using this measurements rather than these basic actions. The collected data from timekeepers provides scheduled arrivals and departures for each bus at the stop and actual arrival and departures are recorded by timekeepers. Most of recorded data are applicable for measurements. The data is sufficient for measuring EI.

This model allows tolerance. There is an improve version and the EI is also new index. This is literary improve for Saberi, K, Feng, & El-Geneidy, Definition and properties of alternative bus service reliability measures at the stop level, 2013 article. As recommendation, in here it is only considering about scheduled headway. But in future if anybody is considering about the actual headway and trying to develop a method for that, that might help for improve the development of measuring bus service reliability at bus stops in public transport.

For future researches topics can be introduce as studying characteristics of headway distributions and delays using more data, networks and knowledge; Cost variance happens along with the unreliability services at stop levels and practical side implementing of high technology BRT systems in Sri Lanka for service quality improvement of public transport. The study shows the limitations of data collection availability and the study is limited by technological systems used by other countries where Sri Lanka doesn't have. Mostly in every research articles transport data is collected through AVL (Automated Vehicle Location) systems where Sri Lanka is doing it manually, the accurate level of the information cannot be compared with the systematic results of information.

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