THE RELIABILITY STUDY OF TWO BUS ROUTES  
WITH OVERLAPPING SECTIONS

by

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Abstract

Given a particular route and a time period, there is an inherent variation in the travel time. Engineers and planners can only do a very little to reduce this variability. The travel time reliability of a particular route is normally defined as a percentage of vehicle arrivals with less than a fixed time deviation from Schedule.

This paper deals with the reliability determination of two bus routes (154 and 155) in Colombo South Transport Region, in terms of passenger waiting times and travel times. It makes an attempt to quantify the "Reliability" of a bus route so that public transport planners could evolve methods to improve urban bus passenger operations.

1. Introduction

The current state of public transport planning is not a well-developed science. The complexity of the problems involved, the noncatastrophic mode of functional failure, the lack of trained planners, political interference in detailed planning and the failure of transport professionals with alternative planning tools to communicate their ideas to front line planners are some of the reasons for the present situation - Wirasinghe (1986).

In the typical public transport planning, we are concerned with providing a good public transport service, which has a minimal environmental impact, at a reasonable cost to the public transport owners and to the users. The level of service of a bus transport system is a function reliability, comfort, safety, efficiency, journey, speed, accessibility in time and space etc. The precise definition of the objectives to be satisfied in providing the transit service let alone their attainment is a difficult task. The public transport system is a failure if the objectives with which it was planned are not attained. However, this is different to many "engineering failures" which are of catastrophic nature. In "transport failures" the system generally continues to function and satisfies the objectives at least to some degree - Wirasinghe (1986).

Total delay to a bus consists of the following:

a. Delays at the terminal
b. Delays at bus stops
c. Delays between bus stops

Delays at the terminals can be reduced by a better despatch policy. Delay at bus stops will depend on the arrival and boarding rates of passengers. If the ratio of arrival rate of passengers to boarding rate is low, delays will be reduced - Newell and Cotts (1964).

Delays between bus stops are hard to predict, hence allowance has to be made when selecting the schedule travel time.

The reliability of a bus operation is one of the key parameters of its level of service. Generally it is difficult to quantify the reliability of a bus transport system due to its complexities. In a country like Sri Lanka, where the buses are in under supply compared to passenger demand, the reliability concept will be more complicated.

Most commuters who travelled by the bus which has been delayed or have waited for the bus that did not arrive on time consider the service to be unreliable. Each commuter wants his or her bus to arrive as soon as he or she gets to the bus halt, have a vacant seat in it and go to the destination safely with the least possible delays.

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In general, state bus operators have a dispatching policy for a bus route to serve multiple passenger origins and destinations with a limited number of buses. They will consider a particular route has a good reliability when their buses run according to their planned bus schedule. In general, the private bus operators will plan their bus operations to maximise their profits rather than providing a reliable bus service or to a planned bus schedule.

The timed points are located along a route to attain a desired reliability. At present this is not practised in Sri Lanka and the timed points are located only at the two ends of the route. Hence the bus drivers have a difficulty in ensuring that the bus is not too early or late in arriving at intermediate points. If several timed points are located, they increase the total travel time due to the "killing time" while idling at several points. Therefore it is advisable to keep the timed points to a minimum possible, by providing them at the points with high travel time variations. Timed points are located specially at bus stops with high loading time variations, while ensuring reliability to an acceptable level - Lesley (1975).

A study was undertaken in 1986/87 to determine some aspects of reliability of two bus routes (Nos. 154 and 155) with some overlapping sections. The reliability of the above bus routes were determined in terms of average waiting time at bus halts and average travel time variations.

1.1 Route No. 154

The bus route No. 154 operates from Mt. Levinia to Kiribathgoda, Bavali, Dematagoda, Pelliagoda and Kelaniya (Fig. 1). It goes through many important places like shops, markets, residential areas, two Universities, a large number of industries and offices, hospitals, prison, major cemeteries, recreational spots etc. The bus routing has been done in a very good manner and it is a vital route to public transport passengers.

The above bus route is serviced by both private and state buses. Transport Board buses are jointly operated by Ratanmalana and Kadawatha Depots. At the time of the study there was no proper coordination of private bus operation.

The Ratanmalana and Kadawatha depots have 16 large capacity (type “A”) buses and each depot handles half the above number. The scheduled time headways for Transport Board buses is 10-15 minutes during day time, and 20-25 minutes during early morning and night, respectively. Also, short distance special services are arranged for the convenience of schools and working people.

There are about 50 private buses operating in Route No. 154. Most of them are 26 seater buses, but there are smaller ones as well. The private buses do not strictly adhere to their origin and destination and generally operate only a part of the route to maximise profits depending on the passengers available at bus halts.

The operating fare structure of both state and private buses are the same. There are 11 sections in the route. The fare is Rs. 1.00 for the first sections, with 0.50 cents increments for the next two sections followed by 0.25 cents per section for the balance.

1.2 Route No. 155

The bus route No. 155 operates from Ratanmalana Via Bambalapitiya, Colombo University, Albert Crescent, Town Hall, Hyde Park Corner, Maradana and Grandpass (Fig. 1). This route too goes through a wide variety of places like residences, shops, markets, motor spares shops and garages, hospitals, industries and offices, recreational areas etc. This bus routine too has been done in a very fine manner and is doing a great service to public transport passengers.

The Transport Board operates 15 medium capacity (Type “B”) buses in this route with a scheduled time headway of 10 minutes during day time with a scheduled journey time of 75 minutes.

There are about 60 private buses operating in this route. Most of them are 26 seater buses with a few smaller and larger capacity buses. Most of the private buses terminate at Mhatiyawatte and Kotahena and a fair number of them operate only a part of it.

The operating fare structure for both Transport Board and private buses is the same with 13 sections in the route. The rates are same as for route No. 154.
2.0 Traffic Surveys and Data Collection

2.1 Waiting time measurements

An indirect method of measuring waiting times was used to determine the passenger waiting times. Only bus headways were used to determine the waiting time. However, their accuracy depends critically on the validity of the relationship used to determine the mean passenger waiting time from the bus headways. Bus headways were observed at designated locations. The designated locations for route 154 were Mt. Lavinia, Bambalapitiya, Borella, Dematagoda, Peliyagoda and Kiribathgoda. The designated locations for route 155 were Ratmalana, Bambalapitiya, Kotahena, Hettiyawatta and Mattakkulla.

Several surveyors were requested to determine RTB and private bus headways of the two routes on several days during peak and off-peak periods of the day. The mean values are shown in Figs. 2.1 to 2.4. The expected waiting times were determined using equation 11 and the travel time reliabilities were determined using equation 15.

Set of surveyors were stationed at the above designated locations to determine the passenger arrival rates for the two routes. These values are shown in Figs. 3.1 to 3.4.

3.0 Reliability Study of Bus Routes

The three main parties involved in a transit bus service system are the passengers, the crew and the operator. Successfulness of a bus service will depend on the objectives and responsibilities of the parties involved - Leely (1973).

From the passenger point of view, the service is satisfactory if the buses are run on schedule, which is a measure of the reliability of the system. It is the responsibility of the crew to be on schedule and get the maximum allowable layover time. The bus operator should provide a reliable schedule and should make sure that the buses and the crew are available when needed.

Reliability of a particular route can be defined as the probability of bus arrivals with less than a fixed deviation (Y) from the schedule. A bus is said to be on time if the travel time R is related to the schedule travel time S as follows. - Wiroasinghe (1986).

\[ S - Y \leq R \leq S + Y \]  

(1)

As passengers are generally more concerned to reach the destination in time it is appropriate to define the reliability as the probability that the bus will have a recorded travel time.

\[ R \leq S + Y \]  

(2)

The value will depend on the magnitude of S, though several books have recommended a value of 4 minutes. - Vuchic (1981).

It is possible to increase the reliability by selecting a relatively high S but at the same time, "wasted time" to the passengers and to the bus operators will increase. A large S will also increase the required fleet size and hence the operating cost. Because of the above reasons it is necessary to select S carefully so as to provide reasonably high reliability while keeping the "wasted time" and cost to a minimum.

3.1 Waiting time for Passengers

According to the collected data it is appropriate to consider the headway of a particular route as a random variable. The probability of a passenger arrival in Kth headway (ie, headway between Kth bus & (k+1)th bus) is

\[ H_k \]  

\[ \Sigma H_1 \]  

Where \( H_i \) = Headway between ith bus and (i+1)th bus. The expected wait for a passenger, given that he arrived in Kth headway is

\[ H_k \]  

\[ 2 \]  

Then the expected value of wait is

\[ E(\text{wait}) = \frac{\sum H_k \cdot H_k}{2 \cdot \sum H_1} = \frac{1}{2} \sum \frac{H_k^2}{H_1} \]  

(5)

Assuming all \( H_1 \) have the same probability distribution

\[ \frac{1}{n} \sum H_1 = E(H) \]  

(6)

\[ \frac{1}{n} \sum H_k = E(H') \]  

(7)

From equations (5), (6) and (7)

\[ E(\text{wait}) = \frac{1}{2} \frac{E(H')}{E(H)} \]  

(8)
**Fig. 2.1** Time Headways (154 Buses) From Mt. Lavana to Kiribathgoda

**Fig. 2.2** Time Headways (154 Buses) From Kiribathgoda to Mt. Lavana
Fig. 23 Time Headways (155 Buses) From Ratmalana to Mattakkuliya

Fig. 24 Time Headways (155 Buses) From Mattakkuliya to Ratmalana
Fig. 3.1 Average Passenger Demand From Mt. Lavana to Kiribathgoda

Fig. 3.2 Average Passenger Demand From Kiribathgoda to Mt. Lavana
Fig. 33 - Average Passenger Demand From Ratmalana to Mattakkuliya

Fig. 34 - Average Passenger Demand From Mattakkuliya to Ratmalana
By definition the variance of \( H \), \( V(H) \)
is given by
\[
V(H) = (\sigma(H))^2 = E(H^2) - (E(H))^2
\]  
(9)

From equations (8) and (9)
\[
E(\text{wait}) = \frac{1}{2} \left[ \frac{V(H) + (E(H))^2 - (E(H))^2}{E(H)} \right]
\]  
(10)

or
\[
E(\text{wait}) = \frac{1}{2} \left[ \frac{V(H) + (E(H))^2}{(E(H))^2} \right]
\]  
(10)

That is
\[
E(\text{wait}) = \frac{1}{2} E(H) \left[ \frac{V(H) + 1}{(E(H))^2} \right]
\]  
(11)

or
\[
E(\text{wait}) = \frac{1}{2} E(H)[C(H)^2 + 1]
\]  
(11)

Where \( C(H) = \text{coefficient of variation} \)

\[
C(H) = \frac{\sigma(H)}{E(H)}
\]  
(12)

Using equation 11 the expected waiting time
to passengers is calculated for the data collected
route number 154 and 155 from 3.00 to 6.00
p.m. using equation (7). The values are given
in Table 1:

3.2 Travel time and reliability

The natural travel time \( (T) \) is defined as
the travel time for a particular trip on an
unscheduled route when the driver's objective
is to complete the trip in the shortest possible
time while driving safely and legally. \( T \) will
be a random quantity with a certain minimum
\( t_m \), a mean and a variance - Wirasinghe (1984).

For a given period of time its probability
density function \( f(t) \) will probably take
a shape as shown in Fig. 4 below:

\[ f(t) \]

\[ t_m \quad S \quad t \]

\[ \text{Fig. 4 - The probability density of travel time.} \]
When selecting a schedule travel time $(S)$ for a particular route it is necessary to select $S$ such that the bus driver can adhere to it as safely and legally possible.

During a trip if it appears that $T < S$, the driver will "kill" some time in order to be on schedule, which is in fact waste of time. On the other hand if $T > S$, the bus will be late.

For the practical purposes it is appropriate to assume the p.d.f. of the natural travel time $(T)$ is represented by a normal distribution, with mean and variance $\sigma^2$. If 90% reliability is required in a particular route, $S$ can be selected as follows.

$$P(S > T) = 0.90$$

From eqn. (13) $P \left( \frac{S - \mu}{\sigma} > \frac{T - \mu}{\sigma} \right) = 0.90$ (14)

$$P \left( \frac{S - \mu}{\sigma} > Z \right) = 0.90$$ (15)

Using normal tables, $S - \mu = 1.28$ (16)

$$S = \mu + 1.28$$ (17)

It can be seen that the value of $S$ depends on both $\mu$ and $\sigma$. The amount of reliability that has to be provided is not clearly defined, and it depends on the operation policy.

Since there are no intermediate timed points for the bus routes 154 and 155, the travel time reliability can only be determined for the entire length of the route. If there were timed points, the reliability could have been calculated for the different sub-sectors of the two routes. Since the private bus operators do not have published bus schedule reliability calculations were done with RTB schedule times. However, the reliability of the routes were determined for the combined RTB and private buses. The reliability values were calculated for the two routes during peak and off-peak periods using equations (15). The values are given in Table 2.

4.0 Conclusions

4.1 Route No. 154

a) It is observed that the route No. 154 has a good passenger demand and the variation between peak and off-peak periods is small.

b) Since there is a relatively "good" RTB bus service it has become difficult for private operators to break the journey into sub-routes.

c) The reliability in terms of travel time is about 50% during peak time and 68% during off-peak time.

d) High passenger demand periods are from 7.00 a.m. to 8.00 a.m., 1.00 p.m. to 2.00 p.m. and 4.00 p.m. to 5.00 p.m.

4.2 Route No. 155

a) It is observed that the route No. 155 too has a good passenger demand and the variations between peak and off-peak periods is small.

b) The RTB bus service is relatively "poor" and many private operators run on sub-routes.

c) The reliability in terms of travel time is about 51% during peak time and 62% during off-peak time.

d) High passenger demand periods are from 7.00 a.m. to 8.00 a.m., 1.00 p.m. to 2.00 p.m. and 4.00 p.m. to 5.00 p.m.

e) Most utilized section is from Dohlwala to Kotahena.

5.0 References


2. Lesley, J.S. "The role of the time table in maintaining bus service reliability" Proc. of Symposium, Operating Public Transport, University of Newcastle Upon Tyne, 1975.


### TABLE 1
Expected Waiting Time for Passengers

<table>
<thead>
<tr>
<th>Hour of Day</th>
<th>Direction</th>
<th>SLCTB (mnts)</th>
<th>Private (mnts)</th>
<th>Direction</th>
<th>SLCTB (mnts)</th>
<th>Private (mnts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.00 to 4.00 p.m.</td>
<td>Mt. Lavinia</td>
<td>5.7</td>
<td>4.1</td>
<td>Rataalana</td>
<td>4.6</td>
<td>10</td>
</tr>
<tr>
<td>4.00 to 5.00 p.m.</td>
<td>to</td>
<td>6</td>
<td>2.7</td>
<td>to</td>
<td>17.5</td>
<td>5.8</td>
</tr>
<tr>
<td>5.00 to 6.00 p.m.</td>
<td>Kiribathgoda</td>
<td>8</td>
<td>2.8</td>
<td>Mattakkuliy</td>
<td>7</td>
<td>9.8</td>
</tr>
<tr>
<td>3.00 to 4.00 p.m.</td>
<td>Kiribathgoda</td>
<td>4.1</td>
<td>2.6</td>
<td>Mattakkuliy</td>
<td>10.3</td>
<td>8.5</td>
</tr>
<tr>
<td>4.00 to 5.00 p.m.</td>
<td>to</td>
<td>6</td>
<td>3.1</td>
<td>to</td>
<td>7.1</td>
<td>6.2</td>
</tr>
<tr>
<td>5.00 to 6.00 p.m.</td>
<td>Mt. Lavinia</td>
<td>7.8</td>
<td>4.6</td>
<td>Rataalana</td>
<td>7.7</td>
<td>5.3</td>
</tr>
</tbody>
</table>

### TABLE 2
Travel Time Reliability

<table>
<thead>
<tr>
<th>Route</th>
<th>Scheduled Travel time (mnts) (RTB Service)</th>
<th>Actual Average Travel time (mnts) (for combined private &amp; RTB)</th>
<th>Standard Deviation</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>154</td>
<td>70 (Peak)</td>
<td>77.5</td>
<td>9</td>
<td>60%</td>
</tr>
<tr>
<td></td>
<td>67 (off peak)</td>
<td>67.5</td>
<td>5</td>
<td>70%</td>
</tr>
<tr>
<td>155</td>
<td>75 (Peak)</td>
<td>85</td>
<td>14</td>
<td>95%</td>
</tr>
<tr>
<td></td>
<td>70 (off peak)</td>
<td>75</td>
<td>7</td>
<td>70%</td>
</tr>
</tbody>
</table>

6.0 Acknowledgements

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