Identifying the Potential for Bus Route Mergers using Electronic Ticketing Data

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1. Introduction

Technology based surveys on public transport are rare due to lack of technology uptake in the field. However, the ‘SAHASARA’ pilot project has provided a full year’s Electronic Ticket Machine (ETM) data from 350 buses operating on 48 routes along two corridors - Dumbara and Denuvera- serving the city of Kandy. The Dumbara corridor operates 27 routes with the longest route being 46.1 km, while the Denuvera corridor operates 21 routes with the longest route being 29.7 km [1].

The primary objective of this research is to investigate if the Sahasara ETM data can be used for bus route re-planning also called route rationalising [2]. Route re-planning would investigate a number of potential changes to service routes in a bus network. These could range from new routes to route extensions and route mergers. The ETM data has an inherent limitation in that it can only be used for route mergers since ticket data is only for individual bus trips. Route mergers are when two routes that terminate at a common terminal are spliced together to operate as a through route.

This usually results in two arterial routes becoming a cross town route, thus serving two corridors without terminating in the city Centre. The use of Smart Cards which can provide entire trip details are much more versatile for a wider range of route re-planning efforts that can achieve several outcomes such as reducing passenger travel time and cost, reducing passenger transfers and transfer time as well as reducing bus operational time and distance, thereby increasing bus productivity [3].

However, proposing suitable routes for mergers requires identifying routes that have compatible demand and revenue profiles as well as supply characteristics so that issues arising in route merging can be minimized. The latter is important since in Sri Lanka the private buses are provided by individual small-scale operators on permissions that entitle them to collect the daily revenue while meeting operating expenses thereof [4].

2. Methodology

The main objective of the research was to propose suitable routes which have the ability to integrate with others of similar characteristics. As shown in Figure 1, particular routes should have similar demand profiles, similar supply profiles and similar revenue profiles to be successfully integrated.
Initially similar revenue profile has been identified, and the following equation was used to find out the particular revenue of buses:

\[
\text{Revenue per bus} = \text{Revenue per trip} \times \text{Number of trips per day}
\]

[Equation 2.1: Revenue calculation 1]

When considering revenue per km, the following equation was used:

\[
\text{Revenue per Kilometre} = \frac{\text{Average revenue per trip}}{\text{Distance of the trip}}
\]

[Equation 2.2: Revenue calculation 2]

This gives the revenue per bus/kilometre for each day, and weekly average revenue of each route was calculated. Among these values, values which have similar averages were selected and a T-test was used to identify similar demand and supply profiles. Mean values of each of the above for each of the routes in the Dumbara corridor were compared with that of the Denuvera corridor to study what routes could be spliced and run through town.

A hypothesis testing was carried out to determine if they could be considered having compatible distributions. In this case the null hypothesis (H₀) and the alternate hypothesis (H₁) for testing compatibility were determined as follows:

\[
\text{H₀} = \text{there is no considerable difference between the two routes}
\]

\[
\text{H₁} = \text{there is a considerable difference between the two routes}
\]

The null hypothesis was accepted as a p value higher than 0.05 using the t-test. Routes that satisfied all three requirements were identified for route merger.

2.1 Compatible Demand Profile

Routes having compatible demand profiles from the two corridors as shown in Table 1 were selected to carry out the t-test. The four route pairs that returned p values higher than 0.05 were selected as having compatible demand profiles.
Table 1: Testing for similarity in demand profile

<table>
<thead>
<tr>
<th>Compatible Routes (Digana/Denuvera)</th>
<th>Daily Mean Passenger Demand</th>
<th>Correlation</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kandy-Digana Kandy-Kadugannawa</td>
<td>10,720 10,943</td>
<td>90%</td>
<td>0.225</td>
</tr>
<tr>
<td>Kandy- Mahawaththa Kandy- Nethulemada</td>
<td>1,631 1,881</td>
<td>76%</td>
<td>0.093</td>
</tr>
<tr>
<td>Kandy-Theldeniya Kandy-Pilimathalawa</td>
<td>7,744 7,475</td>
<td>97%</td>
<td>0.774</td>
</tr>
<tr>
<td>Kandy-Ayuruweda Hospital Kandy-Aladieniya</td>
<td>1,734 2,038</td>
<td>78%</td>
<td>0.187</td>
</tr>
<tr>
<td>Kandy-Aluthwatha Kandy-Dehianga</td>
<td>2,379 2,233</td>
<td>89%</td>
<td>0.800</td>
</tr>
<tr>
<td>Kandy-Aluthwatha Kandy-Madamahanuwara</td>
<td>2,379 2,584</td>
<td>86%</td>
<td>0.121</td>
</tr>
</tbody>
</table>

2.2-Compatible Supply Profile

Table 2: Testing for compatibility in supply profile

<table>
<thead>
<tr>
<th>Compatible routes (Digana/Denuvera)</th>
<th>Daily Mean Supply Trips</th>
<th>Correlation</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kandy-Digana Kandy-Kadugannawa</td>
<td>150.00 148.00</td>
<td>80%</td>
<td>0.125</td>
</tr>
<tr>
<td>Kandy- Aluthwatha Kandy- Madamahanuwara</td>
<td>38.00 35.00</td>
<td>76%</td>
<td>0.103</td>
</tr>
<tr>
<td>Kandy-Mahawaththa Kandy-Aladieniya</td>
<td>26.86 26.57</td>
<td>96%</td>
<td>0.253</td>
</tr>
<tr>
<td>Kandy-Madamahanuwara Kandy-Dehianga</td>
<td>35.00 36.00</td>
<td>83%</td>
<td>0.541</td>
</tr>
<tr>
<td>Kandy-Aluthwatha Kandy-Ayuruweda Hospital</td>
<td>38.00 40.30</td>
<td>93%</td>
<td>0.876</td>
</tr>
<tr>
<td>Kandy-Aluthwatha Kandy-Dehianga</td>
<td>38.00 36.00</td>
<td>72%</td>
<td>0.192</td>
</tr>
</tbody>
</table>

The average daily frequency of bus supply profiles as shown in Table 2 were selected to carry out the t-test. The four route pairs that returned p values higher than 0.05 were selected as having compatible supply profiles.

2.3-Compatible Revenue Profile

The average revenue per km of buses operated as shown in Table 3 were selected to carry out the t-test. The four route pairs that returned p values higher than 0.05 were selected as having compatible revenue profiles.
Table 3: Testing for compatibility of revenue profile

<table>
<thead>
<tr>
<th>Compatible routes (Digana/Denuvera)</th>
<th>Mean Revenue per km(Rs)</th>
<th>Correlation</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kandy-Digana</td>
<td>83.00</td>
<td>82%</td>
<td>0.114</td>
</tr>
<tr>
<td>Kandy-Kadugannawa</td>
<td>85.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kandy-Ayuruweda Hospital Kandy-Nethulemada</td>
<td>70.40</td>
<td>88%</td>
<td>0.236</td>
</tr>
<tr>
<td>Kandy-Nethulemada</td>
<td>71.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kandy-Aluthwaththa Kandy-Dehianga</td>
<td>61.53</td>
<td>72%</td>
<td>0.106</td>
</tr>
<tr>
<td>Kandy-Aluthwaththa</td>
<td>64.26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kandy-Aladeniya</td>
<td>89.20</td>
<td>92%</td>
<td>0.353</td>
</tr>
<tr>
<td>Kandy-Mahawaththa</td>
<td>88.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kandy-Nethulemada</td>
<td>71.60</td>
<td>86%</td>
<td>0.413</td>
</tr>
<tr>
<td>Kandy-Theldeniya</td>
<td>72.30</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.4. Selection of Routes for Merging

Routes with compatible demand, supply and revenue profiles were identified and summarized as shown in Table 4.

Accordingly, only two routes have high potential for merging, while others could be considered at a lower level of suitability.

Table 4: Selection of Routes for merging

<table>
<thead>
<tr>
<th>Considerable Routes</th>
<th>Demand Profile</th>
<th>Supply Profile</th>
<th>Revenue Profile</th>
<th>Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kandy-Digana</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Yes</td>
</tr>
<tr>
<td>Kandy-Theldeniya</td>
<td>✓</td>
<td>×</td>
<td>×</td>
<td>No</td>
</tr>
<tr>
<td>Kandy-Pliimathalawana</td>
<td>✓</td>
<td>×</td>
<td>×</td>
<td>No</td>
</tr>
<tr>
<td>Kandy-Aladeniya Kandy-Ayuruweda Hospital</td>
<td>✓</td>
<td>×</td>
<td>×</td>
<td>No</td>
</tr>
<tr>
<td>Kandy-Aluthwaththa Kandy-Dehianga</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Yes</td>
</tr>
<tr>
<td>Kandy-Aladeniya Kandy-Mahawaththa</td>
<td>×</td>
<td>✓</td>
<td>✓</td>
<td>No</td>
</tr>
<tr>
<td>Kandy-Madamahahanuvara Kandy-Dehianga</td>
<td>×</td>
<td>✓</td>
<td>×</td>
<td>No</td>
</tr>
<tr>
<td>Kandy-Ayurveda Hospital Kandy-Nethulemada</td>
<td>×</td>
<td>×</td>
<td>✓</td>
<td>No</td>
</tr>
<tr>
<td>Kandy-Nethulemada Kandy-Theldeniya</td>
<td>×</td>
<td>×</td>
<td>✓</td>
<td>No</td>
</tr>
<tr>
<td>Kandy-Aluthwaththa Kandy-Madamahnuwara</td>
<td>✓</td>
<td>✓</td>
<td>×</td>
<td>No</td>
</tr>
</tbody>
</table>
3. Conclusion and Recommendation

The main outcome of this research is identifying routes on two corridors terminating at a common point that are suitable for merging. Two sets of routes from a total of 48 routes have shown suitability for merging to operate as two cross town routes without terminating in Kandy as is the current practice. With overcrowding of the terminal in Kandy and bus parking and loading issues, this would be a useful identification of suitability. According the routes shown in Table 5, (i) Kandy-Digana with Kandy-Kadugannawa, and (ii) Kandy-Aluthwaththa with Kandy-Dehianga can be merged.

Table 5: Characteristics of routes chosen for merging

<table>
<thead>
<tr>
<th>New Route</th>
<th>Trip Distance</th>
<th>Travel Time</th>
<th>Number of One-way Trips per Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digana-Kadugannawa</td>
<td>33.2 km</td>
<td>110 minutes</td>
<td>8 trips per day</td>
</tr>
<tr>
<td>Aluthwaththa-Dehianga</td>
<td>35.1 km</td>
<td>100 minutes</td>
<td>6 trips per day</td>
</tr>
</tbody>
</table>

However, there are other parameters such as operator’s agreements as well as regulatory aspects that may also have to be considered in making a final decision.

References


Keywords: Bus Transport Reforms, Route Merging, Electronic Ticket Machine Data, Sri Lanka, Bus Route Planning