A Study on the Design Process of Median Lane Bus Stop Based on the Smart Card Data from the Cheongnyangni Transfer Station

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Abstract: Median lane bus stops are installed at places where transfers to other modes of public transportation are generally made. Therefore, they aid in the efficient transfer from one mode to another. Despite such advantages, median lane bus stops are a threat to the public safety and are not convenient to passengers because they were designed not taking into consideration appropriate analyses such as the passenger demand and required capacity for the bus stop. Recently, “Smart Card Data” has become an epochal data to estimate the amount of demand for using public transportation. Thus, this paper was written to develop a proper design process for median lane bus stops using Smart card data to analyze demand in order to increase the service satisfaction of the passengers.

Key Words: Smart card data, Median lane bus stop, Level of service

1. INTRODUCTION

Median lane bus stops are installed at places where transfers to other modes of public transportation are generally made. Therefore, they aid in the efficient transfer from one mode to another. Despite such advantages, median lane bus stops are a threat to the public safety and are not convenient to passengers because they were designed not taking into consideration the appropriate analyses such as passenger demand and required capacity for the bus stop. Thus, some general considerations and standards for the design of median lane bus stops are necessary.

Recently, “Smart Card Data” has become an epochal data to estimate the amount of demand for using public transportation. At present, Smart card data has a massive users’ pass database containing information for metropolitan areas including Seoul, GyeongGi, and Incheon.

Almost all public transportation passengers are using smart cards, and their usage of the public transportation system is recorded automatically. It means Smart card data is highly useful and reliably because as data goes, it is nearly complete.

Therefore, this paper looks at the method for designing median lane bus stops by estimating accurate capacity and demand using the Smart card data.
2. THEORETICAL BACKGROUND

Since introducing the median bus lane system, many studies were done about it from a multi-faceted approach, but it is not active.

KHCM (Korea Highway Capacity Manual, 2005) presents a method of estimating the capacity of a bus stop. The capacity of a bus stop is dependent upon the size of a bus and frequency allocation and is restricted by the number of buses, by the comfort and safety of the passengers, and by the volume of cars on the same road and so on. In particular, KHCM emphasizes the capacity inside of a car, the frequency allocation, the volume of the bus berth bay, and the volume of the passenger waiting bay because they are relatively metrizable. But KHCM does not consider the demands of the passengers using each bus-station.

Therefore, Smart card data will offer precise data about passenger demands. However, the amount of Smart card data is so enormous that it is not easily obtained. Therefore, a large amount of the data is not widely used.

This paper introduces a method for handling the large amount of Smart card data and incorporates it into the design of median lane bus stops.

3. METHOD OF ANALYSIS FOR SMART CARD DATA

3.1 Current state of median lane bus stops

The median lane bus stop system was first started in 2004, and as of 2009, the number of sections was 60 and the total length was 207.4km.

The advantage of this system is that it allows the buses to travel at a fast velocity fast and keeps them on schedule according to the timetable. But the median lane bus stop system has had some problems in connection with the capacity of the bus berth bay and safety of the passengers. In case of a full time system, a median lane bus stop can be constructed if the number of arrival buses per hour is more than 120 buses per hour. But thus far, due to the difficulty of determining the correct amount of demand for each bus stop, the median lane bus stop system has been designed without considering the characteristics of passenger demand for each stop.

Accordingly, it is possible that the buses arriving at a station can exceed the fixed capacity of the bus berth bay, and the passengers are exposed to the danger of being hit by a bus.

3.2 Analysis of Smart card data

Smart card data contain transport index as presented in table 1.

<table>
<thead>
<tr>
<th>No.</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The number of passengers per each station</td>
</tr>
<tr>
<td>2</td>
<td>The number of passengers per public transport line or mode</td>
</tr>
<tr>
<td>3</td>
<td>Passenger type</td>
</tr>
<tr>
<td>4</td>
<td>Transport performance per vehicle</td>
</tr>
<tr>
<td>5</td>
<td>Average auto occupancy per vehicle</td>
</tr>
</tbody>
</table>

Table 1 Transport index in a Smart card
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Average travel time per passenger</td>
</tr>
<tr>
<td>7</td>
<td>Average travel length per passenger</td>
</tr>
<tr>
<td>8</td>
<td>Average frequency of travel per passenger</td>
</tr>
<tr>
<td>9</td>
<td>Average usage time per mode</td>
</tr>
<tr>
<td>10</td>
<td>Confusion ratio</td>
</tr>
<tr>
<td>11</td>
<td>Average fare per passenger</td>
</tr>
<tr>
<td>12</td>
<td>Transportation income per car</td>
</tr>
<tr>
<td>13</td>
<td>Transportation income per line</td>
</tr>
<tr>
<td>14</td>
<td>Average transfer frequency</td>
</tr>
<tr>
<td>15</td>
<td>Average transfer time</td>
</tr>
<tr>
<td>16</td>
<td>Average transfer fare</td>
</tr>
<tr>
<td>17</td>
<td>The number of trips between origin and destination</td>
</tr>
</tbody>
</table>

This paper used the following from the index: (1) the number of passengers per each station, (2) the number of passengers per public transport line, (3) transport performance per vehicle, and (4) confusion ratio (It allows for the analysis of the number of simultaneous bus arrivals); and from the above mentioned method, (5) the average the number of people waiting per station and (6) dwell time per vehicle were calculated.

Smart card data which is used in this paper was provided in 2009 by the Smart Card Company. And the data used was the average of the numerical value of the week/weekend.

**3.2.1 Method of analysis for the number of passengers per station**

Smart card data has an index of the getting on / getting off station ID. From this, the number of passengers per station was determined. It was calculated by extracting the data from the user record and matching what was known to the bus line ID.

**3.2.2 Method of analysis for the number of passengers per bus line**

The number of passengers per public transport line was calculated from the data for the number of passengers per each station divided by each bus line.

**3.2.3 Method of analysis for transport performance per vehicle**

Using the calculated number of passengers per bus line, the transport performance per vehicle was calculated. The number of passengers per bus line was divided by the number of operation vehicles during one day yielding the average of the transport performance per vehicle in one day.

In addition, from this, the auto occupancy per vehicle was calculated.

**3.2.4 Method of analysis for the number of simultaneous bus arrivals**

It is necessary to analyze the number of simultaneous bus arrivals to estimate the capacity of the bus station. The factors that affect bus arrival at a station are bus intervals and signal phase. Through these factors, the number of simultaneous bus arrivals was calculated.

There is another method that was used the Smart card data. The Smart card data includes the passenger’s time for getting on and off the bus. Passengers who are using the bus must tag
their card on the terminal equipment when getting on and off the bus. Thus by extracting the time data during the same time record, it is possible to calculate the number of simultaneous bus arrivals.

3.2.5 Method of analysis for the average number of people waiting per station

The number of simultaneous bus arrivals is used to estimate the average the number of people waiting per station. Each bus has information on the passengers in the Smart card data. Using this information, the passengers were divided into two groups; one group was the passengers getting on the bus, and the other was the passengers getting off the bus. The number of people waiting per station is the sum of the total number of passengers getting on all the buses for a particular station.

3.2.6 Method of analysis for the average wait time per station

Some assumptions needed to be made to estimate the average wait time per station. They were the following:

- Passengers who will use the bus don’t know the arrival time of each bus
- Passengers’ arrival probability to the station follows a normal distribution.
- Every bus arrives on time

Therefore, a passenger’s average wait time is half of the bus intervals. To estimate the average wait time per station under the assumptions, the calculated bus intervals from the Smart card data were used.

3.2.7 Calculation of the average dwell time per vehicle

The average dwell time of a bus can be calculated using the following equation:

$$T_s = T_c + \max[N_{on} \times T_{on}, N_{off} \times T_{off}] + T_d$$

where, $T_c$ : Dwell time [s]
$T_d$ : Opening/closing time of doors [s]
$N_{on}$ : The number of people getting on [persons]
$N_{off}$ : The number of people getting off [persons]
$T_{on}$ : The time for Getting on per person [s]
$T_{off}$ : The time for Getting off per person [s]

The bus entering the bus stop needs time to decelerate to come to a stop at a station (deceleration time) and leaving the bus stop needs time to accelerate to return to its normal cruising speed (acceleration time). The clearance time was the sum of these two times. The opening and closing time of the doors and the time for getting on/off the bus were also needed for the calculation. Dwell time is the sum of the clearance time, the time for opening and closing of the doors, and the time for getting on/off the bus.
4. METHOD OF DESIGN FOR A MEDIAN LANE BUS STOP

4.1 Defined LOS (Level of Service) for a bus stop

A bus stop is divided into two sections; one is the bus berth bay for buses stopping, and another is a passenger waiting bay for people waiting to get on a bus. Therefore, when designing bus stations, both two sections need to be taken into consideration.

4.1.1 LOS of a bus berth bay

The length of a bus berth bay is 15m, and the width is 3m per one face. And generally, 3-4 faces can be installed per one lane. The reason passengers feel uncomfortable is when there is more than 4 faces and the bus berth bay is more than 60m in length.

The capacity of a bus berth bay should not only consider the number of simultaneous bus arrivals but also the signal phase. A defined LOS for a bus berth bay taking these things into consideration is presented table 2.

<table>
<thead>
<tr>
<th>Classify</th>
<th>Process rate of the simultaneous bus arrivals per one phase of advance signal (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>&gt; 200</td>
</tr>
<tr>
<td>B</td>
<td>151 ~ 200</td>
</tr>
<tr>
<td>C</td>
<td>101 ~ 150</td>
</tr>
<tr>
<td>D</td>
<td>76 ~ 100</td>
</tr>
<tr>
<td>E</td>
<td>51 ~ 75</td>
</tr>
<tr>
<td>F</td>
<td>0 ~ 50</td>
</tr>
</tbody>
</table>

And total dwell time per one signal phase which is the sum of the time for all bus arrivals during one signal phase getting out of the bus station perfectly can be calculated by the following equation:

\[
T_{t_s} = \max \left( T_{t_s} \right) + n \times T_c + \frac{L_{eb}}{2v_a}
\]

where, \( T_{t_s} \): Total dwell time per one signal phase [s]
\( T_m \): Average dwell time per vehicle [s]
\( n \): The number of simultaneous bus arrivals per one signal phase [veh]
\( T_c \): Clearance time (accelerate/decelerate time) [s]
\( L_{eb} \): The effective length of a bus berth bay [m]
\( v_a \): The velocity of a bus passing through a station (≒ 10km/h)
If $T_s$ is more than one long signal phase, a delay happens due to not being able to process all of the arriving buses. LOS is defined following this principle.

### 4.1.2 LOS of a passenger waiting bay

LOS of a passenger waiting bay is defined by the area criterion of KHCM(2005) and is presented in table 3,

<table>
<thead>
<tr>
<th>Classification</th>
<th>Area criterion ($m^2$/person)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$&gt; 1.55$</td>
</tr>
<tr>
<td>B</td>
<td>$0.75 \sim 1.54$</td>
</tr>
<tr>
<td>C</td>
<td>$0.53 \sim 0.74$</td>
</tr>
<tr>
<td>D</td>
<td>$0.41 \sim 0.52$</td>
</tr>
<tr>
<td>E</td>
<td>$0.33 \sim 0.40$</td>
</tr>
<tr>
<td>F</td>
<td>$0.26 \sim 0.32$</td>
</tr>
</tbody>
</table>

### 4.2 Design process for a bus stop

#### 4.2.1 Design process of a bus berth bay

The existing design process is to estimate the capacity of a bus berth bay through averaging the stoppage time per vehicle and classifying the interrupted/uninterrupted flow of an entrance into and out of a bus station. However, now it is no longer necessary to estimate the capacity because the capacity of the bus arrivals can be determined from the Smart card data.

With the information calculated above and by using the standards presented in table 4, a bus berth bay was designed. This process was as follows:

<table>
<thead>
<tr>
<th>Table 4 Standards of installation of a bus stop (KHCM, 2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category</td>
</tr>
<tr>
<td>The width of face</td>
</tr>
<tr>
<td>The length of face</td>
</tr>
<tr>
<td>The length of margin for the entrance and exit</td>
</tr>
<tr>
<td>The length of the cross walk</td>
</tr>
<tr>
<td>Etc</td>
</tr>
</tbody>
</table>

1. Average the number of simultaneous bus arrivals per day
2. Determine the minimum N which is the number of lanes in a bus stop satisfying ‘$1 \geq 4N$’
3. Divide the bus lines so they have equal probability of simultaneous arrivals.
3. Decide whether to install or not install waiting bay / passing lane
4. Determine a suitability signal cycle length

4.2.2 Design method of a passenger waiting bay

Passenger waiting bay is designed by the demand of each bus line and arranged bus line per each lane for a bus stop satisfying the target LOS. The equation is as follows:

\[ C_w = L_{eb} \times W_w = A_{LOS} \times NP_w \]

where, \( C_w \) : The design capacity of the passenger waiting bay \([m^2]\)
\( L_{eb} \): Total effective length of a bus berth bay \([m]\)
\( W_w \): The design width of a passenger waiting bay \([m]\)
\( A_{LOS} \): The possession area by LOS \([m^2/\text{person}]\)
\( NP_w \): Average the number of people waiting per lane \([\text{person}]\)

5. RESULT AND EXTENDED SUGGESTIONS

This paper was written to develop a proper design process for median lane bus stops taking into account the correct demand based on Smart card data in order to increase the service satisfaction of the passengers. The results are as follows: first, the analysis method for the capacity of the bus arrivals per bus station/line was developed based on the Smart card data. Second, the LOS of a bus berth bay and passenger waiting bay was defined. Third, the design process for each bay of a median lane bus stop is suggested based on the correct capacity of the bus arrivals and passenger demand analyzed from the Smart card data.

Aknowlagement

This paper is modified and advanced that published in 64th conference of Korean Society of Transportation

REFERENCES

KHCM(2005), Ministry of Land, Transport and Maritime Affairs, Korea