Development of Transit Evaluation Indicators  
for the efficient operation of public transport links

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Abstract: With a huge amount of information available from transit cards, efficient operation of public transportation can be accomplished using various studies. This study used some of the traffic card data (SD) from a public transport system to promote competitive and efficient transportation and provide information on the smooth transfer of passengers and on how to improve comfort. Depending on the situation for the transit time, the time it takes to walk, especially during transfers, should be taken into account in order to help build a transit system for efficient coordination between the operators. In order to analyze the extent of the delay, this study tried to analyze the transit delay. In this study, the operator, the transit time, and delay time around a metro station were all taken into consideration to reform a system of public transportation routes and thereby improving the efficiency of the operations. The transit bus routes and delay times on the periphery of the regional transit subway could also be calculated to take advantage of transit delay metrics, services, and public transportation routes in coordination with the Metro and could be used as a criterion for efficient operations. Passengers can be provided such information as detour routes depending on the degree of the delay interval and then transfer to partition the transit time or transit delay and minimize the bus latency.

Key Words: key word transit time, key word transit delay time, key word the public transport cards, key word Optimal Estimation of transit times

I. Introduction

1. Background and purpose of the study

Nowadays, metropolitan areas due to the passage of private vehicles are suffering from severe traffic congestion. Thus, environmental pollution has increased and the quality of life has decreased. Existing public transport could not meet the requirements of the users. However, after the
Restructuring of the Seoul Public Transportation system in 2004, there have been a lot of improvements such as affordability and convenience. Also, all of the buses, taxis, subways are interconnected by the Seoul transit card. Currently, access cards and transportation cards affiliated with various types of cards and transportation card terminals throughout the transit system are collecting and managing information from these cards at clearing centers. Proportional to the distance traveled using the transportation cards, especially in Seoul, implementation of the plan has resulted in a wealth of information. And when access cards are used for fare collection and settlement, these transactions include information about the vehicle. With this huge amount of information available from transit cards, efficient operation of public transportation can be accomplished using various studies. This study used some of the traffic card data (SD) from a public transportation system to promote competitive and efficient transportation and provide information on the smooth transfer of passengers improving comfort. Depending on the situation for the transit time, the time it takes to walk, especially during transfers, should be taken into account in order to help build a transit system for efficient coordination between the operators. In order to analyze the extent of the delay, this study tried to analyze the transit delay.

II. Existing literature

JO Nam-Gun (1999) investigated the transport select SP (stated preference) approach using investigative techniques and waiting time, charges, and congestion charging; data were collected on the number of transit. Market segmentation was analyzed using the Logit model to determine the proportion of public transportation utilized. Yang Chang-Hwa and Son Eui-Young (2000) reported on users’ subway transit times. The transit time and the value of escalator availability for the route choice model were analyzed using vehicles on an hourly basis. Lee Kyoung-Jae (2004) focused on the physical facilities of stations such as horizontal distance and stair numbers and its effect on transit time. A model was developed to estimate the escalators transit penalty. And interchange stations and convenience of using them to assess the degree of the perceived transit time was presented. Cha Dong-Duck (2008) focused on the walking distance of target users to the Seolleung subway and external pedestrian streets and its effect on transit impedance, and satisfaction survey responses of the users were studied. Kim Hwang-Bae and Kwan Yeoung-Jong (2010) focused on transit facilities and facilities for their domestic research and user surveys (RP) based on the means of transit and transit paths. The physical properties of select users were presented by calculating the transit time experience.

III. Research Methodology

1. Definition of transit time and transit delay time

Transit time is the time takes to transfer from one mode of transportation to another in a transit system. Having to transfer to various modes of transportation in a transit system during a passenger’s commute is time consuming. Adequate transit time is the public transportation user taking the shortest path between a transit move to the transit section while moving at a regular walking speed and is the total
amount of time required for the transfer. The transit delay time of public transport users is the transit to other public transportation within the proper transit time other than when the transit time is the time of delay. Transits between bus and subway stations are divided into Riding transit and Alighting transit. First of all, riding transit is from getting off the bus to riding the subway. And Alighting transit is from getting off the subway to riding the bus.

For users of public transportation after the bus stops, waiting time does not occur when passing through subway ticket gates for transit and has to be taken into account when calculating the appropriate transit time. And relative to before, the difference between the riding transit and transit stop is used to calculate the latency of the bus.

![Figure 1 Methods Flowchart](image)

2. Select Transit Evaluation Indicators utilizing public transport cards

If using efficiency metrics for an objective analysis, it may be appropriate for the standard of comparison to use this criterion which can be evaluated using more diverse transit service levels. The average transit time per unit was selected as the efficiency metric in this study. The degree of the transit delay interval can be compared to the transit time using the average per unit. Other delay intervals can provide information on transit using a variety of routes from the user and provide information on the efficiency of transit Mobility due to users’ satisfaction.

<table>
<thead>
<tr>
<th>division</th>
<th>Transit</th>
</tr>
</thead>
<tbody>
<tr>
<td>indicator</td>
<td>The average transit time per 1m</td>
</tr>
<tr>
<td>unit</td>
<td>sec/m/person</td>
</tr>
<tr>
<td>Expression</td>
<td>(Adequate transit time - Transit time)/Transit People/Transit distance</td>
</tr>
</tbody>
</table>

3. Development Plan for Transit indicators

The developed metrics for transit were based on the analysis of the flow chart on how the proposed research was done. Selection of the target area, public transport card processing and extraction, evaluation of efficiency utilizing transit time (transit delay time analysis), and other processes were used. A typical data analysis process is outlined below.
1) Evaluation of selected target areas

Using public transportation card data to analyze all areas of Seoul, the station transit center route was chosen at key points for evaluation to do the analysis due to time constraints and space limitations. The locations of a range of selected target areas should be the first thing considered for subway and bus transit times and should be analyzed in conjunction with the smooth region. Major transit hubs in Seoul for a wide variety of public transportation services operate through the transit cards, and users of public transport very frequently transit from one mode of public transport to another, and various information can be obtained from the cards.

2) Extraction and processing of public transport cards

In order to do this study taking advantage of the card data from public transportation, we analyzed the card data in the following order.

![Figure 2 Public transportation card processing and extraction flow chart](image)

Current public transport card data is shown below. The personal data of all the required information is recorded on the card data. But for the day to day operations, there is a huge amount (2G) of data on the cards. Therefore, to extract the data necessary for the analysis, the data was minimized for convenience.

<table>
<thead>
<tr>
<th>information</th>
<th>contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 The card number of the day</td>
<td>On a day when using the card, the number granted</td>
</tr>
<tr>
<td>2 Departure time</td>
<td>Contact time of the boarding means</td>
</tr>
<tr>
<td>3 transaction ID</td>
<td>Transit Means ID</td>
</tr>
<tr>
<td>4 Means</td>
<td>Subway or bus ID</td>
</tr>
<tr>
<td>5 Transit times</td>
<td>30 minutes transit times after alighting</td>
</tr>
<tr>
<td>6 Bus line ID</td>
<td>Granted to the bus line ID</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th></th>
<th>User Identification Code</th>
<th>a section is Elementary School Students, youth, Public Boarding station ID</th>
<th>Granted to the boarding station ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Arrivel time</td>
<td>Get off at the Public transportation when it's time to contact the card.</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>alighting station ID</td>
<td>Get off at bus stop ID is granted</td>
<td></td>
</tr>
</tbody>
</table>

Transit systems provide a variety of information from the transit cards, but the amount of information is huge, and it takes a long time to analyze the data. Therefore, a C++ language program was used to extract the necessary data for the analysis.

The following materials were necessary for the analysis of transit time: card number, the transaction for transit of the user to distinguish between ID, Transit times (limited number of one-time transit), elementary school students and youth, the general public to distinguish between public users classification codes (analysis limited to the public), Boarding station ID, Boarding time, alighting station ID, and alighting time. A C++ program was used to extract the file data through the card number and transaction ID and transit times, and transit times were classified into the lineup.

The average value for the over transit time, no bus stop ID, and error data were removed. For the transit of passengers using public transport, or use other facilities to look for another job, or if longer than necessary transit time because of errors in the card data, an abnormal transit time would be the result. This would cause the removal of outliers considering the adequacy of data mining in the transit time.

A standard deviation of 95% for the data analysis was used based on a value less than the appropriate value from the transit time.

In the present public transport card data, there is data on public transportation for all times of the day and separately for weekdays and weekends for the analysis of changes in trends by the day of week to calculate the transit time.

Removing some of the unnecessary data, usage time and the get off time of the ride sorted with the data for transit time (in seconds) will be calculated.

In this study, in order to properly calculate the transit time, the location of the bus stops and subway KSCC (public transport card) must be known. These are provided by the Transportation Information Center in Seoul and by BMS ID by matching with the required ID to calculate the distance interval.

3) Utilizing the transit time to evaluate the efficiency

After removing some more of the unnecessary data, it would be appropriate to calculate the transit time by time of day.

Using the transit time and transit distance intervals from public transport card, the total transit time will be calculated. The Optimum transit time between the total traffic using the public transport card total time and the existing traffic was also calculated.

\[ OTT_{ij} = KSCC_{time} - \{(Walk_{sec} / Walk_{speed}) + (ES_{sec} / ES_{speed}) + (Stair_{sec} / Stair_{speed})\} \]  

\( Walk_{sec} \): Walking Section(m)

\( Walk_{speed} \): Walking Speed(m/s)

\( ES_{sec} \): Escalator Walking Section(m)

\( ES_{speed} \): Escalator Walking Speed(m/s)
Some assumptions were made for the proper analysis of the transit time. First, all users had a normal walking speed of 1.2 m/s and were constantly moving. Second, if there was an escalator in the transit route, the speed of the escalator was 0.5 m/s. And third, if there was no escalator but stairs in the transit route, the walking speed was assumed to be 1.06 m/s. Applying the above assumptions to the analysis of the transit time for each section, the extent of transit delays through the analysis was determined.

IV. Application and verification of Transit Evaluation Indicators

1. Optimal Estimation of transit times

1) Analysis section for calculating the distance

For transit card users of public transportation, transit times prior to the analyses were provided by the Transportation Information Center, Seoul and the information from the BMS was used to calculate the distance between the bus stops and the subway stations. Subway Line 2 and Line 4 were divided into two sections.

Table 3 summarizes the available interval analysis using matching items and stops for subway lines and buses. The point of arrival and departure point were analyzed separately for each unit.

<table>
<thead>
<tr>
<th>Order</th>
<th>Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>departure point</td>
</tr>
<tr>
<td>1</td>
<td>Sa-dang Subway Line 4</td>
</tr>
<tr>
<td>2</td>
<td>Sa-dang Subway Line 2</td>
</tr>
<tr>
<td>3</td>
<td>Sa-dang Subway Line 4</td>
</tr>
<tr>
<td>4</td>
<td>Sa-dang1dong in front of Gwanak market(bus)</td>
</tr>
<tr>
<td>5</td>
<td>Namseoul nonghyup(bus)</td>
</tr>
<tr>
<td>6</td>
<td>Namseoul nonghyup(bus)</td>
</tr>
<tr>
<td>7</td>
<td>Sa-dang Subway Line 2</td>
</tr>
<tr>
<td>8</td>
<td>Sa-dang Subway Line 2</td>
</tr>
<tr>
<td>9</td>
<td>Sa-dang Subway Line 2</td>
</tr>
<tr>
<td>10</td>
<td>Sa-dang Subway Line 4</td>
</tr>
<tr>
<td>11</td>
<td>Sa-dang Subway Line 4</td>
</tr>
<tr>
<td>12</td>
<td>Sa-dang Subway Line 4</td>
</tr>
<tr>
<td>13</td>
<td>Sa-dang Station(bus)</td>
</tr>
<tr>
<td>14</td>
<td>Sa-dang Station(bus)</td>
</tr>
<tr>
<td>15</td>
<td>Sa-dang Station(bus)</td>
</tr>
<tr>
<td>16</td>
<td>Sa-dang Station(bus)</td>
</tr>
<tr>
<td>17</td>
<td>Sa-dang Station(bus)</td>
</tr>
<tr>
<td>18</td>
<td>Sa-dang Station(bus)</td>
</tr>
</tbody>
</table>
In the process of extracting the data traffic, the study was presented in a way. The following expression \( (Walk_{\text{sec}/\text{speed}}) + (ES_{\text{sec}/\text{ES}_{\text{speed}}}) + (Stair_{\text{sec}/\text{Stair}_{\text{speed}}}) \) was used to calculate the appropriate transit time taking into account passengers use of walking, escalators, and stairs.

Another rate period, the normal walking speed (1.2m/s), walking speed on the escalator (0.5m/s), walking speed on the stairs (1.06m/s) were applied to the expression.

### 2. Transit travel time by analysis of public transportation cards

From the analysis of the transit time, it was the highest on Friday.

From the analysis of the high points for the transit time on Friday, the transit to the bus from the subway stop had increased transit times most of the time associated with a heavier traffic load normally experienced at the end of the week compared to Sunday through Thursday which had less traffic.

with moving last weekdays worth of road work the last week Cause is determined to be lower than other days.
From the analysis of the transit time, more transit time was spent on the weekend than on the weekdays. The minimum transit time was 175s during the week with an interval distance between the nearest section number 16 shown on Table 3 {Sa-dang Station (bus) ~ Sa-dang Subway Line 4}. The maximum transit time was 1,058 seconds during the weekend between section number 2 shown on Table 3 {Sa-dang Subway Line 2 ~ Namseoul nonghyup(bus)}. A reduction in the amount of data analyzed revealed a large standard deviation, according to the characteristics of pedestrian traffic, and transit times had significant differences. If all the data were analyzed during one year, the difference would probably went out the exact value so the analysis of the data was limited to one month.

3. Estimation of Transit delay time

1) Analysis of Transit delay time

For the analysis of the transit delay per person for each day, it became clear from the various changes in the delay for each section during the week that the highest value for transit delay was generally on Friday.

![Figure 4 Transit delay time each day](image)

From the analysis of the transit delays, if the transit was from the bus to the subway, it was found that public transport users were close to being on time if almost all of the proper connections were made. This is the nature of public transportation because of the high value for the path of the bus compared to the metro time generally considered to be a tendency to try to move the shortest distance.

2) Analysis of Indicators

Finally, an analysis was done to calculate the metrics that can be compared to other segments via the transit delay. Using the Metrics from the analysis, the indicators for the benchmark were first calculated and analyzed as a measure of 1m per transit time in units of sec / m /person. The index value of the analysis was divided into units of measure for the transit delay which is the difference between the transit time and adequate transit time using the public transportation card. The difference between the metric values in the analysis was lowest for section 18 in Table...
3{Sa-dang Station(bus) ~ Sa-dang Subway Line 4}. And a lot of the samples even had a small difference in the standard deviation.

This section was to analyze the degree of decrease in transit traffic delays on the subway if the user valuable time if the bus transit to the subway.

From the metric analysis, the difference in average Indicators did not change significantly. But when the analysis of the indicators and criteria were analyzed separately, the indicator was about 0.17(sec/m/person) revealed by the differences.

Table 5 Analysis of Indicators

<table>
<thead>
<tr>
<th>Order</th>
<th>Benchmark of indicators</th>
<th>Analysis of indicators</th>
<th>Index difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.49</td>
<td>1.45</td>
<td>0.25</td>
</tr>
<tr>
<td>2</td>
<td>1.74</td>
<td>1.72</td>
<td>0.34</td>
</tr>
<tr>
<td>3</td>
<td>1.37</td>
<td>1.40</td>
<td>0.32</td>
</tr>
<tr>
<td>4</td>
<td>0.43</td>
<td>0.45</td>
<td>0.32</td>
</tr>
<tr>
<td>5</td>
<td>0.79</td>
<td>0.82</td>
<td>0.27</td>
</tr>
<tr>
<td>6</td>
<td>0.09</td>
<td>0.09</td>
<td>0.08</td>
</tr>
<tr>
<td>7</td>
<td>0.31</td>
<td>0.31</td>
<td>0.14</td>
</tr>
<tr>
<td>8</td>
<td>0.54</td>
<td>0.54</td>
<td>0.06</td>
</tr>
<tr>
<td>9</td>
<td>0.78</td>
<td>0.78</td>
<td>0.29</td>
</tr>
<tr>
<td>10</td>
<td>0.70</td>
<td>0.74</td>
<td>0.44</td>
</tr>
<tr>
<td>11</td>
<td>0.40</td>
<td>0.40</td>
<td>0.08</td>
</tr>
<tr>
<td>12</td>
<td>0.56</td>
<td>0.53</td>
<td>0.18</td>
</tr>
<tr>
<td>13</td>
<td>0.48</td>
<td>0.48</td>
<td>0.11</td>
</tr>
<tr>
<td>14</td>
<td>0.28</td>
<td>0.28</td>
<td>0.05</td>
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<tr>
<td>15</td>
<td>0.07</td>
<td>0.07</td>
<td>0.04</td>
</tr>
<tr>
<td>16</td>
<td>0.18</td>
<td>0.18</td>
<td>0.05</td>
</tr>
<tr>
<td>17</td>
<td>0.38</td>
<td>0.37</td>
<td>0.14</td>
</tr>
<tr>
<td>18</td>
<td>0.03</td>
<td>0.03</td>
<td>0.01</td>
</tr>
</tbody>
</table>

V. Conclusions and future work

From the transit cards used by the public transportation system, an analysis of transit times was done; different results were analyzed by the day of the week for the transit time.

The transit time was longer on the weekdays than the weekends since the weekday traffic use of public transportation was mainly used for the purpose of going to work or school. To reduce the waiting time occurs when you use public transport flights shorter than that of the weekend, compared to the weekend, and analyzed by the short transit time To use the transit time difference between using public transportation and transit time card basis. From the analysis of the transit delay, the transit delay increased over the weekend compared to the weekdays. In addition, Friday appeared to have the best transit time and the smallest transit delay.

In this study besides the operator, the transit time and transit delay time around a metro station were taken into account to reform a system of public transportation routes thereby improving the efficiency of the operations.

The transit bus routes and delay time on the periphery of the regional transit subway can also be calculated to take advantage of transit delay metrics and the services and public transportation routes in coordination with Metro which could be used as a criterion.
Depending on the degree of the transit delay interval, the user can be provided information on detour routes and transfer to different routes to partition the transit time or transit delay and minimize bus latency.

To calculate the transit time determined in this study, transit time analysis using public transport cards was done. The use of transport cards will be more diverse by both the administrators and passengers of a public transportation system in the future.

In this study, the transit time calculated the shortest path of transit between a bus and subway stop through the analysis of latency and transit delay. For future research, the appropriateness of the location of bus stops in relationship to subway stops needs to be analyzed.

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V. Reference

Yang Chang-Hwa, Son Eui-Young(2000) 「Seoul subway transit passengers, estimated the value of the relevant variables(Revelation of preferences on the awareness and preference analysis)」, Journal of Korean Society of Transportation, Korean Society of Transportation, Volume 18 No. 4


Jo Nam-Gun(1999) 「(A) Study on the impact of road pricing on car owner's mode choice for work trips」, Seoul National University

Cha Dong-dok, Park Wan-Yong, Park Sun-Bok(2008) 「A model of a relative evaluation of the transit distance between two modes」, 59th Korean Society of Transportation Scientific Presentation, Korean Society of Transportation

Kim Hwang-Bae, Kwon young-jong(2010) 「Modeling of Transit of based an Express Bus Terminal use Behavior」

Choi Jun-Ho, Jeon Eun-Myeong, Hong Won-Hwa, Ryou Hong-Sun(2009) 「Calculation of Revision Coefficient of Evacuee's Walking Speed to Operate an Evacuation Simulator aiming at a High-rise Building」

Seoul Traffic Information Center (http://topis.seoul.go.kr/)