Efficient Usage of Transfer Based System in Intracity Bus Transit Operation: Sample of Izmir

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Abstract

In this study, intracity bus transit lines based on transfer system are reorganized by using O-D matrix that are obtained from analyzing smart card data. Vertical bus routes that reach the rail system stations are designed and also bus lines that have connection with city center are converted to the regional bus lines. In this way travel times will be decreased thus agency can serve with efficient and reliable bus routes. Decreasing the number of lines and buses that using arterials in the city center can provide more regular headways. Additionally, existing bus line system and transfer based line system are compared and operational benefits (number of vehicles, number of services, total route length, etc.) are examined.

1. Introduction

Increasing the urban populations and reaching the growth of urban areas to the peripheries of cities cause inefficient use of capacity and decrease the level of service quality of public transportation. Insufficiency in public transportation is also a factor that increases the use of private transportation in cities. Whereas the most cost-effective way of resolving problems caused by traffic is canalizing the transportation users to the public...
transportation. For this reason, keeping a high level of public transport services, especially in bus transit systems, providing the reliability of passengers to the consistency of the system are required.

Although bus transit systems can provide flexibility of bus line planning, operating and revision, they are mostly operated on mixed vehicle traffic and thus their performance is directly affected by the traffic conditions. Integration of the system with itself and other public transportation systems and optimization of schedules depending on travel times in different hours of a day have a great importance for passenger satisfaction and operational efficiency. In addition, a management approach that follows the developing technology, will improve customer satisfaction and minimize operational and maintenance costs and provide the easier management.

In designing routes of bus lines, passengers demands should be considered as well as the operational efficiency. All passengers that live in residential areas request progressive transit lines but transportation agencies can not provide all of these transportation demands in current population density. For these reasons bus transit lines should be designed as providing an equilibrium between operational efficiency and passenger demands. In designing procedure some goals like decreasing saturations of the traffic flows on main arterials and city center, increasing the efficiency of bus transit lines, using shorter bus lines with higher frequencies, decreasing waiting times at the bus stops should be considered.

Transit line systems that have branches enables transportation of passengers without any delays in the transfers by providing continuous service between the city center and periphery areas. In this case many of the routes are long and so these routes cause high operational costs and low efficiency. Additionally, it is observed that bus agencies which have limited fleet size serve with low service frequency. On the other hand, in the transit line systems that have feeders, each route section can be optimized according to the transportation mode, vehicle type and travel time. Increasing the passenger demand potential and minimizing the fleet size can be the factors for decreasing the operational costs. In this operational system main and regional bus lines are designed for preventing the problems like bunching, long passenger waiting times and exceeding the passenger capacities of the bus stops that use by many different bus lines especially on the main arterial streets in city centers. In this systems passengers which use bus lines that serve residential areas are transferred in a transfer center to the main bus lines (Elker, 2002) (Vuchic, 2005) (Fig. 1).

![Fig. 1 Integration of bus routes.](image-url)
Vuchic (2005), is summarized the characteristics of the transit line systems types as follows.

Table 1. Advantages and disadvantages the transit line systems types (Vuchic, 2005).

<table>
<thead>
<tr>
<th>Advantages of Branches</th>
<th>Advantages of Feeders</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Provide for passengers a continuous service without transfers and delays between center city and suburban areas.</td>
<td>*Each line section can be optimized with respect to mode and vehicle type used, schedule, etc.; load factors are higher, fleet size smaller and operating costs lower.</td>
</tr>
<tr>
<td>*lines are longer, truck and branches have smaller percentage of cycle times</td>
<td>*Use of higher performance vehicles or mode (usually rail) on the trunk provides superior service at lower operating cost than smaller vehicles from branches (buses) can provide.</td>
</tr>
<tr>
<td>*Transfer stations are not needed.</td>
<td>*Regular headways can be operated on the trunk and on each feeder line.</td>
</tr>
<tr>
<td></td>
<td>*More reliable service: delays are less likely to transfer between trunk and feeders.</td>
</tr>
<tr>
<td></td>
<td>*Suburban terminals for trunks offer not only trunk / feeder transfers, but also transfers among feeder lines, providing greater network connectivity.</td>
</tr>
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</table>

2. İzmir Transportation System and Intra-city Bus Operation

İzmir province is located in western part of Anatolian peninsula and eastern border of Aegean Sea. İzmir is third biggest city in Turkey, has 11.973 km² area. Total province population is 3,965,232 and 91% of the total population lives in metropolitan area (TUİK, 2011). In İzmir metropolitan area, there are 21 central district and also 744 quarters (Fig. 2).

![Fig.2 İzmir City’s Districts.](image)

By the year 2013, public transportation in İzmir has been provided by wheeled public transportation systems (bus system and paratransit systems), rail systems (light rail system and heavy rail system) and ferry system. All
transportation systems except paratransit systems are operated by Izmir Metropolitan Municipality (ESHOT, 2012).

In the current situation, public transportation service based on highway is supplied by 336 bus lines, 1450 buses and about 6000 bus stops. There is a light rail system that have 12 station and is 11.2 km length, heavy rail system that have 31 station and is 79 km length. Ferry transportation is serviced by 15 ferry lines, 6 ferry docks, 27 ferries as well (Fig. 3).

In the city, the average number of boarding passengers per day on the weekdays is 1,378,729, the average number of boarding passengers on Saturdays is 1,127,050 and on Sundays is 780,155 by the year 2012. 77% of the transactions are made in bus system, 11% of the transactions are made in light rail stations, 9% of the transactions are made in heavy rail stations and 2% of the transactions are made in ferry docks. That results show that a large proportion of public transportation in Izmir is provided by public bus system.

In 1999, public transportation agency changed the technology of fare collection system and passengers have started to use smart cards instead of paper tickets. In 2000, first stage of integration of public transportation modes was begun and by this year all of the modes have been operating by the same fare collection system based on smart cards. Since 2008, a single tariff has been implemented on transportation modes and the payment system is such that each passenger pays a fare when entering the system that allows him/her to make up to unlimited transfers within 90 minutes (ESHOT, 2012).

Izmir Metropolitan Municipality General Directorate of ESHOT, operator of urban bus transit in Izmir, has made studies about transfer based system that include integration of existing bus line system by itself and with the other public transportation modes (metro, ferry and heavy rail systems). Because of passenger demands that are ignored in planning and incomplete railway constructions, this study could not be implemented (ESHOT, 2011). The study called as “Fully Integrated System in Public Transportation”, implemented partly and the northern and southern settlements linkage has been obtained thanks to this study. Also, mostly central-based bus lines which have direct connection with the city center are transformed to regional-based bus lines and a lot of
transfer-based vertical lines were designed that serve suburban and heavy rail system instead of parallel lines (ESHOT, 2011) (Fig. 4).

![Fig. 4 Integrated Public Transportation in Izmir](image)

### 2. The Prediction Of Passenger Demand In Public Transport By Using Smart Card Data

Passenger boarding data which collects from transit systems that operates by Izmir Metropolitan Municipality, are stored in a smart card data system. Many information which can be used in transportation planning, is obtained using Smart card data based on fare collection system and GPS data based on vehicle location system using in Izmir Metropolitan Area.

In this study, an algorithm which can analyze the following outputs by using smart card data is developed for Izmir metropolitan area: converting smart card boarding data (ID’s) to person-based data, determining travel routes of passengers in a particular date, determining daily passenger volumes of main and secondary transfer locations, obtaining regular travel data with analyzing travel routes of passengers (regular travel is defined as the trip made by the person who travels between the same origin and destination points over a particular day), calculating zone-based travel trends of passengers and obtaining origin-destination matrix of the regular users (Fig. 5) (Deri & Kalpakci, 2012) (Deri, Özuysal, Tanyel, Kalpakci, 2013).

For the study, 1,398,065 smart card boarding data which was recorded in 10th May, 2011 is analyzed. According to the analyses it is found that 221,323 passengers make regular trips in the total passenger number traveling in this selected day (495,559). After the examining the zone-based travel demand, it is seen that there is an intensive demand to the city center and also the areas where educational and health facilities are located. Zone-based travel demands are regrouped and thus county-based travel demands are obtained (Fig. 5). Results of the district-based travel demands shown that destination point of 105,245 regular travels is the city center of Izmir (Konak District). This number is equal to approximately 47% of regular travels. Additionally, it is found that every district has a significant internal travel demand (Deri & Kalpakci, 2012) (Deri, Özuysal, Tanyel, Kalpakci, 2013).
3. Revision of Intra-city Bus Line System

In this study, intra-city bus transit lines based on transfer system are reorganized by using O-D matrix that obtained from analyzing smart card data. Following principles are considered in revision process:

1. Improving a transfer based system and bus priority system that are obtained from Izmir Master Plan of Transportation
2. Generating feeder bus lines that serve between residential areas and transfer centers, generating main bus lines that serve between transfer centers and city center.
3. Decreasing the number of lines and buses that using arterials in the city center for providing more regular headways and preventing bus bunching in stops.
4. Designing vertical bus routes that reach the rail system stations and converting bus lines that have connection with city center to the regional bus lines as well.
5. If it is possible, canalizing the transportation users to the ferry transportation for increasing the utilization of ferry transportation and decreasing the over passenger loads in some bus lines.
6. Serving efficient and reliable bus line system that provide faster and comfortable travel for passengers.

Existing bus line system and transfer based line system are compared and operational benefits (number of vehicles, number of services, total length of routes, etc.) are examined. The results are summarized as follows:

Table 2. Comparison of Integrated Systems

<table>
<thead>
<tr>
<th></th>
<th>Before First Stage Integration</th>
<th>After First Stage Integration</th>
<th>Before Second Stage Integration</th>
<th>After Second Stage Integration</th>
<th>Current Stage</th>
<th>After Fully Integrated System Proposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Number of Lines</td>
<td>306</td>
<td>291</td>
<td>314</td>
<td>288</td>
<td>313</td>
<td>267</td>
</tr>
<tr>
<td>Number of Buses in Service (Morning Peak)</td>
<td>1421</td>
<td>1414</td>
<td>1412</td>
<td>1357</td>
<td>1405</td>
<td>1269</td>
</tr>
<tr>
<td>Number of Buses in Service (Afternoon)</td>
<td>1045</td>
<td>991</td>
<td>959</td>
<td>932</td>
<td>959</td>
<td>852</td>
</tr>
<tr>
<td>Number of Buses in Service (Evening Peak)</td>
<td>1320</td>
<td>1267</td>
<td>1282</td>
<td>1240</td>
<td>1278</td>
<td>1164</td>
</tr>
<tr>
<td>Number of Buses in Service (Night)</td>
<td>558</td>
<td>555</td>
<td>536</td>
<td>518</td>
<td>536</td>
<td>473</td>
</tr>
<tr>
<td>Total Number of Service (per a day)</td>
<td>11300</td>
<td>12290</td>
<td>11792</td>
<td>13313</td>
<td>11752</td>
<td>11949</td>
</tr>
<tr>
<td>Total Length of Service-km (per a day)</td>
<td>327509</td>
<td>330448</td>
<td>314050</td>
<td>312211</td>
<td>319793</td>
<td>287283</td>
</tr>
<tr>
<td>Total Length of Lines(km) (per a day)</td>
<td>9841</td>
<td>8378</td>
<td>9317</td>
<td>7842</td>
<td>9427</td>
<td>7427</td>
</tr>
</tbody>
</table>

The effectiveness of the procedure can be appreciated by comparing the proposed system with the one already exists. A comparison between two systems shows that (fig. 6):

- The total length of the bus transit network has been considerably reduced in design plan (7427 km compared to 9427 km)
- The number of vehicle-km of the design bus system decreases by 11% compared to the current system (287,283 versus 319,793)
- The number of vehicles necessary for the during the AM peak hour (06:00 – 09:00) is equal to 1405; while in the design system only 1269 vehicles are necessary.
- The number of daily services increases from 11,752 to 11,949.
- The percentage of design system lines is nearly 85 that for the existing system.
- The existing system offers a high concentration of lines and terminals in the city center of Izmir.
The high number of vehicles and vehicle-km of the existing system depends on the use of a network spread of low frequency lines. The design network, on the other hand, offers high frequency and straight routes.

Fig. 6 Results and comparisons
4. Conclusions

In this study, intra-city bus transit lines based on transfer system are reorganized by using O-D matrix that obtained from analyzing smart card data. Vertical bus routes that reach the rail system stations are designed and therefore bus lines that have connection with city center are converted to the regional bus lines. The findings show that the fleet is used efficiently after the fully-integrated system design. Vertical bus routes that reach the rail system stations are designed and therefore bus lines that have connection with city center are converted to the regional bus lines. In this way travel times will be decreased thus agency can serve with efficient and reliable bus routes. This is a framework for the public transit agencies. Nevertheless, results should be tested with using various simulation and assignment models that provide more realistic results for implementation.

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References