Evaluation of urban public transportation efficiency in Kutahya, Turkey
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Abstract
In this study, the public transport system in the city of Kutahya and its current transportation problems were firstly mentioned. Then, the transit quality of service in Kutahya was evaluated from various aspects such as transit availability, comfort and convenience. For this purpose, at first, transit availability was examined in terms of service frequency, hours of service and service coverage. Secondly, the comfort and convenience provided by the transit system in Kutahya was studied. For this reason, the overall crowding levels within the vehicles, headway adherence, and transit-automobile travel time were considered. In order to carry out most of these analyses, the procedures in Transit Cooperative Research Program (TCRP) Report 100 were followed. However, determining the level of service of public transport in terms of transit-automobile travel time by comparing the public transport travel times with automobile travel times constituted the essence of this study. In order to accomplish this aim, the feature of “driving directions” in Google Maps was used in terms of being a reference to automobile usage. So, the travel times on all the bus transit lines in Kutahya were compared with private car travel times determined by Google Maps for the same routes. By founding the difference between the public transport and car travel times, the public transport service level in terms of transit-automobile travel time was evaluated. Finally, several recommendations for increasing public transport usage were given.

Keywords: The City of Kutahya, public transport, level of service, quality of service, Google Maps

1. Introduction

As a result of the industrial revolution, the production boom took place in the world. Thus, the need for transportation has increased significantly because of the necessity of carrying large amounts of materials and products throughout the world. In addition to the freight transport, passenger transport also increased, depending on economical development. Consequently, the traffic densities at all transportation modes have grown tremendously.

The industrial revolution has also caused the growth of cities. The various inventions and developments in transportation have played a significant role in this growth. Therefore, the need for transportation in these cities has increased significantly. As a result, many cities face with traffic congestion and its serious negative effects. So,
cities implement intermodal transportation systems that minimize these problems. In these efforts, city governments recognize urban public transportation as the critical element for achieving balanced transportation. In other words, it has been accepted that public transport has the goals of simplifying people’s daily lives and meeting the needs of them.

Rapid increase in private car usage caused the public transportation systems operated in some cities to remain idle, and even led to the closure of some of the lines within these systems. Especially, rail systems were affected from this development. For example, most of the tramway lines operated in Istanbul were closed during 1960s. In addition to the insufficiency of road networks, the rapid increase in the number of vehicles caused traffic congestion to occur within cities. As a result, various studies were carried out to find solutions to these problems.

In the transportation plans made in 1950s, no studies were performed for the recovery of rail systems. During these years, the problem was thought to be only traffic jam, and new highways were built in order to facilitate the movement of private cars. Thus, the demand for public transport modes reduced further, and private car usage increased rapidly. This understanding continued until Buchanan published a report in 1962. Thus, with this report, it was first pointed to the fact that private car usage increased the severity of urban traffic problem. In order to solve this problem, public transport was found to be essential and came into question again. Therefore, transportation planning studies giving priority to public transport were carried out during this period. In these studies, private car usage was delimited, and emphasis was given to rail systems (Lawrence and Pivo, 1997).

When the decision-making organs do not observe the transportation systems carefully, these systems easily get out of their main objectives and lose their functions. Therefore, urban planners consider the growth of cities along with their transportation systems. People expect from a transportation system to have several major characteristics. At first, safety factor should be large while people are using the transportation system. Secondly, the transportation system should carry people, materials and products at minimum time and cost. Finally, it should provide the greatest possible comfort (Vuchic, 2007).

Transport investments are high-cost investments that have long-term effects. For this reason, the accurate determination of priorities for such projects and the use of limited economic resources in the most beneficial way are very important. Hence, it is necessary to plan the transportation system as a whole, taking into account its interactions with land use planning (De Corla-Souza et al., 1997).

Transportation investments should be compared from various aspects such as congestion, air pollution, noise, land use, costs, energy consumption and security. Similarly, many different factors such as number of passengers carried, capacities, frequencies and volumes are taken into consideration in determining public transport system to be used. Even though these factors generally vary from place to place, the system used for transportation should be safe, fast, affordable, punctual and frequent (Uludag, 2005). Hence, as the system is determined for a city or a region, many factors such as topography, geology, climate and socioeconomic structure should be considered (Sallis et al., 2004).

In this study, the transit quality of service in the city of Kutahya was evaluated from various aspects such as transit availability, comfort and convenience. For this purpose, at first, transit availability was examined in terms of service frequency, hours of service and service coverage. Secondly, the comfort and convenience provided by the public transport system in the city of Kutahya was studied. For this reason, the overall crowding levels within the vehicles, headway adherence, and transit-automobile travel time (the door-to-door difference between automobile and transit travel times, including walking, waiting, and transfer times for both modes) were considered. In order to carry out most of these analyses, the procedures in Transit Cooperative Research Program (TCRP) Report 100 were followed. However, determining the level of service of public transport in terms of transit-automobile travel time by comparing the public transport travel times with automobile travel times formed the essence of this study. In order to accomplish this aim, the feature of “driving directions” in Google Maps was used in terms of being a reference to automobile usage. So, the travel times on all the bus transit lines in Kutahya were compared with private car travel times determined by Google Maps for the same routes. By founding the difference between the public transport and car travel times, the public transport service level in terms of transit-automobile travel time was evaluated.

2. Existing Public Transport System in Kutahya and Its Current Problems

Kutahya is a developing city that lies in the west of Turkey. The city has one university with nearly 30,000 students. The city of Kutahya has a population of approximately 210,000 inhabitants within the limits of the
Municipality Region. Because of the growing impact of increasing passenger demand, the car ownership and congestion levels in Kutahya have begun to rise considerably.

Private public buses are used as a means of public transport in the city of Kutahya. The buses used in the public transport system are small ones, and have a seating capacity of 22 passengers. These buses can also accommodate 20 standees. These private public buses have been running on 15 different lines. The general condition of these bus lines are shown in Figure 1 (Kutahya Mun., 2010).

According to the data obtained from Kutahya Municipality, the time periods and line lengths of 15 bus lines are as in Table 1. The number of passengers carried per month on these lines is also given in this table (Kutahya Mun., 2011). From this table, except for Line 11 which is express line operating between the Central Campus (Merkez Kampusu) and the Germiyan Campus during peak hours, it can be seen the number of passengers carried per month for 14 lines. Again, from this table, it can be found that the Lines of 1, 2, 4, 5, 6 and 7 carry much more passengers than other lines.

| Line Number | Starting Point of Line | Endpoint of Line | Time Period (minutes) | Line Lengths (km) | The Number of Passengers Carried per Month |
|-------------|------------------------|-----------------|-----------------------|------------------|------------------------------------------|
|             |                        |                 | Departure | Return | Departure | Return |                      |
| 1           | Zafertepe              | Merkez Kampusu  | 45        | 45     | 21.8      | 21.8   | 248,819               |
| 2           | Zafertepe              | Evliya Celebi   | 45        | 45     | 16        | 15.8   | 289,958               |
| 3           | Evliya Celebi          | Selale Villalar | 40        | 38     | 22        | 22     | 27,908                |
| 4           | Zafertepe              | SSK Hastanesi   | 40        | 30     | 24.64     | 24.64  | 213,234               |
| 5           | Zafertepe              | Bahcelievler    | 48        | 48     | 15.64     | 16.66  | 269,904               |
| 6           | Zafertepe              | Merkez Kampusu  | 50        | 50     | 21.3      | 21.3   | 222,821               |
| 7           | Eski Garaj             | Merkez Kampusu  | 30        | 28     | 13.3      | 13.3   | 236,588               |
| 8           | Toki                   | Yimpas          | 40        | 40     | 15.7      | 15.7   | 119,128               |
| 9           | Ok Meydan              | Sanayi          | 35        | 40     | 8.61      | 8.43   | 61,389                |
| 10          | Sakak                  | Osmangazi       | 40        | 43     | 10.78     | 11.47  | 65,860                |
| 11          | Yurtlar                | Merkez Kampusu  | 20        | 20     | 20.2      | 20.2   | -----                 |
| 12          | Eski Fen Lisesi        | Parmak Oren     | 42        | 38     | 11.4      | 11.3   | 10,696                |
| 13          | Otogar                 | Organize        | 30        | 30     | 12.7      | 8.35   | 5,804                 |
| 14          | Toki                   | Transfer Istasyonu | 27    | 32     | 11.34     | 11.34  | 27,806                |
| 15          | Transfer Istasyonu     | Kumus           | 22        | 22     | 8.35      | 8.35   | 9,561                 |

There is no fast and efficient public transportation network in the city of Kutahya. In some cases, the time elapsed in public transport is 2-3 times longer than the time spent during automobile travel. Some bus routes are longer than
necessary. Besides, due to lack of coordination among the lines, lengthy waiting times occur at transfer points. A region with a distance of 10 minutes by car can be reached by public transport approximately at 40 minutes in case that making transfer between lines is necessary. This situation decreases the efficiency of public transportation. For this reason, especially most car owners do not prefer public transportation.

3. Evaluation of Urban Public Transportation Efficiency in Kutahya

As mentioned previously, the public transport quality of service in the city of Kutahya was evaluated from various aspects such as transit availability, comfort and convenience. For this purpose, at first, transit availability was examined in terms of hours of service, service frequency, and service coverage. Secondly, the comfort and convenience provided by the public transport system in the city of Kutahya was studied. For this reason, the overall crowding levels within the vehicles, headway adherence, and transit-automobile travel time (the door-to-door difference between automobile and transit travel times, including walking, waiting, and transfer times for both modes) were considered. In order to carry out most of these analyses, the procedures in Transit Cooperative Research Program (TCRP) Report 100 were followed (TCRP, 2003).

3.1. Evaluation of the Transit Availability in Kutahya

The headways and hours of service of all lines as well as the service coverage for the whole city were considered in order to evaluate the transit availability in Kutahya. For this purpose, based on the procedure described in TCRP Report 100, hours of service LOS was firstly determined for all lines. To calculate hours of service, the departure time of the last run was subtracted from the departure time of the first run, and 1 hour was added to this subtraction. This additional hour accounts for the last hour when service is provided. Then, any fractional hours were rounded down. When service was not operated throughout the day, the number of hours of service for each portion of the day when service was provided was calculated, and then the total was used in determining the LOS, based on Table 2 (TCRP, 2003). As for the results obtained from this analysis, they are given in Table 3. From Table 3, it can be seen that all lines except for Line 11, which is peak hour express service, provide LOS “D” or better. While all lines from 1 to 10 offer LOS “B” in terms of hours of service, Lines 12 and 15 provide LOS “D”. As for Lines 13 and 14, they offer LOS “C”.

| LOS | Hours of Service | Comments |
|-----|----------------|----------|
| A   | 19 - 24         | Night or “owl” service provided |
| B   | 17 - 18         | Late evening service provided |
| C   | 14 - 16         | Early evening service provided |
| D   | 12 - 13         | Daytime service provided |
| E   | 4 - 11          | Peak hour service only or limited midday service |
| F   | 0 - 3           | Very limited or no service |

Secondly, service frequency LOS was determined for all lines in order to evaluate the transit availability. The procedure described in TCRP Report 100 was used again. As it is known, service frequency determines how many times an hour a user has access to the transit mode. Service frequency also measures the convenience of transit service to choice riders, and is one component of overall transit trip time. However, the service measure used is usually average headway, which is the inverse of the average frequency. Therefore, Table 4, which is taken from TCRP Report 100, lists service frequency LOS by both headway and frequency. In order to carry out this analysis, average headways were firstly calculated for 15 bus lines in Kutahya, and based on these values, service frequency LOS of bus lines were determined by using Table 4. The results obtained from this analysis are also summarized in Table 3. From Table 3, it can be seen that all lines except for Line 13 and Line 15 provide LOS “D” or better. As the Lines of 1, 2, 4, 5, 6 and 7 offer LOS “A” in terms of service frequency, Line 8 and Line 9 provide LOS “B”. On the other hand, the service frequency LOS for Line 10 is “C”. As for the Lines of 3, 12 and 14, they offer LOS “D”.

Table 3 Fixed-Route Hours of Service LOS and Service Frequency LOS of 15 bus lines in Kutahya

| Line Number | Daily Operation Hours of Line | Hours of Service of Line | LOS of Line in Terms of Hours of Service | Average Headway of Line (minutes) | LOS of Line in Terms of Average Headway |
|-------------|-------------------------------|--------------------------|--------------------------------------|----------------------------------|-----------------------------------------|
| 1           | 06:00-23:59                   | 18                       | B                                    | 5                                | A                                       |
| 2           | 06:00-23:59                   | 18                       | B                                    | 5                                | A                                       |
| 3           | 07:00-23:59                   | 17                       | B                                    | 30                               | D                                       |
| 4           | 06:00-23:59                   | 18                       | B                                    | 5                                | A                                       |
| 5           | 06:00-23:59                   | 18                       | B                                    | 5                                | A                                       |
| 6           | 06:00-23:59                   | 18                       | B                                    | 5                                | A                                       |
| 7           | 06:00-23:59                   | 18                       | B                                    | 5                                | A                                       |
| 8           | 06:00-23:59                   | 18                       | B                                    | 10                               | B                                       |
| 9           | 07:00-23:59                   | 17                       | B                                    | 10                               | B                                       |
| 10          | 07:00-23:59                   | 17                       | B                                    | 15                               | C                                       |
| 11          | Peak Hour Express Line        | 2                        | F                                    | ---                              | ---                                     |
| 12          | 07:00-19:59                   | 13                       | D                                    | 30                               | D                                       |
| 13          | 07:00-22:59                   | 16                       | C                                    | 60                               | E                                       |
| 14          | 07:00-20:59                   | 14                       | C                                    | 30                               | D                                       |
| 15          | 07:00-19:59                   | 13                       | D                                    | 60                               | E                                       |

Table 4 Fixed-Route Service Frequency LOS

| LOS  | Average Headway (min) | veh/h | Comments                                      |
|------|-----------------------|-------|-----------------------------------------------|
| A    | < 10                  | > 6   | Passengers do not need schedules             |
| B    | 10 - 14               | 5 - 6 | Frequent service, passengers consult schedules |
| C    | 15 - 20               | 3 - 4 | Maximum desirable time to wait if bus/train missed |
| D    | 21 - 30               | 2     | Service unattractive to choice riders         |
| E    | 31 - 60               | 1     | Service available during the hour             |
| F    | > 60                  | < 1   | Service unattractive to all riders            |

In order to evaluate the transit availability in Kutahya, the coarse service coverage for Kutahya was also considered. As it is known, service coverage is a measure of the area within walking distance of transit service. Similar to the other availability measures, it does not provide a complete picture of transit availability by itself. However, when it is combined with frequency and hours of service, it helps identify the number of opportunities that people have in order to access public transport from different locations. Since it is an area-wide measure, service coverage LOS takes more time to calculate, and requires more information than do other transit availability LOS measures. This task can be simplified by using a geographic information system (GIS). However, in this study, the percentage of the system area served by transit was calculated roughly by manual method without using GIS software. As it is known, service areas, by themselves, are not the best basis for developing service coverage performance measures because land uses as well as population and job densities may vary greatly from one system to another. That is, urban transit system boundaries might include large tracts of undeveloped land. These areas would not generate transit trips in the near term. Nevertheless, this study is limited to only the calculation of service areas and the determination of the percentage of the system area served by transit. As a result, the calculation of the transit service coverage was approximately performed manually by outlining on a map all of the area within 400 m. This approximation assumes reasonable bus stop spacings, which are generally the case in Kutahya. Sections of a route where pedestrian access from the area adjacent to the route was not possible were not included in the service coverage area. From this analysis, the percentage of the system area served by transit was roughly found as 82%. This value was compared with the threshold values in Table 5, which gives fixed-route service coverage LOS and is explained in TCRP Report 100. As a result, the fixed-route service coverage LOS was determined as “B”, meaning...
that most major origins and destinations served. This situation can also be seen from Figure 1, which clearly indicates how the public transport system covers most of the residential or employment-related areas in Kutahya.

Table 5 Fixed-Route Service Coverage LOS

| LOS | % Transit Supported Area (TSA) Covered | Comments |
|-----|--------------------------------------|----------|
| A   | 90.0 - 100.0 %                       | Virtually all major origins & destinations served |
| B   | 80.0 - 89.9 %                        | Most major origins & destinations served |
| C   | 70.0 - 79.9 %                        | About ¾ of higher-density areas served |
| D   | 60.0 - 69.9 %                        | About two-thirds of higher-density areas served |
| E   | 50.0 - 59.9 %                        | At least ½ of the higher-density areas served |
| F   | < 50.0 %                             | Less than ½ of higher-density areas served |

3.2. Evaluation of the Comfort and Convenience Offered by the Transit System in Kutahya

The overall crowding levels within the vehicles, headway adherence, and transit-automobile travel time were considered for evaluating the comfort and convenience provided by the public transport system in Kutahya. To this end, the overall crowding levels within the vehicles are firstly observed during peak and non-peak hours, and passenger load LOS was roughly determined by taking into account the values in Table 6, which provides the LOS thresholds for passenger loads. Table 6 was also taken from TCRP Report 100. From these observations and analyses, it was found that a wide range of passenger load LOS was experienced by passengers depending on time of day, line and section. During peak hours, it is not uncommon to encounter LOS “E” or even “F” in terms of passenger load on some sections of lines carrying a large number of passengers such as the Lines of 1, 2, 4, 5, 6, 7, and 8. In addition, people using the Lines of 3, 10 and 14 also sometimes experience excessive crowding levels although these lines do not carry many passengers. On the other hand, LOS “A”, “B” and “C” in terms of passenger load are mostly observed on sections of all lines during off-peak hours. Passenger load LOS “D” is also encountered rarely on lines carrying a large number of passengers during these hours.

Table 6 Fixed-Route Passenger Load LOS

| LOS | Load Factor (p/seat) | Standing Passenger Area ft²/p | m²/p | Comments |
|-----|----------------------|--------------------------------|------|----------|
| A   | 0.00 - 0.50          | > 10.8†                         | > 1.00† | No passenger need sit next to another |
| B   | 0.51 - 0.75          | 8.2 - 10.8†                     | 0.76 - 1.00† | Passengers can choose where to sit |
| C   | 0.76 - 1.00          | 5.5 - 8.1†                      | 0.51 - 0.75† | All passengers can sit |
| D   | 1.01 - 1.25*         | 3.9 - 5.4                       | 0.36 - 0.50 | Comfortable standee load for design |
| E   | 1.26 - 1.50*         | 2.2 - 3.8                       | 0.20 - 0.35 | Maximum schedule load |

*Approximate value for comparison, for vehicles designed to have most passengers seated. LOS is based on area. †Used for vehicles designed to have most passengers standing.

Afterwards, headway adherence LOS was determined for the lines operating at headways of 10 minutes or less in order to evaluate the comfort and convenience provided by the public transport system. As it is known, for transit service operating at headways of 10 minutes or less, headway adherence is used to determine reliability. For this purpose, the procedure described in TCRP Report 100 was used again. In this procedure, the measure is based on the coefficient of variation of headways of transit vehicles serving a particular route arriving at a stop, and is calculated as follows:

$$c_{vh} = \frac{\text{standart deviations of headway deviations}}{\text{mean scheduled headway}}$$

where:
Headway deviations are calculated by subtracting the scheduled headway from the actual headway. As shown in Table 7 which is taken from TCRP Report 100, the coefficient of variation of headways can be related to the probability \( P \) that a given transit vehicle’s headway will be off-headway by more than one-half the scheduled headway \( h \). This probability is measured by the area to the right of \( Z \) on one tail of a normal distribution curve, where \( Z \) is \( 0.5 \) divided by \( c_{v_{th}} \) in this case.

### Table 7 Fixed-Route Headway Adderance LOS

| LOS | \( P ( > 0.5 \text{ h}) \) | Comments             |
|-----|-----------------|----------------------|
| A   | \( 0.00 - 0.21 \) | \( \leq 1 \% \) Service provided like clockwork |
| B   | \( 0.22 - 0.30 \) | \( \leq 10 \% \) Vehicles slightly off headway |
| C   | \( 0.31 - 0.39 \) | \( \leq 20 \% \) Vehicles often off headway |
| D   | \( 0.40 - 0.52 \) | \( \leq 33 \% \) Irregular headways, with some bunching |
| E   | \( 0.53 - 0.74 \) | \( \leq 50 \% \) Frequent bunching |
| F   | \( \geq 0.75 \)   | > 50 \% Most vehicles bunched |

Note: Applies to routes with headways of 10 minutes or less.

Because headway adderance is applied to routes with headways of 10 minutes or less, calculations have been made for the Lines of 1, 2, 4, 5, 6, 7, 8 and 9. These calculations are summarized in Table 8. The results obtained from this analysis are also given in this table. From this table, it can be seen that a wide range of headway adderance LOS was encountered on lines. While Line 5 and Line 6 offer LOS “C” in terms of headway adderance, the Lines of 1, 7 and 8 provide LOS “D”. On the other hand, the service frequency LOS for Line 4 is “E”. As for Line 2, it offers the worst headway adderance LOS “F”. On the contrary, the headway adderance LOS of Line 9 is “A”, which is the best one among those of all lines.

### Table 8 Fixed-Route Headway Adderance LOS of 15 Bus Lines with Headways of 10 Minutes or Less in Kutahya

| Line Number | \( P ( > 0.5 \text{ h}) \) | LOS of Line in Terms of Headway Adderance |
|-------------|-----------------|---------------------------------------|
| 1           | 0.41            | \( \leq 33\% \) D                     |
| 2           | 0.80            | > 50 \% F                             |
| 4           | 0.56            | \( \leq 50 \% \) E                    |
| 5           | 0.38            | \( \leq 20 \% \) C                    |
| 6           | 0.38            | \( \leq 20 \% \) C                    |
| 7           | 0.51            | \( \leq 33\% \) D                     |
| 8           | 0.40            | \( \leq 33\% \) D                     |
| 9           | 0.10            | \( \leq 1 \% \) A                     |

One of the most important factors in a potential transit user’s decision to use transit on a regular basis is how much longer the trip will take as compared to the automobile. In order to analyze this, the level of service measure used is transit-auto travel time; that is, the door-to-door difference between automobile and transit travel times, including walking, waiting, and transfer times (if applicable) for both modes. In other words, it is a measure of how much longer or shorter a trip will take by transit. Therefore, in this study, transit-automobile travel time was also considered for evaluating the comfort and convenience provided by the transit system in Kutahya.

Travel time for transit includes walking time from one’s origin to transit, waiting time, travel time on transit vehicle, walking time from transit to one’s destination, and any transfer time required. On the other hand, travel time for cars includes travel time in the car and time required to park one’s car and walk to one’s destination.
time is based on a maximum of 400-m walk to transit stop at a speed of 5 km/h, which will take about 5 minutes. Since all transit users do not walk the maximum distance, it is generally assumed to be an average of 3 minutes.

It is harder for small cities to achieve high levels of service for this measure as compared to large cities. For example, in large cities, it can be travelled faster between downtown and a suburban area by public transport system with high quality such as rail rapid transit. On the other hand, for a small city with a population less than 50,000, the walk and wait time for transit by itself is nearly as much as the total of automobile travel time. Therefore, the calculated LOS will be very low. For small cities or for short trips, the total transit travel time will be, in general, significantly larger than the automobile travel time.

Because transit-auto travel time is a system measure, its data requirements are greater than those for transit stop and route segment measures. It can be calculated by using a transportation planning model or by hand. As with many of the other service measures, transit-auto travel time can be measured at peak and off-peak times. Because peak hour traffic congestion tends to lengthen automobile trip times, the calculated LOS will be usually better during peak hours than during the rest of the day. Table 9 gives the transit-auto travel time LOS thresholds

Table 9 Fixed-Route the Transit-Auto Travel Time LOS

| LOS | Travel Time Difference (minutes) | Comments |
|-----|---------------------------------|----------|
| A   | ≤ 0                             | Faster by transit than by automobile |
| B   | 1 - 15                          | About as fast by transit as by automobile |
| C   | 16 - 30                         | Tolerable for choice riders |
| D   | 31 - 45                         | Round-trip at least an hour longer by transit |
| E   | 46 - 60                         | Tedious for all riders; may be best possible in small cities |
| F   | > 60                            | Unacceptable to most riders |

The manual method is useful in areas which do not have a transportation model or when a faster assessment of travel time LOS is desired. Therefore, in this study, the manual method which has been explained in TCRP Report 100 was also preferred for carrying out the analysis. A sampling of 15 pair of locations was used for each line. The CBD and other important trip generators were generally used for analysis, taking into account a balance of residential and employment generators and a balance of geographic locations. One example of this is given for Line 8 in Figure 2, which shows 10 locations considered for the analysis. Thus, 15 pair of locations for Line 8 have been composed from these 10 locations as follows: Toki-Demiryolu, Toki-SSK, Toki-Istasyon, Toki-Yimpas, Demiryolu-SSK, Demiryolu-Isbank, Demiryolu-Istasyon, Demiryolu-Yimpas, Isbank-Istasyon, Isbank-Yimpas, Yimpas-Vefa, Yimpas-DSI, Yimpas-Sanayi and Yimpas-Hotas Oteli.

The analysis was carried out in three steps. In the first step, travel times between locations were estimated for both transit and automobiles. A spreadsheet of travel times between locations was created for use in subsequent steps. During step 1, only travel times between locations were considered; access and wait times were not taken into account at this stage. Because existing conditions were analyzed, transit travel times were derived from published schedules. On the other hand, automobile travel times were determined by utilizing the feature of “driving directions” in Google Maps. As it is known, Google Maps is an online and free mapping service. Directions feature defines the shortest path between two locations with respect to some specific conditions. In addition, when the shortest path defined is travelled by automobile or on foot, the estimated time spent can be calculated. The shortest driving directions between the first location and the second location can also be obtained by using Google Maps. In order to verify whether automobile travel times determined by using Google Maps are close to real travel times experienced by drivers, several test drivings were carried out between some locations. After comparing real automobile travel times with the ones determined by Google Maps, it has been found that there is considerably close agreement between them. As an example, Figure 3 shows the shortest path between two locations (DSI and Demiryolu), which has been plotted by using Google Maps for the analysis of Line 8.
In step 2, travel time differences between locations were estimated. So, for each pair of locations, the auto travel time was firstly subtracted from the transit travel time. Transit access and waiting times were then added. Finally, any auto access time (e.g., walks to or from parking garages) was subtracted. In this analysis, several assumptions were also used. At first, it has been accepted that passengers walk average 4 minutes at each end of their trip. Secondly, waiting time for transit has been assumed to be half of the headway of the line considered at the start of a trip if this headway is equal to or smaller than 10 minutes. When the headway of the line is larger than 10 minutes, it has been supposed to be constant and 5 minutes, considering that passengers tend to use timetable in the case of large headways (Vuchic, 2007). Finally, it has been accepted that auto trips add 2 minutes on average for parking and walking at each end of the trip.
In Step 3, the level of service in terms of transit-auto travel time was calculated. For this purpose, the average of the travel time differences of each pair of locations was calculated for each line, and the resulting value was used with Table 9 in order to find the transit-auto travel time LOS of the line. The results obtained from this analysis are given in Table 10. In this analysis, the circumstances in which transfer between two lines is made have not been taken into consideration because of limited space. However, by adding appropriate transfer times to transit times and subtracting the automobile travel times obtained for the same pair of locations from these transit times, point-to-point LOS can be directly found by using Table 9.

Table 10 Transit-Auto Travel Time LOS of 15 Lines in Kutahya

| Line Number | Average of Transit Travel Times Obtained for 15 O-D Pairs of Each Line (minutes) | Average of Automobile Travel Times Obtained for 15 O-D Pairs of Each Line (minutes) | Difference between Transit and Automobile Travel Times (minutes) | LOS of Line in Terms of Transit-Automobile Travel Time |
|-------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|-----------------------------------------------------------------|------------------------------------------------------|
| 1           | 33.30                                                                           | 18.20                                                                           | 15.10                                                           | B                                                    |
| 2           | 28.83                                                                           | 15.66                                                                           | 13.17                                                           | B                                                    |
| 3           | 29.40                                                                           | 13.80                                                                           | 15.60                                                           | C                                                    |
| 4           | 31.83                                                                           | 15.53                                                                           | 16.30                                                           | C                                                    |
| 5           | 34.03                                                                           | 16.46                                                                           | 17.57                                                           | C                                                    |
| 6           | 34.76                                                                           | 17.86                                                                           | 16.90                                                           | C                                                    |
| 7           | 25.03                                                                           | 13.66                                                                           | 11.37                                                           | B                                                    |
| 8           | 31.46                                                                           | 13.06                                                                           | 18.40                                                           | C                                                    |
| 9           | 31.53                                                                           | 11.93                                                                           | 19.60                                                           | C                                                    |
| 10          | 33.13                                                                           | 12.40                                                                           | 20.73                                                           | C                                                    |
| 11          | Peak Hour Express Line                                                          | Peak Hour Express Line                                                          | --                                                              | --                                                  |
| 12          | 35.00                                                                           | 12.20                                                                           | 22.80                                                           | C                                                    |
| 13          | 25.66                                                                           | 15.00                                                                           | 10.66                                                           | B                                                    |
| 14          | 29.15                                                                           | 13.53                                                                           | 15.62                                                           | C                                                    |
| 15          | 24.93                                                                           | 9.40                                                                            | 15.53                                                           | C                                                    |

From Table 10, it can be seen that a limited range of transit-auto travel time LOS was encountered on lines. Most of the lines provide LOS “C” in terms of transit-auto travel time. On the other hand, the transit-auto travel time LOS for Line 1, 2, 7 and 13 is “B”, meaning that the service offered by transit is about as fast as the service provided by automobile. In order to explain this result, several reasons can be given. At first, public transport vehicles and automobiles use the same routes for most O-D pairs. Secondly, the roads on these routes are not so congested.

4. Conclusions

In this study, the public transport quality of service in the city of Kutahya was evaluated from various aspects. For this purpose, the transit availability was firstly studied in terms of service frequency, hours of service and service coverage. The comfort and convenience provided by the public transport system in the city of Kutahya was then examined. To this end, the overall crowding levels within the vehicles, headway adherence, and transit-automobile travel time were considered. For each line, different service levels in terms of public transport parameters considered were obtained. These service levels have provided important information for efficiency and sustainability of the public transport system.

For the public bus system in Kutahya, the time elapsed in public transport is sometimes 2-3 times longer than the time spent during automobile travel, as mentioned before. Some bus routes are longer than necessary even though they provide a good level of service in terms of the service coverage area. Furthermore, the waiting times at transfer points are considerably long because of lack of coordination among the lines. This situation decreases the efficiency
of public transportation. Therefore, many passengers are displeased with the bus system. Thus, time wastes occur, and especially car owners do not prefer public transportation.

Car drivers should be directed to public transport in order to ensure sustainable transportation. Making the inner city bus trips in shorter times can direct private car drivers to public transport. Consequently, it is not possible to attract automobile drivers to public transport with bus time periods that are 2-3 times longer than those achieved by car. Shortening the time periods of public transport and providing more comfortable transportation service will direct car drivers to public transport. In order to accomplish this, the line lengths should be reduced at first, and then the lines should be simplified. In addition, express lines should be operated among the major attraction centers of the city such as the Vase, the central campus and Germiyan campus throughout the day at reasonable headways. Furthermore, coordination among bus lines should be provided in order to make the public transport attractive. As a result, a fast and comfortable public transport system will both improve the quality of life and solve the major traffic problems that may occur in the future.

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