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Performance Measures and Level of Transit Service Assessment of Public Transport Bus Network in Baghdad City during 2002-2003

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ABSTRACT

Buses of General Company for Passenger Transport was the primary mode for public transportation in Baghdad City. This system suffers from many problems, part of which were related to bus routes, while the other part was related to the bus and its operators. These problems have a direct effect on the users of public transport buses. The objective of this study was to assess the performance of eight public transport bus routes which they represented by the Al-Tahrir bus network and adopting the level of the transit service method. Seven transit performance measures were selected in this study, such as bus travel time, hours of service during the day, service frequency (headway), total delay on the route, running speed of the bus, bus occupancy, and capacity of the route. The results of this study showed that bus routes No. (72, 36, 13, 114, 11, 30, 37, and 9) were operating at overall Level of Transit Service LOTS (D, E, E, E, E, D, E, and E) respectively, whereas the bus network (Al-Tahrir bus network) was operating at overall LOTS (E); therefore, the performance of Al-Tahrir bus network was not acceptable, and improvements were needed to increase the level of transit service of this network.

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تقييم مقاييس الاداء ومستوى خدمة النقل العام لشبكة حافلات ساحة التحرير داخل مدينة بغداد للفترة 2002-2003

تان يكو/كلية هندسة النقل/معهد هاربين التكنولوجي/الصين
لي هو كون/كلية حفظ المياه والهندسة المدنية/جامعة الشمال الشرقي الزراعية/ الصين.
عماد اسماعيل /فرع هندسة الطرق والجسور/قسم الهندسة المدنية/الجامعة التكنولوجية/ العراق
علي فاضل ناصر/قسم هندسة البناء والانشاءات/الكلية التقنية المسيب/جامعة الفرات الاوسط التقنية/العراق

الخلاصة

حافلات الشركة العامة لنقل الركاب هو الأسلوب الأساسي لنظام النقل العام داخل مدينة بغداد. يعاني هذا النظام من مشاكل عديدة. يتعلق قسم من هذه المشاكل بمسار الحافلات، بينما يتعلق القسم الأخر بالحافلات ومشغليها. إن هذه المشاكل تؤثر بصوره مباشرة على مستخدمي حافلات النقل العام. ان الغرض من هذه الدراسة هو تقيم أداء ثمانية خطوط لحافلات النقل العام والتي تمثل شبكة حافلات ساحة التحرير بالاعتماد على طريقة مستوى الخدمة. ضمن هذه الدراسة تم اعتماد سبعة من مقاييس أداء النقل العام، وهذه المقاييس تشمل زمن الرحلة للحافلة والفترة الزمنية الفاصلة بين حافلة وأخرى و عدد ساعات العمل في اليوم و التأخير على الخط و السرعة الجارية للحافلة على الخط و كثافة الركاب داخل الحافلة و والقدرة الاستيعابية للخط. إن نتائج هذه الدراسة قد بينت بان الخطوط (72و36و13و114و11و30و37و9) تعمل ضمن مستوى خدمة (D,E,E,E,E,D,Eو E) على التوالي، بينما الشبكة ككل تعمل ضمن مستوى خدمة (E). لذلك ان اداء شبكة باصات ساحة التحرير غير مقبول وغير فعال ويحتاج الى تحسين الاداء من خلال زيادة مستوى الخدمة للشبكة.

الكلمات الدالة: النقل العام, مسار الباص, شبكة الباصات, التقييم, الاداء.

1. INTRODUCTION

Transportation systems local and nationwide included the networks of intersected facilities and services. The transportation system deals with moving people and goods from one area to another by using different types of transport modes such as vehicles, busses, trains, airplanes, and ships which cross a variety of structures systems. The transportation networks consist of highways, rails, waterways, and pipelines and their links. There are two main investigative necessities for the transportation network model system. Firstly, it is must be topologically correct to the real network, and secondly, it must permit network movements along associated routes. [1, 2, 3]

Public transport is defined as a general term that is used to explain all of the transit modes existing to urban and rural citizens. Public transport is a significant component of the total transportation services providing within large or small cosmopolitan areas. Public transport can be known as mass transit which includes the movement of a large number of people between different places. The main purpose of the public transport system is to offer suitable structures, human, and formal incomes to ensure the safety, fast, comfortable, and consistent transport of travelers. [4, 5]

The function of public transport is differed according to the size and topographical position of the urban region. The conservative bus workers show an important function in the movement of passengers from one city to another in an urban region. It plays a main part in permitting passengers from with low income and other disadvantaged groups to entree employment and services. It also contributes to the development of social networks within the city by helping passengers to transport between cities to see their friends and shopping. [6, 7]

Public transport can be additional attractive by offering door-to-door movement, and increasing transportation services is a significant issue of societal excellence. Public transport availability has added energetic significance in designing and assessing the transit system in terms of movement and sustainability. Public transport in urban zones has extended better consideration in the latest years for improving sustainability and the value of urban life. The commercial and environmental performance of cities can be improved by joining resources to terminuses successfully and facilitating mass mobility. [8, 9]

The primary objective of public transport availability assessment is to offer well connecting of passengers and position in order to achieve a reduction of the jamming on streets. In general, mobility over and done with public transport offers a chance to reduce unpromising effects of vehicles usages on environmental situation and health of people. Additionally, the poorly operative urban transport network has inferences on the effectiveness of the private part to create employments. [10, 11, 12]

There are six components of the bus transit system. The first is the known bus transit vehicle which is a significant element of the urban transport system in developing countries, where the passengers seriously trust mass transport because of small levels of domestic salary. The second element is the transport ways, including public roads and highways, earmarked lanes, special lanes, transit roads, and busways. The thirds element is bus stops which are one or more buses that load and unload people, and it involves one or more loading bays. The fourth part is bus stations and terminals areas. Bus stations are areas or buildings with arranged bus stops for some bus routes, and the bus terminal is the end station of one or more bus routes. The fifth part is bus garages that are buildings used as bus storage, executes for vehicles maintenance, and washing services. The sixth part is the bus network which is assembled of all bus routes in a city. Bus routes involve fixed roads or separated right-of-way, which buses frequently

attend. There are four main kinds of bus networks. These types are grid bus networks, radial bus networks, trunk lines with feeder bus networks, and territorial bus networks. [13, 20]

Barricades of public transport are diverse types of obstacles, problems, or troubles associated with using public transport. In general, there are five sets of barricades. These sets are barricades of information, physical, psychological, cultural, and practical. Bus routes planning center and layout include consideration of road shape, main entry points, territory, employment positions, and service regularity. Bus routes absorbed on important roads will offer a clear idea of the service and will put sufficient buses there to create a significant treatment possible. [21, 22, 6]

A transit system performance measure includes the passenger capacity supplied, the quality of service created, comparison of costs vs. benefits, and environmental influence. It offers a perfect recommendation of how fine it is offering transport service to the passengers in the area attends. Transit performance is typically stated in terms of efficiency and output services that relate to source inputs such as labor and passengers–miles of transportable. Productivity is normally measured in terms of efficiency and success. There are many different transit performance measures. These measures included the operator's opinion, passenger's viewpoint, and vehicles operation. [15, 23]

The Highway Capacity Manual (2000) presented six levels of transit service (LOTS A to F) to assess the performance factors of the public transport system. These factors are included bus route travel time, bus route speed, bus route capacity, bus route passenger loading (i.e., passenger density), bus route hours of service, bus route frequency (headway), bus route reliability, bus route comfort, and bus route safety. The level of transit service software was used in the assessment procedure for the public transport system by Ryus et al. (2000). The software offers an only measure of public transport obtainability that includes service handling region, hours of service, service frequency, and population job density, as well as account for the routes passengers transport to and from public transport stop. [15, 24].

2. PUBLIC TRANSPORT MODES IN BAGHDAD CITY

Baghdad City is the capital of Iraq which lies on the banks of River Tigris, and it is the most significant business and commercial center in Iraq. The first survey of Baghdad's population was carried out in 1870, and it showed that the population of 66000 males in Baghdad and neighboring Ad'dhmiya and Kadhimiya. Baghdad City has an area of about (734 km^2). Baghdad's population reached 2.04 million in 1970 and increased to 3.189, 3.841, and 5.423 million in 1977, 1987, and 1997 respectively. The street networks and intersections in Baghdad City have been improved rapidly since the end of 1970. In the urban area and CBD, the ratios of major roads to the whole network are 23.2% and 25.6%, respectively. [25, 17, 26]

The services of public transport in Baghdad City are provided by General Company for Passengers Transport (GCPT). It is one of the main companies of the State Organization for Land Transport of the Ministry of Transport and Communication. It represents the main public authority of public transport for passengers in Baghdad City. The GCPT provided four types of services to the public. These types of services are fixed-route regular bus services to different parts of Baghdad City, express bus for special routes and special limited-stop services, contract services to some government agencies, passenger transport between Baghdad city and other city centers of Iraq provinces. The number of routes working in Baghdad city was 120 bus routes. The fleet size of buses is composed of 540 buses. The GCPT has 13 bus terminals; some of these terminals are presented within CBD, such as Bab-Al-Muadam, Al-Askary, Al-Tahrir square, and Al-Naser square. These terminals are known as main bus terminals. Other bus terminals, such as Al-Bayaa, Al-Dora, New Baghdad, and Quriesh Square, are known as secondary terminals. [6, 18, 26].

3. PROBLEMS OF PUBLIC TRANSPORT SYSTEMS IN BAGHDAD CITY

Buses are the main public transport mode in Baghdad City. However, the public transport bus system suffers from many problems, which have direct effects on the passengers. These problems make this system unable to provide services to its users. These problems are related to the route features such as a delay due to traffic congestion, absence of bus priority treatments; bus stop signs are not visible for both drivers and users, lack of comfortable shelters of bus stops. The second problem is related to buses and operators performance, such as conditions of passenger comfort; bus drivers stop outside bus stops (i. e., illegal bus stops) to collect a large number of passengers on the one-man operation buses (single deck buses), the drivers have an additional task of collecting fares, change giving, checking passes, and assessing their passengers loads. Therefore, all these tasks will cause more delay and bus speed to be slower. Field observations showed that some routes do not have a sufficient number of buses, whereas other routes have a number of buses more than that needed to serve the expected size of passengers.

4. BUS NETWORKS IN BAGHDAD CITY

Public transport bus networks in Baghdad City can be classified into major and minor bus networks. A network of seven routes, or more, is considered a major bus network, whereas a bus network of fewer than seven routes is considered a minor bus network. [6]. In the present study, according to the information obtained from the GCPT operational plan, the GCPT has nine major bus networks and four minor bus networks. Each network has a number of routes, which serve the public within the

network area. Table 1 lists the name of the bus network and the number of routes in each network.

Table 1

The GCPT bus networks and number of routes

Type of bus network	Name of the bus network	Number of routes
Major bus networks	Al-Maidan square	28
	New Baghdad	14
	Bab. Al-Muadham	13
	Al-Bayaa	11
	Al-Tahrir square	10
	Al-Askary square	10
	Al-Mat'haf square	8
	Quraish square	7
	Al-Kadhimia	7
Minor bus networks	Al-Dora	6
	Al-Sadr City	6
	Al-Tala'a square	6
	Al-Naser square	5

5. SELECTION OF BUS ROUTES

The selection of bus routes in this study is based on the following criteria:

1. The CBD district is considered part of the network area due to its effect on many bus routes and their performance.
2. The selected bus routes should serve high demand in terms of the number of passengers carried.
3. The selected bus routes within a network should have a path in a different direction within Baghdad City.

In this study, eight from ten bus routes have been selected in Baghdad City to assess the performance of public transport bus routes by adopting the level of the transit service method. These routes are patented from the Al-Tahrir bus network, and they have numbers as 72, 36, 13, 114, 11, 30, 37, and 9. Fig. 1 illustrates the selected bus routes (Al-Tahrir bus network). Table 2 and Table 3 list the operational features, paths, and length of each one of the selected bus routes.

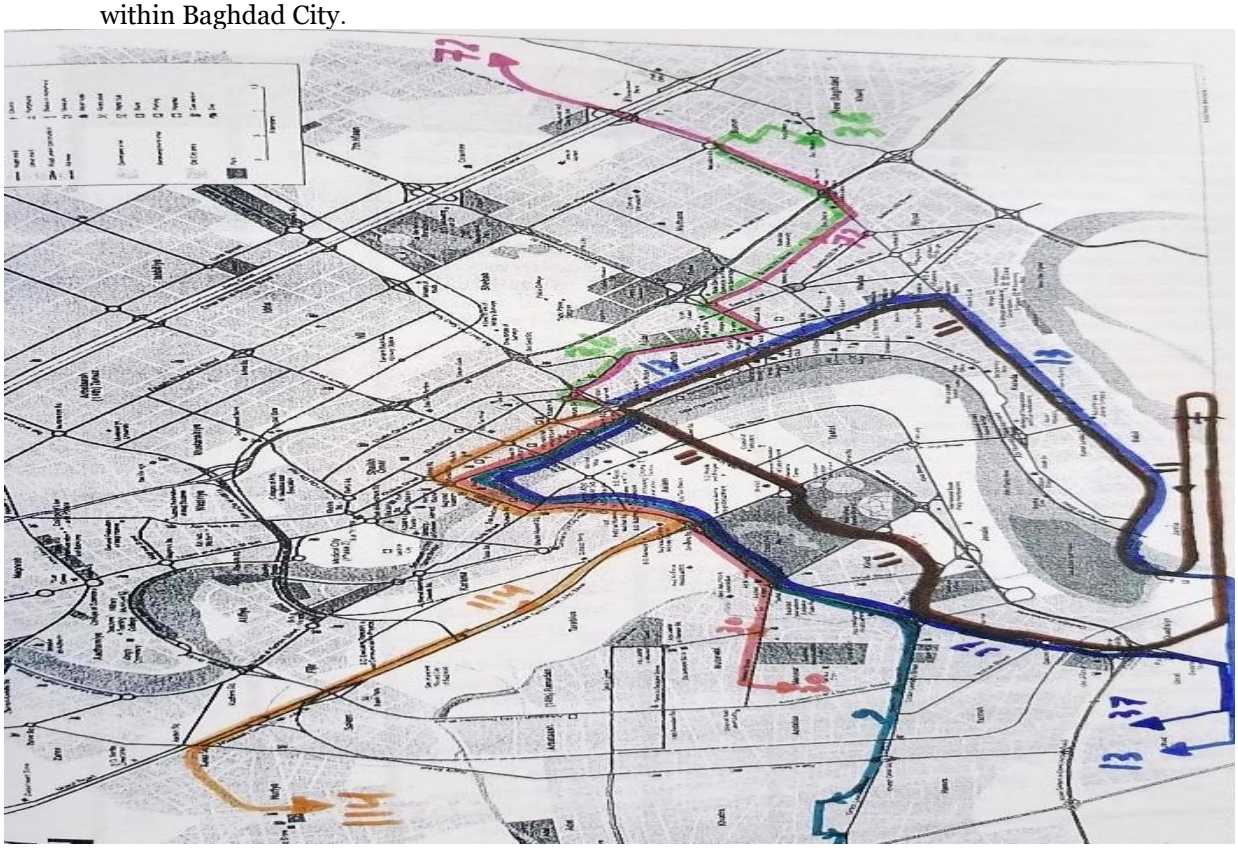


Fig. 1. The selected bus routes (Al-Tahrir bus network)

Table 2

Operational characteristics of the selected bus routes

Route No.	No. of legal bus stop	No. of signalized intersection	No. of un-signalized intersection	Bus flow rate (bus/hr)	No. of working hours (hr/day)	No. of total buses	No. of working buses	Type of route trip
72	16	12	1	2	13.5	4	4	End
36	13	9	2	2.5	12	6	6	End
13	14	14	3	2	12	6	6	End
114	21	14	2	1.5	12	5	5	End
11	32	20	3	2	14	6	6	Round
30	24	15	1	2	13	7	7	End
37	27	7	1	3	13	7	7	End
9	30	14	1	1	12	4	4	End

Table 3

Paths and length of the selected bus routes

Garage site	Route No.	Origin-to-Destination	Route length(km)	Route path
Bus terminal No.1 (inside Al-Tahrir Square private garage)	72	Al-Tahrir square-to-Al-Baladiate bus station	14	Al-Tahrir square, Al-Nidhal street, Al-Andulus square, Al-Alwai hospital, University of Technology, Maysaloon square, Al-Baladiat bus station.
	36	Al-Tahrir square-to-NewBaghdad bus terminal	11	Al-Tahrir square, Al-Nidhal street, Al-Andulus square, Al-Alwai hospital, University of Technology, Maysaloon square, New Baghdad bus terminal.
	13	Al-Tahrir square-to-Al-Bayaa bus terminal	17.5	Al-Taheir square, Al-Saduone street, Kahramani square, Al-Huriya square, University of Baghdad, Al-Jadiriya bridge, Al-Bayaa bus terminal.
	114	Al-Tahrir square-to-Al-Huriya bus station	21	Al-Tahrir square, Al-Kuhlaffa street, Al-Ruasafi square, Shuhadaa bridge, Al-Mat'haf square, Adeen square, Al-Huriya bus station.
	11	Al-Tahrir square-to-Al-Dorra bus station-to-Al-Tahrir square	47	Al-Tahrir square, Al-Jamhoriya bridge, Baghdad Watch, Al-Nasure square, Al-Yarmuk hospital, Baghdad-Haila street, Al-Dorra district, Haila-Baghdad street, Al-Jaddiriya bridge, University of Baghdad, Al-Huriya square, Kahramani square, Al-Saduone street, Al-Tahrir square.
Bus terminal No.2 (inside GCPT garage)	30	AL-Tahrir square-to-AL-Mansure bus station	15	Al-Tahrir square, Al-Rasheed street, Al-Rusafi square, Al-Shuhadaa bridge, Al-Mat'haf square, Al-Zwara garden, Hi-Drag, Al-Mansure bus station.
	37	Al-Tahrir square-to-Hay Al-Amel bus station	17	Al-Tahrir square, Al-Rasheed street, Al-Rusafi square, Al-Shuhadaa bridge, Al-Mat'haf square, Al-Nasure square, Al-Yarmuk hospital, Bayaa central shopping, Al-Bayaa intersection, Hi- Al-Amel bus station.
	9	Al-Tahrir square-to-Al-Gazalyia bus station	23	Al-Tahrir square, Al-Rasheed street, Al-Rusafi square, Al-Shuhadaa bridge, Al-Mat'haf square, Al-Nasure square, Al-Yarmuk hospital, Al-Mamoon street, Hay-Al-Kathra, Al-Gazalyia bus station.

6. INSPECTION PROCESS DURING DAY

The survey process is taken on typical weekdays from Sunday to Wednesday, whereas Saturday, Thursday, and Friday were not included in the inspections because the movement of vehicles and passengers on Saturday is high, Friday is a holiday, and Thursday working hours are shorter than other weekdays. In this study, the result of the inspection process and the personal interview with bus operators and bus passengers showed that the noon peak period (12:00 PM-to-3:00 PM) is the dominant period for the selected bus routes because the zone of Al-Tahrir network in Al-Rusafa side which it contains the CBD and many of government offices such as ministries, hospitals, and universities. Therefore, in the morning peak period, the movement of passengers to Al-Rusafa side from Al-Karhk side is high, while in the afternoon peak period, the movement of passengers to Al-Karhk side from Al-Rusafa side is high (i.e., return to home). When two types of inspections are used together, three observers have to perform the inspection on each bus. Two observers have to sit near the middle door, which is used for boarding and alighting passengers. The first observer is equipped with a stopwatch and survey form. When a bus movement starts at Al-Tahrir bus terminal, the inspector records the following parameters :

1. Departure time for the bus at the start bus terminal (run start time)
2. Dwell time at bus stops for boarding and alighting passengers.
3. Delay time on the path of bus route due to stop at traffic intersections (signalized and un-signalized), traffic congestion, the crossing of pedestrians, parked vehicles, right turn, and left turn.
4. Arrival time for the bus at the end terminal (run end time).
5. Other information such as date of inspection, seating capacity of the bus, weather condition, period of the survey, and type of bus.

Headway between sequential buses for each bus route is recorded. This factor is determined in the peak period by taking the average of headway between sequential buses for each route at a middle bus stop on the path of the bus route. Hours of service for buses are recorded by interviewing bus operators. Car travel time is recorded by using passenger cars on the same path of each bus route.

7. TRANSIT PERFORMANCE MEASURES AND LEVEL OF TRANSIT SERVICE ASSESSMENT

There are many measures that will be used in the assessment process. Some of these measures are related to vehicle operation, whereas the others are related to the quality of service. In the following topics, each of these measures and application of the level of transit service (LOTS) assessment process for the selected bus routes in Baghdad City will be discussed.

7.1. Measures and Assessment of Bus Travel Time

Bus travel time can be defined as the time that passengers have to spend on-board between their origin and destination bus stops. It consists of four parts. These parts are acceleration time, running time, deceleration time, and dwell time (time spent at a scheduled stop without moving). [18], [27]
The level of transit service for bus travel time can be calculated by using the travel index, which is equal to bus travel time divided by car travel time. [23]. Table 4 lists the bus travel time level of transit service. In the present study, delays at intersections, and delays due to traffic congestion, parked vehicles, pedestrian crossing, and left or right turning are also included within in-bus travel time. Table 5 lists the values of bus travel time, car travel time, travel index, and level of transit service for the selected bus routes. From this Table, it can be noted that the values of bus travel times range between 52 min for bus route No. (36) and 113 min for bus route No. (11), and the car travel times range between 18 min for bus route No. (36) and 50 min for bus route No. (11). The travel index values range between (1.82) for bus route No. (13) and 2.91 for bus route No. (72). After comparing the values of the travel index with the values in Table 4, the level of transit service values for all bus routes are LOTS (F) except bus route No. (13), which has LOTS E.

Table 4
Bus travel time level of transit service [23]

LOTS	Travel index= bus travel time/car travel time
A	< 1.00
B	1.0 - 1.1
C	1.11 – 1.34
D	1.35 – 1.50
E	1.51 – 2.0
F	> 2.00

Table 5
Values of bus travel time LOTS for the selected bus routes.

Route No.	Bus travel time (min)	Car travel time (min)	Travel index	LOTS
72	67	23	2.91	F
36	52	18	2.88	F
13	53	29	1.82	E
114	84	35	2.40	F
11	113	50	2.26	F
30	60	25	2.40	F
37	62	28	2.21	F
9	82	38	2.15	F

7.2. Measures and Assessment of Bus Route Service Frequency

Bus route service frequency can be defined as the number of buses departing the bus stops per hour. [14]. Service frequency is also measured as one part of over bus transit trip time. Therefore, the service frequency level of transit service for urban scheduled bus public transport service is measured by headway between sequential buses. Headway can be defined as the time which it passes from the immediate front end of the leading bus passes a given point until the front end of the following bus passes that same point. Table 6 lists the values of service frequency level of transit service for urban scheduled bus service. The minimum headway can be calculated by using equation No. 1. [15[, [23].

H min = 2 to .....(1)

Where:

H min = minimum headway between sequential buses (in a minute)

td = average dwell time (in minute).

The values of real headway and scheduled headway for the selected bus routes are shown in Table 7. The values of actual headway range between 17.1 min for bus route No. (72) and 75 min for bus route No. (9). The values of scheduled headway range between 10 min for bus routes No. (36, 13, 37, and 30) and 30 min for bus route No. (114). This Table also gives LOTS values for actual headway that range between LOTS (C) for bus route No. (72) and bus route No. (30), and LOTS (F) for bus route No. (13) and bus route No. (9). The values of LOTS for scheduled headway range between LOTS (C) for bus routes No. (72 and 11) and LOTS (D) for bus routes No. (114 and 9).

Table 6

Values of service frequency level of transit service for urban scheduled bus service [15]

LOTS	Headway (min)	Comments
A	<10	Passengers do not need schedules
B	>10-14	Frequent service; passengers consult schedules
C	>14-20	Maximum desirable time to wait if bus missed
D	>20-30	Service unattractive to choice riders
E	>30-60	Service available during the hour
F	>60	Service unattractive to all riders

Table 7
Values of service frequency level of transit service for the selected bus routes

Route No.	Actual headway (min)	LOTS	Scheduled headway (min)	LOTS
72	17.10	C	15	C
36	23.26	D	10	B
13	70.60	F	10	B
114	38.25	E	30	D
11	31.62	E	15	C
30	19.86	C	10	B
37	21.78	D	10	B
9	75.00	F	30	D

7.3. Measures and Assessment of Bus Route Hours of Service

Hours of service can be defined as the number of hours during the day when public transport bus service is provided along a route, a segment of the route, or between two locations. Additionally, hours of service play a significant role as frequency and service coverage in determining the availability of transit service to potential users. Table 8 lists hours of service LOTS, whereas the values of hours of service for the selected bus routes are shown in Table 9. From this Table, it can be noted that these values range between 12 hr/ day for bus routes No. (36, 114, 13, and 9) and 14 hr/ day for bus route No. (11). Hours of service LOTS values range between LOTS (C) for bus routes No. (72, 11, 30, and 37) and LOTS (D) for bus routes No. (36, 13, 114, and 9).

Table 8

Hours- of -service level of transit service [15]

LOTS	Hours-of-service (hr/day)	Comments
A	>18-24	Night or owl service provided
B	>16-18	Late evening service provided
C	>13-16	Early evening service provided
D	>11-13	Daytime service provided
E	>3-11	Peak-hour service or limited midday service
F	0-3	Very limited or no service

Table 9

Values of hours- of -service level of transit service for the selected bus routes

Route No.	Hours-of-service (hr/day)	LOTS
72	13.5	C
36	12	D
13	12	D
114	12	D
11	14	C
30	13	C
37	13	C
9	12	D

7.4. Measures and Assessment of Bus Route Delay Time

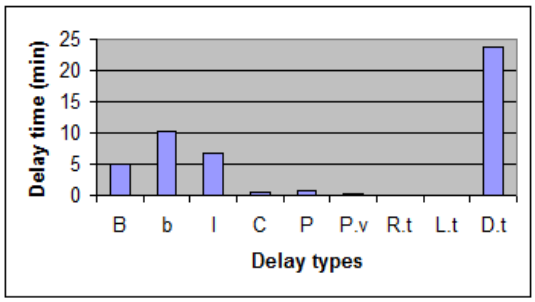
Delay time can be defined as the time lost by buses due to traffic frictions and traffic control devices, and it consists of two types. The first type is the fixed delay, which is the delay that buses are subjected to unrelatedly of the amount of traffic volume and interference present. Therefore, this type of delay cannot be eliminated but can be reduced. This type includes delays at bus stops, delays at intersections, and delays bus to left or right turns. The second type of delay is the operation delay, which is the delay caused by parked vehicles, traffic congestion, and pedestrians crossing. Therefore, this type of delay can be eliminated or substantially reduced by suitable bus priority treatments, such as bus lanes or busy streets. [17]. In this study, other types of delay have been considered to determine the total delay for each selected bus route, such as parked vehicles delay (P.V), left and right turns delay (L.T and R.T), and pedestrians crossing delay (P). Delay time due to unsuitable conditions of pavement is not taken in the present study. Table 10 lists the total delay level of transit service.

Table 10.

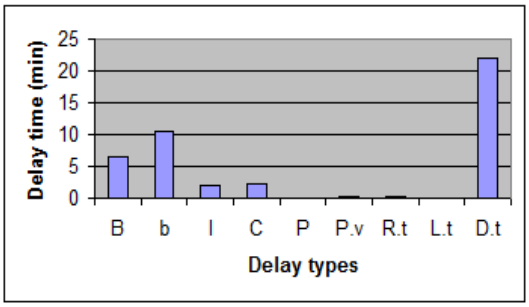
The total delay level of transit service [29]

LOTS	Delay time (min)
A	0
B	0-1
C	1-2
D	2-4
E	4-8
F	>8

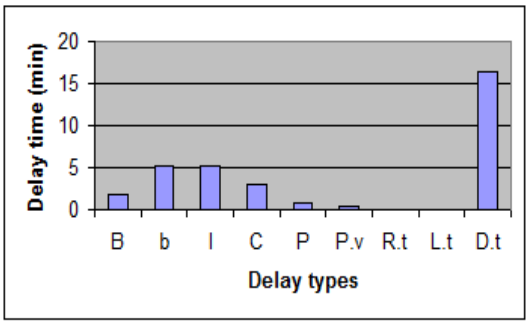
The values of total delay, the percentage of total delay to travel time, and level of transit service for the selected bus routes are shown in Table 11. From this Table, it can be noted that bus stops (legal and illegal bus stops) are the major cause of delay. At legal bus stops (B), delays range between 1.71 min for bus route No. (13) and 11.79 min for bus route No. (11), whereas at illegal bus stops (b), delays range between 2.73 min for bus route No. (9) and 14.80 min for bus route No. (11). The values of traffic congestion delay (C) range between 0.55 min for bus route No. (72) and 4.64 min for bus route No. (37). Thus, it is clear that bus routes No. (114, 30, 37, and 9) have higher values of traffic congestion delay because some higher links are within dense CBD areas such as Al-Shurja district and Al-Rasheed street. The values of delay due to stop at signalized intersections (I) range between 1.44 min for bus route No. (37) and 9.13 min for bus route No. (11). These values depend on some factors, such as the number of signalized intersections, the type of intersections, and the ratio of green time to the cycle length (g/c) for the signalized intersection. Other types of delay, such as pedestrians crossing delay (P), right and left turn delay (Rt and L.t), and parked vehicles delay (P.v), have a marginal effect on the total delay for all bus routes except bus route No. (114) which has a delay of 2.82 min from parked vehicles delay. The values of total delay (D.t) range between 16.43 min for bus route No. (13) and 31.72 min for bus route No. (11). The values of total delay for bus route No. (11) is higher than values for other bus routes because this route has a round trip type and longer route length (47 km). The percentage of total delay to travel time ranges between 23.37% for bus route No. (9) and 42.16% for bus route No. (36). The level of transit service values for all bus routes are LOTS (F). The results of delay types are shown graphically in Fig. 2.



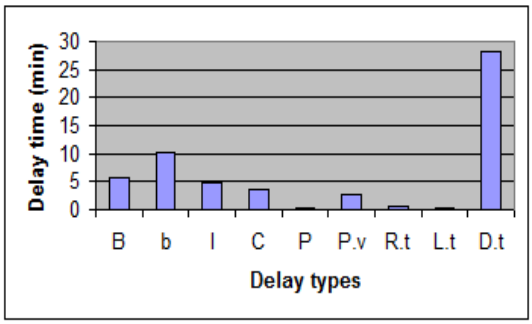
(a) Delays of route 72



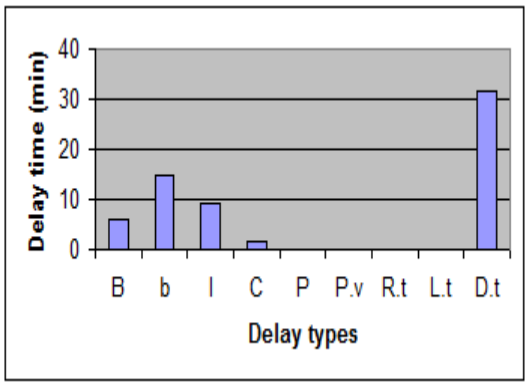
(b) Delays of route 36



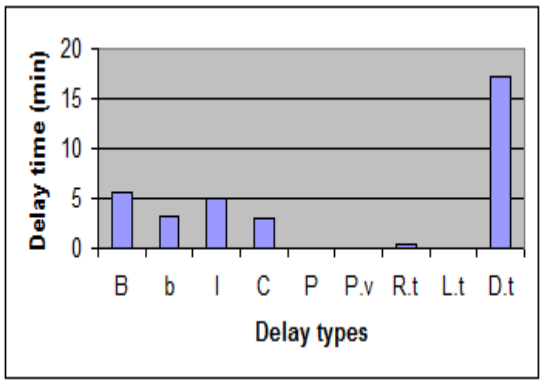
(c) Delays of route 13



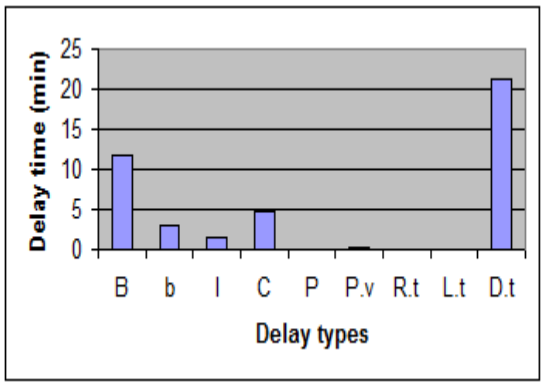
(d) Delays of route 114



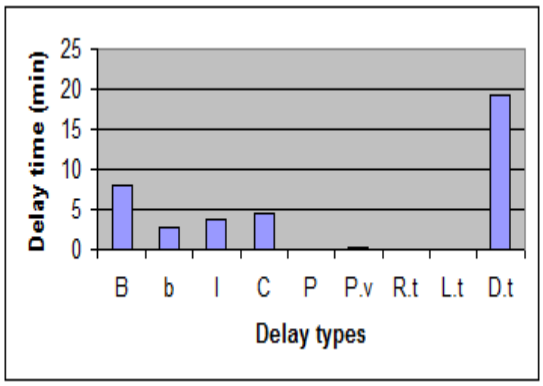
(e) Delays of route 11



(f) Delays of route 30



(g) Delays of route 37



(h) Delays of route 9

Fig. 2. Values of delay types and total delay (D.t) for selected bus routes

Table 11.

Values of delay level of transit service for the selected bus routes

Route No.	Total delay (min)	% of total delay from travel time	LOTS
72	23.66	35.31	F
36	21.92	42.16	F
13	16.43	31.01	F
114	28.16	33.53	F
11	31.72	28.07	F
30	17.28	28.80	F
37	21.19	34.17	F
9	19.17	23.37	F

7.5. Measures and Assessment of Bus Route Running Speed

Bus running speed can be found by dividing the route length (km) by the running time (hr), and running time does not include bus stops delay, signals delays, traffic congestion delays, and any types of other delays. [28], [15]. Table 12 lists the level of transit service values for the adjusted running speed, whereas Table 13 gives the values of travel and running time (time without delay), total delay, average headway, and adjusted running time. The values of travel time range between 52 min for bus route No. (36) and 113 min for bus route No. (11), whereas the values of running time range between 30.07 min for bus route No. (36) and 81.27 min for bus route No. (11). The values of total delay range between 16.43 min for bus route No. (13) and 31.72 min for bus route No. (11). The adjusted running time range was between 41.70 min for bus route No. (36) and 100.3 min for bus route No. (11). The average headway range is between 17.10 min for bus route No. (72) and 75 min for bus route No. (9).

Table 12
Adjusted running speed level of transit service [29]

LOTS	Adjusted running speed (km/hr)
A	>96.56
B	56.3 – 96.56
C	40.2 – 56.30
D	24.1 – 40.20
E	9.6 – 24.10
F	0.0 – 9.6

Table 13

Values of adjusted running time for the selected bus routes

Route No.	Bus travel time (min)	Total delay (min)	Running time (min) (1)	Headway (min)	Adjusted running time (min) (2)
72	67	23.66	43.33	17.10	51.88
36	52	21.92	30.07	23.26	41.70
13	53	16.43	36.56	70.60	71.86
114	84	28.16	55.83	38.25	74.95
11	113	31.72	81.27	31.62	97.08
30	60	17.28	42.72	19.86	52.65
37	62	21.19	40.81	21.78	51.70
9	82	19.17	62.83	75	100.33

(1)

Running time = travel time – total delay

(2) Adjusted running time = running time + ½ headway

The values of speeds and LOTS for the selected bus routes are shown in Table 14. From this Table, it can be noted that the values of travel speed range between 12.53 km/hr for bus route No. (72) and 24.95 km/hr for bus route No. (11), whereas the values of running speed range between19.38 km/hr for bus route No. (72) and 34.69 km/hr for bus route No. (11), and the values of adjusted running speed range between 13.75 km/hr for bus route No. (9) and 29.04 km/hr for bus route No. (11). The values of LOTS range between LOTS (D) for bus route No. (11) and LOTS (E) for other bus routes.

Table 14

Values of the adjusted running speed level of transit service for the selected bus routes

Route No.	Route length (km)	Travel speed (km/hr)	Running speed (km/hr)	Adjusted running speed (km/hr)	LOTS
72	14	12.53	19.38	16.19	E
36	11	12.69	21.94	15.82	E
13	17.5	19.81	28.71	14.61	E
114	21	15.00	22.56	16.80	E
11	47	24.95	34.69	29.04	D
30	15	15.00	21.06	17.09	E
37	17	16.45	24.99	19.72	E
9	23	16.82	21.96	13.75	E

7.6. Measures and Assessment of Bus Route Passenger Loads (Density)

Passenger load is the number of passengers in a single public transport bus. The occupancy of the bus is normally related to the number of seats. Therefore, passenger load reflects the comfort level of the on-board bus portion of public transport trip both in terms of being able to find a seat and in terms of overall crowding levels within the bus. The passenger loads level of transit service values depends on some factors which are related to bus sizes, such as bus dimensions, number of seats in the vehicle, and standing capacity. These values can be obtained by determining a load factor that is equal to the number of passengers in–bus dividing by the number of seats. When load factor is equal to (1.0), indicating that all seats are occupied, and when it is greater than (1.0), indicating that there is a need to increase service frequency or bus size in order to reduce crowding and to provide a more comfortable ride for passengers. Tables 15 and Table 16 lists the values of the level of transit service for single and double-deck buses, respectively.

Table 15

Passenger load level of transit service for single deck buses with 49 seats and 240 sq. ft bus [15]

LOTS	In-bus passengers	Load factor (passenger/seat)
A	0.0-24	0.00-0.51
B	25-37	0.52-0.75
C	38-49	0.76-1.00
D	50-55	1.01-1.12
E	56-71	1.13-1.45
F	72-75	1.46-1.53

Table 16.
Passengers load level of transit service for double-deck buses with 58 seats and 580 sq. ft bus. [15]

LOTS	In-bus Passengers	Load factor (passenger/seat)
A	0.0-29	0.00-0.50
B	30-44	0.51-0.75
C	45-58	0.76-1.00
D	59-63	1.01-1.08
E	64-77	1.09-1.33
F	78-80	1.35-1.38

Table 17 lists the values of passenger load level of transit service for selected bus routes. From this Table, it can be noted that the total number of passengers served per bus for the selected bus routes range between 77 passengers/bus for bus route No. (30) and 285 passengers/bus for bus route No. (11), whereas the average number of in-bus passengers range between 21 passengers/bus for bus route No. (30) and 103 passengers/bus for bus route No. (11). The values of load factor are also shown in Table 17 and range between 0.53 for bus route No. (30) and 1.30 for bus route No. (11). The values of LOTS range between LOTS (B) for bus routes No. (30, 37, and 9) and LOTS (E) for bus routes No. (36, and 11). These results show that bus route No. (11) serves a large number of passengers in comparison with other bus routes, while bus route No. (30) serves a small number of passengers because this route has single deck buses and there are many routes passing through the same street.

Table 17
Values of passengers loads level of transit service for the selected bus routes

Route No.	Total number of passengers served per bus	Average number of in-bus passengers	Load factor passenger/ seat	LOTS
72	164	71	0.90	C
36	203	94	1.19	E
13	131	68	0.86	C
114	254	81	1.02	D
11	285	103	1.30	E
30	77	21	0.53	B
37	148	56	0.70	B
9	143	53	0.67	B

7.7.Measures and Assessment of Bus Route Capacity

Public transport bus route capacity can be divided into two types. The first type is passenger capacity of public transport bus which reflects the number of people that can be carried past a given location during a given time period under specified operating conditions without unreasonable delay, hazard, or restriction and with reasonable certainty. There are many effects on passengers' capacity. These effects include operator policy, passenger demand characteristics, and vehicle capacity. The second type is public transport bus capacity which reflects a number of public transport units (buses or trains) that can be served by loading area, transit stop, guideway, or route during a specified period of time. [15], [30] The values of the capacity level of transit service can be shown in Table 18. These values depend on the capacity factors values. Table 19 gives the values of vehicle capacity (Cv), the number of in-bus passengers (S), person capacity (Cp), (g/c) ratio, average dwell time, average clearance time, reduction factor I, and LOTS. From this Table, it can be noted that the values of vehicle capacity (Cv) range between (0.34) bus/hr/lane for bus route No. (9) and 1.0 bus /hr/lane for bus route No. (37), whereas the average values of person capacity (Cp) range between 14 passenger/hr for bus route No. (30) and 84.6 passenger/hr for bus route No. (36). The values of average dwell time range between 10.64 seconds for bus route No. (13) and 24.71 seconds for bus route No. (37), whereas the values of average clearance time range between 1005.34 seconds for bus route No. (72) and 4487.4 seconds for bus route No. (9). The calculated reduction factors I range between 0.37 for bus route No. (72) and 1.57 for bus route No. (13). The values of LOTS shows that bus route No. (72) operates at LOTS (A), bus route No. (30) operates at LOTS (B), the bus route No. (114) operates at LOTS (C), the bus routes No. (36, 11, and 37) operate at LOTS (D), the bus route No. (9)operates at LOTS (E), and the bus route No. (13) operates at LOTS (F).

Table 18

Values of capacity level of transit service

LOTS	Reduction factor I
A	0.00-0.40
B	0.41-0.50
C	0.51-0.66
D	0.67-0.75
E	0.76-1.00
F	>1.00

Table 19

Values of the capacity level of transit service for the selected bus routes

Route No.	C.v (bus/hr /lane)	S (pass /bus)	C.p (pass/hr)	(g/c)	D (sec)	Tc (sec)	Reduction factor I	LOTS
72	0.67	71	47.5	0.50	20.66	1005.34	0.377	A
36	0.90	94	84.6	0.50	22.24	1373.36	0.692	D
13	0.67	68	45.5	0.50	10.64	4225.35	1.570	F
114	0.50	81	40.5	0.50	19.32	2275.68	0.634	C
11	0.67	103	69	0.50	14.24	1882.96	0.703	D
30	0.67	21	14	0.50	16.35	1175.25	0.438	B
37	1.00	56	56	0.50	24.71	1282.09	0.719	D
9	0.34	53	18	0.50	12.57	4487.40	0.847	E

8. OVERALL LEVEL OF TRANSIT SERVICE FOR THE SELECTED BUS NETWORK

In this study, the performance index (P.I) is calculated for each bus route by using the LOTS matrix that is shown in Table 20. Delay has been given a weight of 25 out of 100, service frequency has 20, adjusted running speed has 15, bus travel time has 15, passengers loads (bus occupancy) has 10, capacity has 10, and hours of service has 5 out of 100. These values represent the higher performance index for each measure. Table 21 lists the overall routes level of transit service for the selected bus routes. From this Table, it can be noted that each one of the performance measures has allocated points according to its LOTS. The summation of these points will give the route performance index (P.I), which is used to obtain the overall route LOTS.

The overall LOTS for the selected bus routes (i. e Al-Tahrir bus network) is computed by multiplying the percent of bus route flow rate by the performance index of each route. Table 22 shows bus flow rate for the selected bus routes. The network level of transit service can be computed by using the following procedure:

Bus network (P.I) = 12.5% (34) + 15.625% (19) + 12.5% (14) + 9.375% (16) + 18.75% (26) + 12.5% (34) + 12.5% (19) + 6.25% (15) = 23.15

By using Table 20, the network level of transit service is equal to LOTS (E), indicating that the performance of the selected bus network (Al-Tahrir bus network) is not acceptable, and it needs to improve to increase the level of transit service of this network.

Table 20
The level of transit service matrix

Performance measures	A	B	C	D	E	F
Delay	25	20	15	10	5	0
Frequency	20	16	12	8	4	0
Adjusted running speed	15	12	9	6	3	0
In-bus travel time	15	12	9	6	3	0
Density	10	8	6	4	2	0
Capacity	10	8	6	4	2	0
Hours of service	5	4	3	2	1	0
Range of P.I	100-91	90-71	70-51	50-31	30-11	10-0

Table 21
The overall routes level of transit service for the selected bus routes

Route No.	Total delay		Service frequency		Adjusted running speed		In-bus travel time	
	LOTS	P.I	LOTS	P.I	LOTS	P.I	LOTS	P.I
72	F	0	C	12	E	3	F	0
36	F	0	D	8	E	3	F	0
13	F	0	F	0	E	3	E	3
114	F	0	E	4	E	3	F	0
11	F	0	E	4	D	6	F	0
30	F	0	C	12	E	3	F	0
37	F	0	D	8	E	3	F	0
9	F	0	F	0	E	3	F	0

Table 21
Continued

Route No.	In-bus density		Capacity		Hours of service		Total	
	LOTS	P.I	LOTS	P.I	LOTS	P.I	P.I	LOTS
72	C	6	A	10	C	3	34	D
36	E	2	D	4	D	2	19	E
13	C	6	F	0	D	2	14	E
114	D	4	C	3	D	2	16	E
11	E	2	D	4	C	3	19	E
30	B	8	B	8	C	3	34	D
37	B	8	D	4	C	3	26	E
9	B	8	E	2	D	2	15	E

Table 22

Percent of bus-flow rate for the selected bus routes

Route No.	Bus-flow rate (bus/hr)	Percent of flow rate (%)
72	2	12.50
36	2.5	15.62
13	2	12.50
114	1.5	9.375
11	2	12.50
30	2	12.50
37	3	18.75
9	1	6.250
Total	16	100

9. CONCLUSIONS

The main conclusions of this study are:

1. This study was designed to assess the performance of eight public transport bus routes that are selected in Al-Tahrir bus network in Baghdad city.

2. The results of data analysis showed that the values of bus travel time level of transit service range between LOTS (E) and LOTS (F). Hence, all the selected bus routes are operating with a low level of transit service for bus travel time. For service frequency (headway), the values of the level of transit service were ranged from LOTS (C) to LOTS (F). Generally, bus scheduling is poorly designed for the selected bus routes. Therefore, there is needing to redesign the bus schedule for the selected bus network. The level of transit service for hours of service of bus network appeared to have a good level of transit service ranging from LOTS (C) to LOTS (D). The values of the total delay level of transit service for all selected bus routes in the network are equal to LOTS (F). Therefore, all the chosen bus routes are operating with a low level of transit service for the total delay. For adjusted running speed, the values of the level of transit service were ranged from LOTS (D) to LOTS (E). Therefore, all the selected bus routes are operating with low LOTS for the adjusted running speed. Passengers loads levels of transit service values were ranged from LOTS (C) to LOTS (E). Therefore, most of the selected bus routes are operating with good LOTS for in-bus density. The level of transit service values was ranged between LOTS (A) and LOTS (F). Therefore, most of the selected bus routes are operating with good LOTS for route capacity.

3. According to analysis results of the level of transit service for the selected parameters which are used in the assessment process of public transport bus routes performance, the values of overall routes level of transit service are LOTS (D, E, E, E, E, D, E, and E) for bus routes No. (72, 36, 13, 114, 11, 30, 37, and 9) respectively. The overall bus network level of transit service is LOTS (E). This value indicates that Al-Tahrir bus network is operating with a low level of transit service.

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