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Implementation of Some Remedial Actions to Improve the Performance and Level of Transit Service for Public Transport Bus Routes in Baghdad City

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ABSTRACT

The objective of this study was to improve level of transit service of public transport bus routes in Baghdad city through the implementation of some remedial actions. Eight public transport bus routes were selected to evaluate and improve the Level of Transit Service (LOTS). These routes represent Al-Tahrir bus network (A) which was located in the center of Baghdad city (capital of Iraq). The suggested remedial actions include reduction of legal bus stops delay (B), the elimination of illegal bus stops delay (b), the elimination of signalized intersections delay (I), and the reduction of traffic congestion delay (C). These suggested remedial actions are leaded to improve the values of total delay, bus travel time, service frequency (headway), adjusted running speed, and capacity. The values of level of transit service for these transit performance measures were improved. The overall routes level of transit service were improved for bus routes No. (72, 36, 13, 114, 11, 30, 37, and 9) from LOTS (D, E, E, E, E, D, E, and E) to LOTS (C, D, C, D, D, C, D, and D) respectively. The overall network LOTS was improved from LOTS (E) to LOTS (D), indicating that the application of the suggested remedial actions was effective and suitable to improve the performance and Level of Transit Service for public transport bus routes in Baghdad city. Therefore, this study recommended to use the remedial actions which proposed by authors to improve level of transit service for others bus networks.

Keywords: Improvement; bus route; performance measures; LOTS; total delay; speed

INTRODUCTION

Public transport can be defined as high-capacity vehicles moving on fixed routes and schedules. It is the mainstay of urban public transport systems in global cities, especially in heavily populated urban regions. Public transport is an assembly and distribution process that offers passengers with movement and reasonable entrance to preferred social, professional, marketable, and recreational area. The planning of public transport objects to ensure safety, public needs, financial development, present and future property, and traffic demand. The objective of public transport economics is to create this organization more effective, make sure optimum source distribution to explain all societal benefits of mass movement. The public transport is an significant network system which are many urban residences have come to depend on ease of access and connection to important urban regions (Daniel & Alejandro 2021; Abdullahi et al. 2018; Dinesh 2005; Ning 2011; Amirah 2015; Munzilah et al. 2013).

The Capital area of any country needs to reconsider its public transport buses because of the traffic jamming is increased and employment entrance experiments are continuing for several populations and employers due to population increasing. Buses are the main mode in public transport system. Buses are the slowest vehicles on the street and the trip of latest option for many passengers. Buses poor service do a slight to conflict traffic jamming that costs passengers the time and money. Defective public transport makes it stiffer for labors to discover business. Buses service are not the last in itself, but somewhat an income toward making the Capital area the best places for living and have jobs (GWP 2017; GWP 2018).

All modes of public transport system have many features which affect the performance level of transit service. In general, the performance bus service can be adopted by some factors such as service work hour, service frequency (headway), passenger load factor (density), speed, delay time, cost, travel time, and availability (Japan International Cooperation 2014; Shuhairy et al. 2019; Yaakub & Napiah 2011).

The plan of public transport improvement can provide some of essential outputs such as mode move from private car to public transport, so that less private cars on the

road will lead to eliminate traffic crowding, reducing the pollution, transportation costs, travel time, in addition to increasing the accessibility. Improving of public transport structures includes official, accurately designed and positioned terminals, intermodal facilities, suitable bus stops location and design, bus importance measures lanes, and garage and factory facilities (Siti et al. 2021).

Improvements of bus routes level of transit service needs for strong government provision and official variations in bus managing, implementation of bus priority lanes and perfect signage, improving the position and feature of bus stops and exchange bus stations, using of GIS position technical in travel information, and providing of more fuel-efficient buses (Kerati & Pat 2016; Agarwal & Singh 2010).

Effective operation of public transport bus system is significant to develop cities in any country. There is a general confidence on buses for public transport as they provide significant mobility with in urban regions all over the world. Conversely, people desire to use their private cars due to the ineffective operation of city bus service. The present of private cars and public transport buses together on the streets lead to eliminate the spacing of streets and cause jamming, accidents and pollution. The improvements in public transport bus systems a challenging task because public transport bus systems are affected by economic state, commercial, environmental, and radical features along with technical factors and physical problems. Performance improvements of public transport bus systems are influenced by some measures such as increasing of the number of buses, the number of bus stops, and the number of passengers, and modifications along streets and in land uses. Therefore, the different problems will cause ineffective operation of public transport bus systems which are needed to be recognized and suitable techniques and measures should be expressed for determination of these problems (Sarvareddy 2008; Yu & Jason 1982).

Generally, several public transport bus systems are suffering from economic difficulties which caused by increasing costs and dropping incomes. If these inclinations continue, it will be difficult for public transport bus system to efficiently report these significant social difficulties. There are several approaches which they make public transport bus system more useful. Generally, public transport bus systems production improvement approaches make public transport more effective to operate and more pretty to customers (Andrew 2006).

The objective of this study is to improve level of transit service of public transport bus routes in Baghdad city by the application of some remedial actions.

DESCRIPTION OF BUS ROUTES

Eight public transport bus routes are selected to evaluate and improve the level of transit service. These routes represent Al-Tahrir bus network (A) located in the center of Baghdad city (capital of Iraq). Table 1 and Table 2 gives the operational properties and bus routes paths and lengths for the selected bus routes.

TABLE 1. Operational features of the selected bus routes [Tan et al. 2021]

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
A-72	16	12	1	2	13.5	4	4	End
A-36	13	9	2	2.5	12	6	6	End
A-13	14	14	3	2	12	6	6	End
A-114	21	14	2	1.5	12	5	5	End
A-11	32	20	3	2	14	6	6	Round
A-30	24	15	1	2	13	7	7	End
A-37	27	7	1	3	13	7	7	End
A-9	30	14	1	1	12	4	4	End

TABLE 2. Bus routes paths and length [Tan et al. 2021]

Garage site	Route No.	Origin-to-Destination	Route length (km)	Route path
Bus terminal No.1 (inside Al-Tahrir Square private garage)	A-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.
	Square private garage)	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.
	A-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.
	A-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.
	A-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)	A-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.
	garage)	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.
	A-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.

IMPROVEMENT OF DELAY LEVEL OF TRANSIT SERVICE

In this study, there are eight types of total delay. These types include delay due to legal bus stops which is known as (B-delay), illegal bus stops which is known as (b-delay), stop at signalized intersections which is known as (I-delay), traffic congestion which is known as (C-delay), pedestrians crossing which is known as (P-delay), parked vehicles which is known as (P.V-delay), right turn which is known as (R.T-delay), and left turn which is known as (L.T-delay). Therefore, the reduction in the delay at one or more of the these types can result in reduction in the total delay values for the selected bus routes, leading to improve the values of LOTS for total delay, bus travel time, headway, adjusted running speed, and capacity, then improve the overall route and network LOTS.

REDUCTION OF BUS STOPS DELAY (LEGAL-B AND ILLEGAL-B)

Bus stop delay consists of two types. The first type is legal bus stop delay (B), which is the time taken by the bus in the location of bus stop (i. e., shelters or signs of bus stop). The second type is illegal bus stop delay (b), which is the time taken by the bus outside bus stop location. This type of delay cannot be eliminated or reduced because it represents the service time for passengers (i. e., boarding and alighting time). In Baghdad City, the bus takes time longer than time that required for boarding and alighting of passengers. Therefore, there is additional time lost at any bus stop in addition to service time for passengers. This additional time is caused by bus drivers who often stop and wait passengers at bus stops. Nevertheless, preventing bus drivers from stopping for longer time than the service time for passengers can eliminate this additional time.

To reduce the additional time at bus stops, the average passenger boarding and alighting time must be obtained. Table 3 gives the values of average passenger boarding and alighting for each bus route. The number of passengers boarding and alighting is collected for each bus stop, and the actual service time for passengers can be calculated as the number of passengers boarding (pb) multiplied by the average boarding time (tb) plus the number of passengers alighting (pa) multiplied by the average alighting time (ta) for each bus route. Figure 1 shows the values of legal bus stops delay before and after the improvement for the selected bus routes. Table 4 list the reduction of legal bus stops delay

for the selected bus routes. From Table 4 it can be noted that the delay due to legal bus stops has been reduced by (56%, 25%, 14%, 13%, 23%, 34%, 42%, and 35%) for bus routes No. (72, 36, 13, 114, 11, 30, 37, and 9) respectively. Bus route No. (72) has the higher percentage of reduction (56%), meaning that the additional time at legal bus stops is 56% of the stopping time which is not necessary and can be reduced. Bus route No. (114), on the other hand, has the lower percentage of reduction (13%) and this means that the additional time at legal bus stops is 13% of the stopping time which is not necessary and can be eliminated.

Illegal bus stop delay (b-delay) can be reduced because it represents the time that bus drivers take at illegal bus stops according to desire of passengers. To reduce this type of delay, the GCPT should force its bus drivers to stop only at the legal bus stops. Figure 2 shows illegal bus stops delay (b) before and after improvement. Table 5 shows the reduction in illegal bus stops delay for the selected bus routes. From Table 5 it can be noted that the percentages of reduction for all selected bus routes are 100%.

TABLE 3. Average passenger boarding and alighting time for the selected bus routes[Tan et al. 2021]

Route No.	Average passenger boarding time (sec)	Average passenger alighting time (sec)
A-72	3.37	3.57
A-36	4.09	4.28
A-13	3.48	3.74
A-114	3.05	2.84
A-11	4.33	3.94
A-30	3.31	3.73
A-37	2.69	2.65
A-9	2.81	3.33

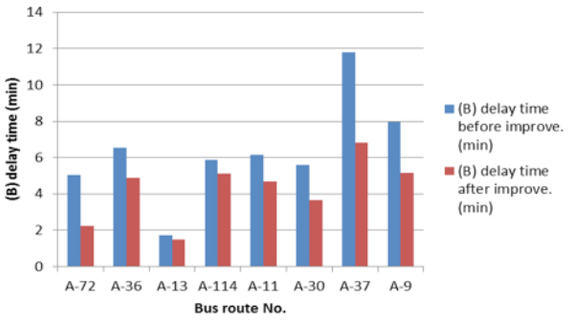

FIGURE 1. Legal bus stops delay (B) before and after improvement

TABLE 4. Reduction of legal bus stops delay for the selected bus routes

Route No.	Reduction in legal bus stop delay (min) (1)	% of the reduction
A-72	2.80	56 %
A-36	1.66	25 %
A-13	0.24	14 %
A-114	0.75	13%
A-11	1.44	23 %
A-30	1.93	34 %
A-37	4.99	42 %
A-9	2.78	35 %

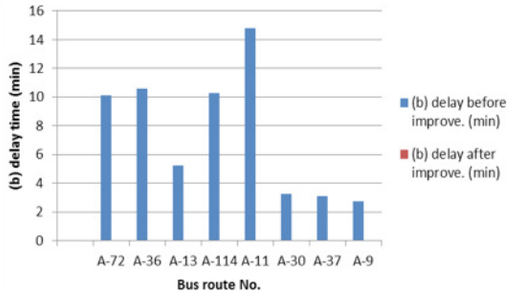

FIGURE 2. Illegal bus stops delay (b) before and after improvement

TABLE 5. Reduction of illegal bus stops delay (b) for the selected bus routes

Route No.	Reduction of (b) delay(min)	% of elimination
A-72	10.13	100 %
A-36	10.59	100 %
A-13	5.21	100 %
A-114	10.25	100 %
A-11	14.80	100 %
A-30	3.25	100 %
A-37	3.10	100 %
A-9	2.73	100 %

REDUCTION OF SIGNALIZED INTERSECTION DELAY (I)

This type of delay can be eliminated by using bus signals priority treatments at signalized intersection. In this study, signals preemption treatment are suggested to reduce the delay at signalized intersections along the paths of the selected bus routes. By giving the green phase in the

direction of bus route can do this treatment, and this allows the bus to cross the intersection without any delay. Figure 3 shows signalized intersections delay (I) before and after improvement. Table 6 shows the reduction of signalized intersections delay for the selected bus routes. From the above table, the percentages of reduction for signalized intersections delay are 100% for the selected bus routes.

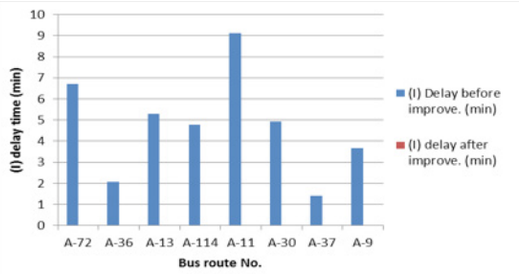

FIGURE 3. Signalized intersections delay (I) before and after improvement

TABLE 6. Reduction of signalized intersections delay for the selected bus routes

Route No.	Reduction of (I) delay(min)	% of elimination
A-72	6.72	100 %
A-36	2.08	100 %
A-13	5.28	100 %
A-114	4.77	100 %
A-11	9.13	100 %
A-30	4.93	100 %
A-37	1.41	100 %
A-9	2.73	100 %

REDUCTION OF TRAFFIC CONGESTION DELAY (C)

Traffic congestion delay (C) can be reduced by using bus-lane for bus route No.(114) which passes through the CBD (i. e., Al-Shurja district), and bus routes No. (30, 37, and 9) which pass through Al-Rasheed street. Thus, this study suggests using curbside bus-lane along the path of bus route in Al-Shurja district and Al-Rasheed street. This type of improvement will help to reduce the traffic congestion delay approximately by 50%. This type of delay cannot be eliminated by 100%, because there are many buses for other routes use this lane. Figure 4 shows traffic congestion (C) delay before and after improvement and Table 7 lists the reduction of traffic congestion delay for bus routes No.(114, 30, 37, and 9).

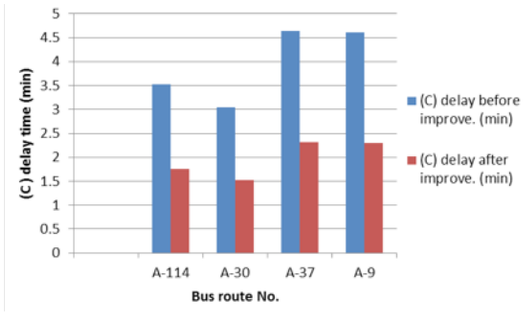

FIGURE 4. Traffic congestion (C) delay before and after improvement

TABLE 7. Reduction of traffic congestion delay

Route No.	Reduction of (C) delay(min)	% of reduction
A-114	1.76	50 %
A-30	1.52	50 %
A-37	2.32	50 %
A-9	2.30	50 %

THE TOTAL DELAY LOTS AFTER IMPROVEMENT

The values of total delay for the selected routes will be reduced due to the reduction of legal bus stops delay (B-delay), the reduction of illegal bus stops delay (b-delay) and signalized intersections delay (I-delay), and the reduction of traffic congestion delay (C-delay). Therefore, the reduction in the values of total delay will give new improved LOTS values for the selected bus routes. Figure 5 shows the values of total delay before and after improvement. Table 8 gives the values of reduction in total delay with LOTS before and after improvements. From these figures and tableS, it can be noted that the total delay of bus route No. (72) is reduced from 23.66 min. to 4.01 min. and its LOTS value is improved from LOTS (F) to LOTS (D). The total delay of bus route No. (36) is reduced from 21.92 min. to 7.59 min. and its LOTS value is increased from LOTS (F) to LOTS (E). The total delay of bus route No. (13) is reduced from 16.43 min. to 5.69 min. and its LOTS value is raised from LOTS (F) to LOTS (E). The total delay of bus route No. (114) is reduced from 28.16 min. to 10.63 min., but its LOTS value remains at LOTS (F). For bus route No. (11), the total delay is reduced from 31.72 min. to 6.39 min. and its LOTS value is raised from LOTS (F) to LOTS (E). The total delay of bus route No. (30) is reduced from 17.28 min. to 5.65 min. and its LOTS is raised from LOTS (F) to LOTS (E). The total delay of bus route No.(37) is reduced from 21.19 min. to 9.37 min., but its LOTS remains at LOTS (F). Finally, the total delay of bus route No. (9) is reduced from 19.17 min. to 7.67 min. and its LOTS is raised from LOTS (F) to LOTS (E).

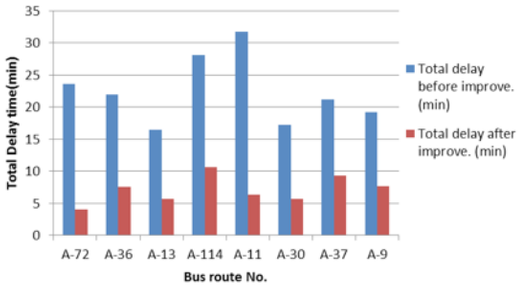

FIGURE 5. Total delay before and after improvement

TABLE 8. The Values of total delay lots before and after improvements

Route No.	Delay LOTS before improve.	Delay LOTS after improve.	% of reduction
A-72	F	D	83 %
A-36	F	E	65 %
A-13	F	E	65 %
A-114	F	F	62 %
A-11	F	E	80 %
A-30	F	E	67 %
A-37	F	F	56 %
A-9	F	E	60 %

REDUCTION OF BUS TRAVEL TIME LOTS AFTER IMPROVEMENT

Bus travel time is composed of running time and total delay. Therefore, the reduction in total delay will lead to reduce bus travel time. Figure 6 shows bus travel time values before and after improvements for the selected bus routes. Table 9 gives the of level of transit service for bus travel time before and after improvement for the selected bus routes. From Table 9 it can be noted that the value of travel index of bus route No. (72) is reduced from 2.91 to 2.0 and its LOTS value is increased from LOTS (F) to LOTS (E). The value of travel index of bus route No. (36) is reduced from 2.88 to 2.0 and its LOTS value is improved from LOTS (F) to LOTS (E). For bus route No. (13), the value of travel index is reduced from 1.85 to 1.47 and its LOTS is raised from LOTS (E) to LOTS (D). For bus route No.(114), the value of travel index is reduced from 2.42 to 1.92 and its LOTS value is raised from LOTS (F) to LOTS (E). The value of travel index of bus route No. (11) is reduced from 2.24 to 1.73 and its LOTS value is raised from LOTS (F) to LOTS (E). The value of travel index for bus route No. (30) is reduced from 2.44 to 1.97 and its LOTS value is raised from LOTS (F) to LOTS (E). For bus route No. (37), the value of travel index is reduced from 2.23 to 1.80 and its LOTS value is raised from LOTS (F) to LOTS (E). Finally the value of travel index of bus route No. (9) is reduced from 2.18 to 1.87 and its LOTS value is raised from LOTS (F) to LOTS (E).

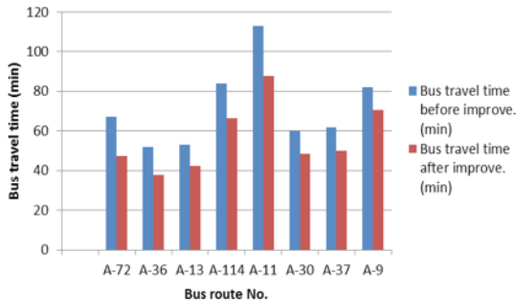

FIGURE 6. Bus travel time values before and after improvements

TABLE 9. Values of level of transit service for bus travel time before and after improvements

Route No.	Reduction in total delay (min)	Car travel time (min)	Travel index (T.I)
A-72	19.65	23.0	2.91
A-36	14.33	18.20	2.88
A-13	10.74	28.60	1.85
A-114	17.53	34.60	2.42
A-11	25.33	50.40	2.24
A-30	11.63	24.50	2.44
A-37	11.82	27.80	2.23
A-9	11.50	37.60	2.18

TABLE 9. Continued

Route No.	Travel index(T.I) after improve.	before improve.	LOTS after improve.
A-72	2.0	F	E
A-36	2.0	F	E
A-13	1.47	E	D
A-114	1.92	F	E
A-11	1.73	F	E
A-30	1.97	F	E
A-37	1.80	F	E
A-9	1.83	F	E

HEADWAY LOTS AFTER IMPROVEMENT

In general, headway is the time from instant the front end of leading bus passes a given point until the front end of the following bus passes the same point. Figure 7 shows headway values before and after improvements for the selected bus routes and Table 10 lists the values of headway LOTS before and after improvements for the selected bus routes From the above table it can be noted that the values of headway of bus route No. (72) is reduced from 17.1 min to 11.83 min and its LOTS value is raised from LOTS (C) to

LOTS (B). The value of headway of bus route No. (36) is reduced from 23.26 min to 6.27 min and its LOTS value is raised from LOTS (D) to LOTS (A). For bus route No. (13), the value of headway is reduced from 70.6 min to 7.04 min and its LOTS is raised from LOTS (F) to LOTS (A). For bus route No. (114), the value of headway is reduced from 38.25 min to 13.29 min and its LOTS value is raised from LOTS (E) to LOTS (B). The value of headway of bus route No. (11) is reduced from 31.62 min to 14.61 min and its LOTS value is raised from LOTS (E) to LOTS (C). The value of headway of bus route No. (30) is reduced from 19.86 min to 8.11 min and its LOTS value is raised from LOTS (C) to LOTS (A). For bus route No. (37), the value of headway is reduced from 21.78 min to 7.16 min and its LOTS value is raised from LOTS (D) to LOTS (A). Finally the value of headway of bus route No. (9) is reduced from 75.0 min to 17.65 min and its LOTS value is raised from LOTS (F) to LOTS (C).

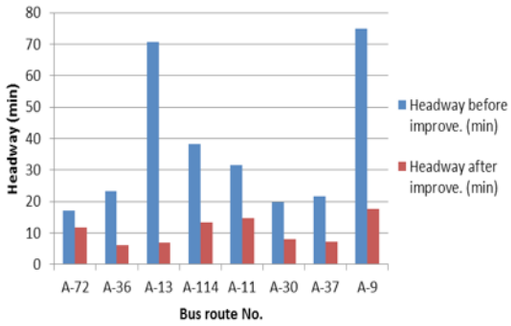

FIGURE 7. Headway values before and after improvements for the selected bus routes

TABLE 10. Values of headway LOTS before and after improvements for the selected bus routes

Route No.	Headway before improve (min)	Bus travel time after improve (min)	Number of buses	Headway after improve (min)	Headway LOTS before improve	Headway LOTS after improve
A-72	17.10	47.35	4	11.83	C	B
A-36	23.26	37.67	6	6.27	D	A
A-13	70.60	42.26	6	7.04	F	A
A-114	38.28	66.47	5	13.29	E	B
A-11	31.62	87.67	6	14.61	E	C
A-30	19.86	48.37	7	8.11	C	A
A-37	21.78	50.18	7	7.16	D	A
A-9	75.00	70.60	4	17.65	F	C

ADJUSTED RUNNING SPEED LOTS AFTER IMPROVEMENT

The reduction in total delay, bus travel time, and headway will lead to increase in bus travel speed and adjusted running speed. Table 11 gives the values of bus travel speed, adjusted running speed and its LOTS. From this table it can be noted that the value of the adjusted running speed of bus route No. (72) is increased from 16.19 km/hr to 17.65 km/hr and its LOTS value remains at LOTS (E). The value of the adjusted running speed of bus route No.(36) is increased from 15.82 km/hr to 19.87 km/hr and its LOTS value remains at LOTS (E). For bus route No. (13), the value of the adjusted running speed is increased from 14.61 km/hr to 26.19km/hr and its LOTS is raised from LOTS (E) to LOTS (D). For bus route No.(114), the value of the adjusted running speed is increased from 16.80 km/hr to 20.16 km/hr and its LOTS value is raised from LOTS (E) to LOTS (D). The value of the adjusted running speed of bus route No. (11) is increased from 29.04 km/hr to 31.91 km/hr and its LOTS value remains at LOTS (D). The value of the adjusted running speed of bus route No.(30) is increased from 17.09 km/hr to 19.24 km/hr and its LOTS value remains at LOTS (E). For bus route No.(37), the value of the adjusted running speed is increased from 19.72 km/hr to 22.97 km/hr and its LOTS value remains at LOTS (E). Finally the value of the adjusted running speed of bus route No. (9) is increased from 13.75 km/hr to 19.23 km/hr and its LOTS value remains at LOTS (E). Table 11 also gives the values of the adjusted running speed LOTS of bus routes No. (72, 36, 11, 30, 37, and 9) are low, even after the improvements. Thus, this study recommends using bus-only lane along the paths of these routes to increase bus adjusted running speed.

TABLE 11. Values of adjusted running speed lots before and after improvements for the selected bus routes

Route No.	Adjusted running time after improve (min)	Bus travel speed after improve (km/hr)	Adjusted running speed before improve (km/hr)	Adjusted running speed after improve. (km/hr)	LOTS before improve	LOTS after improve
A-72	49.25	17.74	16.19	17.65	E	E
A-36	33.21	17.52	15.82	19.87	E	E
A-13	40.09	24.84	14.61	26.19	E	D
A-114	62.48	18.95	16.80	20.16	E	D
A-11	88.36	32.16	29.04	31.91	D	D
A-30	46.77	18.60	17.09	19.24	E	E
A-37	44.39	20.32	19.72	22.97	E	E
A-9	71.75	19.54	13.75	19.23	E	E

CAPACITY LOTS AFTER IMPROVEMENT

After improving the values of LOTS for total delay, bus travel time, headway, and adjusted running speed, the values of capacity LOTS are improved for the selected bus routes. Equation (1) is used to compute the reduction factor (R). In this equation, the additional time for legal bus stops delay (B) and illegal bus stops delay (b) are not included in average dwell time (i. e., average dwell time is equal to legal bus stops delay (B) after improvements). The ratio of (g/c) is not included, because signals preemption treatment is used to eliminate the delay at signalized intersections. Bus-flow rate (bus/hr) is also improved after the improving of the values of headway. Equation (2) is used to compute the bus-flow rate after improvements. This equation is: (Khisty & Lall 1998)

$$C.v=3600*R/H=3600*R/(D+Tc) \quad (1)$$

$$\text{Bus-flow rate} = 1*60/H \quad (2)$$

Where:

C.v = vehicle capacity (vehicles/ hour per channel)
R = reduction factor for dwell time and arrival variation
T.c = Average clearance time between successive vehicle (sec)
D = Average dwell time (sec)
H = headway after improvement (min)

Figure 8 and Figure 9 give the values of bus-flow rate and C.v before and after improvements. From these Figures it can be noted that the values of bus-flow rate for the selected bus routes are increased. Therefore, GCPT must add other number of buses to meet the bus-flow rate after improvement. These buses are added to bus routes No. (72, 36, 13, and 37), whereas bus routes No. (114, 11, and 9) have sufficient number of buses to meet the bus-flow rate after improvements.

The values of reduction factor (R) and their LOTS before and after improvements can be shown in Table (12). From this table it can be noted that the value of reduction factor of bus route No. (72) is reduced from 0.377 to 0.330 and its LOTS value remains at LOTS (A). The value of reduction factor of bus route No. (36) is reduced from 0.692 to 0.330 and its LOTS value is raised from LOTS (D) to LOTS (A). For bus route No. (13), the value of reduction factor is reduced from 1.57 to 0.331 and its LOTS is raised from LOTS (F) to LOTS (A). For bus route No. (114), the value of reduction factor is reduced from 0.634 to 0.333 and its LOTS value is raised from LOTS (C) to LOTS (A). The value of reduction factor of bus route No. (11) is reduced from 0.703 to 0.326 and its LOTS value is raised from LOTS (D) to LOTS (A). The value of reduction factor of bus route No. (30) is reduced from 0.438 to 0.315 and its LOTS value is raised from LOTS (B) to LOTS (A). For bus route No. (37), the value of reduction factor is reduced from 0.719 to 0.320 and its LOTS value is raised from LOTS (D) to LOTS (A). Finally, the value of reduction factor of bus route No. (9) is reduced from 0.847 to 0.294 and its LOTS value is raised from LOTS (E) to LOTS (A).

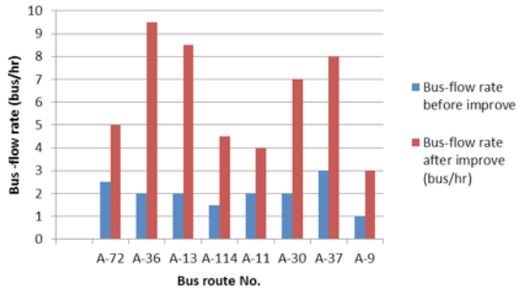

FIGURE 8. Values of bus-flow rate before and after improvements

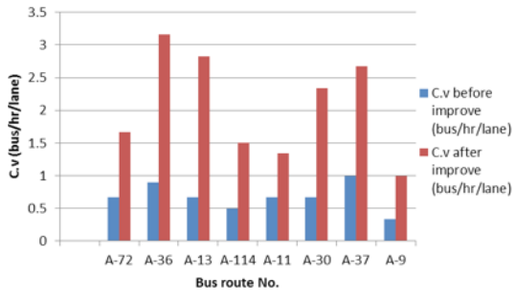

FIGURE 9. C.v values before and after improvements

TABLE 12. The values of reduction factor (R) and their LOTS before and after improvements

Route No.	(R) before improve	(R) after improve	LOTS before improve	LOTS after improve
A-72	0.377	0.330	A	A
A-36	0.692	0.330	D	A
A-13	1.57	0.331	F	A
A-114	0.634	0.333	C	A
A-11	0.703	0.326	D	A
A-30	0.438	0.315	B	A
A-37	0.719	0.320	D	A
A-9	0.847	0.294	E	A

OVERALL ROUTE AND NETWORK LOTS AFTER IMPROVEMENTS

After improving the values of LOTS of total delay, bus travel time, service frequency (i. e., headway), adjusted running speed, and capacity, the overall route LOTS is computed for the selected bus routes by using the LOTS matrix. [18]. Table 14 gives the values of performance index (P.I) for the selected bus routes. From this table it can be noted that the values of overall LOTS for the selected bus routes are improved, and their performance index (P.I) is raised. For bus routes No. (72 and 30), the values of the overall LOTS are raised from LOTS (D) to LOTS (C), whereas for bus routes No.(36, 13, 114, 11, 37, and 9), the values of the overall LOTS are raised from LOTS (E) to (D). After computing the overall route LOTS for the selected bus routes, the overall network LOTS can be computed by multiplying the route performance index (P.I) shown in Table 14 by the percent of the bus-flow rate in the total network flow rate after improvements. Table 13 shows the percentages of bus-flow rate after improvements.

TABLE 13. The percentages of bus-flow rate in the total network flow rate

Route No.	Bus-flow rate after improve (bus/hr)	% of bus-flow rate from total network flow-rate
72	5	10.10 %
36	9.5	19.19 %
13	8.5	17.17 %
114	4.5	9.10 %
11	4.0	8.08 %
30	7.0	14.14 %
37	8.0	16.16 %
9	3.0	6.06 %
Total	49.5	100 %

TABLE 14. The values of overall route lots before and after improvements for the selected bus routes

Route No.	Total P.I before improve	Total P.I after improve	Total LOTS before improve	Total LOTS after improve
72	33	51	D	C
36	19	45	E	D
13	14	55	E	C
114	16	41	E	D
11	19	41	E	D
30	34	52	D	C
37	26	47	E	D
9	15	43	E	D

Network (P.I) = 51(10.10%)+45(19.19%)+55 (17.17%)+41(9.10%)+41(8.08)+52(14.14%)+47(16.16%)+43(6.06%)

Network (P.I) = 5.15+8.63+9.44+3.73+3.31+7.35+7.59+2.60

Network (P.I) = 47.80

By using table 20 in reference [18], Network LOTS = LOTS (D)

From the above computation it can be shown that the overall network LOTS is improved from LOTS (E) to LOTS (D).

CONCLUSION

1. Eight public transport bus routes are selected to evaluate and improve the level of transit service. These routes represent Al-Tahrir bus network (A) which located in the center of Baghdad city (capital of Iraq).
2. The suggested remedial actions include reduction of legal bus stops delay (B), the elimination of illegal bus stops delay (b), the elimination of signalized intersections delay (I), and the reduction of traffic congestion delay (C). These suggested remedial actions are leaded to improve the values of total delay, bus travel time, service frequency (i. e., headway), adjusted running speed, and capacity. The values of LOTS for these transit performance measures are improved.
3. After the application of these remedial actions, the values of overall bus routes LOTS have been improved from LOTS (D, E, E, E, E, D, E, and E) to (C, D, C, D, D, C, D, and D) for the selected bus routes No. (72, 36, 13, 114, 11, 30, 37, and 9) respectively, whereas the overall bus network LOTS has been improved from LOTS (E) to LOTS (D).

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DECLARATION OF COMPETING INTEREST

None

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