

Research Article

Operation and Economic Analysis for Ring Road: Baqubah City as Case Study

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Many cities in Diyala governorate are suffering from traffic congestion due to high percentage of through traffic. One of the most applicable solutions to such problem is the construction of ring road by which the through traffic is avoided. In this research, Baqubah city is subjected to economic analyses in order to determine whether the establishment of a peripheral ring road to downgrade the traffic congestion in the city center would be economically feasible. The planned road is divided into three segments linking the three major entries to the city. The first segment is already existing, while the second and third segments are following a predetermined orbital route that has not been utilized yet. Hence, the first segment is not considered in the economic analyses, which included the second and third. The traffic data was collected for all entries, and then the fractions of traffic that expected to utilize the new ring road were estimated and projected for the design lifetime of the road taken as 20 years after two years of design and construction. The suggested road was proved profitable by the use of two economic parameters: the first is the benefit cost ratio, which returned the values of 7.44 and 5.92, for the second and third segments, respectively. The net present value calculations revealed the values of \$50,399,966 and \$43,991,883 for the second and third segments, respectively.

1. Introduction

In recent years, traffic congestions are becoming a huge problem in the core centers of most of the rapidly growing cities in the middle sector of Iraq [1]. The growth pattern of the urban sectors over the last four decades often took radial directions outward the converging commercial business centers in these cities [2]. This configuration may compel a considerable portion of the through traffic, that has no interest in any destination inside the city, to inter the crowded city centers and provoke the congestion problem. The ring road may be considered as a suitable solution for this problem for it may provide the means by which the through traffic can avoid the city center by taking a bypass that links the city entrances by following a peripheral path around the city [3].

Ring roads represent an important component of the transportation system in large metropolitans [4], not only for reducing the traffic flow entering the city center but also

for improving the transportation in the undeveloped suburb areas surrounding the metropolitan, which may facilitate the reorientation of commercial businesses towards the orbital ring roads [5].

Despite the relative importance of this issue with respect to local cities, it was scarcely investigated. In fact, former plans for cities and road networks rarely discussed the economic point of view, where the peripheral roads are following the jurisdiction line unlike nowadays in which the economic feasibility is required before the establishment of any project.

In this research, the feasibility of constructing a ring road around the city of Baqubah is studied in the following sequence. Section 2 contains the reviewing of literature on ring roads importance and cost effectiveness. Section 3 includes the description of the characteristics of the study area represented by the city of Baqubah and its vicinity. Section 4 explains the methodology and data collection process by which the traffic counts in all city entries are gathered as well as the road network characteristics. Section 5 includes the feasibility calculations of the construction of the proposed ring road and their results. Section 6 presents the conclusions drawn from this research.

2. Literature Review

Ring roads were presented in transportation network as early as the thirties of the last century in central Europe [3,6], which may reflect their importance in this early stage since the traffic congestion was not an issue due to the scarce number of automobiles these years; in fact, they were constructed to highlight and sustain cities' natural spatial structure, as well as to create massive monuments that may be used for nationalistic objectives [7].

Ring roads generally encircle the cities they meant to serve and often integrate with the existing road network in order to establish new movement paths [8]. These roads are mostly designed to serve mobility rather than accessibility despite the presence of many connections with local roads and streets [9]. Sometimes these roads are referred to as motorways or highways, depending on the connectivity degree with the road network of the urban area encircled by these ring roads [10]. The principal objective of ring roads is to minimize the traffic congestion compiled in the core center of the city by diverting the through traffic to orbital bypasses towards its destination [8, 11, 12]. In the United States, these roadways now count some 100 forming a complete beltway, which accommodate the heaviest traffic in their regions [13].

Another role of the ring roads is represented by highlighting the peripheral boundary to the urban sprawl towards which the urban constructions is going to be decentralized [3] and reconfiguring the concentration of shops and commercial entities [14]. This decentralization may very well increase the traffic between suburbs. Most of this traffic is accommodated by the ring road, which may witness an irregular traffic flow especially in the presence of speed or acceleration constraints due to at grade entrances, intersections, or traffic signal control [15]. This type of roads makes a suitable peripheral path linking many cities. Hence, the ring road is improving access to suburban areas, boosting their location importance and prices [4, 11, 16].

In planning process for the construction of new ring road, as in any other construction project, the feasibility analysis usually controls the decision maker options. The economic feasibility consists of typical comparison between the road construction costs and the savings gained by the reduction in the road user costs due to the enhancement in the smoothness of the new road and the saving in travel time when using it instead of the existing roads [17, 18]. The highway construction cost estimation is very important to come up with appropriate feasibility assessment. Many efforts were paid to enhance the assessment procedure for better analysis [19-21]. The cost benefit analysis has long been used as in economic feasibility studies, in which the net present value of the total benefits is divided by the net present value of the total costs. It is regarded as one of the most powerful tools utilized in the evaluation processes

concerning the investment in transportation infrastructures [22–24]. The net present value refers to the difference between value of future benefits and investment cost for the entire life of project discounted to the present at a specified rate. The project is considered financially viable when the net present value is positive. This methodology in feasibility analysis is also widely used [25, 26]. It is of great importance to give a proper estimate to the road user cost in order to ensure a robust economic analysis. The road user cost refers to the traveler's cost increment caused by the road construction activities, and it represents the summation of the vehicle operating costs and passengers' delay costs [27, 28], and in certain cases the accidental costs are added as well [29, 30].

3. The Study Area

The city of Baqubah is the capitol of Diyala governorate, which represents the biggest and the most important city in the province. Its importance comes mainly due to the concentration of the governmental and administrative authority centers inside or near its center, besides the presence of many commercial centers that manipulate a very big portion of the governorate trading economy, which makes this city a very important transferring node for goods and people. The road system that connects Baqubah city with other surrounding cities has its own nature, which is affected to a great deal by the evolution and development of the city especially in the last three decades [2, 31]. The growth of the city took a unique pattern that occupied big portions of the principal arterials extending to the south and east, with less propagation towards the west or north.

Although the total number of cars nearly doubled in the last decade, no new streets were added, leaving the road network intact and making an increase in the congestion in the central sectors of the city, which leads to increasing delay and lowering the level of service, which may necessitate the establishment of a ring road to divert the entering through traffic.

The city has three principal entries located in the north, south, and east. The proposed ring road should surround the city of Baqubah and facilitate an alternative route for the through traffic to take instead of the city center.

The proposed path for this ring road has already been decided by the former local administrative authorities following the outlines of previous planned suburb network of roads which can, with relatively small adjustments, be developed into a ring road surrounding Baqubah city (see Figure 1). It is composed of three segments: the first links the northern with the eastern entries, the second links the eastern and the southern entries, and the third links the northern with the southern entries.

4. Methodology and Data

Since the path of the suggested ring road is already decided by the local authorities, the economic feasibility analysis will not include any alternative route options [32]. Accordingly, the geometric data of the planned route segments are to be



FIGURE 1: The suggested ring road around Baqubah city.

collected, including the current conditions of the existing parts of the roadway as well as the requirements of the construction of the newly added parts in addition to the rehabilitation process needed for certain deteriorated parts. This data is crucial to give an accurate assessment for the investment cost of the ring road.

The traffic data should also be collected from all entries to determine, not only the average daily traffic in each entry, but also the percentage of traffic headed towards the city center and the percentages of through traffic destinated to other entries. This data requires high attention during the collection process in order to produce a proper origindestination matrix [33], on which depends the estimation of the portion of traffic intended to use any segment of the proposed ring road.

The economic analysis then could be conducted by calculating the road user cost for the traffic crossing the city center first and then calculate it for the same traffic when utilizing any segment of the proposed ring road. The difference between the two costs represents the benefits, which are discounted to the year of establishment for the sake of the comparison with the investment cost [34].

4.1. Route Setting. The presupposed route of the ring road comprises three segments for it is planned to link between the main three entries to the city represented in the roundabout of Al-Quds in the north and Abdullah Ibn Ali roundabout in the east and the intersection checkpoint of Al-Uthmaniya in the south. The route is bounded from the north by the arterial highway No. 5, which links the eastern Iraqi borders with the capitol Baghdad and other governorates. This principal arterial is in a very good condition and capable of functioning as a viable portion of the ring road without the need for any enhancements.

The first segment links the eastern entry with the northern one. This segment lies totally on the principal arterial, and it is considered already available. The second segment, which links the northern entry with the southern one, is about 10.5 km long. The northern arterial makes the first two kilometers of this segment and needs no enhancement at all. But the remainder 8.5 km is in a very poor condition and needs a major upgrade process in order to be capable of carrying the subjected traffic properly (Figure 2). The traffic flow that is expected to utilize this segment is in fact switching the old route, which is about 6.9 km long; all of it has a relatively high roughness and low operating speed.

The third segment that links the eastern and southern entries is composed of three parts (Figure 3). The first one is 4.7 km and is in good shape that requires only minor rehabilitation to be fully functional. The second part is 6.13 km long and in a very poor condition that requires major upgrade and reconstruction to become viable. The third part, 3.3 km long, is in fair condition and medium rehabilitation, which makes it suitable for traffic accommodation. This segment represents the replacement of the old route passing through the city whose length is 14 km, the first 3.5 km is in good shape while the rest 10.5 km is very congested and of high IRI.

It should be stated that it is planned for all segments shall be consisted of four-lane divided highway by the end of upgrading process to be compatible with the existing parts of the ring road.

The condition of the existing local road network on which through traffic is compelled to use ranges between poor and fair conditions in terms of serviceability. For the sake of quantitate analysis, the International Roughness Index (IRI) was used in this research due to its high acceptability worldwide [35]. The existing road network roughness in average is about 6 m/km. Many other characteristics of the existing roads are compatible with its roughness as it will be discussed later.

The condition of the new ring road, on the other hand, is expected to be less rough than the existing network due to the resent upgrade process to facilitate its function. The designed IRI for the ring road is 4 m/km.



FIGURE 2: The second segment parts.



FIGURE 3: The third segment parts.

4.2. Traffic Data. The annual average daily traffic AADT may represent the most influential traffic volume on economic analysis. It is utilized to determine the road user coat on annual bases. Hence, attention should be paid to determining this volume in each entry to Baqubah city. As stated earlier, Bagubah city has three entries: the northern is in the form of roundabout called (Al-Quds), which represents the northern threshold of Baqubah city, through which all the traffic coming from the north and the west is compulsory passing through the city center. The southern entry is called Al-Uthmaniya intersection, which receives all the traffic coming from the south especially the capitol Baghdad through the old roadway linking Baghdad with the northern governorates. The third entry is called Jurf Al-Milih intersection, which receives all the traffic coming from the east especially from the Iraqi Iranian boarders.

Traffic counts were conducted in the three entries labeled (*A*, *B*, and *C*) for the northern, southern, and eastern entries,

respectively, for seven consecutive days from 7:00 am to 7:00 pm using digital surveillance cameras, which facilitates the counting process to a great deal. Another survey was conducted in each entry by spreading a questionnaire on sample drivers on both ways to gather information about their destinations. The information collected through this questionnaire is crucial to determine the origin-destination trip matrix from which the expected traffic flow on each segment of the ring road could be estimated and consequently, the economic analysis could be easily performed.

The summary of the traffic flow counts showed that the morning peak is the highest and the traffic volumes in all entries are as in Table 1, in which these traffic volumes are distributed into two parts, the first, whose destination is the city center while the second whose destination is outside the city and headed towards another entry passing through the city center. These volumes are estimated depending on the questionnaire results through which the origin-destination matrix shown in Table 2 has been made.

4.3. Traffic Alteration Scenarios. The main function of the ring road is to decrease the congestion in the city center by diverting the through traffic along the bypass channels to avoid passing through the congested road network in the center of the city. In the case of Baqubah ring road, it is orbitally linking three main entries, the northern, the southern, and the eastern. The entering traffic flow in each one of these entries is either headed towards the city center or headed to another entry in order to exit towards an outside destination. The first portion of the entering traffic has nothing to do with the ring road and does not need to be considered. The other portion of the entering flow, which is forced to pass through the city while its destination is outside, will mostly be deviated to avoid congestion in the following orders:

As for the northern entry represented by Al-Quds roundabout, labeled here as (A), the traffic going to Baqubah is the south exit of the roundabout as in Figure 4 in the current situation, the origin of this traffic is either the southbound coming from the north and passing through the roundabout or the left turn of component of the westbound traffic or the right turn of the eastbound traffic flow. There are two destinations for this traffic: the first is the center of Baqubah city and the second is the southern intersection checkpoint of Al-Uthmaniya, while there is no component of this traffic goes towards the eastern entry due to the presence of the direct highway link between the northern and the eastern entries. The traffic headed to the second destination represents the through traffic which may very well change its route when the ring road is established by utilizing the second segment instead of the city center.

In the southern entry at the intersection checkpoint of Al-Uthmaniya labeled as entry (B) as in Figure 5, the northbound traffic enters the city almost completely because the east and west branches of this intersection are shortly extended to serve some local residential small areas at the current time. The traffic generated by these small areas is quite negligible as compared with the northbound traffic

TABLE 1: Traffic peak hour volumes in all entries.

		Peak volume Veh/ł	nr
Traffic direction	Al-	Al-	Abdulla
frame ancenon	Quds	Uthmaniya	Bin Ali
	Α	В	С
Entering city center	3630	1792	2211
Departing city center	2540	2141	1842

TABLE 2: Trip origin-destination matrix.

Trip matrix			Enter			
		Α	В	С	C.C	traffic
	Α	_	1017	726	1887	3630
	В	395	—	268	1129	1792
Origin	С	553	222	_	1436	2211
c .	С. С	1592	902	848	—	3342
Out traffic		2540	2141	1842	4452	



FIGURE 4: The northern entry (Al-Quds roundabout).



FIGURE 5: The southern entry (Al-Uthmaniya intersection).

coming from Baghdad and the southern governorates. This traffic flow has three components: the first is going to the city center and does not have any influence on the ring road. The second component is headed towards the north and needs to go through the congested area of Baqubah on route. This component is expected to use the second segment of the ring road to avoid the congestion and gain time. The third component is headed east and has to pass through more congested roads to reach the eastern entry of the city. This component is likely to use the third segment to save time and cost.

The eastern entry, on the other hand, is represented by the Abdulla Bin Ali roundabout, labeled (C) as shown in Figure 6 in which the entering traffic is divided into two components, the first is seeking the city center and consequently is irrelevant to this research, while the second component that seeks the southern entry would have to endure the congestion in the city center to reach the destination and is expected to alter the route and utilize the third segment to avoid the congestion and minimize the delay.

4.4. Traffic Future Projection. Since the economic analysis that depends on the future traffic is expected to be accommodated in any roadway project, it is very important to make a suitable forecasting to this future assessment. In the case of the ring road around Baqubah, traffic forecasts must be provided for each segment depending on the present traffic volumes shown in Table 2, which are considered as the design hourly volumes [36, 37], from which the annual traffic volumes are estimated according to equation (1). In this equation, the proportion of the AADT occurring in the peak hour, or *K*-value, is estimated to be 10% since the roadway is an urban orbital or circumferential highway, as stated in [38].

$$DHV = AADT \times K,$$
 (1)

where DHV is the design hourly volume, AADT is the annual average daily traffic, and K is the proportion of AADT occurring in the peak hour.

The present annual traffic is then calculated as in equation (2) on each route. The future projections of traffic annual volumes on each segment of the ring road are forecasted according to equation (3), in which the annual rate of increase in traffic is assumed as 3% [17, 39]. The project lifetime, as mentioned earlier, is considered as 20 years in addition to two years of construction services.

Annal Traffic Volume =
$$AADT \times 365$$
, (2)

$$F = P\left(1+r\right)^n,\tag{3}$$

where F is future traffic, P is present traffic, r: annual rate of increase in traffic, and n is time.

A

The forecasted annual traffic volumes are calculated according to the traffic hourly volumes in Table 2, from which the traffic volumes on each segment are determined and projected to the next 22 years as shown in Table 3.



FIGURE 6: The eastern entry (Abdulla Bin Ali roundabout).

TABLE 3: Annual traffic volume forecasts on all segments.

Year	Future	traffic volume (vehic	le/year)
	First segment	Second segment	Third segment
0	4668350	5153800	1788500
1	4808400	5308414	1842155
5	5411897	5974666	2073361
10	6273872	6926276	2403594
15	7273137	8029452	2786424
20	8431559	9308336	3230229
22	8945041	9875213	3426950

5. Feasibility Analysis

The feasibility of the newly established ring road is determined through the comparison of the project costs, including the investment and maintenance costs with the expected benefits both calculated along the projects lifetime and discounted to the base year. In this research, the benefit cost ratio and the net present value are used to inspect the feasibility of the ring road project.

5.1. Costs. Costs are divided into construction costs, annual maintenance costs, and road user costs. It is worthwhile to mention that in all cost estimates, taxes, tariffs, and subsidies are excluded for they adopt the whole community perspective. The details of estimating each one of these costs are explained in the following.

5.1.1. Construction Costs. As stated earlier, the suggested ring road lies partially on some existing highways in perfect condition and no construction services nor cost are required for these parts, such as the first segment and the first part of the second segment. Minor rehabilitation processes are required for the first part of the third segment, a medium rehabilitation is required for the third part of the third segment, and major rehabilitation is required for the second part of the third segment.

The minor rehabilitations include partial patching for the damaged areas with minimal amount of overlay, shoulders grading with the side slopes, installation of guard rails, completing the drainage facilities, and road marking. The medium rehabilitations include all the previous processes plus a complete overlay with an asphalt layer or two, which often requires elevating the shoulders grades and side slopes. The major rehabilitation includes much more items, starting from earth works in certain locations followed by the subbase layer and three asphalt layers pavement with all the roadway requirements according to the general specifications of roads and bridges [40]. Such constructions are bounded by the price's limitations specified by the owning directorate. The departments of roads and bridges in Diyala governorate have their own pricing policy, which is revised annually according to the local market requirements. According to this pricing limitations, the ring road rehabilitations and reconstruction costs are estimated to be more than 16 million US dollars as detailed in Table 4.

5.1.2. Maintenance Costs. Maintenance of roadway is very important to keep it viable, efficient, and safe on regular bases [41]. The annual maintenance usually includes all the components of the roadway, such as travel lanes, shoulders, side slopes, and drainage structures, as well as safety appurtenances. The annual cost of these types of maintenance varies with the age of the roadway and the type and extent of its last rehabilitation. The department of roads and bridges estimates the maintenance cost as an annual amount that stays constant for the newly constructed roadway lifetime. This constant cost is increased after any major rehabilitation process [42]. This procedure continues until a reconstruction of the roadway is due. Since the ring road encircling Baqubah city is composed of many parts that are different in age and serviceability conditions, the annual maintenance costs are not expected to be uniformly distributed along the complete roadway. The total annual maintenance cost is calculated as detailed in Table 5.

5.1.3. Road User Costs. As stated earlier, the road user cost (RUC) is an important measure by which the revenue of the newly constructed road could be estimated in terms of the reduction in the RUC by utilizing it instead of the old (existing) road. This reduction is often achieved due to the high serviceability and operational standards of the new road. The RUC represents the summation of the vehicle operating cost (VOC) attributed to the roadway pavement condition and level of serviceability and the travel time cost (TTC) endured by travelers using the road.

(1) Vehicle Operating Cost (VOC). The VOC is mainly attributed to the road pavement roughness. As the roughness increases, the VOC increases as well across all classes of vehicles [43]. In fact, the pavement condition affects many components of VOC; the most important of which are the fuel consumption, coming at first, then the repair and maintenance followed by the tire wear and oil consumption [43, 44]. In this research, the components of VOC are calculated for the existing routes across Baqubah city and for the segments of the suggested ring road that are supposed to be utilized instead.

Segment	Part	Current condition	Upgrade	Length (km)	Cost \$/km	Amount (\$)
1	1	Excellent	Non	10.5	0.0	0.0
2	1	Excellent	Non	2	0.0	0.0
2	2	Very poor	Major	8.5	900,000	7,650,000
	1	Good	Minor	5	300,000	1,500,000
3	2	Very poor	Major	6.11	900,000	5,500,000
	3	Fair	Medium	3.3	500,000	1,650,000
		Te	otal			16,317,000

TABLE 4: Construction costs details.

Table 5:	Annual	maintenance	costs	details.	

Segment	Part	Upgrade status	Length (km)	Cost \$/km	Amount (\$)
1	1	Old	10.5	4,000	40,500
2	1	Old	2	4,000	8,000
	2	New	8.5	2,500	21,250
	1	New	5	3,000	15,000
3	2	New	6.11	2,500	15,275
	3	New	3.3	3,000	9,900
		Total			109,925

TABLE 6: Characteristics of road pavement as they affect VOC.

	Vehicle type	IRI (m/km)	Average IRI influence speed (km/h)	Fuel consumption (l/km)	Oil consumption (l/1000 km)	Tire life (1000 km)	Tire per vehicle
	PC	10	46	0.102	3.05	11.5	4
Old route	MT	10	37	0.231	4.57	11.5	8
	LT	10	28	0.301	6.65	11.5	16
	PC	4	100	0.075	2.15	40.7	4
New route	MT	4	80	0.143	3.67	40.7	8
	LT	4	60	0.16	5.75	40.7	16

For calculating VOC components on local roads, the prices of consumed materials, such as fuel, oil, and tires, in addition to the required services, such as repairing and maintaining automobiles in local market, would have to be adopted. Accordingly, the pricing procedure previously adopted by local authorities and several similar studies is going to be dependent on in this research [17, 18, 36, 39]. The characteristics of road pavements included in this research, either in the old routes inside the city of Baqubah or the new ring road surrounding it, as they affect the VOC components in terms of fuel and oil consumptions and tire wear, are listed in Table 6. The unit costs of the consumed and deteriorated items in the local market are listed in Table 7 along with the maintenance cost which has been estimated depending on the IRI of the road pavement and the vehicle type average value and longevity assuming that the average personal car value is \$10,000 and keeps running for some 250,000 km, while the heavy vehicles average value of \$50,000 and works for about 500,000 km. The maintenance cost is estimated as 30% of the vehicle value on the old routes and 15% on the new ring road segments [17, 45].

These unit costs are distributed over the kilometrage performed by the vehicles as detailed in Table 8 in which the costs of all the component of VOC are summarized and aggregated to produce the kilometrage cost for the old and new routes. The total VOC in dollar per vehicle-kilometer

TABLE 7: Unit cost for consumed items.

Item	Price
Gasoline	0.35 \$/1
Gasoil	0.2 \$/1
PC oil	10 \$/l
HV oil	5 \$/1
PC tire	50 \$
HV tire	250 \$

was found as 0.1769 \$/vehicle-km on the existing road network which is reduced to be 0.0834 \$/vehicle-km on the new ring road. Accordingly, the change in VOC over each segment in the ring road is dependent on the length of the new and old routes. This change has been detailed in Table 9, which shows a reduction in the VOC along the second segment from 1.239 \$/vehicle to 0.8757 \$/vehicle while the use of the new route of the third segment instead of the old route inside the city reduces the VOC from 1.858 \$/vehicle to 0.9 \$/vehicle.

(2) Travel Time Cost (TTC). The most influential factors affecting the travel time cost (TTC) are the length of the roadway and its average speed. Of course, the socioeconomic factors also have their impact, but they are considered neutral when the estimation of TTC is used in cross-comparison process for feasibility analysis.

	Vehicle type	Fuel consumption cost (\$/km)	Tire life cost (\$/km)	Oil consumption cost (\$/km)	Vehicle maintenance cost (\$/km)	Total cost (\$/km)	Vehicle (%)	Cost per vehicle- kilometer	Total cost (\$/vehicle- km)
Old route	PC MT LT	0.0357 0.0462 0.0602	0.01739 0.1739 0.3478	0.0305 0.02285 0.03325	0.012 0.03 0.03	0.09559 0.27295 0.47125	72 12 16	0.068825 0.032754 0.0754	0.176979
New route	PC MT LT	0.02625 0.0286 0.032	0.00491 0.0491 0.09828	0.0215 0.01835 0.02875	0.006 0.015 0.015	0.05866 0.11105 0.17403	72 12 16	0.042235 0.013326 0.027845	0.083406

TABLE 8: The vehicle operating cost calculation for old and new routes.

TINTE O.	Vahiala	norating	conto on	mina	mand	componto
IABLE 9:	venicie o	Derating	COSIS OII	11112	roau	segments.
		···· 0				· · · · · · · ·

	$VOC(\ell/mhight la lm)$	Secon	d segment	Third sea	gment
	VOC (\$/venicle-km)	Length (km)	VOC (\$/vehicle)	Length (km)	VOC (\$/vehicle)
Old route	0.176979	7	1.238853	10.5	1.8582795
New route	0.083406	10.5	0.875763	10.8	0.9007848
	Net VOC reduction		0.36309	Net VOC reduction	0.9574947

Although new routes are often longer than the old routes, the time consumed in passing them is usually shorter due to the higher average speed. In this study, the cost of time consumed by passenger during trip is assumed to be 1.2752 \$/h-passenger, while the cost of travel time for freight is assumed to be 0.0184 \$/h-ton and the average vehicle occupancy is supposed to be 6 passengers per personal vehicle and 1.5 passengers per truck, either medium or large. The tonnage, on the other hand, is assumed to be 27 ton for the medium trucks and 47 ton for large trucks [18, 39, 46].

For calculating the TTC for the Baqubah ring road and the existing routes inside the city, each segment should be regarded separately. The first segment is not included due to its existence already. The second segment whose length is 10.5 km is designed to alter an existing route inside the city with a total length of 7 km. The total TTC for this segment and the old route are detailed in Table 10, which reveals that the TTC is reduced from 1.0\$/vehicle to 0.69\$/vehicle by utilizing the new route instead of the old one despite the longer distance.

As for the third segment in which the old route is about 10.5 km and the new one is 10.8 km, the TTC calculations are shown in Table 11. In this segment, the TTC is reduced from 1.53 \$/vehicle, on the old route, to 0.725 \$/vehicle on the new route (i.e., gaining a total reduction in TTC of about 0.805 \$/vehicle).

5.2. Benefits. The benefits are usually estimated on the basis of the reduction acquired in the road user costs. In the case of the ring road project, these benefits are to be estimated on segment-by-segment basis. The first segment is to be excluded as stated earlier. The benefits expected to be attained by the second and third segments are the summation of their reduction to the VOC and TTC. The second segment was found to make a reduction of 0.36309 (\$/vehicle) and 0.309959 (\$/vehicle) in the VOC and TTC, respectively, which makes a total benefit gained in RUC of 0.673049 (\$/vehicle). The third segment, on the other hand, makes a reduction of 0.9574947 (\$/vehicle) and 0.805492 (\$/vehicle)

in the VOC and TTC, respectively, making a total reduction of 1.7629867 (\$/vehicle). These results show that the third segment makes almost twice the benefit of the second one mainly due to the proximity in length between the new and old routes unlike the second segment whose new length is about one and a half the length of the old route.

5.3. Economic Analysis. In order to inspect the economic viability of the project, there is a vital need to utilize the future traffic forecasts to estimate the expected benefits along the project life time, which is designed to be 20 years similar to all local highway projects, and to discount these future benefits to their equivalent value in present. The costs, on the other hand, including the initial construction costs along with the future maintenance costs are also estimated and discounted to the present year. The equivalent present values of benefits and costs are compared in order to come up with one or more of the economic indicators to prove economic viability. The present value of future costs is calculated according to the following equation [47, 48].

$$PV = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t},$$
(4)

where PV is the present value of costs, C is the annual cost at time t, n is the lifespan of the project, and r is the discount rate.

Many discount rates are suggested in similar projects' economic analysis and often changing over historical periods, mostly affected by such factors as the inflation rate and governmental funding and many others. In this research, it was deemed reasonable to adopt the discount rate of 5% in light of current inflation rate and the rate of change in road construction funding [26, 49].

The economic evaluations for the second and third segments of the ring road are conducted depending on the initial construction costs in Table 4 and the annual maintenance costs in Table 5 along with benefits in terms of the

	Vehicle type	Average IRI influence speed (km/h)	Length (km)	TT (h)	People per vehicle	Ton/ vehicle	Travel time cost (\$/vehicle)	Vehicle (%)	TTC (\$/vehicle)	Total TTC (\$/vehicle)
Old	PC	46	7	0.152174	6	0	1.164313	72	0.838305	
routo	MT	37	7	0.189189	1.5	27	0.45587	12	0.054704	1.004114
route	LT	28	7	0.25	1.5	47	0.6944	16	0.111104	
Nour	PC	100	10.5	0.105	6	0	0.803376	72	0.578431	
INEW	MT	80	10.5	0.13125	1.5	27	0.31626	12	0.037951	0.694155
route	LT	60	10.5	0.175	1.5	47	0.48608	16	0.077773	
	Total reduction (\$/vehicle)									0.309959

TABLE 10: The travel time cost for the second segment.

TABLE 11: The travel time cost for the third segment.

	Vehicle type	Average IRI influence speed (km/h)	Length (km)	TT (h)	People per vehicle	Ton/ vehicle	Travel time cost (\$/vehicle)	Vehicle (%)	TTC (\$/vehicle)	Total TTC (\$/vehicle)
Old route	PC	46	10.5	0.228261	6	0	1.74647	76	1.327317	
	MT	37	10.5	0.283784	1.5	27	0.683805	13	0.088895	1.530788
	LT	28	10.5	0.375	1.5	47	1.0416	11	0.114576	
New route	PC	100	10.8	0.108	6	0	0.82633	76	0.62801	
	MT	80	10.8	0.135	1.5	27	0.325296	13	0.042288	0.725295
	LT	60	10.8	0.18	1.5	47	0.499968	11	0.054996	
Total reduction (\$/vehicle)								0.805492		

TABLE 12: The second segment economic calculations.

Year	Annual volume	Construction and maintenance cost	Discount rate 5%	Annual benefits (\$)	Discount rate 5%
0	0	3,825,000	3,825,000	0	0
1	0	3,825,000	3,642,857	0	0
5	5,974,667	29,250	22,918	4,021,243	3,150,749
10	6,926,276	29,250	17,957	4,661,723	2,861,894
15	8,029,452	29,250	14,070	5,404,215	2,599,520
20	9,308,336	29,250	11,024	6,264,966	2,361,200
22	9,875,214	29,250	9,999	6,646,503	2,272,106
			7,825,018		58,224,984

reduction in RUCs for the same segments as detailed in Tables 8–11, in addition to the forecasted annual traffic volumes listed in Table 3. The present values of costs and benefits are calculated for both segments and listed in Tables 12 and 13.

Depending on the present value, two economic evaluation techniques are used: the net present value NPV and the benefit cost ratio B/C, which are calculated as follows.

NPV =
$$\sum_{t=0}^{n} \frac{B_t - C_t}{(1+r)^t}$$
, (5)

$$\frac{B}{C} = \frac{\sum_{t=0}^{n} \left((B_t) / (1+r)^n \right)}{\sum_{t=0}^{n} \left((c) / (1+r)^n \right)}.$$
(6)

By using the discount rate of 5%, the calculations revealed that the present value of costs of the second segment is \$7,825,018 and the present value of the benefits is \$58,224,984, while in the third segment, the present value of the costs is \$8,934,609 and the present value of the benefits is \$52,926,493.

Accordingly, the net present value NPV for the second and third segments is \$50,399,966 and \$43,991,883, respectively.

The benefit cost ratio, on the other hand, for the second and the third segments is 7.44 and 5.92, respectively. These results are listed in Table 14.

This means that both segments are economically feasible by far with much preference of the second segment over the third despite the fact that the total benefit in RUC per vehicle in the third segment is much higher than the second one, but the higher annual volume in the second segment makes the difference and produces higher NPV and benefit cost ratio.

A sensitivity check is deemed reasonable in such a study to highlight the economic strength of this project. This check is usually conducted by measuring the effect of the change in a certain factor, while other factors are held constants. The examination here is done by changing two factors. In the first, the traffic annual growth rate is changed from 3% to 1% to see if the reduction in the future annual volume may jeopardize the feasibility of the project. In the second, the discount rate is increased in the order of 5% interval each

TABLE 13: The third segment economic calculations.

Year	Annual volume	Construction cost (\$)	Discount rate 5%	Total benefits (\$)	Discount rate 5%
0		4,325,000	4,325,000		
1		4,325,000	4,119,048		
5	2,073,362	40,175	31,478	3,655,309	2,864,030
10	2,403,594	40,175	24,664	4,237,505	2,601,461
15	2,786,425	40,175	19,325	4,912,430	2,362,963
20	3,230,230	40,175	15,142	5,694,852	2,146,330
21	3,327,137	40,175	14,421	5,865,698	2,105,448
22	3,426,951	40,175	13,734	6,041,669	2,065,344
		Total discounts	8,934,609		52,926,493

TABLE 14: NPV and B/C ratio calculations for second and third segments.

Segment	D.R. (%)	Benefit	Cost	NPV	B/C
	5	58,224,984	7,825,018	50,399,966	7.440875577
	15	24,031,016	7,311,643	16,719,373	3.286677967
Second segment	25	13,152,237	6,977,737	6,174,500	1.884885817
	35	8,489,500	6,720,125	1,769,375	1.263294962
	42.36	6,560,00	6,560,00	0	1.00
	5	52,926,493	8,934,609	43,991,884	5.923761242
Third sogmont	15	21,844,186	8,306,394	13,537,792	2.629803753
mind segment	25	11,955,379	7,912,374	4,043,005	1.510972426
	35.39	7,603,000	7,603,000	0	1.00





FIGURE 7: second segment *B/C* ratio sensitivity to change in growth rate and discount rate.

step until the B/C ratio equals (1) and the NPV equals zero (i.e., to reach the break-even discount rate).

The results showed that the reduction in future traffic volume reduces the NPV in the second segment from \$50,399,966 to \$39,156,109 when the annual growth rate is reduced from 3% to 1%, while, in the third segment, the NPV is reduced from \$43,991,883 to \$33,771,220.

The results also revealed that the second segment breakeven rate is 42.36% while in the third segment it is 35.39%. All these results are illustrated in Figures 7 and 8 for the second and third segments, respectively. These figures may reflect the robustness of the economic feasibility of this project.

FIGURE 8: third segment B/C ratio sensitivity to change in growth rate and discount rate.

6. Conclusions

This research aims to investigate the economic feasibility of establishing a peripheral ring road that encircles the city of Baqubah to decrease the congestion inside the core CBD in the city center and to facilitate a bypass for the through traffic to avoid the congestion. This feasibility study may help the decision maker in the planning process of the project and facilitate monitoring the cost development all over its lifecycle. The new ring road is suggested to follow a predetermined route, which already exists but has not been yet utilized for this purpose. This ring road is composed of three segments orbitally linking the three points of entry leading into the city. The first segment that links the northern with the eastern entries is existing already, while the second links the northern with the southern entries, and the third that links the southern with the eastern entries needs a certain upgrading and reconstruction services to create a four-lane divided roadway to augment the existing portions of the ring road. The traffic volumes are collected and analyzed to determine the peak hour volumes as well as the directional distribution for allocated traffic flows expected to alter their original routes passing through the city to the orbital segments. These traffic flows are converted into annual traffic volumes on each segment and then extrapolated to some 22 years to include two years of constructions and 20 years as the project lifetime. The future projections of traffic volumes on each segment are used to assess the expected benefits in terms of the reduction in RUCs due to the enhancement experienced through the alteration of the old routes inside the city by the new orbital bypasses. The traffic analysis showed that the annual traffic volume expected to utilize the second segment is almost three times that using the third one, mostly due to the existing setting of the road network of the city.

The cost assessment revealed that the highest construction cost would be required for the third segment and the second comes next. The same thing applies for the annual maintenance costs. The expected benefits in terms of reduction in RUCs were found in the third segment about 2.6 as much as that of the second one due to its relatively shorter route path. Yet the annual benefits of the second segment are always higher than the benefits of the third one because of the higher annual traffic volumes.

When a discount rate of 5% is used, the NPV for the second segment was found to be some 15% higher than the NPV of the third segment and the benefit cost ratio for the second segment is about 26% higher than that of the third one. The break-even discount rate for the second segment was proven to be about 20% higher than that of the third segment.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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