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Enhancement of Pavement Condition and Its Impact on Pavement Sustainability: Environmental and Economic Assessments

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Abstract
The cost saving regarding vehicles operation, travel time and road maintenance has one eye-catching benefit via increasing pavement sustainability through maintaining the material sources and reducing the emissions of gases resulted from the processing of derivative products. Furthermore, the rate of increase of traffic on unpaved road is considered as a strong indicator to construct paved roads over this area. In the present paper, the Nasiriya-Abu Ghar road was studied. It is one of the important unpaved roads. Its importance lies in the transport of construction materials from Abu Ghar quarries to the near provinces in Iraq, such as Dhi Qar Province. Abu Ghar quarries are considered as one of the most important quarries because it contains different construction materials such as gravel, limestone and sand. These materials have high engineering properties. Thus, the absence of a paved road linking Abu Ghar quarries with the surrounding areas, especially the province of Dhi Qar, encouraged to conduct a technical and economic feasibility study to highlight it and to help the decision-makers to implement the project. The present study contributes in statement of the economic and environmental feasibility of the construction of a new suggested road over the old unpaved one. The study depends on the hypothesis that the old road has a bad condition while the new one is an asphaltic concrete pavement with a good condition. The manual counting method of traffic volume was used from 7:00 am to 4:00 pm for 7 days to determine the peak hour volume and average daily traffic. Road's construction and maintenance costs were estimated. Saving in the road user costs for both existing (old) and new-suggested roads were calculated to be considered as benefits. The economic study is achieved by comparing the discounted total road costs and their benefits to the basic year (starting year of the project). In the present study, the adopted discount rate is 8%. To find the economic feasibility, some criteria were tested. These criteria are: Net Present Value (NPV), Benefit–Cost Ratio (B/C) and Internal Rate of Return (IRR). The results show that NPV has a positive value equals to 40,269,371 US$, which means that benefits are greater than costs. Furthermore, B/C ratio was 2.54; comparing with a value of 1.0, which is encouraging. Finally, the IRR was located between discount rates of 20% and 25 %, with a value of 22.9% which is higher than 8% "the recommended in the road projects".
Keywords: Pavement Condition, Road User Costs, Economic Feasibility, Benefit –Cost Ratio (B/C), Pavement Sustainability.

1. Introduction

Generally, the cost saving regarding vehicles operation, travel time and road maintenance has one eye-catching benefit via increasing pavement sustainability through maintaining the material sources and reducing the emissions of gases resulted from the processing of derivative products. (Epstein and Buhovac, 2014).

Roads and public transport are important public services that the private sector cannot provide independently of the government.. One of the most important purposes of providing investment for road construction or enhancing the pavement conditions is to raise the level of the economy of the whole country by direct transport of goods, and help in opening up additional areas of entertainment and travel. Furthermore, the landowners will benefit from the new or maintained roads because the surrounding area will be developed accordingly.

The construction of new roads or rehabilitation of existing may enhance the benefit of road users by reducing vehicle operation costs (e.g. fuel consumption, oil consumption, and tires), savings in time, minimizing accidents and increase comfort and ease. On the other hand, the vehicles that use roads lead to clear unsightly results through air pollution and noise. These effects in addition to the bad pavement conditions may cause in exacerbating in the global warming that attributed to the greenhouse effects caused by increased levels of carbon dioxide, chlorofluorocarbons and other pollutants (Gillies et. al., 2005)

From the point of view of the use of resources, it is only possible to achieve the purpose of the invested roads if the net results of them are in the direction of the public interest. In other words, an increase in the cost savings of road users will predominate on the road costs, including some allowance of return of the invested money.

2. Purpose and Objectives of the study

The rate of increase of traffic volume on unpaved road is a strong indicator for the need of construction of a paved road over this area. The Nasiriya-Abu Ghar road is an unpaved road, since its importance in transporting construction materials from Abu Ghar quarries to the provinces of Iraq, especially, the province of Dhi Qar led to an increase in traffic volumes. It is considered one of the most important quarries in the region because it contains construction materials such as gravel, limestone and sand. These materials have high engineering properties. Thus, the absence of a systematic road linking Abu Ghar quarries to the surrounding areas, especially the province of Dhi Qar encouraged researchers to conduct a technical and economic feasibility study to highlight it and encourage decision- makers to implement the project.

The present study contributes in statement of the economic and environmental feasibility of the construction of a new suggested road over the old unpaved one. The study depends on the hypothesis that the old road has a bad condition while the new one is an asphaltic concrete pavement with a good condition.

3. Study area

The studied area is the Nasiriyah-Abu Ghar road. It starts from Expressway No. 1 R7 near Abu Ghar's bridge with a length of 47,872 km. It is parallel to the rail track, which carried out by the German company Dromax during the construction of the expressway (Expressway No.1 / R7) in order to exploit the construction materials from the Abu Ghar quarries .The road passes through some sand dunesand ends with Abu Ghar quarries as shown in Figure (1).

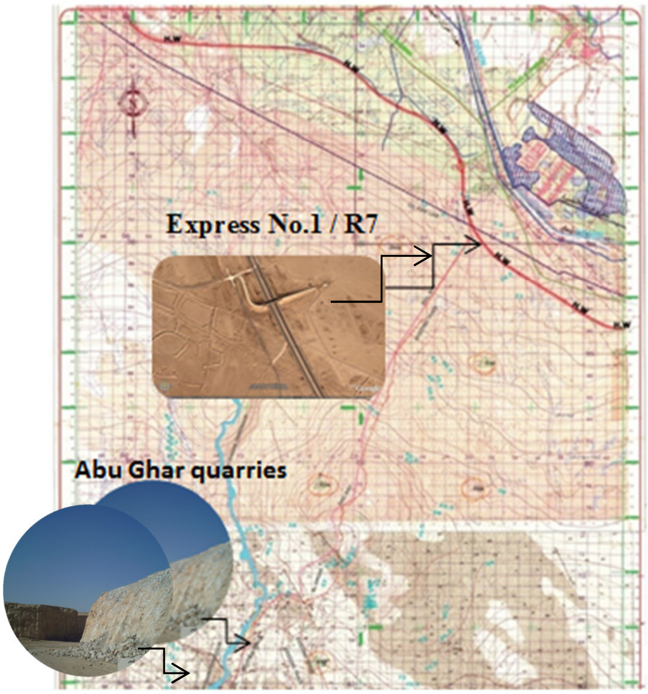

Figure 1. Nasiriyah-Abu Ghar existing road's route

4. Traffic survey and Pavement condition

An important challenge for highway and transportation engineers is to provide data and information in the design of a particular transport system or to determine the efficiency of an existing transport system. This data applies efficient and accurate design standards and achieves the system's goal of transferring efficient and safe transportation to people and goods. This topic is a major part in most researches and studies (Fitzpatrick et.al., 2000).

In the present study, the manual counting method was used from 7:00 am to 4:00 pm and for 7 days to determine the peak hour volume (the highest traffic volume on the existing road during a specific period of time), which represents the design hourly volume in the analysis and calculations of this study. Furthermore, the traffic count has been classified into two main categories: passenger car (PC) and heavy truck (Hv). The peak hour volume was (27) vehicle/ hour, which represents the design hourly volume (DHV). The traffic survey showed that the traffic was classified into 23% passenger cars and 77% heavy trucks. The main types of heavy trucks are Type 3 and Type 3-S2 with 66% and 11%, respectively. In this work, truck Type 3 represents the medium truck (Mt) and truck Type 3-S2 is assumed as the large truck (Lt).

The collected data were analyzed and the anticipated target traffic volume was determined by means of 3%

growth rate with 22 years of analysis period (2 years for road construction and 20 years for design life). The required number of lanes was, then, specified according to the Highway Capacity Manual (HCM) procedures (TRB, 2000). Two-lanes for both directions is suitable to acieve level of service (LOS) (A). The suggested road is classified as A2/13.5 with a lane width of 3.75 meters according to the requirements of the Iraqi specifications (SCRB, 2005).

To determine the annual average daily traffic (AADT), the following equation is used:

AADT=DHV/K ……………………..…………………………………………….. (1)

where:

AADT: annual average daily traffic,

DHV: design hour volume, and

K: (DHV/AADT)*100, in which K=15% for rural road (Garber and Hoel, 2014)

Annual average traffic (AAT) = AADT x 365 ……………………………...………………………. (2)

According to the (ITMP, 2005), and after the reconnaissance survey, the existing road condition is a loose unpaved (bad-very bad pavement condition). The characteristics of this road type are shown in Table (1).

Table (1) Characteristics of the existing road and unit costs (ITMP, 2005)

	IRI [m/km]	Average IRI influence speed [km/h]	Fuel consumption [l/km]	Tyre Life [1000 km]	Oil consumption [l x 1000 km]	Fuel cost [US$/l]	Tyre cost [US$/tyre]	Oil cost [US$/l]	Average number of tyres/vehicle
Passenger Car	14	30	0.157	0.8	7.3	0.035	30	1.75	4
Medium truck	14	27	0.308	0.8	10.34	0.020	200	1.0	8
Large truck	14	21	0.389	0.8	14.5	0.020	200	1.0	16

In addition to the above unit's costs of the vehicle operation, vehicle maintenance cost is taken into account as a 30 % of the vehicle price with 250000 km life for passenger car and 500000 km for heavy trucks. Furthermore, as the suggested car prices are 10000 US$ and 50000 US$ for passenger car and truck vehicle, respectively.

As stated previously, the main aim of the study is to evaluate the economic feasibility of the new-suggested road by calculating benefits resulting from user costs saving (i.e. the differences in costs between the existing and new road conditions) and the costs required to construct the suggested road. As stated in (ITMP, 2005), the type of the new-suggested asphalt pavement can be classified as a good pavement condition, and it has characteristics including a low international roughness index (IRI), as shown in Table (2). In this kind of road condition, the vehicle maintenance costs are assumed equal to15% of the vehicle price with the same vehicle prices stated above (Purdy and Wiegmann, 1987).

Table (2) characteristics of the new road and unit costs (ITMP, 2005)

	IRI [m/km]	Average IRI influence speed [km/h]	Fuel consumption [l/km]	Tyre Life [1000 km]	Oil consumption [l x 1000 km]	Fuel cost [US$/l]	Tyre cost [US$/tyre]	Oil cost [US$/l]	Average number of tyres/vehicle
Passenger Car	4	90	0.073	40.7	2.15	0.035	30	1.75	4
Medium truck	4	70	0.148	40.7	3.67	0.020	200	1.0	8
Large truck	4	55	0.168	40.7	5.75	0.020	200	1.0	16

5. Components of Feasibility Study of Road Projects

The economic feasibility studies of road projects consist of comparing their cost with their revenues (benefits).

5.1 Costs

5.1.1 Construction costs

The major construction costs are earthwork, pavement, bridges, drainage, miscellaneous items and land acquisition (Wolshon, 2001). For roads and bridges, the costs consist of initial construction costs in which the total costs include the engineering work, design, and planning costs. Maintenance cost is another type, which is spent within the service life of the road. Oglesby and Hicks (1982) defined the maintenance as "the observation and keeping of each type of transportation route as nearly as possible in its original condition as constructed or as subsequently improved and the operation of transportation route facilities and services to provide satisfactory and safe transportation."

As mentioned before, the designed class of the suggested road is A2/13.5. In addition, the embankment depth including asphalt concrete and sub-base layers is assumed to be 1.5m. The total construction costs are, then, calculated as shown in Table 3.

Table (3) Estimated costs of the new planned road

	Road construction	Culverts	Design	Total
Cost (US$)	26,819,285	92,160	400,000	27,311,445

It is worth mentioning that the estimates of maintenance costs can be done by reference to the maintenance costs of identical routes. For any proposed highway, the maintenance cost can be assumed on the basis of experiences with existing highways having similar characteristics (Litman, 2009). In the present study, it is assumed that the total road maintenance cost is about 0.8% of the total construction costs (AASHTO, 1987).

5.1.2 Road user Costs

The road user costs (RUCs) consist of vehicle operation costs (VOCs), which increases with low levels of serviceability (e.g. bad road condition, poor maintenance, etc.) and travel time cost (TTC) that spent on the passenger and freight during traveling from origin to destination.

5.1.2.1 Vehicle operation costs (VOC)

In the present study, the main calculated VOCs are fuel, lubricants and tyre costs. It is worth reminding that these costs are not considering all the items that are normally included in the vehicle operating costs, but only those deemed to be the more perceivable ones by the user.

Fuel consumption is generally regarded as a significant component of VOC and influenced by several factors such as vehicle characteristics, road condition and alignment, traffic volume and driving style. Since the fuel unit cost in Iraq is very low at the present time, the related cost is not predominant like in other situation. However, this condition can be suddenly changed in future due to the policy of road user charging.

The total costs per kilometer of the existing (old) road and for all types of surveyed vehicles are demonstrated in Table (4). Similarly, Table (5) shows the total costs per kilometer of the new-suggested road. It is noticeable that the average total costs for the existing (old) road (ATCE) are dramatically decreased as a result of improving the road condition that represented by the new-suggested road. The results show a decrease in average total vehicle costs from 1.837903(US$/vehicle-km) to 0.055034(US$/vehicle-km) for old road and new road, respectively. This reduction will be use later as benefits.

Table (4) Perceived vehicle operation costs per kilometer of the existing road

	Fuel Cost (US$)	**Tyre Cost (US$/km)**	**Oil Cost (US$/km)**	**Vehicle maintenance cost (US$/km)**	**Total Costs (US$/km)**	**Vehicle %**	**Average Total Costs (US$/vehicle-km)**
Passenger Car	0.0054	0.15	0.0127	0.012	0.1802	23	0.0414
Medium truck	0.0061	2	0.0103	0.03	2.0465	66	1.3506
Large truck	0.0077	4	0.0145	0.03	4.0522	11	0.4457
						∑ Costs	**1.8379***

* The average total costs of the existing road (ATCE)

Table (5) Perceived vehicle operation costs per kilometer of the new-suggested road

	Fuel Cost (US$)	**Tyre Cost (US$/km)**	**Oil Cost (US$/km)**	**Vehicle maintenance cost (US$/km)**	**Total Costs (US$/km)**	**Vehicle %**	**Average Total Costs (US$/vehicle-km)**
Passenger Car	0.0025	0.0029	0.0037625	0.006	0.0152	23	0.0035
Medium truck	0.0029	0.0393	0.00367	0.015	0.0609	66	0.0402
Large truck	0.0033	0.0786	0.00575	0.015	0.1027	11	0.0113
						∑ Costs	**0.0550****

** The average total costs of the new road (ATCN)

Figure (2) presents an increase in tyre costs compared with oil and fuel costs regarding vehicle operating costs. It is clear to note that the tyre costs as a percentage of VOC ranging between 82% and 97% for PC and Hv, respectively. Figure (3) illustrates the VOCs for old and new-suggested roads. The figure demonstrates that the VOCs in the old road are, usually, higher than that in the new road. Furthermore, the VOCs of Mt has the largest operating costs of about 72%. This may be attributed to the high volume of traffic of Mt, which reaches to about 66%.

5.1.2.2 Travel time cost (TTC)

Most of the proposed highway improvements affect the increase in travel speed, thereby resulting in appreciable time saving for the driver and passengers they are travelling on the existing routes. Some scholars consider this time saving as intangible costs and would not include them in tangible costs. There are others who determine its value in terms of the costs of driving an extra distance in order to save time (Litman, 2009). However, in the present study, the travel time cost of passenger and freight are assumed 1.2752 US$/hour-passenger and 0.0184 US$/hour-ton, respectively (ITMP, 2005). In addition, the average vehicle occupancy rate (VOR) in a passenger car is assumed 2 persons versus 1.5 persons for heavy vehicles. The travel time needed to drive on the old and new-suggested roads can be calculated by the following relation:

$$\text{Travel time (hour)} = \frac{\text{road length (km)}}{\text{speed(km/hour)}} \quad \ldots\ldots\ldots\ldots (3)$$

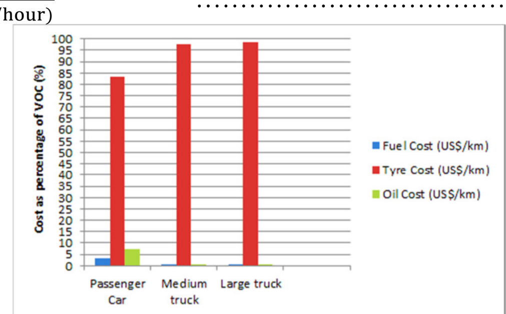

Figure (2) Costs of the vehicle operating components for different vehicles

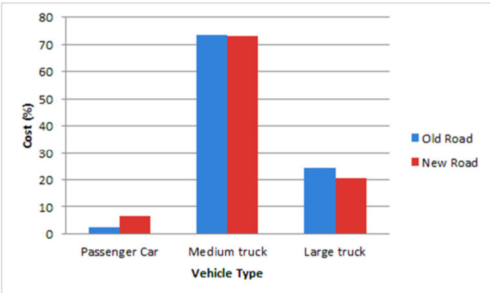

Figure (3) Vehicle operating costs of old and new-suggested roads for different vehicles

Tables 6 and 7 illustrate the average travel time costs of old (existing) and new roads respectively with taking in to account the passengers and freights that are transported. It is clear that the travel time costs of the existing (old) road is significantly minimized due to diminishing the time spent by increasing the traveling speed that is gained from enhancing of the road condition. The results states that the travel time costs are 4.443904 (US$/vehicle) and 1.66243 (US$/vehicle) for the old and new roads respectively. As a result, benefits obtained from travel time costs reduction (saving) can be added to the benefits of vehicle operation, which is determined before.

Table (6): Average travel time costs of the existing road

	Average IRI influence speed [km/h]	**Travel time (h)**	**Person per vehicle**	**Ton per vehicle****	**Travel time costs (US$)**	**Vehicle %**	**Travel time costs (US$/vehicle)**
Passenger Car	30	1.592733	2	0	4.062107093	23	0.934285
Medium truck	27	1.769704	1.5	27	4.264278044	66	2.814424
Large truck	21	2.275333	1.5	47	6.319965867	11	0.695196
						∑ Costs	**4.443904**

** Legal gross weight permitted on motor vehicle in regular operation in Iraq (SCRB, 2005)

Table (7): average travel time costs of the new-suggested road

	Average IRI influence speed [km/h]	Travel time (h)	Person per vehicle	Ton per vehicle**	Travel time costs (US$)	Vehicle %	Travel time costs (US$/vehicle)
Passenger Car	90	0.53	2	0	1.354035698	23	0.311428
Medium truck	70	0.68	1.5	27	1.64479296	66	1.085563
Large truck	55	0.87	1.5	47	2.413077876	11	0.265439
						∑ Costs	**1.66243**

** Legal gross weight permitted on motor vehicle in regular operation in Iraq (SCRB, 2005)

6. Benefits

As mentioned previously, the reductions (saving) of vehicle operation costs in addition to the travel time costs are positively transferred to benefits.

6.1 Benefits due to VOCs saving

Figure (4) shows saving in vehicle operating costs resulting due to the improvement in the old road condition. In the present study, the benefit of VOCs is 1.782 (US$/vehicle-km). Consequently, the total benefit is 85.18(US$/vehicle) for the 47.781 km road length.

6.2 Benefits due to TTC saving

Undoubtedly, the improvement of pavement condition leads to easy and fast movement from one point to another and, consequently, the travel time will be shortened. As mentioned before, the saving in the travel time costs, in both passengers and freights, can be transferred to benefits. The average total benefit is 2.78 (US$/vehicle) as shown in Figure (5).

Finally, the total benefit regarding the saving of vehicle operating cost (VOC) and the saving of travel time costs (TTC) is summed to be 87.96 (US$/vehicle). This benefit is included when the economic feasibility is prepared.

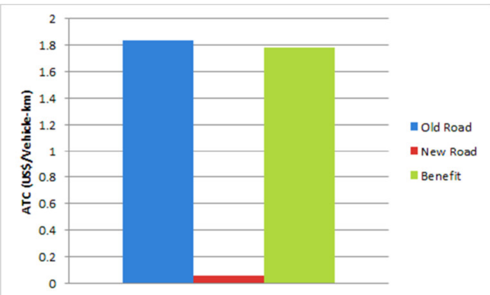

Figure (4) Benefits resulting from vehicle operating costs saving between old and new-suggested road

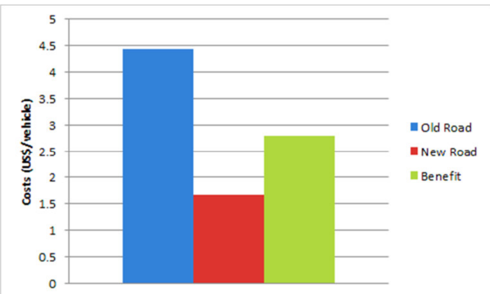

Figure (5) Benefits resulting from travel time costs saving between old and new-suggested road

6.3 Salvage value

Other benefits that can be included in the economic studies are the salvage value of structures, which may be used for longer age than road life. The remaining value of bridges and culverts in the event of road life (after the end of the design age of the road) should be considered as benefits (salvage value). The design age of steel, concrete, and composite bridges is 120 years beside 50 years with respect to concrete culverts (BS 4500), which is more than the design age of the flexible pavement (20 years), as a condition of timely-adequate periodic maintenance. Thus, 75% and 60% of the bridge and culvert construction costs should be taken as a salvage value.

7. Economic evaluation

In this paper and after adopting a discount rate, the economic study is achieved by comparing the discounted total road costs and their benefits to the basic year (starting year of the project). For road projects, the discount rate is 8% (Zhuang et. al., 2007).

Then, some economic criteria should be found to show if the construction of the project is economically feasible or not. These criteria can be summarized as follows:

1- Net Present Value (NPV). It is the difference between the sum of the discounted benefits and the discounted costs. The greater the difference, the better the project is.

2- Benefit –Cost Ratio (B/C). It is the ratio of the discounted benefits and the discounted costs. The project is regarded more feasible if this ratio exceeds 1.0.

3. Internal Rate of Return (IRR). It is the amount of the discount rate in which the discounted costs and the discounted benefits are equal. The greater the difference from the minimum attractive rate of return (MARR= 8%) as discount rate, the more feasible project is.

The present worth (PW) of costs or benefits at future times are discounted. The PW method involves the discounting of all future sums to the present. As mentioned above, the discount rate adopted in the present study is8%. The PW factor for discounting either a future single cost or benefit is calculated by Equation (4).

$$P=F\left(1/(1+i)^{n}\right) \qquad (4)$$

where:

P: discounted present value of costs or benefits

F: future value of costs or benefits

n: years from the basic year (now)

i: discount rate

The average annual traffic (Equation 2) and their future traffic by using 3% traffic growth rate are calculated to find the total annual benefits that saved from reducing the vehicle operation and travel time costs. In addition, the road construction cost is divided into two years. The sum of the discounted present worth for future benefits and costs at different discount rates are found as illustrated in Tables (8 and 9), respectively. As mentioned earlier, the economic study is achieved by comparing the benefits and costs with a specific discount rate (e.g 8% for road projects) via economic parameters (NPV, B/C ratio, and IRR). The results show that NPV has a positive value equals to 40,269,371 US$, which means that the benefits are greater than costs. Furthermore, B/C ratio of 2.54 comparing with a value of 1.0 is an encourage value. Finally, the IRR is located between discount rates of 20% and 25 %, with a value of 22.9% which is higher than that recommended in the road projects (8%). Table (10) demonstrates the economic criteria calculated to find the feasibility of construction of a new road.

Table (8): Discounted benefits with different discount rates

Year	Future Traffic (vehicle/year)	Total Benefits (US$)	DR* 8%	DR 12%	DR 15%	DR 20%	DR 25%
0	65700	0	0	0	0	0	0
1	67671	0	0	0	0	0	0
2	69701	0	0	0	0	0	0
3	71792	6327115	5022668	4503515	4160181	3661525	3239483
4	73946	6516928	4790137	4141626	3726075	3142809	2669334
5	76164	6712436	4568371	3808816	3337267	2697577	2199531
6	78449	6913809	4356872	3502751	2989030	2315421	1812414
7	80803	7121223	4155165	3221280	2677132	1987403	1493429
8	83227	7334860	3962797	2962427	2397779	1705854	1230585
9	85724	7554906	3779334	2724375	2147576	1464191	1014002
10	88295	7781553	3604365	2505452	1923481	1256764	835538
11	90944	8014999	3437496	2304121	1722770	1078723	688483
12	93672	8255449	3278353	2118968	1543003	925904	567310
13	96483	8503113	3126577	1948694	1381994	794734	467464
14	99377	8758206	2981828	1792103	1237786	682147	385190
15	102358	9020952	2843780	1648094	1108625	585509	317397
16	105429	9291581	2712124	1515658	992943	502562	261535
17	108592	9570328	2586563	1393864	889331	431366	215505
18	111850	9857438	2466814	1281857	796531	370256	177576
19	115205	10153161	2352610	1178851	713415	317803	146322
20	118662	10457756	2243693	1084122	638972	272781	120570
21	122221	10771489	2139818	997005	572297	234137	99349
22	125888	11094634	2040753	916888	512579	200967	81864
		SV**=0.6 Culverts	10171	4570	2555	1002	408
		Total Discounted Benefits	**66460287**	**45555036**	**35471318**	**24629432**	**18023287**

*DR: discount Rate , ** SV: Salvage value

8. Environmental evaluation

To find the equivalent pavement condition index (PCI), which is based on the IRI, the following equation has been used (Arhin et. al., 2015):

$\log(\mathrm{PCI}) = 2 - 0.43\log(\mathrm{IRI})$ ……………………………………………………..……….(5)

Table (9): Discounted costs with different discount rates

Year	Total Costs	DR 8%	DR 12%	DR 15%	DR20%	DR 25%
0	0	0	0	0	0	0
1	13655723	12644188	12192609	11874541	11379769	10924578
2	13655723	11707581	10886258	10325688	9483141	8739662
3	218492	173446	155518	143662	126442	111868
4	218492	160598	138855	124923	105368	89494
5	218492	148702	123978	108629	87807	71595
6	218492	137687	110695	94460	73172	57276
7	218492	127488	98834	82139	60977	45821
8	218492	118044	88245	71425	50814	36657
9	218492	109300	78790	62109	42345	29325
10	218492	101204	70348	54008	35288	23460
11	218492	93707	62811	46963	29406	18768
12	218492	86766	56081	40838	24505	15015
13	218492	80339	50073	35511	20421	12012
14	218492	74388	44708	30879	17018	9609
15	218492	68878	39918	26851	14181	7687
16	218492	63776	35641	23349	11818	6150
17	218492	59051	31822	20304	9848	4920
18	218492	54677	28413	17655	8207	3936
19	218492	50627	25368	15352	6839	3149
20	218492	46877	22650	13350	5699	2519
21	218492	43405	20223	11609	4749	2015
22	218492	40189	18057	10094	3958	1612
	Total Discounted Costs	**26190917**	**24379896**	**23234340**	**21601772**	**20217130**

Table (10): Economic parameter values of the present study

Economic parameters	Value
NPV $_{[8\%]}$ (US$) =	40269371
B/C Ratio $_{[8\%]}$ =	2.54
IRR (%) =	22.90

where:
PCI: pavement condition index, and
IRI: international roughness index

As pointed out before, the existing (old) road condition is bad to very bad with approximately IRI value of 14 m/km versus 4 m/km for the new-suggested road. By using the above equation, the anticipated PCI will be (31) and (55) for the old and new roads, respectively.

Another factor that should be considered within the feasibility studies of pavement construction is the increase in combustion of fossil fuels in the last century. This parameter is responsible for the progressive change in the atmospheric composition. Furthermore, air pollution has both acute and chronic effects on the health of humans. The effects range from minor upper respiratory irritation to chronic respiratory and heart disease, lung cancer, acute respiratory infections in children and chronic bronchitis in adults, aggravating pre-existing heart and lung disease, or asthmatic attacks. In the present work, and depending on the pavement condition of the old and new suggested roads, several vehicle emissions such as Carbon monoxide (CO), Carbon dioxide (CO2), nitrogen oxides (NO2), and Sulphur dioxide (SO2) are estimated by utilizing the equations below (Setyawan and Kusdiantoro, 2015), which are based on the PCI. Table (11) shows the vehicle emission of the old and new-suggested roads which has a good condition, in which decreases in total emissions are found. The average reduction in emission is 1.13% as a result of improvement of the pavement condition.

CO Emission (g/km/hour) = 0.1564(PCI)2-24.655(PCI)+21746……………………..………………… (6)
NO2 Emission (g/km/hour) = 0.0025(PCI)2-0.4451(PCI)+495.81…………………………..………… (7)
SO2 Emission (g/km/hour) = 0.00003(PCI)2 - 0.0047(PCI) + 4.4169…………………………...….. (8)
CO2 Emission (g/km/hour) = 9.4609(PCI)2 - 1573.6(PCI) + 2000000…………………….….…...... (9)

Table (11): Anticipated vehicle emissions of old and new-suggested roads

	Old Road	New Road	Reduction %
CO (g/km/hour)	21131.9954	20863.085	-1.27252725
NO_2 (g/km/hour)	484.4144	478.892	-1.140015656
SO_2 (g/km/hour)	4.30003	4.24915	-1.183247559
CO_2 (g/km/hour)	1960310.325	1942071.223	-0.930419137

9. Sensitivity analysis

Sensitivity analysis is used to explore what happens to a project's profitability when the estimated values of study factors are changed. For example, if the annual expenses turn out to be 10% higher than expected, will the project still be acceptable?

Sometimes sensitivity is specifically defined to mean the present change in on or more factors that will reverse a decision among project alternatives or reverse a decision about the economic acceptability of single project.

Another useful sensitivity tool is to measure the impact of changing a single factor estimate on the equivalent worth of project call other values were held constant. We are often concerned about the combined effect of changes in two or more project-factors.

9.1 Effect of increasing fuel unit price on the VOC saving

In the future, if the fuel cost factored to 10 times with the stability of the remaining vehicle operating components (oil and tyre), the saving in VOCs decreased, but at last stills in the positive side as shown in the figure (5).

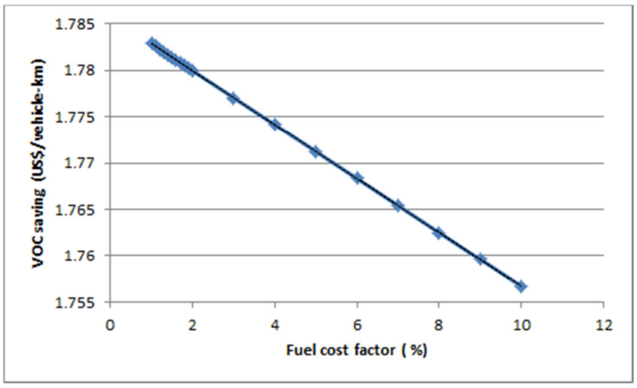

Figure (5): Impact of increasing fuel cost on the VOC saving

9.2 Effect of discount rate on the recovered benefits

The IRR method is the most widely used rate-of-return method for performing engineering economic analysis. It is sometimes called the discounted cash flow method. This method solves for the interest rate that equals the equivalent wort of project cash inflow (receipts or saving) to the equivalent worth of cash outflows (expenditures, including investment costs). The resultant interest rate is termed the internal rate of return (IRR).The (IRR) sometimes referred to as the breakeven interest rate (8%=MARR) as shown in figure (6). Also figure (6) shows the effect of different values of discount rate (i.e. 8% to 25%) on the balancing between inflow (benefits) and outflows (costs).the positive value of the discount accumulated net cash flow refer to acceptable project.(IRR decision rule: if IRR> MARR, the project is economically justified).

9.3 Effect of traffic growth factor and construction costs on the B/C ratio

Figure (7) shows the feasible area (i.e. B/C > 1) at which the project will consider as acceptable one. The range of (1≤B/C<2.5) depending on the decrease or increase of the traffic growth rate versus the increase of the reconstruction costs.

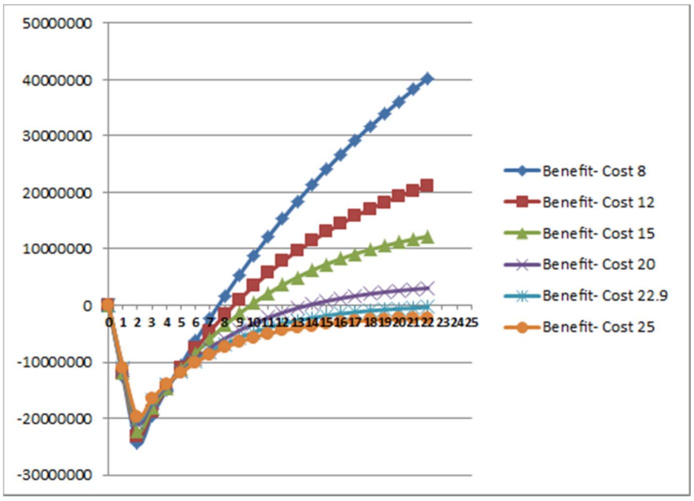

Figure (6): Effect of discount rate on the recovered benefits of the study project

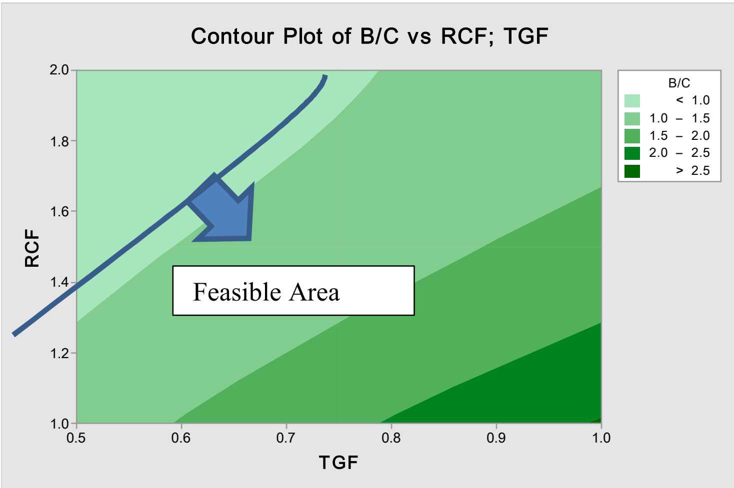

Figure (7): Effect of decreased traffic growth rate and increased reconstruction cost on the B/C ratio of the study project

10. Conclusions

In the present study, efforts were made to evaluate the economic feasibility of construction a new road over an existing road which has a bad condition. The following conclusions were drawn:

- The road user costs dramatically decreased as a result of improving the road condition. Regarding VOC, it is reduced from ((1.837903 US$/vehicle-km) or (87.816 US$/vehicle)) to ((0.055034 US$/vehicle-km) or (2.63 US$/vehicle)) for old and new-suggested roads, respectively.
- With respect to travel time costs, similar trend was found, in which the results stated that the travel time costs are 4.443904 (US$/vehicle) and 1.66243 (US$/vehicle) for the old and new roads respectively.
- The total saving (reduction) in the vehicle operating costs (VOCs) and saving in the travel time costs (TTCs) is 87.96 (US$/vehicle), which is considered as benefits.
- Regarding the economic criteria, the results show that NPV has a positive value equals to 40,269,371 US$ which implies that benefits are greater than costs. Furthermore, B/C ratio was 2.54, comparing with a value of 1.0, which is an encourage value. Finally, the IRR was located between discount rate of 20% and 25 %, with a value of 22.9%, which is higher than that recommended in the road projects (8%).
- Several vehicle emissions such as Carbon monoxide (CO), Carbon dioxide (CO2), nitrogen oxides (NO2), and Sulphur dioxide (SO2) were reduced due to the enhancement in pavement condition, which improves the regularity and encourages rising the driving speeds.
- In terms of sensitivity analysis, several parameters such as traffic growth rate, road construction cost, and discount rate were tested. It was concluded that if the estimated traffic growth rate will be negatively factored to 50 %, the suggested project will be still beneficial in the case that other parameters are unchanged. Moreover, even if the road construction cost increased to 200%, without any changes in other variables, the project remains serviceable.

11. Recommendations

In addition to the above results of promising economic feasibility, there are many planning and economic indicators that support the construction of the road. These indicators are mainly related to strategic planning goals in terms of spatial development, based on what can be achieved from indirect economic benefits and social benefits that are difficult to evaluate within the overall sustainable development approach to reduce spatial disparities and create local development components in the different regions, especially those that contain development funds in order to activate them to serve their communities. These goals were linked to the proposed project in three aspects:

1- The economic basis for the stability of the road area and the expected traffic.
2- Proposed road and urban stability in desert areas.
3- Spatial structure and transport network.

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