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FORMULATION OF THE COST FUNCTION FOR CONSTRUCTING A NEW TRANSPORTATION ROUTE

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ABSTRACT

A principal objective of transportation route design is to minimize the total cost including all significant components. The cost functions for a highway, which is developed in this study, have been incorporated into programmed software named Transportation Route Cost Analysis (TRCA) using VBASIC Language. These functions reflect the costs due to different cost function characteristics such as Administrative Cost, Construction Cost, Maintenance Cost, User Costs, which include: (Tire Cost, Oil Cost, Fuel Cost, Travel Time Cost and Accident Cost) and finally Social and Environmental Costs, while most existing models in Iraq only considered Construction Cost, or even just one component such as earthwork cost. A case study is also presented to evaluate the modeled software of a highway having a length (12.644) km including a bridge crossing Tigris River of length (420) m with three intersections. According to the State Corporation for Roads and Bridges (SCRB), the gross domestic product is about (60,000,000,000) ID. This value is greater than the value obtained by the software (TRCA) because of the elimination of Accident Cost since no information regarding this type of cost is available in (TRCA), also, the duration of each cost considered in this program is only one year.

Keywords: cost function, highway, planning, route design, transportation engineering, economic analysis.

1. INTRODUCTION

Transportation alignment is a very complex process. The selection of a route for any transportation route should take into account topography, soil conditions, socioeconomic factors, environmental impacts, construction, operation and maintenance costs. To arrive at the optimum route, these factors can be considered through a cost function. Traditionally, most regional transportation planning has involved the generation of land use forecasts, usually based on state wide projected econometric forecasts, which then are combined with anticipated transportation networks with any discrepancies noted and possibly corrected before finalizing the projections.

The most frequently used criteria in transportation economic analysis are the costs or savings associated with alternatives. Garmo and Canada (1973) reported that most engineering projects could be carried out by more than one alternative.

According to Winfrey (1968), and Wright *et al.*, (1998), the major cost components of transportation route can be classified into several categories:

a) Planning, Design and Administrative Costs (consulting and supervision costs).
b) Construction Costs (earthwork, pavement, right of way).
c) Operation and Maintenance Costs (pavement, mowing, lighting).
d) User Costs (Vehicle operating costs, Travel time Costs and Accident costs).
e) Social and Environmental costs (noise, air pollution, water pollution).

Transportation alignment design is a complex but repetitive process. Designers must select an economical path based on topography, soil conditions, socioeconomic factors and environmental impacts, such as air pollution and noise. In designing a transportation, the traditional process consists of a series of phases, starting from a broad area, then narrowing down to several possible transportation corridors, finally focusing on detailed alignment designs in the selected corridors, including horizontal and vertical alignments.

2. OBJECTIVES OF THE RESEARCH

The most frequently used criteria in transportation economic analysis are the cost or savings associated with the alternatives. Optimal alignment is influenced by many factors and should be based on various supplier and User Costs component.

Previous works on the selection of route alignment usually have neglected some important components of the total cost function that should influence the optimal solution.

3. FORMULATION OF THE COST FUNCTION FOR A TRANSPORTATION ROUTE

3.1 Planning, design and administrative costs

The Commission's Better regulation strategy is aimed at measuring administrative costs and reducing administrative burdens. However, an assessment based on an extrapolation of Dutch data suggests that Administrative Costs may amount to circa 3.5% of GDP (Gross Domestic Product) in the EU (COM, 2006).

$$A=0.035*GDP \quad \text{..... (1)}$$

where:

A=Administrative Cost in $.
GDP=Gross Domestic Product.

3.2 Construction cost

The major Construction Costs are earthwork, pavement, bridges, drainage, miscellaneous items and land acquisition (Jong and Schonfeld, 1998). Hay (1977) reported that for urban expressways and rapid transit, the construction costs are almost without meaning because of the mile-to-mile variation due to local conditions and land values. Such costs can be exceedingly high.

Construction Cost can be expressed according to the following equation:

$$C = c * L \qquad \text{..... (2)}$$

where:

C= Total Construction Cost in \$.
c= Construction Cost in \$/km.
L= Length of highway in km.

3.3 Maintenance cost

Roberts and Suhbier (1971) defined the transportation route maintenance as "the preserving and keeping of route facilities as nearly as possible, in their original conditions and the operation of these facilities so as to provide satisfactory service and safe transportation. 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". The AASHTO (1987) defined transportation route maintenance as "a program to pursue, repair and restore a system of roadways with its elements to its designed or accepted configuration".

For the purpose of this study it was assumed that the total maintenance cost is about 0.8% of GDP.

$$M = m * GDP \qquad \text{.....(3)}$$

where:

M= Maintenance Cost in \$.
m= Maintenance Cost rate.
GDP=Gross Domestic Product.

3.4 User costs

Route deviation will however cause inconvenience to the transit riders because of increased ride time. The larger the deviation or slack time is the higher the inconvenience will become. Such inconvenience could even lead to loss of transit riders when it exceeds a certain amount. It is therefore necessary to consider this consequence in designing a flex-route service. The inconvenience resulting from route deviation is modeled as a user cost which is assumed to be a function of the increase in transit rider travel time (Δ) (Fu, 2002) as follows:

$$C^u = N_t \,.\, c_t \,.\, \Delta^r \qquad \text{..... (4)}$$

where

C^u = User Costs
N_t = average number of transit riders for each flex-route trip from Stop A to Stop B,
Ct = cost coefficient that can be calibrated on the basis of passenger attitude toward increased ride time, and
r = model parameter representing transit rider sensitivity to deviation time.

In this study, assuming r=1, and consequently the corresponding cost coefficient c_t can be considered as the value of time of the transit riders.

A threshold is used to consider the maximum allowable deviation as follows:

$$\frac{\Delta}{T_0} \le \beta \text{ or } \Delta \le T_0 \beta \qquad \text{.... (5)}$$

where:

β is the maximum allowable deviation ratio.

For the paratransit riders, the quality of service provided by flex-route service and paratransit service is assumed to be similar and no user cost is therefore considered in this analysis (Fu, 2002).

3.4.1 Fuel cost

Besides the geometric feature of a route, such as curvature, gradient and the length of the alignment, the relations between user costs and alignment configuration are linked by the average running speed. For this purpose, Jong and Schonfeld (1998) presented the following linear regression equation:

$$\overline{V} = 55.124 - 0.0363\overline{C} - 0.0332\overline{H} - 0.0081 G_N - 0.0137t - 2.437\overline{D} - 0.1678Q \qquad \text{..... (6)}$$

where:

$\overline{V}$ = average running speed (mile/hr).
$\overline{C}$ = average curvature (degrees/mile).
$\overline{H}$ = average hillness (ft/mile).
G_N = net gradient (ft/mile).
t = truck factor indicating the percentage of heavy vehicles in the traffic stream.
$\overline{D}$ = direction factor indicating the directional distribution of traffic (decimal fraction).
Q = hourly one-way traffic volume (vph).

Jong and Schonfeld (1998) presented the following model, which is used for computing the fuel cost:

$$C_F = \begin{bmatrix} C_F^B\left(G, L_n, \overline{V}_{pp}, \overline{V}_{pn}, \overline{V}_0\right) + \\ C_F^B\left(-G, L_n, \overline{V}_{pp}, \overline{V}_{pn}, \overline{V}_0\right) \end{bmatrix} \left[\frac{e^{(r_1-\rho)^{ny}} - 1}{(r_1 - \rho)} \right] \qquad \text{..... (7)}$$

where:

C_F = net present worth of total fuel consumption cost (\$/year).
ρ = assumed interest rate (decimal fraction).
G = grade of road section (%).

L_n = total length of the alignment (feet).
r_1 = annual growth rate of Annual Average Daily Traffic (AADT).
n_y = analysis period.
C_F^B = fuel consumption cost for traffic in one direction in the base year ($/year) and is given as:

$$C_F^B\left(G, L_n, \overline{V}_{pp}, \overline{V}_{pn}, \overline{V}_0\right) = Q_{pp}\left(154.5H_p\right) \frac{L_n}{5280*1000}\left[T.F\left(G, \overline{V}_{pp}\right)\right] + Q_{pn}\left(154.5H_p\right)\frac{L_n}{5280*1000}\left[T.F\left(G, \overline{V}_{pn}\right)\right] + Q_0\left(6570 - 309H_p\right)\frac{L_n}{5280*1000}\left[T.F\left(G, \overline{V}_0\right)\right]$$

$$C_F^B\left(-G, L_n, \overline{V}_{pp}, \overline{V}_{pn}, \overline{V}_0\right) = Q_{pp}\left(154.5H_p\right) \frac{L_n}{5280*1000}\left[T.F\left(-G, \overline{V}_{pp}\right)\right] + Q_{pn}\left(154.5H_p\right)\frac{L_n}{5280*1000}\left[T.F\left(-G, \overline{V}_{pn}\right)\right] + Q_0\left(6570 - 309H_p\right)\frac{L_n}{5280*1000}\left[T.F\left(-G, \overline{V}_0\right)\right] \quad \text{..... (8)}$$

T = vector of traffic composition for medium car given by:

$$T = \begin{bmatrix} (1-t) \\ P_{2A}t \\ P_{3S}t \end{bmatrix} \quad \text{.....(9)}$$

$$F(G, \overline{V}) = \begin{bmatrix} U_g F_{MC} \\ U_g F_{2A} \\ U_d F_{3S} \end{bmatrix} \quad \text{.....(9.1)}$$

where:

$\overline{V}_{pp}$= average running speed in the peak period and prevalent direction (mile/hr).
$\overline{V}_{pn}$= average running speed in the off-peak period (mile/hr).
$\overline{V}_o$ = average running speed in the peak period and non-prevalent direction (mile/hr).
U_g = Unit prices for gasoline.
U_d = Unit prices for diesel fuel.
F_{MC} = fuel consumption (gallons/1000 miles) for medium car.
F_{2A} = fuel consumption (gallons/1000 miles) for 2-axle single unit trucks
F_{3S} = fuel consumption (gallons/1000 miles) for 3-axle semi trailers.
P_{2A} = Percentage of 2-axle single unit trucks in the heavy truck stream
P_{3S} = Percentage of 3-axle semi trailers trucks in the heavy truck stream
H_p = number of peak hours per day (hours)
Q_{pp}, Q_{pn}, and Q_o= hourly volume (vph) in the peak prevalent direction, peak non-prevalent direction and other direction in non-peak periods respectively.

3.4.2 Tire cost

Tire Cost has been estimated using the following expression (ITMP 2005)

$$TL = 166.47 - 31.83 * \ln(13 * IRI) \quad \text{..... (10)}$$

where:

TL = Tire life in thousands of km
IRI = the Index of Roughness [m/km]
$TC = sum\ (TC_{passenger\ cars} + TC_{large\ cars})$
*TC= (TL*no. of passenger cars*no. of tires*price of the tire) + (TL* no. of large cars * no. of tires *HV* price of the tire)* ... (11)

where:

TC=Tire Cost in $.

Further assumptions have been made for number of tires per vehicle: 4 for passenger vehicle, 8 for medium trucks and 16 for large trucks.

3.4.3 Oil cost

Oil Cost has been estimated using the following expression (ITMP 2005):

$OC=a_0+a_1*IRI$ ... (12)

where:

OC = Oil Consumption in liter x thousands of km
IRI = International Roughness Index (m/km) (the original formulation was considering the *RI*, an adjusted *IRI* for low roughness pavement of less than 3; this is not applicable in our case since considering an average IRI equal to 4 for the best case).
a_0 and a_1= experimentally generated regression coefficients given in Table-1:

Table-1. Coefficient by type of vehicle (Oil Consumption) (ITMP 2005).

Types of vehicle	a_0	a_1
Passenger car	1.55	0.15
Medium car	3.07	0.15
Large truck	5.15	0.15

3.4.4 Travel time cost

Most of the proposed highway improvements affect the increase in travel speed, thereby resulting in appreciable time saving for the driver and the passengers over travel on 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 extra distance in order to

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save time (Sharma, 1985). However, the travel time cost can be computed using the following relation (Jong and Schonfeld, 1998):

$$C_T = C_B^T\left(L_n, \overline{V}_{pp}, \overline{V}_{pn}, \overline{V}_0\right)\left[\frac{e^{(r_1-\rho)ny}-1}{(r_1-\rho)}\right] \quad \text{..... (13)}$$

where:

C_T = net present value of total travel time costs ($/year)

C_B^T = Total travel time cost for two-way traffic in the base year and given as:

$$C_B^T\left(L_n, \overline{V}_{pp}, \overline{V}_{pn}, \overline{V}_0\right) = Q_{pp}\left(309H_p\right)\frac{\left(L_n/5280\right)}{\overline{V}_{pp}}\left(T.v\right) + Q_{pn}\left(309H_p\right)\frac{\left(L_n/5280\right)}{\overline{V}_{pn}}\left(T.v\right) + Q_0\left[2\left(6570-309H_p\right)\right]*\frac{\left(L_n/5280\right)}{\overline{V}_0}\left(T.v\right) \quad \text{..... (14)}$$

where:

v = vector of unit travel time values for medium car which is given as follows:

$$v = \begin{bmatrix} v_{MC} \\ v_{2A} \\ v_{3S} \end{bmatrix} = \begin{bmatrix} 9 \\ 21 \\ 25 \end{bmatrix} \quad \text{..... (15)}$$

v_{MC}, v_{2A}, and v_{3S}= unit values of travel time for medium car, 2-axle single unit trucks and 3-axle semi trailers trucks respectively.

H_p= peak hour per day (hours).

People in developed countries spend an average of about one hour a day in motor vehicle travel. Valuing travel time at $8 per hour indicates an average per capita travel time cost of about $3000 per year (TDM, 2002).

3.4.5 Accident cost

Aiming to estimate the economic costs of traffic accident in Jordan, Al-Masaeid, *et al*., (1999) suggested the following mathematical model for road accident costs in Jordan:

$$U_{ci} = R1_i * UD + R2_i * UIs_i + R3_i * UI_{mi} + R4_i * UI_{si} + R5_i * UP_I + UPO_i + R5 * UA_i \quad \text{........ (16)}$$

where:

U_{ci} = average cost of an accident of severity level i.
$R1_i$....$R4_i$= number of involved persons per accident for each casualty class and accident severity level i.
R5= number of involved vehicles per accident of severity level i.
UD= unit cost of a death.
UIs_i= unit cost of person with serious injury for accident severity level i.
UI_{mi}= unit cost of person with medium injury for accident severity level i.
UI_{si}= unit cost of person with slight injury for accident severity level i.
UP_i= unit cost of property damage for accident severity level i.
UPO_i= unit cost of police activities for accident severity level i.
UA_i= unit cost of insurance administration for accident severity level i.
i = accident severity level (Fatal, Injury, and property damage only PDO).

Al-Masaeid *et al*., (1999) concluded that the average unit cost of each type of casualties in Jordan could be stated as shown in Table-2. Shepherd and Lowe (1982) recommended an exponential model to relate number of accidents with roadway elements and traffic operation features in the following form:

$$Y = \exp\left(a_0 + a_1 x_1 + a_2 x_2 + \ldots + a_i x_i + a_p \log(\text{flow})\right) + E \quad \text{....(17)}$$

where:

Y = number of accidents per million vehicle kilometers.
x_i = Independent variable related to traffic and geometric features, and other conditions.
a_i = calibration coefficient.
flow = volume of traffic.
E = a random error term.

The exponential model is suggested because the occurrence of accident is considered as random and Poisson distributed.

Table-2. Unit costs of casualties for traffic accidents in Jordan after Al-Masaeid, *et al*., (1999).

Accident severity level	**Average unit cost** (JD)		
	Death	**Injury** [b]	**Property damage**
Fatal	46520 (29.24) [a]	5804 (3.65) [a]	1591
Injury	_	5804 (5.89) [a]	985
PDO	_	_	714

a) Values in brackets indicate the ratio of the unit cost of severity level to the unit cost of that involving property damage.
b) Average values are taken to indicate the average unit cost of the different individual classes (serious, medium, and slight injuries).

3.5 Social and environmental costs

Benedeck and Rilett (1998) calculated the marginal environmental cost function as follows:

$$P_L\left(V_L\right) = e^{B\upsilon_L}\left\{\left[f_L\alpha_L\beta_L\left(\frac{V_L}{S}\right)^{\beta_L}\left(1-b\upsilon_L\right)\right]+t_L\left(V_L\right)\right\} \quad \text{..... (18)}$$

where:

P_L (V_L) = marginal environmental cost function on link L as function of V_L ($/year).
V_L = flow on link L (vehicles/hr).
$\upsilon_L = d_L/t_L(V_L)$ = velocity on link L (ft/sec).
f_L = free flow travel time on link L (seconds).
α_L, β_L= constants for link L ($\alpha_L > 0, \beta_L \geq 1$).
b, B, S= constants.
t_L (V_L) = travel time on link L as a function of V_L (seconds).
d_L = length of link L.

4. MODELING THE COST FUNCTIONS USING VISUAL BASIC LANGUAGE

As its name suggests, a big portion of the programming with Visual BASIC is accomplished visually. This means that during design time, it will be able to see how this program will look during runtime. This is a great advantage over other programming languages, because programs are able to change and experiment with the design until satisfied with the colors, sizes and images that are included in the program (Gurewich and Gurewich, 1997).

5. MODELING THE COST FUNCTION

The cost functions of transportation route are modeled using Visual BASIC language as software named (TRCA); it means Transportation Route Cost Analysis. Figure-1 shows the flowchart of this software. The following sections are described in details the programming of each component of the developed cost function, which are presented in details in the previous chapter. The total cost is a criterion reflecting the goodness of an alignment. All required cost computations can be computerized and then incorporated into the model.

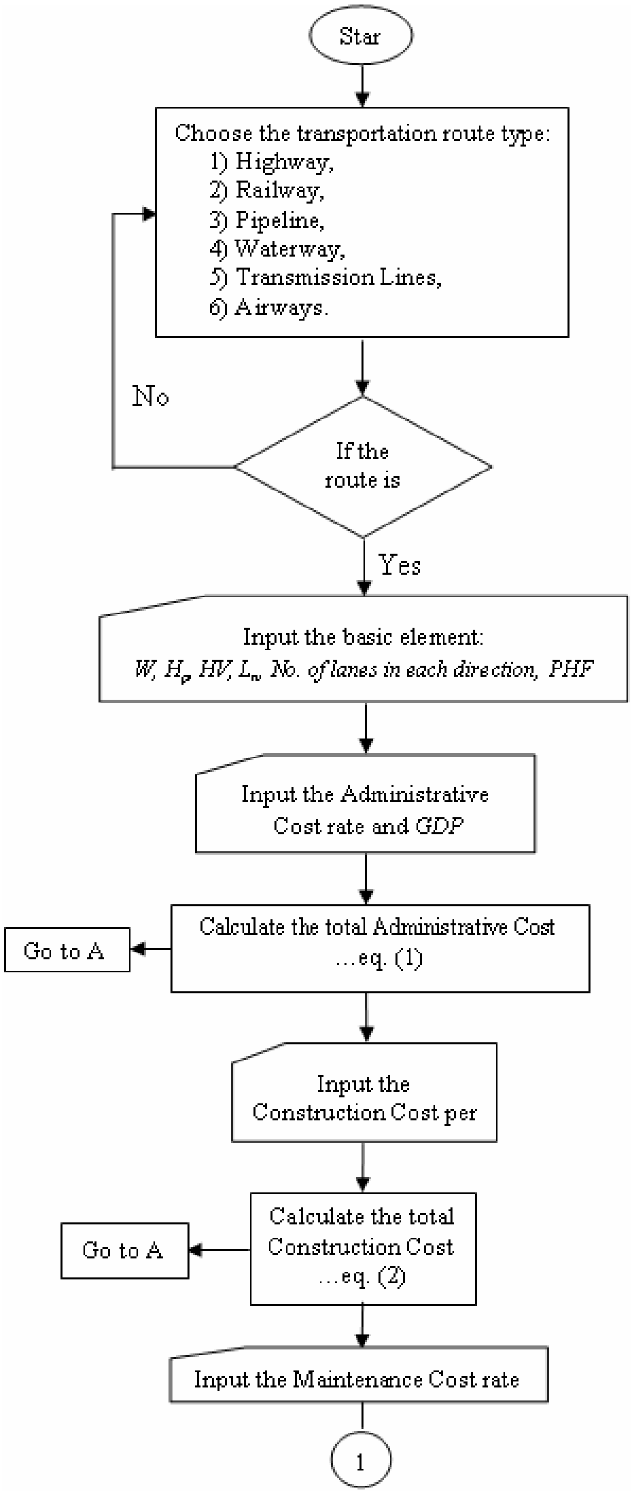

Figure-1. Flowchart of TRCA program.

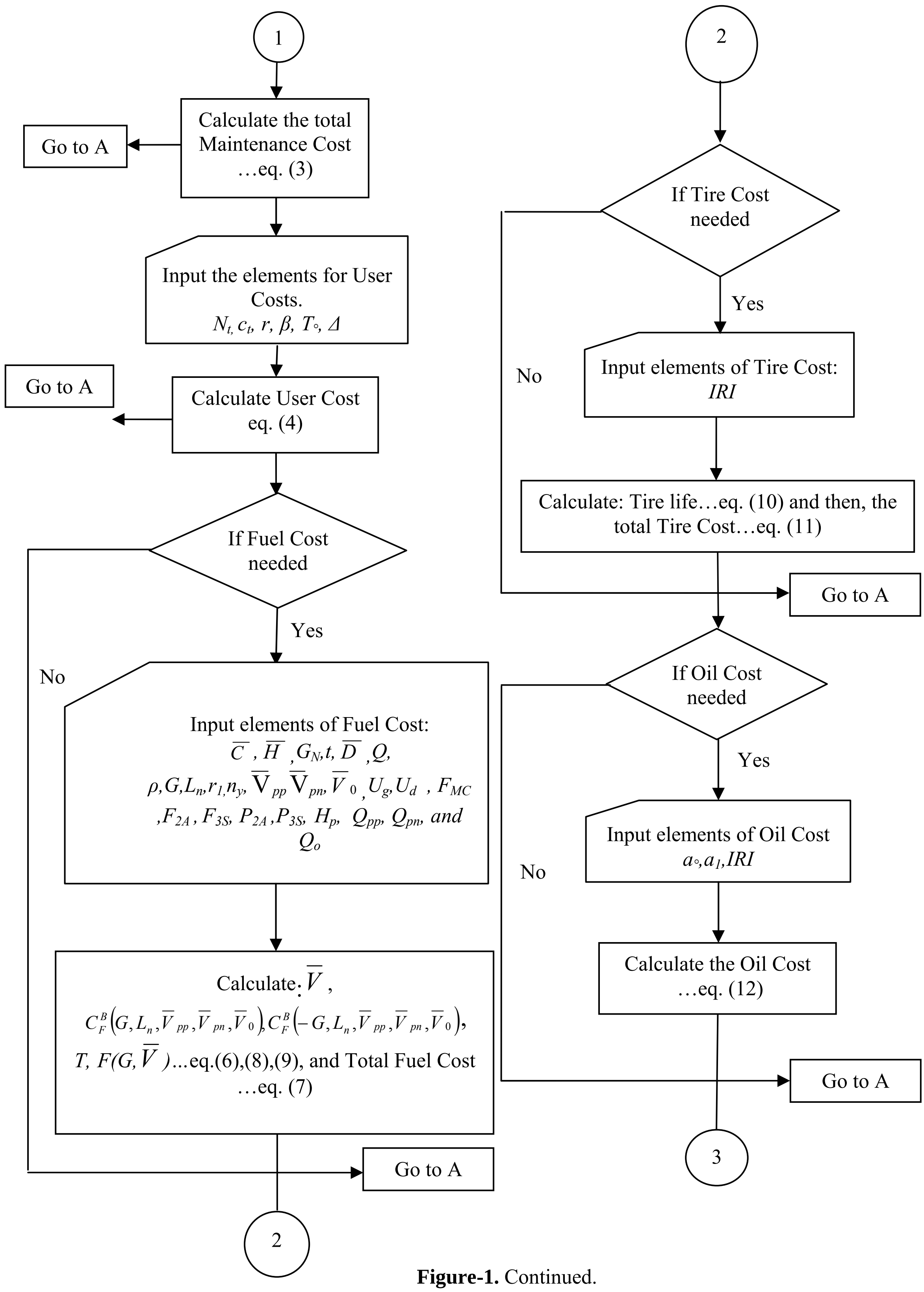

Figure-1. Continued.

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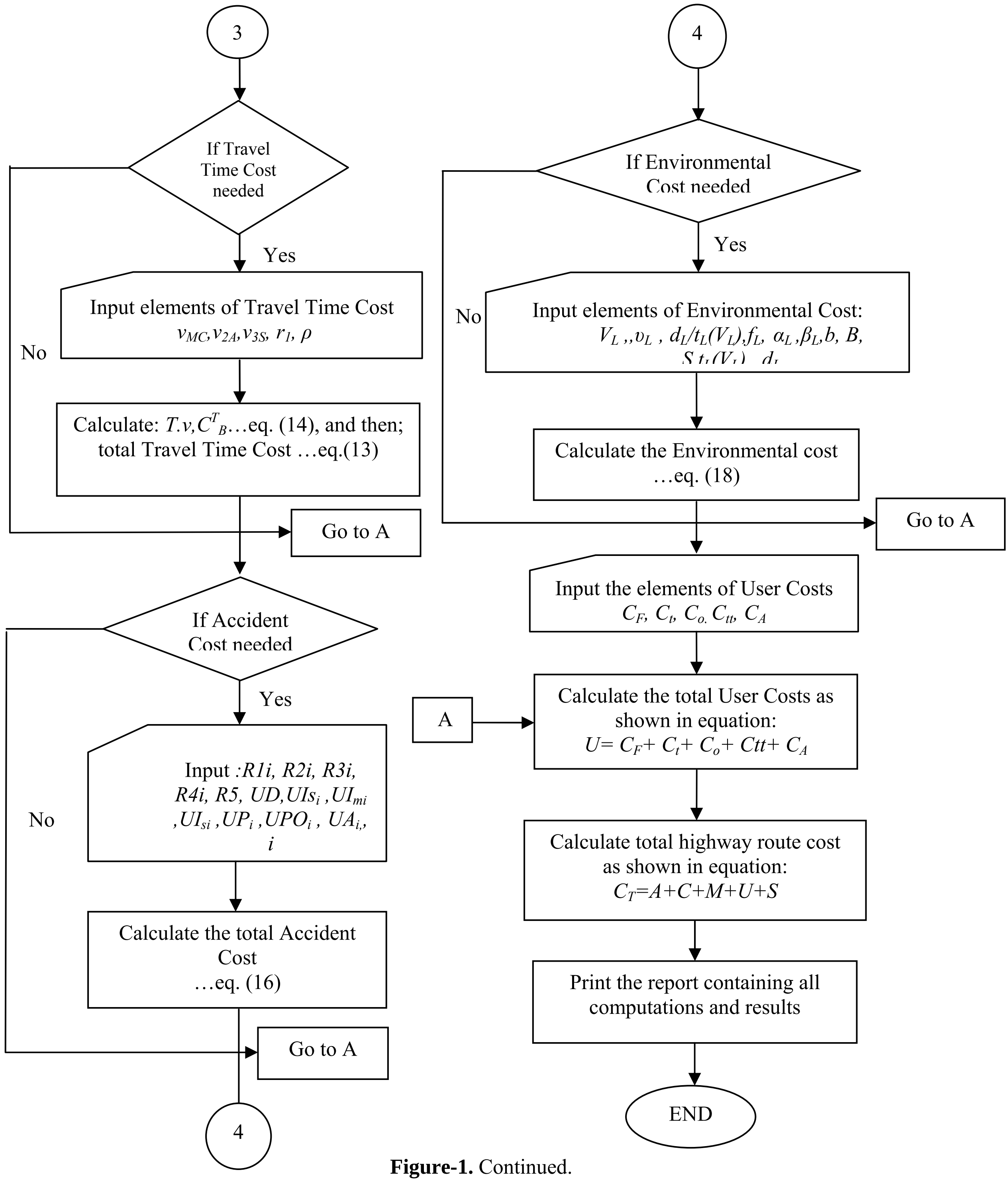

Figure-1. Continued.

6. TRANSPORTATION FACILITIES

The main form of (TRCA) shows the types of transportation routes. As shown in Figure-2, it is classified into six groups (Highway, Railway, Pipelines, Waterway, Transmission lines and Airways). In this research only a highway is chosen as an example of computing the cost function. In the form shown in Figure-3 the elements of highway that must be known before using any equation of any type of transportation route are given. These elements are: type of highway, number of lanes in each direction, percentage of the traffic mix, type of heavy vehicle, 2-axle single and 3- axle semi - trailers.

6.1 Planning, design and administrative costs

Figure-4 shows the inputs and the computations, which are required for cost analysis.

6.2 Construction cost

This cost can easily be calculated by multiplying the construction cost for each kilometer by the length of the highway as shown in Figure-5.

6.3 Maintenance cost

Figure-6 shows the input values of the Maintenance Cost and the final computation.

6.4 User costs

In Figure-7, each icon on this form contains different layers which consist of the elements of each User Costs as described before.

6.4.1 Fuel cost

The elements of Fuel Cost are entered in the form that uses to calculate its value, as shown in Figure-8. The value of Fuel Cost can be calculated by using equation (8) of chapter three as referred before. The inputs contain:

$\overline{C}$, $\overline{H}$, G_N, t, $\overline{D}$, Q, ρ, G, L_n, r_1, n_y, $\overline{V}_{pp}$, $\overline{V}_{pn}$, $\overline{V}_0$, U_g, U_d, F_{MC}, F_{2A}, F_{3S}, P_{2A}, P_{3S}, H_p, Q_{pp}, Q_{pn}, and Q_o.

6.4.2 Tire cost

In Figure-9, the form of Tire Cost appeared together with the equation that is used to calculate it. The inputs contain (*IRI*) as shown.

6.4.3 Oil cost

The form of Oil Cost is shown in Figure-10 with the elements that identify the related equation. In equation (13) the inputs represent the required elements, which contain (a_0, a_1, *IRI*) then the total value of Oil Cost can be calculated.

6.4.4 Travel time cost

Figure-11 shows the inputs of equation (14) in order to calculate the Travel Time Cost. The inputs are v_{MC}, v_{2A}, v_{3S}, Q_{pp}, Q_{pn}, Q_0, V_{pp}, V_{pn}, V_0, H_p, L_n, t, P_{2A}, P_{3S}, n_y, r_1 and ρ then the total value of Travel Time Cost can be calculated.

6.4.5 Accident cost

The last type of User Costs is shown in Figure-12. The Accident Cost can be calculated using equation (17). The inputs of Accident Cost are: *R1i, R2i, R3i, R4i, R5, UD*, UIs_i, UI_{mi}, UI_{si}, UP_i, UPO_i, UA_i, and i, then the total value of Accident Cost can be calculated.

6.5 Social and environmental costs

According to the form shown in Figure-13, the value of Social and Environmental Cost are calculated. The inputs contain (V_L, υ_L, $d_L/t_L(V_L)$, f_L, αL, βL, b, B, S, $t_L(V_L)$ and d_L) then the value of Social and Environmental Costs is calculated.

7. TOTAL COST FUNCTION

Figure-14 shows the final form of the cost function. The (TRCA) represents the total cost function. It represents the algebraic summation of all cost elements.

8. CASE STUDY

To show the accuracy of the TRCA program, one must apply it to a realistic case. Such a suitable case study is a 12.644 km highway including a bridge of length 420 m including three interchanges crossing Tigris River which has been obtained from the State Corporation for Roads and Bridges (SCRB). It represents a new highway under construction between Al- Kut and Al-Basrah as shown in Figure-15. This case study is used to verify the reliability of the developed program.

8.1 Formulation the cost function of the case study

To apply the TRCA program, the following sections give in details the calculations of the cost function. Table-3 shows the summary of the results for all cost elements for this study.

Table-3. Summary of results obtained using TRCA program.

No.	Cost element	Value (ID)	% of total cost
1.	Administrative cost	2,100,000,000	3.800
2.	Construction cost	48,352,400,000	87.501
3.	Maintenance cost	480,000,000	0.869
	i) Fuel cost	3,889,302,375	7.038
	ii) Tire cost	35,606,110	0.064
	iii) Oil cost	292,582,160	0.529
	iv) Travel time cost	100,414,451	0.182
	v) Accident cost	0	0
4.	Total user costs	4,316,621,733	7.812
5.	Social and environmental cost	9,972,235	0.018
Total:		**55,258,993,968**	**100**

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After computing the values of each cost element, the total cost can be obtained as shown in Figure-16. The value of the total cost is less than the gross domestic product specified by the State Corporation for Roads and Bridges because of the elimination of Accident Cost.

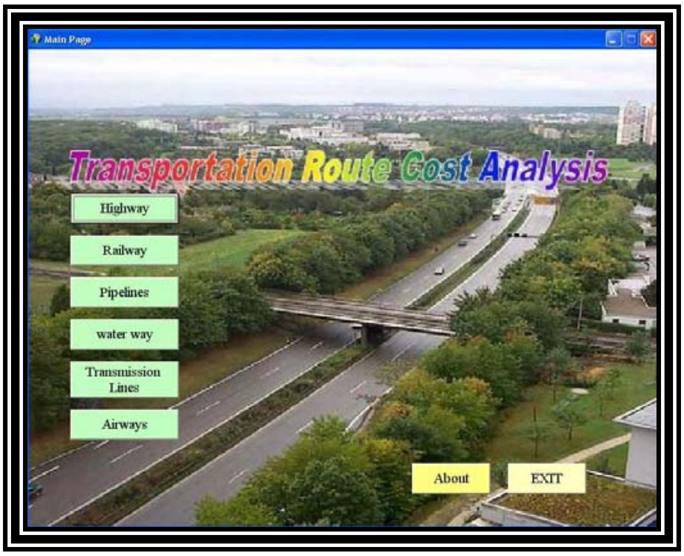

Figure-2. The main menu of TRCA software.

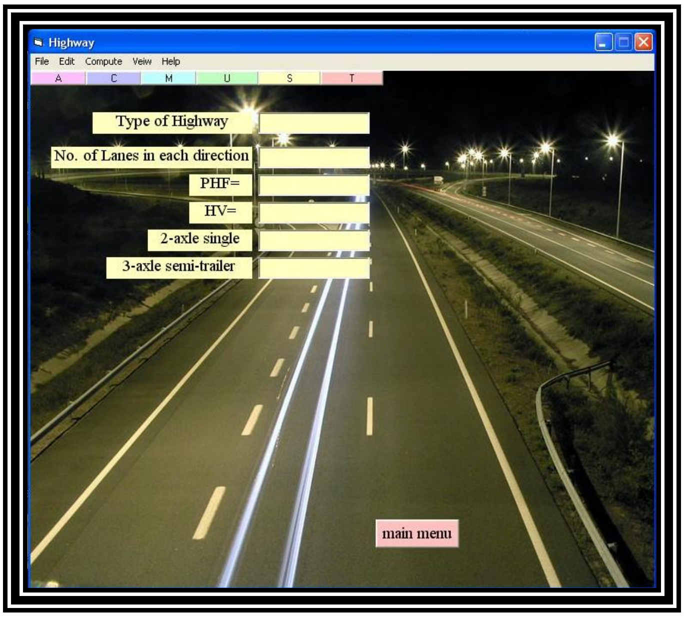

Figure-3. The main page of (TRCA).

Figure-4. Planning, design and administrative costs inputs and computations.

Figure-5. Construction cost inputs and computations.

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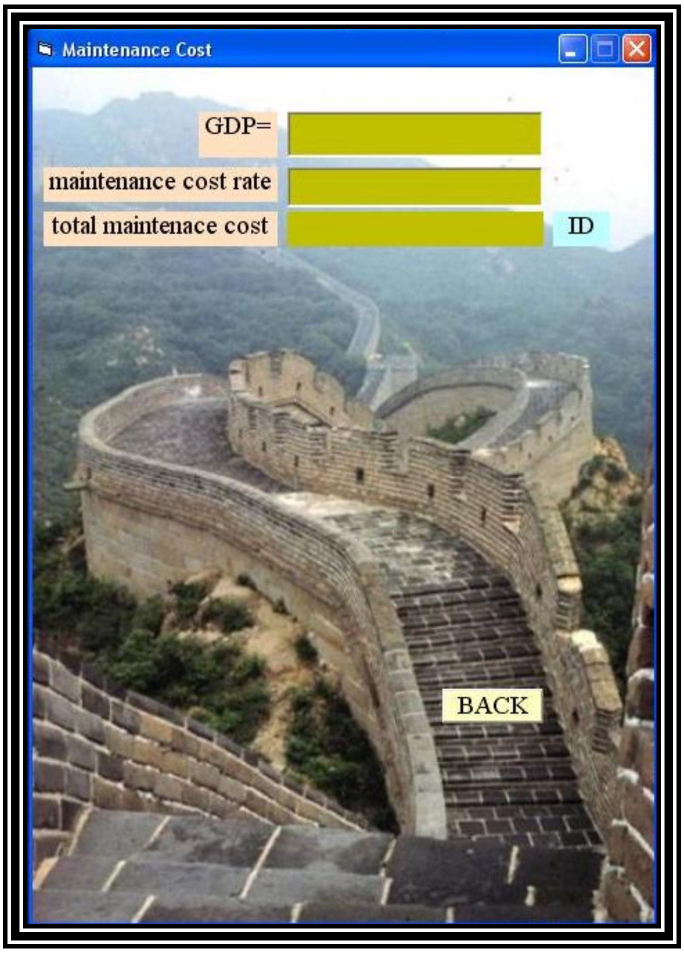

Figure-6. Maintenance cost inputs and computations

Figure-7. User cost.

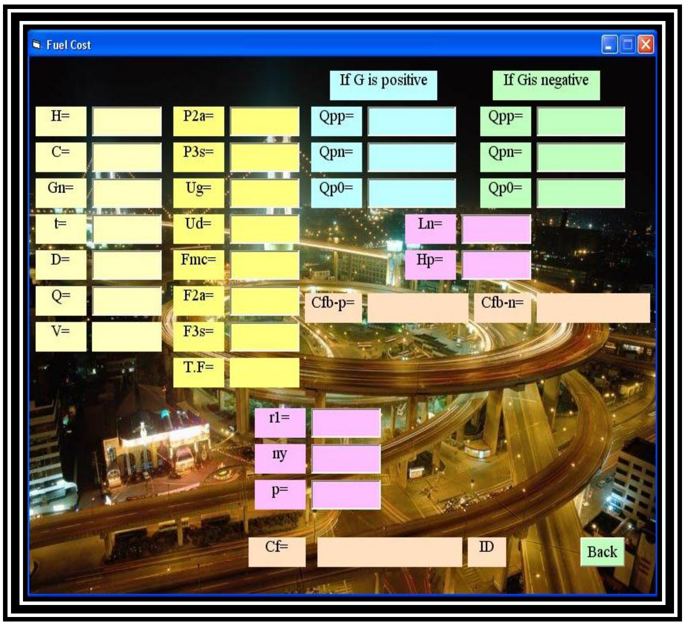

Figure-8. Fuel cost inputs and computations.

Figure-9. Tire cost inputs and computations.

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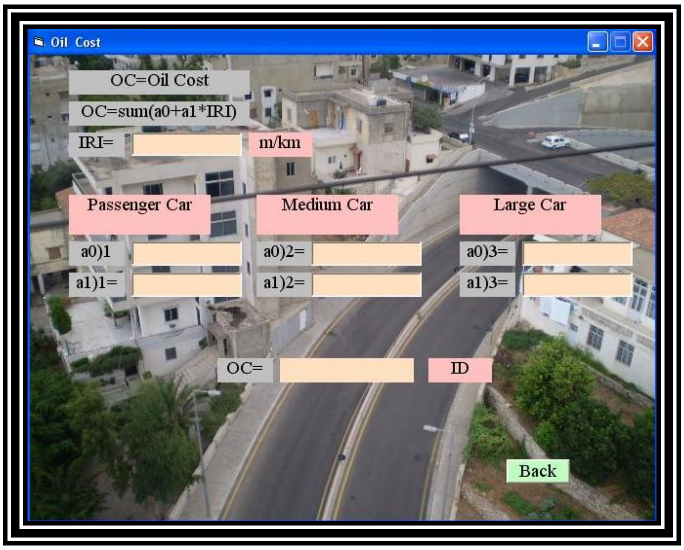

Figure-10. Oil cost inputs and computations.

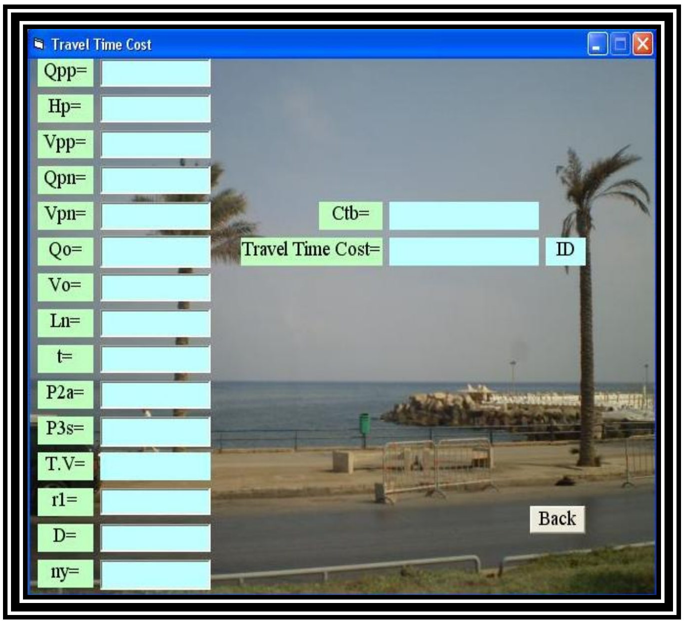

Figure-11. Travel time cost inputs and computations.

Figure-12. Accident cost inputs and computations.

Figure-13. Social and environmental costs.

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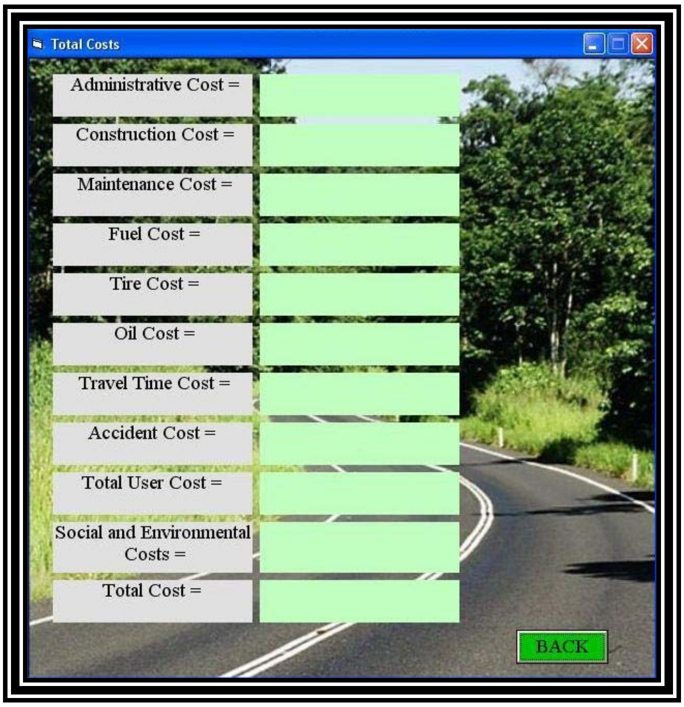

Figure-14. Total cost function.

Figure-15. Total cost function for the case study.

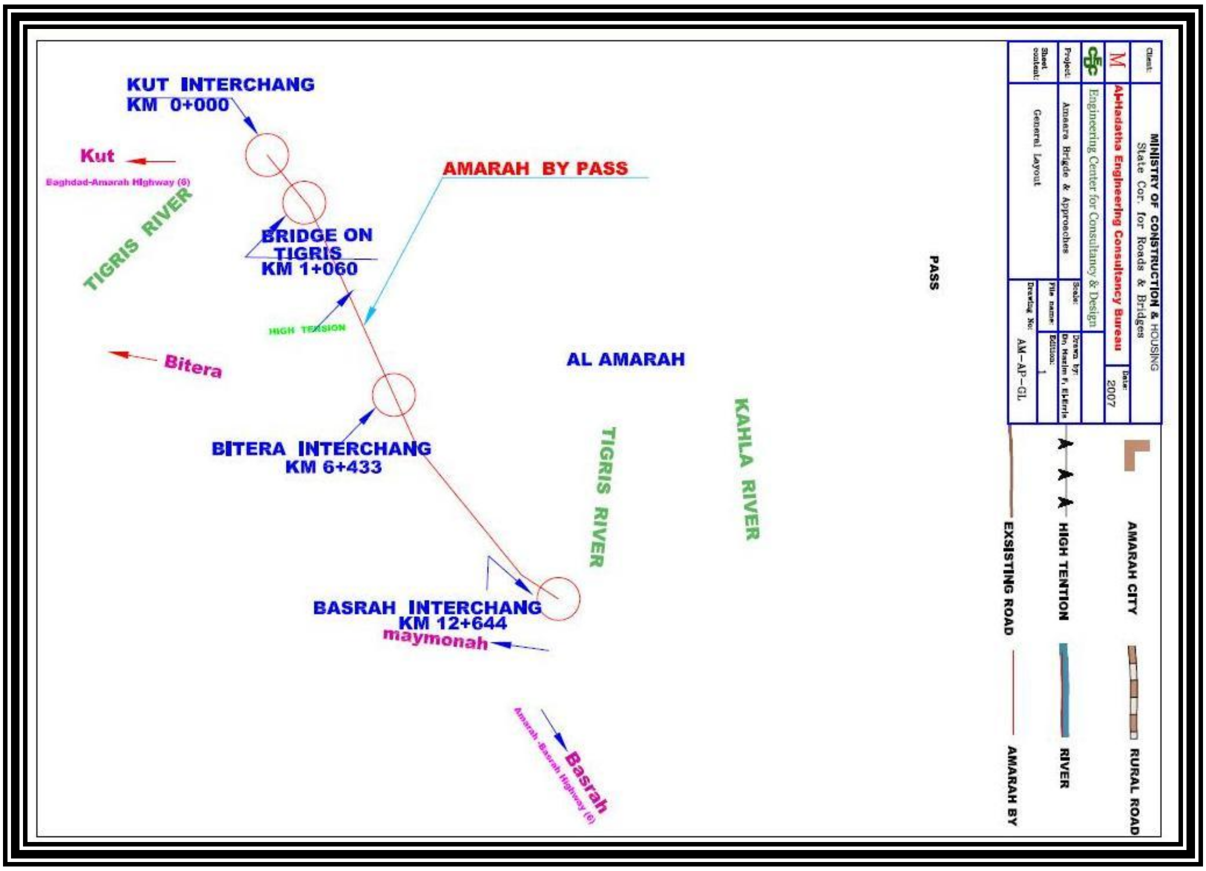

Figure-16. General layout of Amara Bridge (SCRB) (2008).

9. CONCLUSIONS

Based on the formulation of the cost function for transportation route for this case study, the following conclusions can be drawn:

a) It was proved that not only Construction Cost or even just one component, such as earthwork cost is affected in cost function value, but there are other types of cost element which have a great effect in cost function value such as Planning, Design and Administrative Costs, Construction Cost, Maintenance Cost, User Costs (Fuel Cost, Tire Cost, Oil Cost Travel time Cost, and Accident Cost) and Social and Environmental costs;
b) It was concluded that the absence of one element of cost function will lead to a suboptimal or merely satisfactory solution;
c) It was noticed that the design program enables the user to compute each element of cost function visually and when there is no need to compute any element of cost function or in the case of lake of information of any cost element, the program can easily eliminate that cost type;
d) TRCA program proved its ability to compute not only the cost function for a highway put also cost function for railway, pipelines, waterway, transmission lines, airways and any transportation route types;
e) To check the efficiency of the TRCA program, data from a 12.644 Km new constructing highway that connect between Kut and Basrah city were used; and
f) In TRCA program the value obtained from the case study is (55, 260, 277, 331) ID which contain Administrative Cost, Construction Cost, Maintenance Cost, User Costs, which include: (Tire Cost, Oil Cost, Fuel Cost, Travel Time Cost and Accident Cost) and finally Social and Environmental Costs. The obtained value is less than the (GDP) specified by the (SCRB) because of the elimination of Accident Cost which did not obtain any information about it, and because of considering duration of only one year for each cost element.

RECOMMENDATIONS

- The cost functions presented in this study are for highways only, and might not be detailed for other transportation modes. More detailed and precise cost function for the other transportation modes should be developed through future research.
- It is recommended to the State Corporation for Roads and Bridges which did not put any information about Accident Cost to make a study about estimating such cost for planning and design purposes.
- It's recommended to take several case studies by other researchers in order to verify the reliability of the presented program.
- It is recommended to make a detailed study about computing the Social and Environmental Costs for a highway and the other types of transportation routes.

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