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ARTICLE

Comparative Analysis on Road Users' Cost Using HDM-4 Software and Manual Technique: A Case of Addis Ababa-Adama Expressway

Biniyam Kebebew[*] **Emer T. Quezon**

Department of Civil Engineering, College of Architecture & Civil Engineering, Addis Ababa Science and Technology University, Addis Ababa City, Ethiopia

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ABSTRACT

Continuous changes in vehicle technology, road condition, traffic compositions initiate the change or updating of road users' cost models. So that it needs to practice a continuous revision or update periodically for realistic estimation of costs and benefits. This paper presented the relationship and comparison between road users' cost along Addis Ababa-Adama newly constructed expressway using the Highway Development and Management (HDM-4) Software and manually using formulations developed in the Portuguese model. The method started with data collection. All input data were collected from primary and secondary sources. The primary data utilized an interview, and secondary data were sourced out from pertinent documents, both published and unpublished. More data were gathered that related to vehicles. The vehicles using the road are classified based on the manual from the Ethiopian Road Authority as cars, utilities, small bus, large bus, small truck, medium truck, heavy truck, and truck trailer. The collected data have been input into the HDM-4 interface; the output of the analysis was vehicle operating costs, travel time, and road users' cost as a summation. Using manual technique and HDM-4 Software, Birr 128.62/km/vehicle and Birr 139.23/km/vehicle, respectively, were found from road users' costs analysis. The result shows the difference of Birr 10.61. Also, the correlation coefficient of 0.75 is determined, which shows that the two results of road users' costs are highly related. As a result, the study reveals that the application of HDM-4 Software and the manual technique formulations from the Portuguese model can be adopted interchangeably to calculate Road Users' Cost of road sections in Ethiopia. Hence, the study results are expected to be an eye-opener for a future similar project by the concerned agencies.

*Corresponding Author:
Biniyam Kebebew,
Department of Civil Engineering, College of Architecture & Civil Engineering, Addis Ababa Science and Technology University, Addis Ababa City, Ethiopia;
Email: biniyam.moges@aastu.edu.et; binimoges2005@gmail.com

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1. Introduction

Constructing and improving roads with recently found technologies is now experienced around the world. Improvements in a country's road network are intended to counterbalance the road users' cost, which indirectly results in savings for road users [1]. A study was conducted on-road user cost and savings in the UK [2]. As a result, it states that a road project should be assessed in terms of its primary effects, such as economic, social, financial, safety, and environmental effects. Among the above effects, economic analysis is a vital one that includes identifying, measuring, and comparing the social benefits and costs of an investment project or program [3]. Therefore, the economic analysis of road projects is conducted using different tools such as a highway development and management tool (HDM-4) and using different models developed in different countries. From these models developed, the Portuguese road user cost analysis model [4] is used for the calculation of the vehicle operating cost and travel time cost in this study. The models are presented in a way that they can implement using locally available data.

RUCs calculation includes the estimation of monetary and non-monetary effects. Based on the scope of the research, monetary impacts consist of main vehicle operating costs (VOCs) and the value of travel time considered as a cost (TTCs). As mentioned above, these fundamental components of road users' costs would be calculated separately using different parameters and input data [5]. However, the road users cost study is familiar to our country, this study was focused on the analysis of road users' cost (RUCs) in the case of Addis Ababa to Adama newly constructed expressway road, which is located in the south-eastern part of Ethiopia. This expressway selected for the case study is the first expressway in Ethiopia and East Africa. The route has an 83 km length and is a six-lane two-way road with a design speed of 100 km/hr-120 km/hr. The road officially opens for the public in September 2014GC.

To do the research, the following objectives of the study are: (1) To analyze Road Users' Costs using HDM-4 Software; (2) To apply the manual technique for the analysis of Road Users' Costs; (3) To compare the results of post-operational values of Road Users' Cost of both methods.

2. Materials and Methods

The methods started with data collection that includes road network data like (length, width, roughness, pavement type), traffic volume and composition, fuel, engine oil, tire, vehicle maintenance labor costs, crew costs, overhead costs, and interest rate. Data also include annual kilometers driven by vehicle type, hours driven per year by vehicle type, vehicle ages, percent of the time for private use and gross vehicle weight, and costs of working and non-working time. All input data were collected from primary and secondary sources. Then this collected data have been used for HDM-4 Software as an input to analyze the road users' cost. The same data were used to analyze road users' costs using formulations found from the Portuguese model manually. After inserting all required data, the program would run the analysis and generate the results. The expected outputs of the analysis are vehicle operating cost and travel time cost. These outputs were generated in monetary terms, and the results were then compared with both findings, one found from manual technique calculation and one from HDM-4.

2.1 Study Area

The Addis Ababa-Adama Road is selected as a study site since it is handling a heavy volume of traffic along the import-export corridor between the Port of Djibouti and the hinterland of Ethiopia resulting in significant economic and social importance. The length of the expressway is 83 km starting from UNISA Square (Akaki sub-city) to Adama town. This road is geographically located southeast of Addis Ababa and connects the major city of Addis Ababa and Adama thereby and bypasses other cities in between including Dukem, Bishoftu, and Modjo. The new road is 20 km shorter than the old Addis Adaba Adama road while the route is fenced on either side for protection from pedestrians and animals. The following Figure 1 shows the project location of the study area.

2.2 Study Design Process

The design process of the research is shown in the Figure 2 below.

2.3 Sampling Techniques and Sample Size

For this study, non-probability (purposive) sampling techniques were used. Purposive sampling is being used since these road users need to be identified and defined into groups or strata based on their characteristics. The non-probability (purposive sampling) has been used to get easy access to passengers and drivers who frequently use this toll road. And the sample size has been determined from the following formula [6].

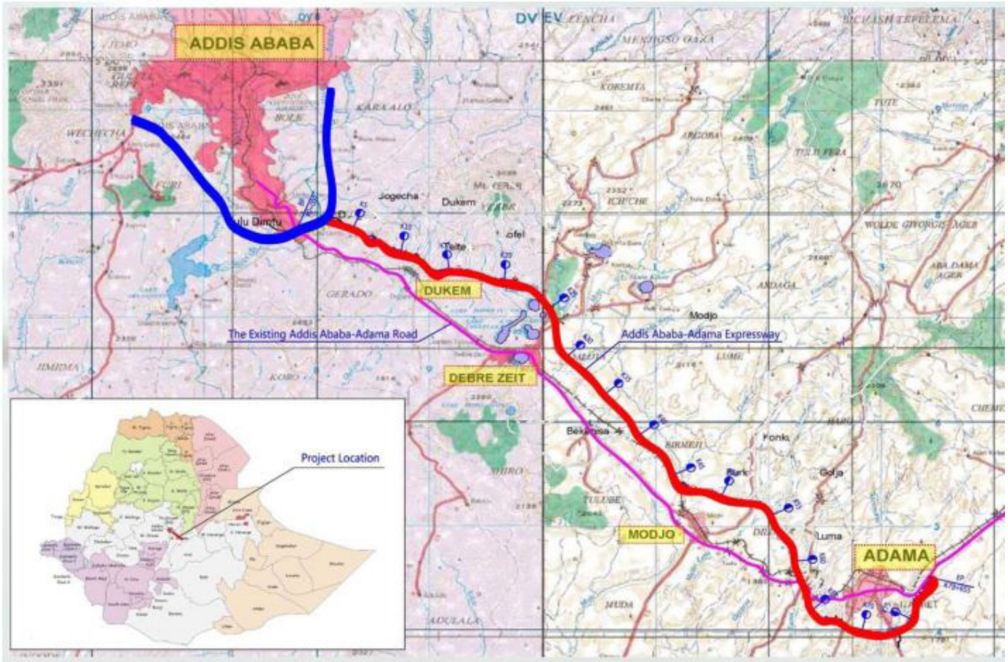

Figure 1. Project location of the study road

Source: Pavement report of Addis-Ababa toll motorway project

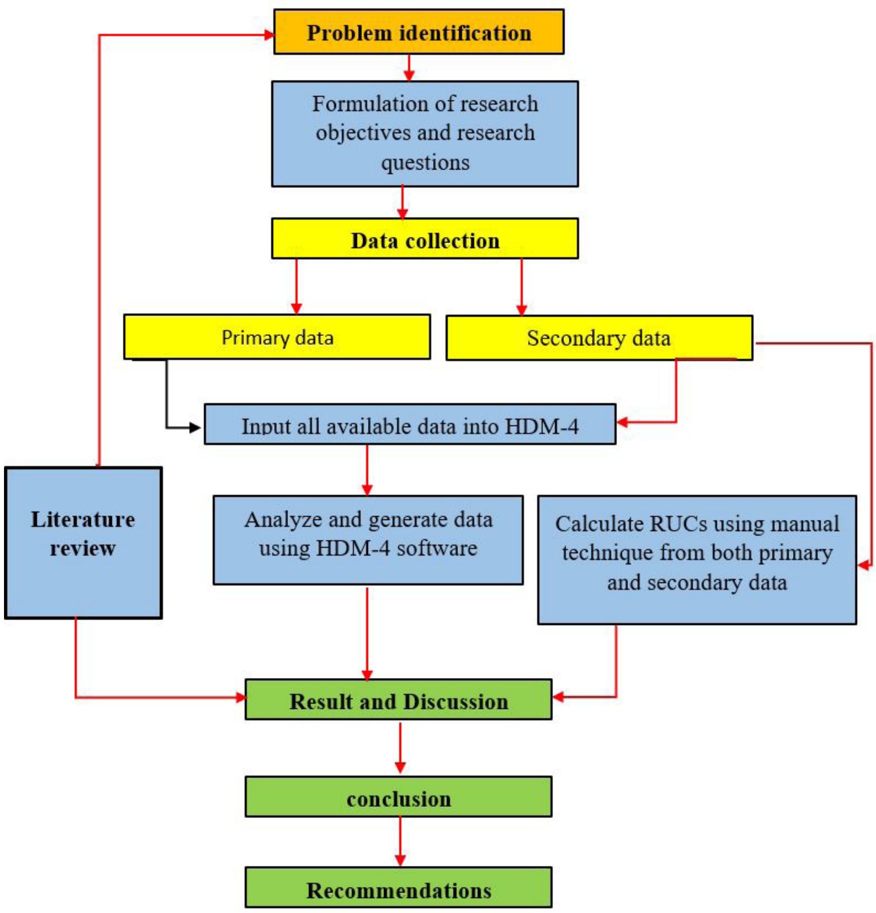

Figure 2. General structure of study methodology

$$n = \left[z^2 \times \frac{p \times q}{d^2}\right] \quad (1)$$

where:

n- sample size

z - linked to 95% confidence interval (use 1.96)

p – expected prevalence (as a fraction of 1.0)

q – 1-p (expected non-prevalence)

d – relative desired precision

Using p (0.5), q (1-0.5=0.5), d (10%), z (1.96), for the population of greater than 100,000 as recommended [6,7], then the sample size becomes 96.04 which is approximately taken as 100.

2.4 Data Requirements

Both methods, the HDM-4, and the manual technique need recently available and updated data to give more realistic results. The HDM-4 needs a wide range of data than the manual technique (formulas from the Portuguese model). The data used for the analysis of RUC by these methods include:

(i.) Road network data – The road network data include all necessary data available about the section under study. The section's functional condition and structural condition are gathered as input data. The data available from ERA (Ethiopian Road Authority), concerning the definition, pavement surface type, condition, and geometry of the section were collected.

(ii.) Vehicle fleet – According to the vehicle classification from the manual of Ethiopian road authority vehicles are classified into eight classes for the study.

(iii.) Cost data – Every vehicle using a road section has a cost associated with it. Vehicle operating costs and time costs for the passengers are significant. There are different components related to vehicle operating cost, i.e., fuel cost, lubricating oil cost, tire cost, maintenance cost, annual overhead cost, etc. And for the travel time cost, passenger working hour cost is also necessary. All this data required are gathered through an interview, from consulting office, government office, and from websites.

Data used for the analysis of the road users' cost, road network data, basic characteristics of the vehicle fleet, economic characteristics of vehicle fleet are presented in the following Table 1, Table 2 and Table 3 respectively.

Table 1. Road network data

Section ID	Section name	Road class	Surface class	Pavement type	Length (km)	Width (m)	No.of lanes	MT AADT	NMT AADT	AADT year
AAD	AA-D/Zeit	Primary or trunk	Bituminous	asphalt mix on granular base	33	12	6	9791	0	2015
DA	D/Zeit-Adama	Primary or trunk	Bituminous	asphalt mix on granular base	50	12	6	12817	0	2015

Table 2. Basic characteristics of the vehicle fleet

Vehicles	Base type	Tire type	Annual kilometer	Annual working hours	Average service life	Passenger occupancy	Initial composition	Growth rate
car	Medium Car	Bias-ply	20,000	2,400	10	1	9.0	23
utilities	Four Wheel Drive	Bias-ply	35,000	2,800	12	3	10.4	11
Small Bus	Light Bus	Bias-ply	40,000	2,800	12	15	17.9	13
Large Bus	Heavy Bus	Bias-ply	70,000	4,200	12	60	6.7	5
Small Truck	Light Truck	Bias-ply	50,000	2,800	15	0	11.2	17
Medium Truck	Medium Truck	Bias-ply	80,000	2,500	15	0	14.6	11
Heavy truck	Heavy Truck	Bias-ply	80,000	3,080	15	0	17.4	11
Truck and Trailer	Heavy Truck	Bias-ply	80,000	3,080	15	0	12.8	14

Table 3. Economic characteristics of the vehicle fleet

Vehicles	New vehicle price **	Tire price **	Fuel (per lit) **	Lubricating price (per lit) **	crew wage (per hr.)	Annual overhead	passenger working	passenger non-working
car	1,514,750	2,490	21.58	166.00	20.83	29,050	0	0
utilities	2,686,295	5,810	19.24	166.00	20.83	46,480	55.00	18.00
Small Bus	1,452,500	7,470	19.24	166.00	31.25	29,880	35.00	9.00
Large Bus	2,697,500	14,525	19.24	166.00	59.89	49,800	35.00	9.00
Small Truck	1,535,500	8,300	19.24	166.00	36.46	29,040	0.00	0.00
Medium Truck	2,241,000	10,790	19.24	166.00	46.87	41,500	0.00	0.00
Heavy truck	4,067,000	16,600	19.24	166.00	54.69	83,000	0.00	0.00
Truck and Trailer	3,901,000	14,940	19.24	166.00	54.69	74,700	0.00	0.00

*All costs are in Ethiopian Birr (ETB)

** Economic cost

2.5 Methods of Analysis

The HDM-4 Software and the formulas from the Portuguese RUC model are used for the analysis of road users' costs.

2.5.1 Highway Development and Management Tool (HDM-4)

Highway development and management tool is a computer-based software developed by the world bank for decision-making and checking the engineering and economic viability of road projects. This software is developed using various data from different countries around the world and is more practiced in developing countries to judge the economic feasibility of upcoming projects of roads. The new HDM-4 requires a wider range of data input when compared to HDM-III [8]. Running HDM-4 provides different outputs, including a report for traffic, deterioration/works effects, road user effects, environmental effects, cost streams, economic evaluation, and multi-criteria analysis [2]. Each report presents the effect of the proposed option. HDM-4 is used by a wider range of users (e.g., governments, consultants, and agencies) in both developed and developing countries. The software performs the following analysis based on engineering and economic aspects of the given project or program and the analysis can be addressed in three ways project analysis, program analysis, and strategy analysis [9].

A project-level pavement management analysis can be performed using the software's "project analysis" application module, which is a focal point of this study. Using the road user effects model of the software the results like vehicle operating cost, travel time cost, and road users' cost as a summation was determined.

2.5.2 Formulations from the Portuguese RUC Model

Simple formulations with the ability to calibrate and calculate road user cost components were developed in the Portuguese RUC model, and these formulations are adopted in this study for calculation of RUC besides the HDM-4 Software using locally available data gathered through an interview and from secondary sources.

3. Results and Discussion

The study covers the road users' cost analysis using both HDM-4 Software and the manual technique using basic formulas developed in the Portuguese RUC model. The same data collected is used for both methods, and a comparison of the results is made finally. The results of the analysis are expressed cost per kilometer of the section. The analysis is done for 6 years (i.e. 2015GC-2020GC). Since the road begins service on 2014GC and post-operational road user cost is needed to attain the period from the beginning of the operation to the year 2020GC is taken. The selected section of the Addis Ababa-Adama Expressway has an 83 km length, and for the matter of analysis, it is divided into two sections. The sections are Addis Ababa-D/Zeit which counts about 33 km in length and D/Zeit-Adama, which counts about 50 km in length. This section is chosen because it is the busiest section that connects the center to the main import-export corridor of Djibouti; it has a large traffic volume; the first expressway and data are available for the analysis. The total traffic in terms of AADT is collected from the annual count conducted by the Ethiopian Road Authority (ERA), and the initial composition of vehicle classes is also expressed. The annual growth rate of each type of vehicle of the selected section is also specified. The maintenance and rehabilitation work costs for the past years were collected from the Ethiopian Toll Roads Enterprise (ETRE), which is a firm that manages the expressway. For the analysis using HDM-4 the discount rate of 10.26% is used as recommended by the Ethiopian road authority. After running the program vehicle operating cost, travel time cost, and summing both road users' cost is generated. These results are generated in the form of tables and figures.

3.1 HDM-4 Results

From the above input data, the software generates outputs for vehicle operating cost, travel time cost, and road users' cost as a summation of operating and travel time costs. As observed from the section Addis Ababa – Debi-rezeit analysis, the minimum value of vehicle operating cost was observed ETB 8.11/km/vehicle for small bus, and a higher value was observed ETB 29.43/km/vehicle for a truck trailer. This means for traversing a kilometre of the section, the vehicles expend 8.11 Birr and 29.43 Birr per kilometer, respectively, resulting from fuel, engine oil, tire consumption, maintenance, and crew cost.

The values estimated for travel time cost showed that the minimum value is observed for a car with the value of ETB 0.49/km/vehicle, and the higher value observed is for a large bus with a value of ETB 9.08/km/vehicle.

The result from the summation of both vehicles operating and travel time cost, which results for road users' cost, observed that the higher value was obtained for truck trailers with the value of ETB 29.47/km/vehicle. The minimum value was obtained ETB 9.14/km/vehicle for a small truck. The remaining vehicle's results for vehicle operating cost, travel time, and road users' cost as summation from the software are presented in the following Figure 3, Figure 4 and Figure 5 respectively.

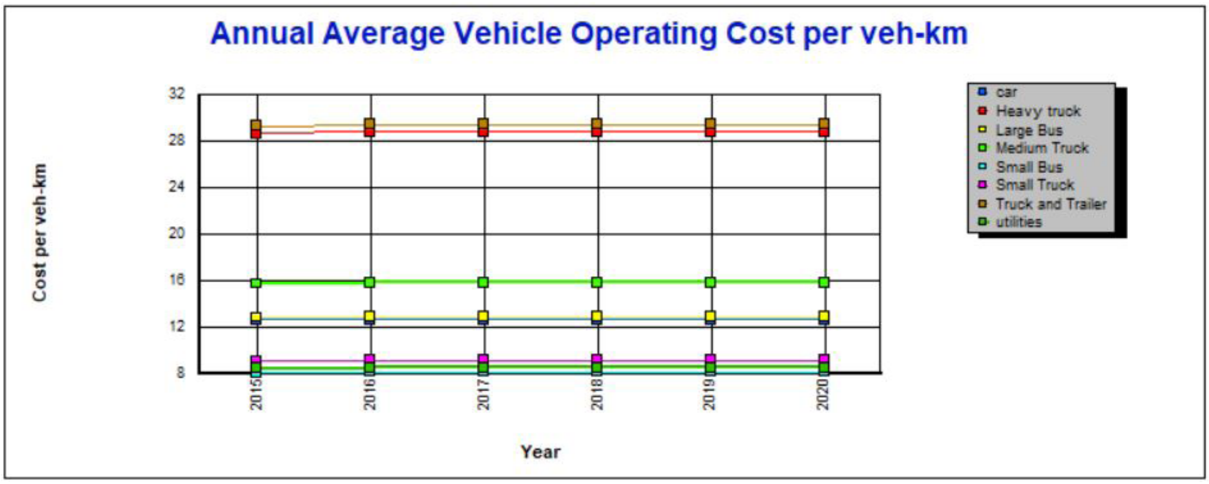

Figure 3. Average vehicle operating cost per kilometer

Figure 4. Average travel time cost per kilometer

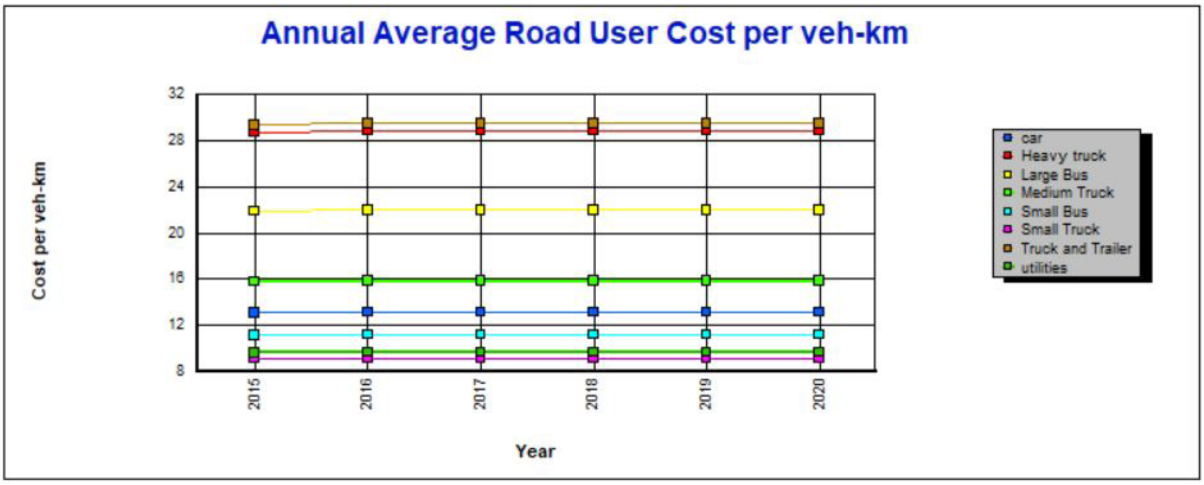

Figure 5. Average road users' cost per kilometer

The values generated from software for vehicle operating cost, travel time cost, and road users' cost respectively in the row as presented in the table below. The analysis is done for six years beginning from 2015GC to 2020GC and the values for all years are presented in the Table4 below.

Table 4. RUC output from HDM-4 Software

Year	Car	Utilities	Small Bus	Large Bus	Small Truck	Medium Truck	Heavy truck	Truck and Trailer	Total
2015	12.63	8.48	8.09	12.83	9.13	15.76	28.68	29.32	124.91
	0.49	1.17	3.09	9.07	0.00	0.01	0.02	0.02	13.87
	13.12	9.65	11.18	21.90	9.13	15.77	28.70	29.33	138.78
2016	12.64	8.49	8.12	12.89	9.16	15.81	28.81	29.45	125.36
	0.49	1.17	3.10	9.08	0.00	0.01	0.02	0.02	13.89
	13.14	9.67	11.22	21.97	9.16	15.82	28.82	29.46	139.26
2017	12.64	8.49	8.12	12.89	9.16	15.81	28.81	29.45	125.38
	0.49	1.17	3.10	9.08	0.00	0.01	0.02	0.02	13.89
	13.14	9.67	11.22	21.97	9.16	15.82	28.83	29.47	139.28
2018	12.64	8.49	8.12	12.89	9.16	15.81	28.81	29.45	125.39
	0.49	1.17	3.10	9.08	0.00	0.01	0.02	0.02	13.89
	13.14	9.67	11.22	21.97	9.16	15.82	28.83	29.47	139.28
2019	12.64	8.49	8.12	12.89	9.16	15.81	28.81	29.45	125.39
	0.49	1.17	3.10	9.08	0.00	0.01	0.02	0.02	13.89
	13.14	9.67	11.22	21.97	9.16	15.82	28.83	29.47	139.28
2020	12.64	8.49	8.12	12.89	9.16	15.81	28.81	29.45	125.39
	0.49	1.17	3.10	9.08	0.00	0.01	0.02	0.02	13.89
	13.14	9.67	11.22	21.97	9.16	15.82	28.83	29.47	139.28
Total	75.85	50.95	48.68	77.29	54.91	94.82	172.75	176.57	751.82
	2.97	7.03	18.60	54.46	0.03	0.06	0.09	0.09	83.34
	78.82	57.98	67.28	131.75	54.94	94.88	172.84	176.67	835.16

Note:

1st Row: Annual average Vehicle Operating Cost per vehicle kilometer.

2nd Row: Annual average Travel Time Cost per vehicle kilometer.

3rd Row: Annual average Road User Cost per vehicle kilometer

3.2 Manual Technique Results

These types of costs are generated by the users of the road themselves, depending on the facility the road provided them. Vehicle operating cost and travel time costs were considered main components of road user cost and were frequently determined. These two mentioned costs were analyzed in this study even though there is a growing interest in the accident, environmental, congestion, crash, and various other social costs that have been shown recently. The following equations are used [4].

$$RUC=VOC+VOT+AC \quad (2)$$

(i) Vehicle operating costs

Vehicle operating costs are travel costs that differ according to vehicle usage and based on vehicle kilometer traveled. Fuel consumption, engine oil consumption, tire consumption, vehicle maintenance, and repair cost, and vehicle depreciation costs that are based on the vehicle's use and service lifespan are all taken into account for assessing the value of vehicle operating cost.

$$\mathrm{VOC} = \mathrm{AADT} \times \sum_{i=1}^{n} (\mathrm{VOC_i} \times \mathrm{P_i}) \quad (3)$$

$$\mathrm{VOC_i} = \mathrm{Cf_i} + \mathrm{Ct_i} + \mathrm{Cm_i} + \mathrm{Cd_i} + \mathrm{Cl_i} \quad (4)$$

$$\mathrm{Cf_i} = \mathrm{cf_i} \times \mathrm{Cmf_i} \quad (5)$$

$$\mathrm{Ct_i} = \frac{\mathrm{nt_i} \times \mathrm{Cmt_i}}{\mathrm{tsl_i}} \quad (6)$$

$$Cm_i = \frac{Cmmt_i}{vsl_i \times kma_i} \quad (7)$$

$$Cd_i = \frac{Cmdt_i}{vsl_i \times kma_i} \quad (8)$$

where:
VOC – total vehicle operating cost
AADT – average annual daily traffic
VOC_i – vehicle operating cost for vehicle type i
P_i – vehicle proportion of class i for the AADT considered
Cf_i – fuel cost for a vehicle i
Ct_i – tire cost
Cm_i – maintenance cost
Cd_i – depreciation cost
cfi – fuel consumption for vehicle i in (lit/km)
cmf_i – fuel market price (economic) in (Br/lit)
nt_i – number of tires for a vehicle i
cmt_i – tire market price (Br/pieces)
tsl_i – tire service life (km)
$cmmt_i$ – total maintenance market price for a vehicle i (birr)
vsl_i – the vehicle i service life in years
kma_i – average annual kilometrages (km/year)
$cmdt_i$ – the total vehicle i depreciation market price (minus tire) in birr

Here in the model, they do not consider the value for the lubricating engine oil. The value of these lubricant costs will be found as:

Cl_i = cli*cmli

where:
Cl_i – lubricant cost (Br/km)
cli – lubricant consumption for a vehicle i in (lit/km)
cmli – lubricant market price in (Br/lit)

(ii) Travel time cost

Travel time cost is a cost generated from the working hour loss of a passenger.

$$\mathrm{VOT} = \mathrm{AADT} \times \sum_{i=1}^{n} (\mathrm{VOT_i} \times \mathrm{p_i}) \quad (9)$$

$$\mathrm{VOT_i} = \frac{1}{\mathrm{S_i}} \times \sum_{m=1}^{2} \left(\mathrm{TC_m} \times \mathrm{OR_{i,m}}\right) \quad (10)$$

$$\mathrm{TC_{m=1}} = \mathrm{NAW} \quad (11)$$

$$\mathrm{TC_{m=2}} = 0.25 \times \mathrm{NAW} \quad (12)$$

where:
VOT – the value of time
VOT_i – the value of time for a vehicle i in Br/km/vehicle
s_i – the average operating speed for a vehicle i in km/h
m – corresponds to travel purpose (m=1 for travel in work time and m=2 for travel in non-working time)
TC_m – the time cost for travel purpose m in Br/h/occupant
$OR_{i,m}$ – the occupancy rate for vehicle i and travel purpose m in occupant/vehicle
NAW – the national average wage in Br/h/person.

(iii) Road user cost from manual technique

The results from vehicle operating cost, travel time cost, and road users' cost are discussed below using figures and tables. The values from vehicle operating cost and from a value of time (travel time cost) are added together to get the aggregated value of RUCs for both sections. The Table 5 below shows the total RUCs result from the manual calculation.

According to the analysis done using the manual technique and results summarized and presented in the table above, it is observed that a small car accounts for a small amount of vehicle operating cost ETB 10.28/km/vehicle. This means a small car has to spend 10.28 Birr to travel a kilometre. This expenditure is not forced or generated by external factors; instead, it is expected to be covered by the users and is generated by the users themselves. For the value of time (travel time cost), small cars have accounted ETB 0.5/km/vehicle expenditure. This means per vehicle of passengers working hours lost counts for 0.5 Birr per kilometre and will be considered a loss by the road user per kilometre. Utilities, small buses, large buses, medium trucks, and truck trailers have accounted for ETB 13.18/km/vehicle, 13.45/km/vehicle, 14.12/km/vehicle, 11.645/km/vehicle, and 23.21/km/vehicle operating costs, respectively.

Moreover, for travel time cost utilities, small buses, large buses account ETB 1.16/km/vehicle, 2.65/km/vehicle, and 8.52/km/vehicle, respectively. Here since small trucks, medium trucks, heavy trucks, and truck trailers have no passengers trip related to work purpose, the value of travel time cost (value of time for travel) becomes zero. Vehicles types with a higher occupancy rate of passengers show higher values of VOTs.

As summarized to road users costs, small cars have the lowest expenditure (10.78 ETB/km/vehicle), and truck trailer accounts for the larger value of road users' cost with (23.21 ETB/km/vehicle). The results discussed above and the remaining results of other vehicles are shown in a summarized figure below.

The results discussed above, and the remaining results of other vehicles are shown in a summarized form in Figure 6, Figure 7 and Figure 8 below.

Table 5. Summarized RUC from manual technique of both sections

Vehicle type	VOCi (ETB/km)	VOTi (ETB/km/vehicle)	RUCi (ETB/km)
Cars	10.28	0.5	10.78
Utilities	13.18	1.16	14.34
Small Bus	13.45	2.65	16.10
Large Bus	14.12	8.52	22.64
Small Truck	11.78	0	11.78
Medium Truck	11.78	0	11.78
Heavy Truck	17.99	0	17.99
Truck & Trailor	23.21	0	23.21

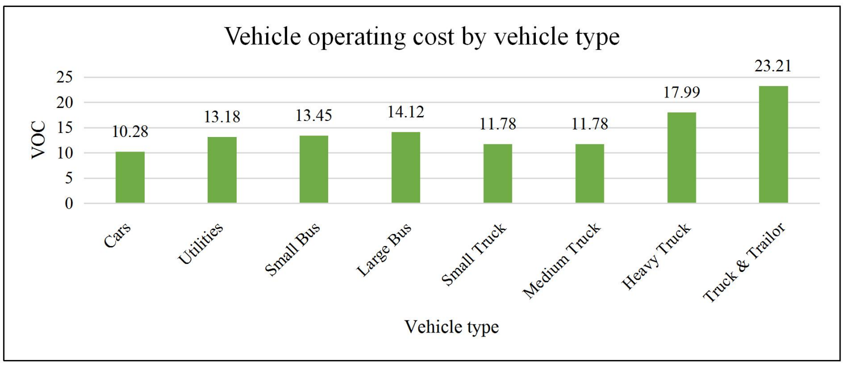

Figure 6. Average vehicle operating cost by vehicle type from manual calculation

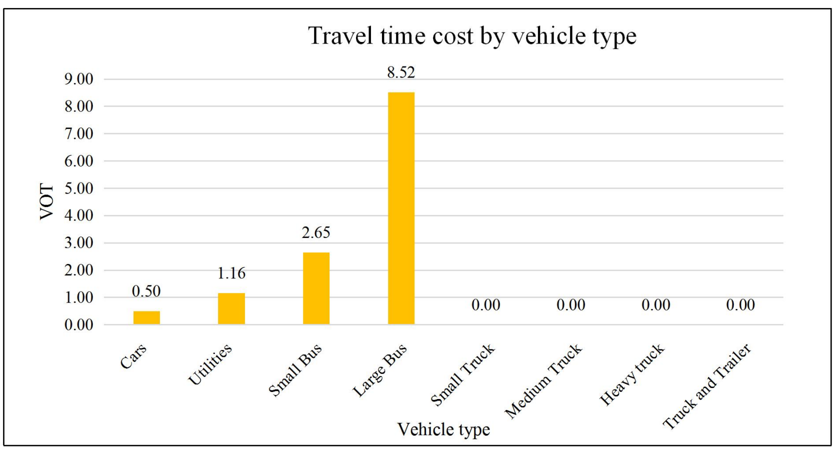

Figure 7. Average travel time cost by vehicle type from manual calculation

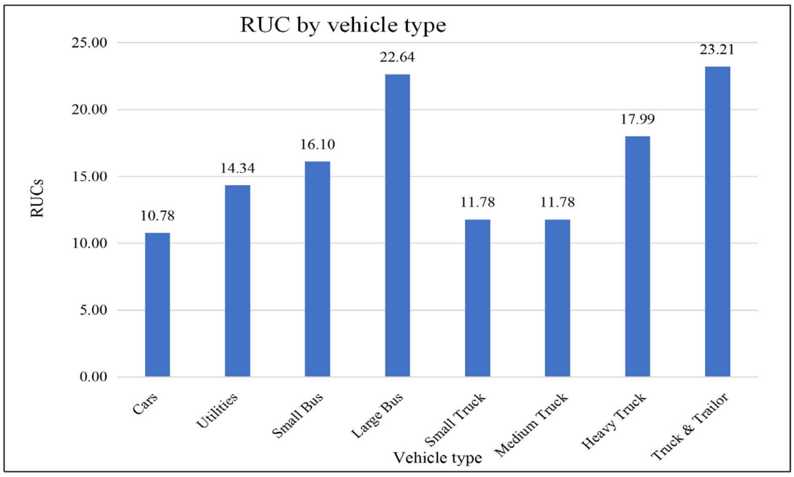

Figure 8. Summary of average RUC by vehicle type from manual calculation

3.3 Comparison of Results from Both Methods

The RUCs results of both methods are presented below. As a result, shows both methods give almost comparable results. A difference between a manually calculated total amount of road users' cost and that of HDM-4 Software result is Birr 10.6. HDM-4 uses more parameters and considers more factors to calculate vehicle operating cost and travel time cost. International roughness index (IRI) and average operating speed are the most concerns for the calculation of vehicle operating cost and more of traveling speed for travel time cost for the HDM-4. As shown in the resulting vehicle operating cost increases with an increasing amount of IRI and decreases with the increase in operating speed of the vehicle till optimum value, where there is an additional cost for fuel if the speed increases. Travel time is also affected by the operating speed, and this is well considered in the HDM-4. When the speed of the vehicle increases, the time is taken to complete the trip decreases, and the time value will increase, and when operating speed decreases, it shows vice versa. The manual technique has a simplified and adoptable equation the fluctuation of IRI and operating speed is not considered as that of appeared in the HDM-4. The manual technique is very easy and friendly for applying and estimating RUCs, and as shown in the table below, the results from this technique are more related to the HDM-4, which is accepted worldwide.

The results obtained from both methods were also checked using correlation coefficient, and the result found 0.75 which shows the two results are highly correlated. The output shown in the Table 6 reflects the correlation relation between the results.

Table 6. Correlation coefficient

	Manual	*HDM-4*
Manual	1	
HDM-4	0.75	1

Table 7. RUC comparison of both manual technique and HDM-4 Software methods

Vehicle type	Manual calculation			HDM-4 calculation			Ratio (HDM-4/manual)
	VOCi (ETB/km)	VOTi (ETB/km/vehicle)	RUCi (ETB/km)	VOCi (ETB/km)	VOTi (ETB/km/vehicle	RUCi (ETB/km)	
Cars	10.28	0.5	10.78	12.65	0.49	13.14	1.22
Utilities	13.18	1.16	14.34	8.5	1.17	9.67	0.67
Small Bus	13.45	2.65	16.1	8.12	3.1	11.22	0.70
Large Bus	14.12	8.52	22.64	12.89	9.08	21.97	0.97
Small Truck	11.78	0	11.78	9.16	0	9.16	0.78
Medium Truck	11.78	0	11.78	15.81	0	15.81	1.34
Heavy Truck	17.99	0	17.99	28.81	0	28.81	1.60
Truck & Trailor	23.21	0	23.21	29.45	0	29.45	1.27
Total	115.79	12.83	128.62	125.39	13.84	139.23	1.08

The results from both methods are presented in the Table 7 above. Also using the results presented, the results obtained from both methods can be easily correlated. As a result, the RUC of both methods has shown increasing and decreasing patterns vary according to the type of vehicle. This is also easily shown in Figure 9 below.

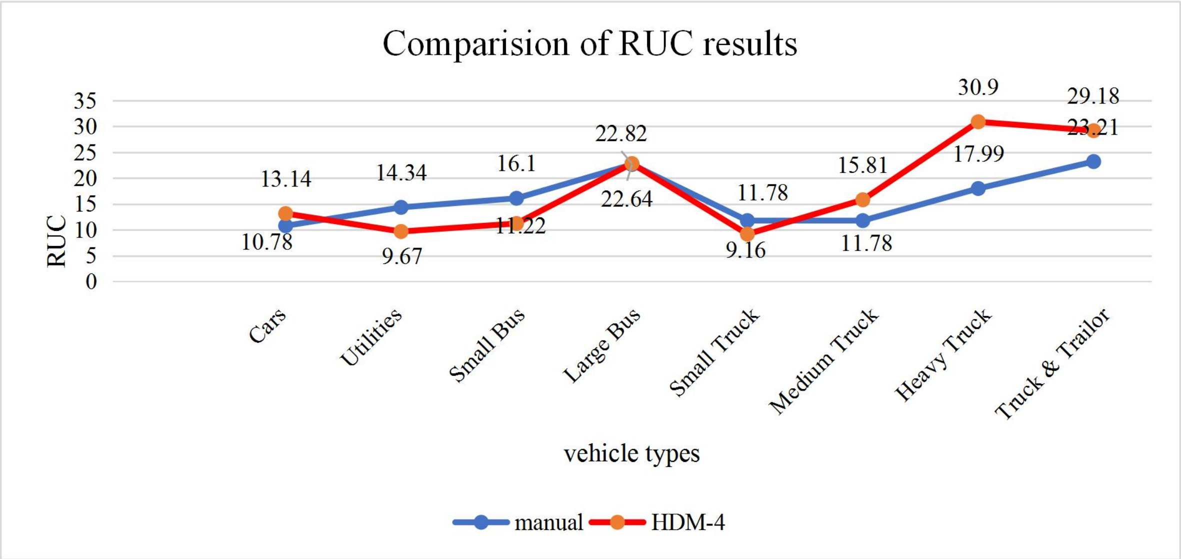

Figure 9. Summary on comparison of RUC of both methods

4. Conclusions

The results obtained from the analysis show minor variations. The VOC estimated using the manual technique and HDM-4 are ETB 115.79/km/vehicle and ETB 125.39/km/vehicle, respectively. On the other hand, the value of time (VOT) estimated are ETB 12.83/km/vehicle and ETB 13.84/km/vehicle, respectively. From the above results, the difference between the two methods becomes ETB 9.60/km/vehicle and ETB 1.01/km/vehicle, respectively. As a result, the RUC model provided by HDM-4 shows better estimates of VOC and VOT for each vehicle class than the manual technique used for analysis.

Generally, according to the findings explained above, one can use both methods or either of them.

- Where there is a lack of data, the manual technique may replace the HDM-4 since this software uses an extensive amount of data.
- From the results mentioned above, the HDM-4 model has estimated a larger value of costs for both VOC and VOT compared to the manual technique. So that for design and feasibility study purposes, the results from the HDM-4 Software can be used since it shows the larger value more concern will be given on the design part for providing a better quality of service for road users.
- It is advised that the fundamental parameters of the provided VOC and VOT valuation model be updated regularly by collecting current market pricing and that the model be thoroughly revised if the new volume is available.

Conflict of Interest

This is to declare that is no conflict of interests.

Findings

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