Estimation of Vehicle Operating Cost for Pakistan

A thesis submitted in partial fulfillment of

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Abstract

Vehicle Operating Costs (VOC) is important considered vital for transport planning to appraise and compare the Highway Improvement alternatives. The major components of this cost include fuel consumption, engine oil, tyres, maintenance and repairs, and depreciation cost.

The comprehensive literature review was done to understand different VOC models adopted by other countries. In this study, local data was collected to develop VOC model for Pakistan. National Transport Research Centre (NTRC) has carried out VOC studies for Pakistan in the last three decades. It was based on the Ministry of Communication (MOC) data which in turn used the study carried out in Kenya and Yugoslavia.

The parameters required for the estimation of VOC using the selected VOC models were identified. The parameter includes the Vehicle parameters, market prices for different VOC components and road characteristics.

VOC in the study were estimated using the NTRC model, the Nepal VOC model and the HDM-4 model. The financial and economic estimates produced after these studies were compared and the composition of different VOC components were analyzed. A separate survey was also carried out from the vehicle operators or drivers for the Hi-aces, Buses and Trucks. The survey was based on a questionnaire formulated to ask the questions about the expenditure incurred during the operation of the vehicle. The results from the survey were used to validate the VOC estimates from the model.

Finally, the VOC sensitivity to speed and roughness was analyzed using the HDM-4 model.

CONTENTS

List of Abbreviations

VOC	Vehicle Operating Cost
NTRC	National Transport Research Centre
MOC	Ministry of Communication
JICA	Japan International Cooperation Agency
IRI	International Roughness Index
GHG	Green House Gas
HDM	Highway Development and Management Model
CRRI	Central Road Research Institute
ISOHDM	International Study of Highway Development and Management Tools
FC	Fuel Consumption
AKM	Annual distance travelled
GDP	Gross domestic product
OGRA	Oil and Gas Regulatory Authority
CPI	Consumer Price Index
AADT	Average Annual Daily Traffic
KPK	Khyber Pakhtunkhwa
RED	Roads Economic Decision
CNG	Compressed Natural Gas
VMT	Vehicle-Miles Traveled

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

To justify certain investment in Highways or analyze transportation policies, Vehicle Operating Costs (VOC) is important to be considered to appraise and compare the Highway Improvement alternatives.

Road user cost is a component of transportation cost on a highway. Always in the past, decisions of the selection of road schemes have been based purely on the Fuel, Lubricants/Engine Oil, Tyres, Vehicle maintenance and Repair are the possible components of VOC and when a vehicle runs on a road, costs are incurred due to the utilization of these components. VOC changes with varying surface type, pavement condition, roadway geometrics, environment, speed of operation, and other factors. Other components of VOC include vehicle depreciation and crew costs which may vary with vehicle operating time and utilization. Finally, the last few components of VOC are overheads and interest charges.

The decision-making process to undertake the highway projects depends on the benefits gained and cost incurred under various scenarios. Reducing the travel time and crash reduction are huge benefits aimed to be obtained from undertaking highway projects. Another major benefit to the highway users is the reduction in the VOC returned from the Highway improvements.

Construction of Highways as a result of major vehicles attraction from and distribution to a region cost huge amount. These highways have different characteristics and their changing level of service and pavement condition have a direct impact on the vehicle operating cost.

cost of initial construction of the facility, overlooking the cost of maintenance and, more importantly, the future road user cost. Only one component, cost of initial construction, has been the guiding factor so far. The Planning division and other agencies concerned with development of transport services and infrastructure including the Ministry of Communication, Provincial Planning and Highways Departments, Transport Authorities need the Vehicle operating cost information for determining transportation costs for different types of traffic-passenger, goods, etc., for appraisal of highway improvement projects and feasibility studies and formulation of policies for energy conservation and efficiency of transport services, etc. Highway agencies in Pakistan should consider VOC when evaluating various strategies related to pavement management. A well-functioning road-transport system is vital to the well-being and prosperity of Pakistan. A vehicle operating study suitable to Pakistan conditions would help in an accurate estimate of VOC which could be used by different highway agencies and analysts for pavement management which will directly affect the road user costs and eventually the economy of Pakistan.

Updating VOC and research studies on the components of VOC has been given little importance in Pakistan. Since VOC are relatively smaller in magnitude, and thus NTRC, research institutes and policy analysts have paid less attention towards it.

VOC estimates carried out in Pakistan by NTRC are very old. Few of the studies have been dealing the inflation only. The general practice of updating VOCs in literature based on price indexes is not an accurate representation of the variation in the main factors affecting operating cost of a vehicle. In order to appraise the Highway projects in Pakistan, updated VOC should be used in order to better evaluate the projects. Indeed, this is one of the major reasons and motivations to carry out this research. This study is aimed to develop updated VOC estimates on current information about vehicle characteristics.

The World Bank carried out a number of studies in different counties to study VOC and affects of pavement characteristic on VOC. Different VOC models have been developed as a result of these studies. VOC models need to be updated regularly to reflect changes in prices of inputs such as fuel, as well as to incorporate any changes in physical consumption units that may arise through technological changes (more efficient engines) or better information on VOCs over different road conditions (e.g. road roughness).

If proper VOC model is developed for Pakistan to assess and predict the contribution of the third component to the total transportation cost, it would be easy to evaluate different alternative improvement plans. The VOCs will be determined from the models opted most suitable for Pakistan condition and based on the VOCs, the best alternative solution would be selected resulting in minimum vehicle operating costs, taking into account factors such as vehicle type, vehicle speed, roughness of road, geometry of road and environmental factors.

After thorough literature review and evaluating VOC models developed by other countries, VOC model suitable to Pakistan condition would be opted for. This practice is most commonly adopted by developing countries which has insufficient resources for conducting their own research studies. Fortunately, there are several VOC models developed by different transportation agencies in various countries, but the main difficulty therefore lies in opting for the most suitable relationships for the country in question.

1.2 PROBLEM STATEMENT

Transportation Agencies in Pakistan has not carried a detail research study for Pakistan in the last two decades. Drastic changes have occurred in VOC since a study on Vehicle Operating costs were carried out in Pakistan due to both advancement in vehicle technology and inflation. Since VOC are a major portion of highway transportation costs, this research has been aimed to estimate the VOC for Pakistan using the best suited VOC model developed across the world. The studies carried out in Pakistan in 1977 and 1985 were majorly based on the studies carried out by other countries like Kenya and Yugoslavia. The studies carried out by Pakistan in the 1980s and 1990s have already become obsolete. The importance of VOC in the evaluation and comparison of various alternative designs and alternative improvement options demands a detail vehicle operating cost study to be carried out for Pakistan.

1.3 RESEARCH OBJECTIVES

The objectives of this research are following:

- Review the previous local and international studies for VOC
- Identify the parameters need to measure and updated for estimation of VOC in Pakistan
- Identify VOC models that better suit the conditions of Pakistan and could be utilized to estimate VOC for all classes of vehicle in Pakistan
- To carry out an estimate based on vehicle drivers or operator which could be used to validate the estimate from the VOC models
- Determine Financial and Economic VOC for Pakistan

1.4 SCOPE OF THE STUDY

The study is aimed to update the vehicle operating cost for Pakistan. The scope of this study includes:

- To identify the parameters required to estimate VOC using different VOC models such as the cost per unit for each component of the VOC, Pavement conditions and representative vehicles Characteristics.
- The data collection will take place in the twin cities of Islamabad and Rawalpindi.
- VOC will be estimated for the following four vehicle classes: a car, a Hi-ace, a Bus and a Truck.
- A questionnaire survey will be conducted from the vehicle operators across Islamabad and Rawalpindi which will help in building a VOC estimate based on the user feedback.
- The VOC estimates will be carried out by the NTRC VOC model, the Nepal VOC model, the HDM-4 model.

1.5 ORGANIZATION OF THE THESIS

The thesis is divided into five chapters. Chapter 1 is the introduction and problem definition and objectives for this study. In chapter 2, the literature review discusses the Vehicle operating cost studies carried around the world, the studies carried out in developing countries which were sponsored by the World bank which were the foundation of the HDM-III and HDM-4. It further discusses the VOC studies carried out in Pakistan over the years, the methodology adopted in these studies to estimate the VOC and the final VOC estimate. Chapter 3 presents the methodology employed in the research for various VOC components. In this chapter the different VOC components has been elaborated. Chapter 4 explains the different VOC parameters required to carry out the VOC estimation. It describes the details of survey carried out to collect the cost data from the authorized vehicle dealers, tyres distributors, Maintenance workshops and vehicle drivers. In chapter 5, the results obtained from the different VOC models and the small-scale user survey carried out for this study. Conclusions and recommendations are described in chapter 6.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Considerable studies have been carried out in the past over Vehicle Operating Costs (VOC) in various countries by different transport agencies and experts. This chapter eLabourates the studies carried out on the aforementioned subject both in developed and developing countries and Pakistan. As far as developing countries are concerned, the major VOC studies has been carried out in four countries that are Kenya, India, Brazil and Caribbean. These four major studies are also the basis for the World Bank VOC model HDM-III and HDM-4. VOC studies are also carried out by other developing countries like Nepal and Bangladesh for their respective country. A sequential pattern has been formulated for the VOC models developed over the years. The data collecting techniques and the empirical or mechanistic models developed for VOC estimations as a result of the VOC studies carried out were also reviewed.

2.2 VEHICLE OPERATING COST STUDIES AND VOC MODEL DEVELOPMENT

Vehicle Costs measurement for motorized vehicles first received attention after the world war 1 in North America (Agg 1928) which influenced the subsequent fuel consumption studies. Over the next few decades, major research studies were carried out to interrelate highway geometry, vehicle performance and costs. Road user surveys were soon carried out in 1960s for various operating cost components by (Kent 1960)and (STEVENS 1960)) and Indian Roads (CONGRESS 1961). (Winfrey 1963) publication filled the gaps available in the VOC studies carried out in the North America over decades and this study eventually influenced the VOC studies that took place in the US and the developing countries over the next 15 years. (WEILLE 1966) carried out the literature review and prepared the cost tables sponsored by the World Bank.

After the De Weille’s publication, the World Bank in 1969 aimed to carry out research to develop Vehicle Operating Cost models for Developing countries which would suit their respective Highway, topographic and weather conditions. The reason for initiating this study was the inadequacy of using the results, based on American studies for evaluating highway investment projects in the developing countries.

Between 1971 to 1982 few major studies were carried out which resulted in investigating the Vehicle Operating Costs in enormous depth. Commercial User surveys were carried out on a far larger scale than had been carried out before 1970s. To investigate the influence of variable highway conditions and the effect of speed on fuel consumption, high number of experiments were undertaken. The results from these studies were also incorporated by the World Bank to develop HDM III.

The major studies carried out were in Kenya, Brazil, Caribbean and India. The objective of the studies in these countries was to establish an accurate statistical relationship between the VOC components and the elements of road characteristics, vehicle characteristics, traffic factors and environmental factors which will help to estimate the VOC for any given combination of varying aforementioned factors and elements.

The collection of data for the VOC components in these studies was carried out for longer duration of time. The methodology adopted for determining the fuel consumption relationships consisted of two approaches. Initially controlled experiments were performed on certain vehicles to predict the fuel consumed by these vehicles over different roads in varying conditions. Then, fuel consumption data was also collected from a number of vehicle operators of different types. Finally, the two data sets from both the approaches was compared. It was very impractical and unmanageable to conduct controlled-experiments for other VOC components such as spare-parts consumption, maintenance Labour, tyre wear, depreciation, and lubricants. A survey of the operation cost was undertaken from a large number of operators in detail and the statistical relationships for the above-mentioned components were determined based on this data.

The studies carried out in these four countries were having very different physical, economic conditions, highway conditions and vehicle fleet composition. The four countries have substantial difference in climatic conditions within and across. India particularly, showed considerable variation across the country ranging from relatively cool Kashmir with frequent rainfall to the hot and humid west coast areas. The Brazilian Plateau region has temperature very low over the year and the winter months are mostly dry. Kenya too enjoys very low to moderate temperature over the year due to its altitude. It experiences moderate rainfall during the March to May period. Caribbean has high rainfall from July to November and the seasonal variation in temperature is very small.

The surface areas of the four countries varied with Brazil the largest, having surface area twice that of India. Brazil terrain is flat or rolling with few mountainous areas mostly like India's. Kenya's surface area is less than a fifth of India's where the Caribbean study was carried out in the Islands which are extremely small, and their collective surface area is less than 1 percent of that of Kenya.

User Cost information can be collected from different sources such as vehicle and part manufacturers, and vehicle dealers or outlets. Data for VOC component like fuel consumption can be measured through experiments using test vehicles equipped with fuel consumption measuring instruments. Other VOC components like tyre and maintenance costs is difficult to be obtained via experiments.

For the four studies the fuel consumption data was collected by carrying out experiments in a controlled manner over road sections which were generally having length equal to one kilometer. In order to allow the test vehicles to attain certain required speeds and gear selection, half kilometer transition sections were also provided prior entering the test sections.

The number of vehicles used for conducting fuel consumption experiments for the four studies are listed below:

Brazil: 10 specially purchased vehicles were used.

Kenya: 3 Instrumented vehicles, a car, a light goods vehicle and a medium truck were used.

Caribbean: 3 Instrumented vehicles were used to measure fuel consumption.

India: 2 cars, a diesel engine jeep and a medium and a heavy truck were used.

The user cost surveys carried out as part of the four studies varied substantially in size, but they had similar structure. The objective of all the studies was to relate the user costs to the highway characteristics. The user cost data was collected mostly from medium and large companies in the Kenya study. The sample size of the Kenya user cost data collected included 43 cars, 47 light good vehicles, 78 medium/heavy trucks and 121 large buses. 1675 vehicles records were gathered from 147 companies in the Brazil study during 1976 and 1979.

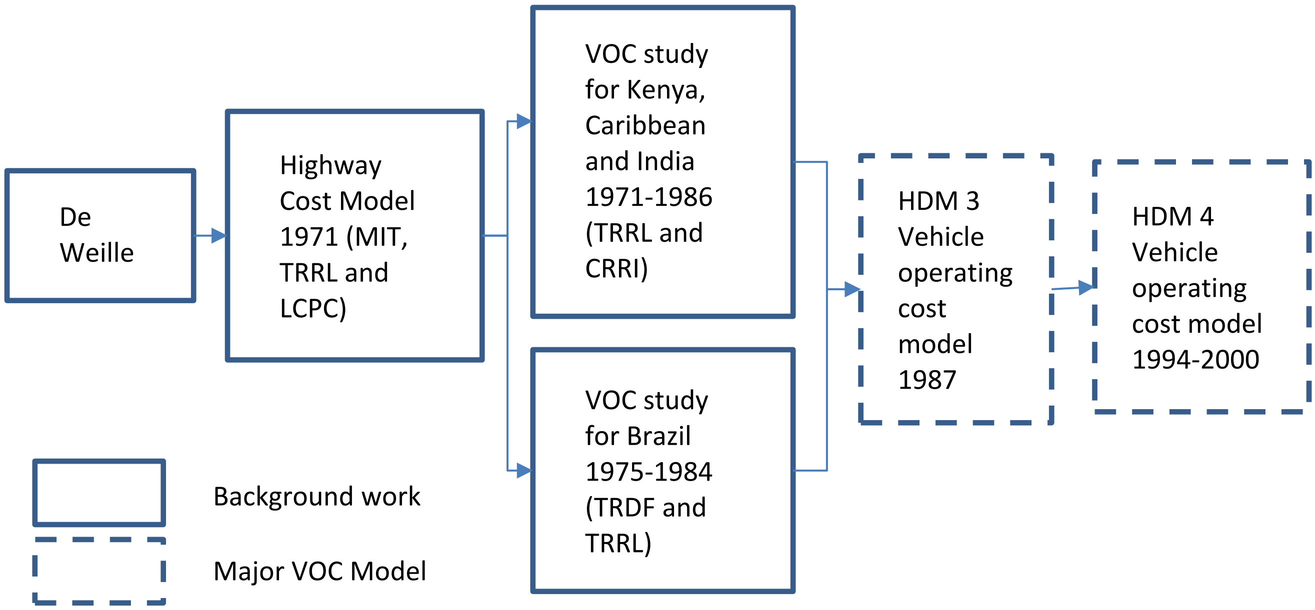
In the Caribbean, owners and drivers were inquired about the consumption of items due to absence of cost recording system with the transport companies or vehicle owners. 40 cars and light goods vehicles drivers were questioned, and 96 truck drivers were inquired about the consumption of items.

The user survey team collected data for 640 buses, 232 trucks and 67 cars and jeeps. Most of the data was gathered from large companies. The maintenance related data was monitored for considerable duration in the four studies. Data was collected for 2 years in Kenya and Caribbean, average survey period of 18 months in Brazil and average survey period of 17 months in India.

Equations were obtained from the four studies for vehicle speed, fuel consumption, engine oil consumption, tyre, maintenance parts and maintenance Labour based on the experiments conducted for fuel consumption and the user survey data collected.

HDM-III was developed in1987 by the World Bank which was a comprehensive model. HDM-III was developed making use of the four studies carried out in Brazil, Kenya, Caribbean and India. The Brazil models were chosen as the primary basis for HDM-III due to more general formulation and stronger statistical qualification. The HDM-III development commenced with the objective to have a general model that could be used in diverse countries around the world with limited local calibration.

The technical relationships used in the HDM III were more than ten years old when the development of HDM-4 was decided to take place. The incorporation of the research being carried out around the world during this period was much needed. Since vehicle technology had drastically evolved after 1980, it was recognized that the VOC could be quiet less than those predicted by HDM III. Figure 2.1 shows the chronological order of the VOC studies carried out and VOC models developed over the years.



Source: Bein (1993)

Figure 2.1 World Bank VOC Models development

FHA sponsored a research was carried out and reported in June 1982 (Zaniewski 1982). The main objectives of the research were to update the information on the interactions between vehicle operating parameters and roadway characteristics and to determine the VOC. Fuel consumption was immensely studied since it is a major component of VOC. Updated VOC tables were presented in this report. Fuel consumption tests were carried out for 8 vehicles. The test sections were selected for these experiments to be homogenous with respect to grade, roughness, and surface type. 8 vehicles were used which represented seven vehicle classes. Fuel consumption tests were conducted at constant speed in 10 mph increments from 10 mph to 70 mph. It was observed that at same pavement roughness larger trucks (3S-2) consumed 20 Percent less fuel on concrete pavements compared to asphalt pavements.

Various other VOC studies were carried out in Australia, South Africa and New Zealand which resulted in the development of Australian NIMPAC VOC module, South African VOC models (du Plessis, 1989) and New Zealand NZ VOC (Bennett, 1989).

2.3 NEPAL VEHICLE OPERATING COST MODEL

The initial VOC model in Nepal was based on the Central Road Research Institute (CRRI) research carried out in India. Most of the trucks and buses in Nepal were from the TATA company. Therefore, it was realized that the Indian VOC studies would be most suitable to be used for Nepal.

However, in July 2001, in order to update the Nepal VOC model, a consultant was appointed. Surveys of trucks and buses were conducted to collect the input prices for the estimation of VOC. The VOC model was based on the Indian VOC relationships and VOC relationships were identified for Nepal which were majorly developed from the following reports.

- A Chesher & R Harrison: HDM Vehicle Operating Costs Evidence from Developing Countries The World Bank 1987, Washington DC.
- T Watanatada et al. The Highway Design and Maintenance Standards Model Volume 1. Description of the HDM III Model, The World Bank 1987, Washington DC.
- Central Road Research Institute: Road User Cost Study In India, Final Report. CRRI, 1982, New Delhi

2.4 HDM-4 VOC MODEL

World Bank in 1987 developed HDM-III, a comprehensive model by, making use of the four studies carried out in the Caribbean, Kenya, India and Brazil. Both controlled experiments and user cost surveys were conducted for developing the relationships. The objective behind the development of the HDM-III was to have a general model that could be used in diverse countries around the world which would require limited local calibration. The effect of road characteristics on VOC were predicted with the relationships it contained.

The technical relationships used in the HDM-III were more than 10 years old when the development of HDM-4 was decided to take place. The incorporation of the research being carried out around the world during this period was much needed. Since vehicle technology had drastically evolved after 1980, it was recognized that the VOC could be immensely less than those predicted by HDM-III models. International Study of Highway Development and Management Tools (ISOHDM), a colLabourative study started in 1993. It was comprised of study teams based in Chile, Japan, Malaysia, Sweden, and the U K, the objective of the

ISOHDM study was develop improved relationships and techniques for economic appraisals of road improvement projects and one of the outcomes of the study was a new version of HDM, HDM-4.

HDM-III was limited with respect to the types of pavements which could be analyzed since the objective of HDM-4 was to develop a model which would be applicable to the full range of pavement types found in both developed and developing countries.

2.5 VEHICLE OPERATING COST STUDIES IN PAKISTAN

National Transportation Research Centre (NTRC) is the only organization in Pakistan which is solely responsible to carry out traffic studies and other research studies related to road and road transport. Following VOC studies have been carried out by NTRC over the years:

- Fuel Consumption Study NTRC-54 (1981)
- Road Vehicle Operating Cost Study NTRC-79 (January 1985)
- Vehicle Operating Costs NTRC-150 (August 1991)
- Vehicle Operating Costs NTRC-177 (April 1994)
- Vehicle Operating Costs (2005) using HDM-VOC Version 4.0 (NTRC-270) dated September 2005.

Other VOC study carried out in Pakistan is the JICA VOC study undertaken under Pakistan Transport Plan study in the Islamic Republic of Pakistan (PTPS) 2006

2.5.1 Fuel Consumption Study (1981)

The fuel consumption study was carried out by Mr. Abdul Majeed in 1981. The objective of the study was mainly to measure the fuel consumed by various vehicle classes in different operating conditions specifically varying operating speed. In this study, fuel consumption has been measured through experimentation for varying speed. The kevel tangent paved road section was selected to carry out the fuel consumption measurements in the vicinity of Islamabad. The final results from the experiments are in the form of average fuel consumption per km on level tangent roads for different classes of vehicles. The same fuel consumption values were used in the succeeding study carried out for the estimation of VOC in 1985 as base fuel consumption per 1000 km.

2.5.2 NTRC VOC model and VOC study "NTRC-79" dated January 1984

Earlier VOC studies were carried out in Pakistan by Ministry of Communication which was the VOC studies carried out in Kenya and Yugoslavia. NTRC too used the VOC study carried out by Ministry of communication (1977). However, NTRC utilize their own base fuel consumption for different vehicle classes changing for varying speed. NTRC carried out this study for 3 types of pavement that are paved, unpaved and shingle and 4 types of vehicles.

Using the same relations and VOC model used by NTRC, updated input costs and updated vehicle utilization and other VOC parameters, a VOC estimate was carried out. The costs of different components have been compiled by given road characteristics and quantity unit costs were multiplied with the prices of each component.

2.5.3 Vehicle Operating Costs NTRC-150 (August 1991)

It was felt that the 1985 study became outdated due to inflation in prices, deterioration of roads and the variation in volume and composition of traffic on road. Therefore, this study was carried out with an objective to work out VOC of the conventional classes of vehicles on paved and unpaved roads for the conditions prevailing in Pakistan. 6 types of vehicles were considered that are car, Wagon, Mini Bus, Bus, Medium Truck and Heavy Truck. The VOC was calculated by using two different methods.

- Theoretical calculations, Using the Conventional VOC models such as RTIM2 developed by TRRL, UK
- Empirical study based on the experimental studies carried out by NTRC in 1985 and Road Freight Industry Survey based on the road side interviews conducted in Pakistan by Mr. John L. Hine of TRRL in 1987.

The study was carried out for 8 different vehicle types. Suzuki-800 cc had become the most common car in the country and recently Pakistan had start assembling Suzuki-1000 cc vehicles. But Toyota Corolla (1300 cc) was taken as a typical car which was similar to other popular cars such as Honda, Nissan, Mazda and Lancer. Other vehicles considered in this study for the estimation of VOC were a wagon, a minibus, a bus, a medium truck and a heavy truck.

Different ranges of road characteristics were considered and used in equations since data for surface roughness, rise plus fall and degree of curvature were not available for roads across different regions in the country. Table 2-1 shows the Road Characteristics used in this study:

Table 2-1 Road Characteristic used in NTRC VOC study 1991

Type	Rise and Fall (m/km)	Roughness BI (mm/km)	Curvature (mm/km)	Pavement Width (m)
Paved	5 to 20	2000-4000	50-200	8
Unpaved	5 to 30	6000-8000	100-250	4
Source: VOC (AUG 1991) NTRC-150				

The VOC costs calculated by the RTIM2 model under this study for paved and unpaved roads are shown in Table 2-2 and Table 2-3:

Table 2-2 VOC/1000 km for paved roads estimated in NTRC study 1991

VOC/1000 km for paved Roads								
Vehicle Class	Car (Toyota)	Car Suzuki (1000 cc)	Car Suzuki (800 cc)	Wagon (Ford)	Mini Bus (Mazda)	Bus (Bedford)	Medium Truck (Bedford)	Heavy Truck (Nissan)
Vehicle Speed (km/hour)	86.5	86.5	86.5	75.55	61.19	61.19	59.63	59.61
Fuel	1355.9	1120.1	966.8	929.2	959.5	1383.7	914.1	1489.7
Oil	32.4	32.4	32.4	48.6	108	108	108	108
Tyres	111.2	83.4	78.8	51.2	135.5	533.5	505.9	821.7
Maintenance Parts	193.66	26.37	12.83	13.496	290.5	296.8	60.64	139.161
Maintenance Labours	358.638	125.109	88.512	60.331	147.886	346	92.269	179.163
Depreciation	174.34	67.993	46.769	938.21	618.537	502.249	523.534	496.134
Crew	159	159	159	182	361	361	433	433
Interest	299	117	80	83	63	45	47	45
Total	2684.138	1731.372	1465.111	2306.037	2683.923	3576.249	2684.443	3711.858

Table 2-3 VOC/1000 km for Unpaved roads estimated in NTRC study 1991

VOC/1000 km for Unpaved Roads								
Vehicle Class	Car (Toyota)	Car Suzuki (1000 cc)	Car Suzuki (800 cc)	Wagon (Ford)	Mini Bus (Mazda)	Bus (Bedford)	Medium Truck (Bedford)	Heavy Truck (Nissan)
Vehicle Speed (km/hour)	54.72	54.72	54.72	50.54	47.19	47.19	42.82	42.82
Fuel	1296.9	1061.1	896	863.6	1095.8	1509.9	1045.4	1610.9
Oil	64.8	64.8	64.8	97.2	97.2	216	216	216
Tyres	661.3	496	468.4	590.6	221.6	873.7	828.5	1345.9
Maintenance Parts	451.26	61.18	29.739	33.32	261.741	633.975	79.586	195.505
Maintenance Labours	351.643	122.215	86.371	43.902	221.724	737.959	121.411	251.801
Depreciation	232.76	90.776	62.44	740.05	741.974	627.486	697.865	619.847
Crew	251.4	251.4	251.4	227	451	451	542	542
Interest	200	155.7	107.1	104.17	78.21	56.33	62.66	66.8
Total	3510.063	2303.171	1966.25	2699.842	3169.249	5106.35	3593.422	4848.753

2.5.4 Vehicle Operating Costs NTRC-177 dated April 1994

In 1994, NTRC updated the Vehicle Operating Costs study carried out in 1984. It was carried out for the same vehicle types and same road characteristics and VOC components. The pattern adopted was same as the previous study. Summary of Vehicle operating costs updated in 1994 by NTRC per kilometer is shown in Table 2-4.

Table 2-4 Summary of NTRC VOC Estimation (1994)

Summary of Vehicle Operating Costs (per km)							
Vehicle Type	Speed	Financial Costs			Economical Costs		
		Improved	Unimproved	Gravel	Improved	Unimproved	Gravel
Car	30	8.21	9.81	11.91	5.80	6.86	8.27
	40	7.12	8.73	10.86	4.98	6.05	7.47
	50	6.59	8.27	10.47	4.56	5.66	7.12
	60	6.26	8.02	10.28	4.29	5.43	6.92
	70	6.11	7.97	10.37	4.14	5.34	6.90
	80	6.22	8.26	10.85	4.10	5.45	7.11
	90	6.67	9.31	12.46	4.39	5.99	7.94
Wagon	30	5.58	7.11	8.56	4.14	5.09	5.97
	40	4.84	6.39	7.87	3.55	4.51	5.40
	50	4.38	6.02	7.61	3.18	4.19	5.14
	60	4.14	5.87	7.54	3.00	4.05	5.04
	70	4.00	5.89	7.72	2.89	4.03	5.10
	80	3.96	6.07	8.15	2.85	4.11	5.31
	90	4.06	6.83	9.66	2.90	4.50	6.09
Bus	30	10.00	11.90	13.60	8.50	9.97	11.29
	40	8.59	10.49	12.21	7.20	8.68	10.01
	50	7.84	9.88	11.67	6.46	8.01	9.38
	60	7.71	9.88	11.73	6.25	7.86	9.26
	70	8.17	10.68	12.60	6.51	8.31	9.74
	80	8.67	11.64	13.74	6.70	8.80	10.32
	90	10.38	15.06	17.62	7.69	10.65	12.41
Truck	30	8.88	9.98	11.70	7.22	8.09	9.45
	40	7.51	8.61	10.35	6.06	6.93	8.31
	50	7.17	8.39	10.21	5.71	6.64	8.06
	60	6.96	8.33	10.22	5.46	6.46	7.92
	70	7.09	8.77	10.72	5.50	6.68	8.16
	80	7.90	10.03	12.13	6.04	7.46	9.02

2.5.5 Vehicle Operating Costs (2005) using HDM-VOC Version 4.0 (NTRC-270) dated September 2005

This VOC study was based on Free Flow Vehicle Operating Cost Model Version 4.0 (HDM-VOC) of the World Bank. The prices for vehicles, tyres, fuel and lubricants were collected from the market in June 2005. A range of values for the input parameters were used in the VOC model such as surface type, road roughness, gradient, horizontal curvature and altitude of terrain. The HDM-VOC model estimated the VOC for different vehicle classes and vehicle types.

It was analyzed that the contribution of fuel in the VOC is 26 percent and the lubricants and tyres count for 12 percent of the total VOC.

Furthermore, the impact of roughness and horizontal curvature on VOC was also evaluated. VOC was estimated for specific values of International Roughness Index (IRI) and Horizontal Curvature (degree/km) for different vehicle types.

An analysis was also carried out for different types of vehicles by varying the roughness values and operating speed.

Finally, a comparison was made between the NTRC VOC study 1994 (NTRC-177) and this HDM-VOC based study (NTRC-270). Table 2-5 shows the comparison at the same road roughness and operating speed between both studies.

Table 2-5 Comparison of VOC per 1000-km (2005)

Comparison of VOC per 1000-km (Rupees)			
Financial			
	2005	**1994**	**Percent increase**
Car	8,575.10	4,301.74	100
Wagon	10,735.40	4,295.30	149
Bus	20,297.80	8,385.61	142
Truck 2-Axle	12,306.00	5,252.97	134
Truck 3-Axle	15,753.00	6,804.02	132
Truck Multi-Axle	19,911.40	8,174.08	144
Economic			
	2005	**1994**	**Percent increase**
Car	5,547.20	2,670.73	108
Wagon	9,397.90	3,472.76	171
Bus	19,133.80	6,983.04	174
Truck 2-Axle	8,370.40	4,110.00	104
Truck 3-Axle	11,049.90	5,226.00	111
Truck Multi-Axle	13,940.90	6,308.00	121
Source: NTRC			

2.5.6 JICA VOC study undertaken under "Pakistan Transport Plan study in the Islamic Republic of Pakistan (PTPS) 2006"

The Vehicle operating cost study conducted by JICA was based on the study carried out by NTRC in 1993 (NTRC-177) published in 1994 and the 2005 study (HDM-VOC). The assumptions and physical parameters adopted were same as the above study. VOC was computed for 8 classes of vehicles and 3 types of roads. The prices and costs used were from November 2005. Table 2-6 shows the VOC at average speed by vehicle type.

Table 2-6 Financial and Economical VOC estimated by JICA (2006)

Vehicle Operating Cost at Average Speed by Vehicle Type						
						(Rs/km)
Vehicle Type	Average Speed	Financial Cost				
		Road Condition (Roughness)				
		Very Good (r-2500)	Good (r-3000)	Fair (r-3500)	Poor (r-5000)	Very Poor (r-7000)
Motorcycle	40	2.07	2.08	2.09	2.34	2.61
Car	50	6.95	7.06	7.16	7.86	8.78
Wagon	45	12.46	12.96	13.48	15.41	18.47
Minibus	45	15.80	16.77	17.77	21.46	26.04
Bus	50	24.09	25.35	226.58	32.09	38.73
Truck (2-Axle)	40	18.93	19.38	19.81	22.72	26.01
Truck (3-Axle)	40	22.27	22.88	23.45	26.51	30.08
Truck (Trailer)	40	27.81	28.47	29.10	33.11	37.60

Vehicle Operating Cost at Average Speed by Vehicle Type						
						(Rs/km)
Vehicle Type	Average Speed	Economic Condition				
		Road Condition (Roughness)				
		Very Good (r-2500)	Good (r-3000)	Fair (r-3500)	Poor (r-5000)	Very Poor (r-7000)
Motorcycle	40	1.45	1.46	1.47	1.65	1.84
Car	50	4.83	4.91	4.98	5.48	6.12
Wagon	45	9.24	9.59	9.96	11.41	13.58
Minibus	45	12.57	13.32	14.10	16.97	20.52
Bus	50	19.19	20.14	21.06	25.23	30.21
Truck (2-Axle)	40	13.76	14.06	14.35	16.41	18.71
Truck (3-Axle)	40	16.46	17.87	17.25	19.39	21.86
Truck (Trailer)	40	21.22	21.67	21.11	25.00	28.18
Source: JICA (2006)						

2.6 SUMMARY

The vehicle Operating Cost (VOC) models developed as a result of VOC studies carried out in different countries were discussed. The major studies were carried out in the developing countries which were sponsored by the World Bank. These studies became the basis for the development of HDM-III which was assumed to be an ideal and standard model for Vehicle Operating Costs estimation which could be transferable across countries. HDM-III was supposed to be used by different countries by calibrating the values of the necessary regional factors. Later HDM-III led into the development of HDM-4 which is the Highway development and Maintenance management model and it is still used around the world for road management. Estimation of Road User Cost can be carried out as a subsection of HDM-4. Furthermore, the VOC studies carried out in Pakistan has been discussed in this chapter. The methodology adopted in these studies and the results were presented.

CHAPTER 3

METHODOLOGY

3.1 GENERAL

This chapter explains in detail various components of vehicle operating cost and the methodology adopted for updating the vehicle operating cost in this study.

3.2 METHODOLOGY

The Estimate for the vehicle operating cost was carried out by starting with the literature review in which the vehicle operating cost studies carried out in other countries were reviewed thoroughly. The VOC models developed as a result of the studies carried out and the methodology adopted to collect the user data was studied. After, the studies carried out in Pakistan for estimation of VOC were also reviewed. The components of the VOC were identified, and various studies were reviewed to know the composition of VOC components in total Vehicle operating costs. The input parameters which included costs for different components, road conditions and vehicle characteristics were also identified, and same parameters were used throughout the VOC models to have consistency of estimation. Different authorized vehicle dealers were visited to know the cost of various types of vehicles ranging from small cars to heavy vehicles. Surveys were also conducted from vehicle drivers to get an idea about their response and perspective about the expenditure incurred for different VOC components. Finally, the estimated VOC from the models were analyzed and a report was generated based on the results.

Figure 3.1 explains the planned methodology for this study.

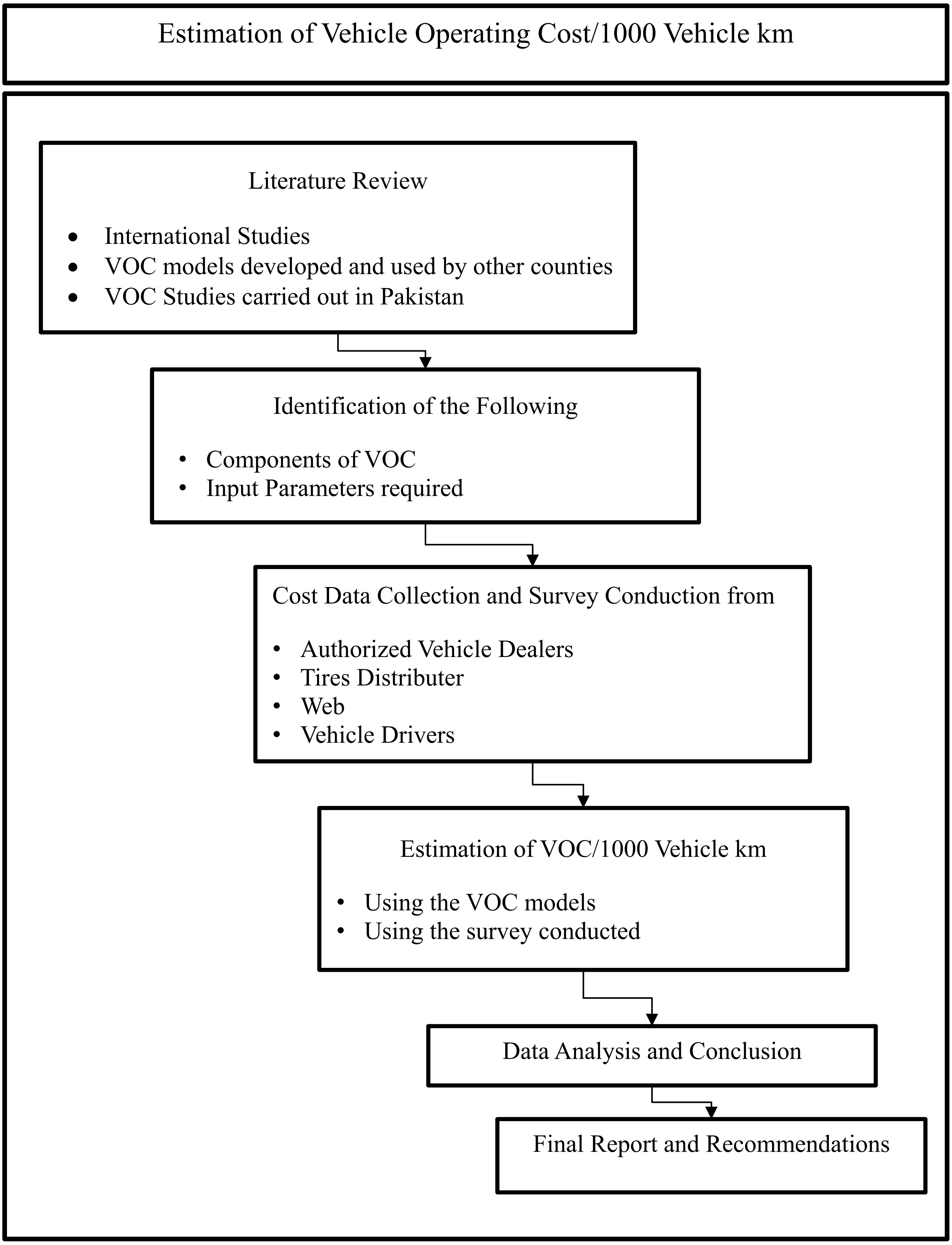


Figure 3.1 Methodology adopted to carry out the VOC estimate

3.3 COMPONENTS OF VOC:

Vehicle operating costs is made up of costs incurred by the road users. Table 3-1 shows the contribution of various VOC components in the total VOC.

Table 3-1 Composition of VOC components

VOC Component	Percentage Contribution	
	Private Cars	Trucks
Fuel	10 to 35	10 to 30
Lubricating Oil	<2	<2
Maintenance parts	10 to 40	10 to 30
Maintenance labour	<6	<8
Tyres	4 to 10	5 to 15
Depreciation	15-40	10 to 40
Crew costs	0	5 to 50
Other costs and overheads	10 to 15	5 to 20
Source: A guide to Road Project Appraisal, Overseas Road Note 5, Overseas Development Administration, 1988, p51		

These costs incurred due to the consumption of VOC components vary for different vehicle types, road surface conditions and speed of the vehicles. Therefore, VOC are correlated with the pavement type (e.g. bitumen, concrete or gravel surface), the composition of the traffic flow and road congestion.

As shown in Table 3-2, total VOC is not affected by all the components equally and for the same reason, major research has been carried out only for those components which has a greater impact on VOC.

Table 3-2 Impact of components on VOC

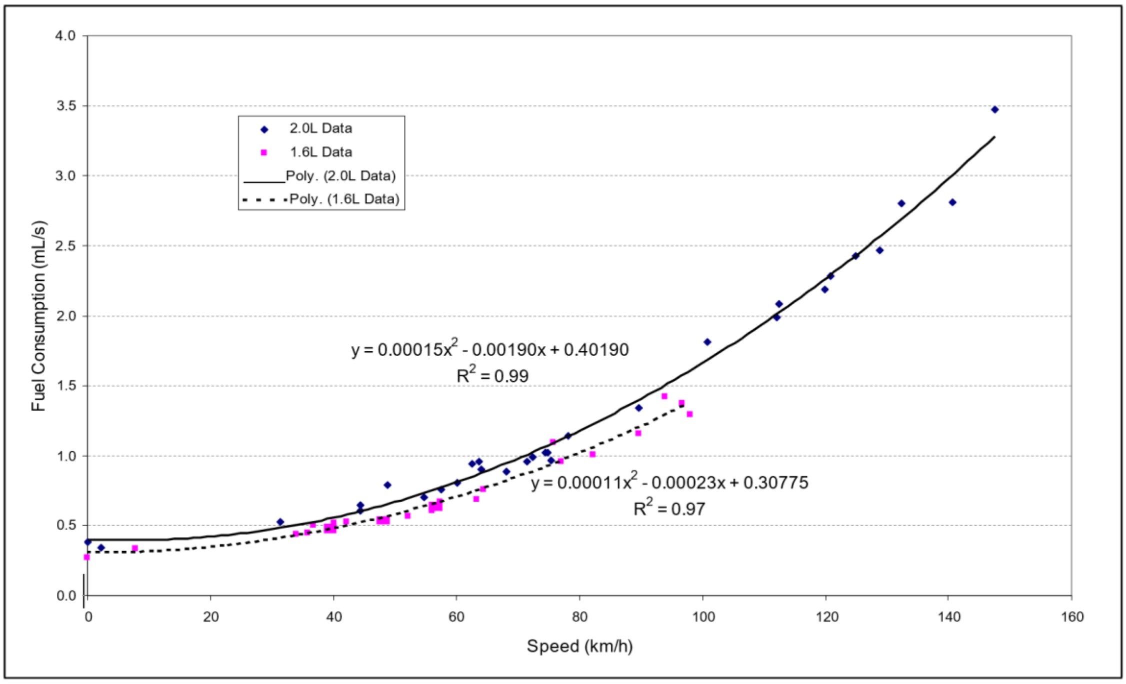
VOC Component Impact Matrix			
Impact on vehicle operating cost	**High**	**Medium**	**Low**
Fuel			
Oil			
Tyres			
Maintenance & Repair			
Depreciation and Interest			
Source: Adapted from Anderson, et al. (1992)			

3.3.1 Fuel

Fuel has very strategic importance. The importance of the fuel consumption of vehicles cannot be overlooked. The fuel expenses incurred during the vehicle operation are high enough and new road projects are economically justified by huge savings in fuel consumption. Fuel consumption is affected by pavement condition, vehicle characteristics, traffic congestion and the driving style.

In literature fuel consumption is often related to vehicle speed. A study in Thailand for 1.6 Liter and 2.0 Liter passenger vehicles illustrates that the fuel consumption increases three-fold

Table 3-3 Relationship of Fuel Consumption to speed variation



if the vehicle speed in increased from 70 to 140 km/hour as shown in the figure 3-3 (Greenwood 1999)

The National Transport Research Centre (NTRC) Pakistan has also conducted field experimentation to measure the effects of speed over fuel consumption for different vehicle types in July 1985. No other experimentations have taken place in Pakistan to measure the fuel consumption varying with the road conditions or speed. It was intended to carry out these studies as part of this research, but it couldn't happen due to unavailability of the equipment to carry out the field runs at right time. Therefore, while estimating the VOC using the NTRC model, the same basic fuel consumption values were used which were conducted in 1985 by NTRC. Table 3-4 shows the fuel consumption experiment results from 1985.

Table 3-4 Fuel consumption of NTRC experiments 1985

Average fuel consumption on Level tangent Road							
Speed km/hour	30	40	50	60	70	80	90
Vehicle Type	Fuel Consumed Liters/1000 km						
Cars	68	62	70	79	91	111	139
Toyota Hi-ace M.C.V (Petrol)	101	98	102	108	115	124	137
Ford Transit M.C.V (Diesel)	87	75	67	75	86	98	106
Bus (Diesel)	237	193	164	201	303	323	336
Truck (Diesel)	294	253	226	196	226	293	
Source: NTRC Fuel Consumption Study 1985							

The high fuel consumption with respect to speed at the two extremes can simply be explained by considering the aerodynamic forces and the tractive forces of the vehicle. The aerodynamic forces become dominant requiring high amount of fuel to be consumed since it is related to the square of velocity. White the tractive forces become dominant at low speed to fulfil the idle fuel consumption requirements that powers the engine drag and accessories.

3.3.2 Factors Influencing Fuel Consumption

There are several factors which influence fuel consumption of vehicles. A change in the fuel consumption in eminent if a change in the road conditions, traffic conditions or the vehicle type occurs. Furthermore, a change in the driving behavior also causes change in the fuel consumption. Forces opposing motion will be affected if a change in the road attributes takes place and hence it will have an impact on the fuel consumption.

The primary attributes relating to the road are:

- Gradient;
- Roughness;
- Texture; and,
- Curvature.

In addition to the above, the traffic conditions cause change in the mean vehicle operating speeds and the resultant fluctuation in speeds causes the increased fuel consumption.

Different vehicles will have different vehicle parameters which affects the fuel consumption. Vehicular factors like frontal area, vehicle curb weight, and tyre size and pressure all plays an important role in the total fuel consumption.

The VOC studied carried out by NTRC in 1985 caters for all the variations due to the above-mentioned factors. The NTRC study used the Kenyan model to adjust the effects of gradient on the total fuel consumption. While it used the study carried out by Ministry of Communication to adjust the changes in fuel consumption due to changes in curvature, roughness, traffic condition and speed fluctuation. The same adjustments were used in this study to calculate VOC/1000 vehicle km during the estimation carried out by the NTRC model. Studies have not been carried out in Pakistan to measure the effects of such changes on the fuel consumption. The scope of this study was limited, and the affects couldn't be measured.

The other model used to estimate the VOC in this study is HDM-4. HDM-4 opted for the ARFCOM mechanistic model to estimate the consumption of fuel. Mechanistic models predict that the fuel consumption of a vehicle is proportional to the forces acting on the vehicle. A mechanistic model has several advantages over empirical models such as they can allow for changes in the vehicle characteristics and are more flexible when trying to apply the models to different conditions.

3.3.3 Engine Oil Consumption

Engine oil consumption makes a very small portion of the total vehicle operating costs and for the said reason or the technical difficulties to measure the impact of speed and other factors, research has not been carried out in detail for this component of VOC.

Engine oil is consumed either due to contamination or oil loss. Combustion process produces impurities which results in oil contamination or it may occur due to external sources. The manufacturer recommends changing the vehicle engine oil after a certain distance is travelled due to the contamination.

Whereas, faulty seals or leaking of oil past the pistons which eventually burns with the fuel during the combustion results in the oil loss.

National Transport Research Centre (NTRC) used the values for the engine oil consumption from the Ministry of Communication study which in turn used the Kenyan study. The values used during the estimation of vehicle operating cost by NTRC in1985 are illustrated in table 3-5.

Table 3-5 Engine Oil Consumption from Kenya Study Used by NTRC

Engine Oil Consumption L/1000 km							
Vehicle Class	**Speed km/hour**						
	30	40	50	60	70	80	90
Car	1.44	1.44	1.44	1.44	1.44	1.2	1.2
Hi-ace	2.16	2.16	2.16	2.16	2.16	1.8	2.16
Bus & Truck	6.22	5.8	5.53	4.86	3.86	3.56	3.8
Source: NTRC, Ministry of Communication 1977 (Kenya Study)							

Another study was carried out by (Pienaar 1984) to investigate the operating conditions effects on the engine oil consumption. A fleet of ten vehicles was used. Table 3-6 gives the values of oil loss for different types of vehicles.

Table 3-6 Engine Oil Consumption suggested by Pienaar

Pienaar Oil model coefficients			
Vehicle Class	**Distance Until Change (km)**	**Engine Oil Capacity (L)**	**Rate of Oil consumption (L/1000 km)**
Passenger Car	9,290	4.1	0.44
Light Delivery Vehicles	7,300	4.9	.67
Medium Truck	9,000	13.6	1.73
Heavy Truck	10,000	30.6	3.06
Bus	8,000	19.6	2.43

A slight adjustment was made to the engine oil consumption for the different types of vehicles in the NTRC study since it was analyzed that the values suggested by the NTRC were exaggerated and outdated after comparing them to the study carried out by Pienaar (Pienaar 1984) and the survey carried out from the manufacturers and vehicle drivers for this study. Since these adjustments were totally empirical, therefore fixed values were used with respect to the vehicle speed for all vehicle types and no experiments were conducted to investigate the effects of operating conditions on oil consumption. Table 3-7 gives the values of the oil consumption for the different vehicle classes used in this study.

Table 3-7 Engine Oil consumption from Survey carried out under this study

Engine Oil Consumption L/1000 km			
Vehicle Class	**Distance Until Change (km)**	**Engine Oil Capacity (L)**	**Rate of Oil consumption (L/1000 km)**
Passenger Car	5,000	4.2	0.84
Hi-ace	3,500	5	1.43
Medium Truck	6,500	12.7	1.95
Heavy Truck	10,000	30.6	3.06
Bus	6,000	19.6	3.27

The oil consumption model used in the HDM-4 which is incorporated to estimate the user road cost was also based on the study carried out by (Pienaar 1984). The HDM-4 oil consumption model related oil consumption to operation which is a function of fuel consumption and contamination which is a function of the oil capacity and the distance between oil changes.

The model adopted for HDM-4 is following:

$$OIL = OILCONT + OILOPER \times FC$$

where OIL is the oil consumption (L/1000 km)
OILCONT is the oil loss due to contamination (L/1000 km)
OILOPER is the oil loss due to operation (L/1000 km)
FC is the fuel consumption (L/1000 km)
The engine oil loss due to contamination is calculated as follows:

$$OILCONT = DISTCHNG/OILCAP$$

where OILCAP is the engine oil capacity (L)
DISTCHNG is the distance between oil changes (1000 km)

3.3.4 Tyre Consumption

Tyres are continuously consumed as the vehicle travels. Tyre consumption is a major component of vehicle operating costs, especially for heavy vehicles. For example, in New Zealand for heavy trucks towing, tyre costs constitute 18 percent of the total road user costs where as it accounts only 5 percent for passenger cars (Opus-TRL 1999). According to the Brazilian, for rolling terrain the tyre costs for trucks were 23 percent of the total user cost (Watanatada, et al. 1987)

The major factors which influences the tyre consumption includes:

- Pavement condition including type of surface and roughness effects the tyre consumption. With increase roughness the tyre consumption increases due to the increased vertical loading on the tyres.
- Tyre consumption also varies greatly with the change in the horizontal curvature of the road.
- It is also affected by the traffic conditions such as congestion since the traffic interaction causes the accelerations and decelerations.
- Vehicle load also comes into play when tyre consumption is considered. Overloading added to poor road condition increases the detrimental effects.

Despite its contribution in the vehicle operating cost, tyre consumption has received much less attention in the literature than the other VOC components. Two approaches have been used to develop tyre consumption models:

- Tyre consumption measurement through controlled experiments on a small number of tyres.
- Tyre consumption monitoring vehicle fleet surveys by relating the tyre consumption to aggregate description of pavement condition.

Following studies have been carried out over the years to relate the tyre consumption to the various factors such as pavement type, road conditions, road alignment and traffic condition.

- According to (Claffey 1971) the tyre consumption was 3 times for a 4-lane urban arterial with traffic signals than a controlled access road with free-flowing traffic.
- Horizontal Road curvature has a greater effect on the tyre consumption. A road having a 60° curve causes tyre consumption as high as 5 times compared to a 30° curve (Claffey 1971).
- The tyre consumption also varied for the pavement types. Tyre wear on an asphalt pavement was 75 percent greater than a concrete pavement (Claffey 1971).
- Tyre consumption was 23 percent greater for urban areas than the rural areas according to a study conducted by Thoreson in 1993 to study the effect of traffic conditions over tyre consumption. The urban areas were having lower speed which further elaborates the effects of acceleration and deceleration over tyre consumption due to traffic congestion.

The VOC study carried out by NTRC (1985) used the data from the Ministry of communication study (1977) which in turn is based on the Kenya and Yogoslavia studies. It contains the tyre consumption due to roughness, the additional tyre wear due to road horizontal curvature and the traffic congestion. The same values have been used for the VOC estimate by NTRC model for this study.

The HDM tyre consumption model is based upon the principles of slip-energy. Tyre slip is the circumferential motion of the tyre relative to the wheel rim. Slip-energy is the product of the total distance slipped by a tyre multiplied by the horizontal force on the tyre.

3.3.5 Maintenance and Repair costs

The benefits from the road improvements causes reduction in maintenance costs significantly. Maintenance costs are composed of two components.

- Maintenance parts consumption
- Maintenance Labour hours

Maintenance costs are both difficult to measure empirically and to predict of all the vehicle operating cost components. This is due to the following reasons:

- The maintenance costs are incurred sporadically over the life of the vehicle.
- The costs are majorly affected by the maintenance practices of the owners/operators, for example the variation in costs between operators was greater than that due to different road conditions (Chesher and Harrison,1987).
- The costs for same vehicles can vary significantly between manufacturers
- Associating maintenance costs to operating conditions is difficult since vehicles tend to operate over a range of roads, so the costs are averaged out.

Vast research has been carried out across the globe in different countries for vehicle maintenance cost due to its importance in economic appraisals. Few of the studies carried out are the Indian Study, the Brazilian Study, the American Research, the South African Research, the New Zealand Research, the Swedish Research and the HDM-III model.

In Pakistan, Labour is relatively cheaper than the cost of parts. The vehicle owners prefer to repair than to replace the parts. So, there are significant differences over countries in maintenance and repair costs. Labour costs has been treated separately from the parts consumption due to above mentioned issues. The number of hours required per 1000 km are multiplied to the cost of Labour (Cost/hour) which gives the Labour costs. The parts consumption was predicted as a percentage of the replacement vehicle price.

NTRC used the Ministry of communication value for Labour hours and Maintenance parts. The labour hours are expressed in hours whereas the maintenance parts are expressed in percentage of the value of new vehicle. The same values are used for estimating VOC using NTRC model in this study.

The HDM-4 after addressing the identified shortcomings model adopted the HDM-III maintenance parts consumption model.

3.3.6 Depreciation and Interest

The loss in the vehicle value due to the use of the vehicle over time or technical obsolescence which is not recovered by the vehicle maintenance or repairs.

Interest costs are the costs that would have been received if the cost incurred to purchase the vehicle would have been invested elsewhere.

3.4 EMPIRICAL COSTS

In order to compare the Vehicle Operating Cost estimated by the different VOC models, a small-scale survey has also been carried out to calculate the vehicle operating costs based on the experience of the vehicle drivers/operators. For this survey, a questionnaire was designed to collect the requisite information from the drivers. The sample questionnaire has been provided in the appendix section at the end of this report.

CHAPTER 4

IDENTIFICATION OF PARAMETERS FOR VOC

In this section, the parameters required for each VOC model to estimate the Vehicle operating cost will be identified and discussed. There are number of variables, which effect the cost of operation of vehicles. These parameters have been incorporated in different VOC models which we will be using in this study. The Parameters required in these Models are Vehicle Perimeters, Market Prices for different VOC components and Road Characteristics. Figure 4 shows the VOC parameters required for each model. These parameters will be discussed in detail in the respective sections.

4.1 COST DATA COLLECTION AND SURVEY CONDUCTION

The factors and parameters identified for VOC were collected and analyzed. The data was collected from different resources, and field visits were done to collect the latest data. The latest market rates for different parameters were collected by contacting Vehicle Makers, Engine Oil Brands, Dealer for Spare Parts, Maintenance Workshops, Tyre dealers, and Web. The information gathered was used to in these models to estimate the VOC.

4.2 REPRESENTATIVE VEHICLES

The traffic stream in Pakistan is composed by a large variety of cars, Hi-aces, Buses and Trucks. In order to make the results realistic, it would be desirable to have a sample of vehicles which is representative of country's fleet composition. One way of having such a sample would be to classify the vehicles according to main category, according to makes and models and to select vehicles from each sub-group but it is not possible to estimate VOC for each individual type of vehicle. Besides, the selection of such a sample would not be possible at this stage due to lack of data as the information required to estimate VOC using different VOC models require information about certain input parameters which may not be available for almost every type of vehicle and it will also be too much time consuming to collect information for each individual type of vehicle. Therefore, it was adopted in this study that the major classes of vehicles will be considered that are Cars, Hi-aces, Buses and Trucks. In order to consider the characteristics of certain vehicles from these vehicle classes and to use the prices of the vehicle and their components, a set of vehicles were considered to be representative of all the vehicles within a certain class.

For example, most of the trucks in Pakistan nowadays are Hino 2-axle or 3-axle trucks. Therefore, the costs of new Hino 2-axle truck required as an input parameter was selected.

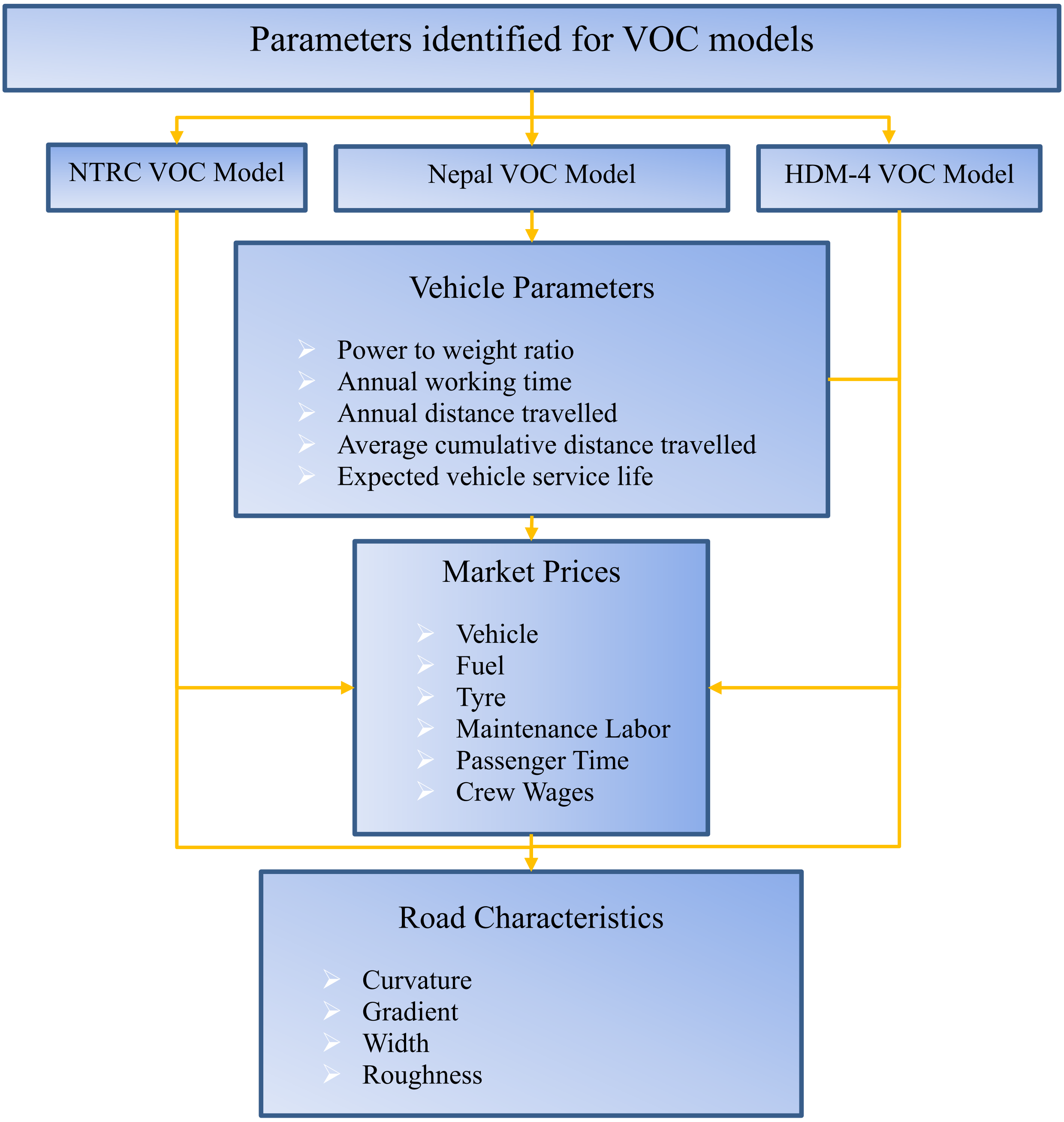


Figure 4.1 VOC parameters required to estimated VOC

4.3 MARKET PRICES

4.3.1 Vehicle Purchase Costs

Vehicle purchase costs were derived from a survey of established motor vehicle outlets in Islamabad at the end of 2018. The established motor vehicle outlets visited were Toyota Capital Motors, Hino Twin City, Suzuki Islamabad Motors and Honda Classic. Vehicle price lists were collected from the outlets. The vehicle costs obtained were the actual cost to the purchaser and it has to be broken down into its constituent parts to identify taxation and other cost elements to obtain the economic cost of the vehicle.

Table 4-1 Costs of new vehicles

Reference Vehicle	**New vehicle price (Rupees)**
Toyota Corolla Xli 1.3 MT	2,076,000
Toyota Hi-ace STD Roof Dual Petrol 2.7 L	4,648,000
Hino FM8JKKB Truck 4x2	8,600,000
Hino FM8JNKD Truck 6x4	11,800,000
Hino RN8JSKA Kazay Bus	14,000,000

4.3.2 Fuel Cost and Lubricant Costs

Fuel has very strategic importance. The importance of the fuel consumption of vehicles cannot be overlooked. The fuel expenses incurred during the vehicle operation are high enough and new road projects are economically justified by huge savings in fuel consumption. Fuel consumption is affected by pavement condition, vehicle characteristics, traffic congestion and the driving style.

Engine oil consumption makes a very small portion of the total vehicle operating costs and for the said reason or the technical difficulties to measure the impact of speed and other factors, research has not been carried out in detail for this component of VOC.

The fuel costs adopted are as per OGRA Pakistan effective from July 2019. Different Lubricants are available on the market and their prices vary depending on the grade and lubricant type. The costs used are given in Table 4-2:

Table 4-2 Fuel cost in Pakistan per OGRA

Vehicle Type	**Rs/Liter**
Petrol (Altron Premium)	113.24
Diesel	127.14
Lubricant (Shell Helix HX3)	565.00

4.3.3 Tyres

Tyres are continuously consumed as the vehicle travels. Tyre consumption is a major component of vehicle operating costs, especially for heavy vehicles.

Two types of tyres are available in Pakistan. One is the locally manufactured by the General tyre company and the other is imported. The tyre costs vary according the quality, manufacturer and tyre size.The costs for the tyres has been obtained from distributors and online web sources as well as the survey conducted from the vehicle operators for different vehicle classes. An average tyre costs from these sources of information has be shown in the table which is used for the VOC cost estimation in different VOC models.

4.3.4 Vehicle Maintenance parts and Labour Costs

The benefits from the road improvements causes reduction in maintenance costs significantly. Maintenance costs are composed of two components.

- Maintenance parts consumption
- Maintenance Labour hours

Established vehicle outlets along with the schedule for periodic maintenance which also contained the Labour tariff. The local maintenance workshops were also visited to know the price difference from the authorized dealer's workshops. The vehicle parts costs were provided by the workshop.

Figure 4.2 Conducting User Survey from local maintenance Workshop

Figure 4.3 Conducting User Survey from NUST Transport Maintenance workshop

The data in Table 4-3 was collected from a variety of sources including vehicle dealers, mechanics, tyre distributors and vehicle drivers.

Table 4-3 Different VOC Components Cost assumed for the Estimate

Vehicle Type	**New Tyre (Rs/Tyre)**	**Maintenance Labour (Rs/hour)**	**Crew Remuneration (Rs/hour)**	**Annual Overhead (Rs/year)**	**Annual Interest (Percent)**
Car	10,700	400.00	0.00	20,000	12.70
Hi-ace	13,500	400.00	115.00	64,000	12.70
Truck	33,500	520.00	105.00	120,000	12.70
Bus	35,000	550.00	130.00	178,000	12.70

4.3.5 Depreciation

The loss in the vehicle value due to the use of the vehicle over time or technical obsolescence which is not recovered by the vehicle maintenance or repairs.

The data for vehicle sale prices for different vehicles was collected from online websites such as Pakwheels. The vehicle model, millage and type were mentioned in the vehicle description. The price of the new vehicle at the launch time was known from the web. Using CPI for the current year and the year in question, the current price of the vehicle was evaluated at the time of the launch year. The devaluation of the vehicle over the years was finally calculated based on the millage and an average was calculated for a number of vehicles. Finally, the depreciation cost per 1000 km was calculated.

4.3.6 Passenger Time Cost

The passenger time cost for passengers travelling through a commercial vehicle was calculated. Following assumptions were made for the calculations:

- A passenger works 24 days a month and 8 hours a day.
- The monthly salary of a passenger equals to Rs 20000.
- The passengers' trips are 20 percent work oriented and 80 percent non-working.
- The total number of working hours each year for a passenger are equal to 2304 hours.
- A car accommodates on average 4 passengers per vehicle.
- An average occupancy for a Hi-ace is 10 passengers.
- The bus can accommodate an average 35 valued occupants.

The calculations are explained as follows:

Car/ Hi-ace/ Bus

20 percent for working trips valued at 1.0

80 percent for non- working trips valued at 1/3

8 hours/day and 24 days/month

GDP per capita of Pakistan according to Pakistan Economic Survey 2018-2019 is 1497.3 $.

Working hours per year= 24*8*12=2304

Therefore Cost/person (Rupees)= $\frac{1497.3*158}{2304} = 102.68\ Rupees$

Weighted by trip purpose= Rs.102.68 x (work 20 percent x weight 1+ non-work 80 percent x (1/2)) = Rs 61.61/hour/person

<u>Car, Cost/vehicle for 4 valued occupants= 4*61.61= Rs. 246.43/vehicle</u>

<u>Hi-ace, Cost/vehicle for 10 valued occupants= 10*61.61= Rs. 616.08/vehicle</u>

<u>Bus, Cost/vehicle for 35 valued occupants= 35*61.61= Rs. 2156.27/vehicle</u>

4.3.7 Crew Remuneration on Commercial Vehicles

The average driver and helper wage for each category of vehicle is mentioned below.

Hi-ace

Driver wage per month= Rs. 22000/month at Rs 800 per trip if a trip is made daily for 24 days (per user survey)

Bus

Driver wage per month= Rs. 25000/month (varies with the distance of the destination)

Helper wage per month= Rs. 15000/month

Truck

Usually there are 2 truck drivers and no helper

Driver wage per month= Rs. 15000-20000/month each (per user survey)

Helper wage per month= Rs. 10000/month

4.4 PAVEMENT CHARACTERISTICS

Different pavement characteristics were required as input parameters in the VOC models. Few of these parameters identified are roughness, curvature, gradient and width of the pavement/carriageway width. A lot of research has been carried out to study the effects of pavement conditions and pavement type on the vehicle operating cost. Road Roughness has attracted major attention among the pavement characteristics. “Roughness” can be defined as irregularities of pavement surface that affect driver safety and increase user costs, including fuel consumption, repair and maintenance, depreciation, and tire costs. Road geometry parameters such as Curvature, gradient and width of carriageway are also taken into consideration while VOC estimates are carried out. The tables 4-4 and 4-5 show the road condition and road geometry parameters used in the different VOC models.

Table 4-4 Road Condition Parameters

Surface Type	**Paved/Improved**	**Unpaved/Unimproved**	**Gravel**
Road Roughness (R)	1.5	3.5	5.5
Carriageway Width (m)	10.5	9	6

Table 4-5 Road Geometry Parameters

Road Geometry		
Rise & Fall	(m/km)	10
Number of Rise & Fall per km	(#)	2
Horizontal Curvature	(Degrees/km)	100
Super Elevation	(Percent)	0.01
Altitude	(m)	500

4.5 VEHICLE PARAMETERS

The vehicle parameters required as input in the Nepal VOC model and HDM-4 model are gross vehicle weight, power to weight ratio, annual working time, annual distance travelled, average cumulative distance travelled and expected vehicle service life. These parameters have been collected through surveys conducted from the vehicle operators.

The Table 4-6 shows the vehicle input parameters used in the VOC models for different vehicle classes.

Table 4-6 Vehicle Parameters for different vehicles

Vehicle Type	**Gross Vehicle Weight (ton)**	**Power to weight ratio (hp/ton)**	**Annual working time (hours)**	**Annual distance travelled (km)**	**Average cumulative distance travelled (km)**	**Expected vehicle service life**
Car	1.73	94.58	900	25,000	-	15
Hi-ace	4.5	-	1,200	54,000	-	15
Truck	29.5	44.36	1,750	1,00,000	500	25
Bus	16.5	27.8	1,200	80,000	400	20

4.6 VOC MODELING IN EXCEL

Excel Spreadsheets were developed using the NTRC VOC model for Cars, Hi-aces, Buses and Trucks.

The user will be required to select specific input parameters and the model will automatically select values for the VOC components based on the NTRC models.

The User also must enter the market price for the unit cost of a vehicle, fuel, Lubricating Oil, Tyre, and hourly cost for Maintenance Labour and passenger time.

The User will get the quantity of components consumed per 1000 km. It will also return the VOC per 1000 vehicle for each VOC component and the total VOC per 1000 vehicular km for the selected vehicle class.

Figure 4.4 shows the user interface of the Excel spreadsheet developed for the estimation of VOC using NTRC VOC Model.

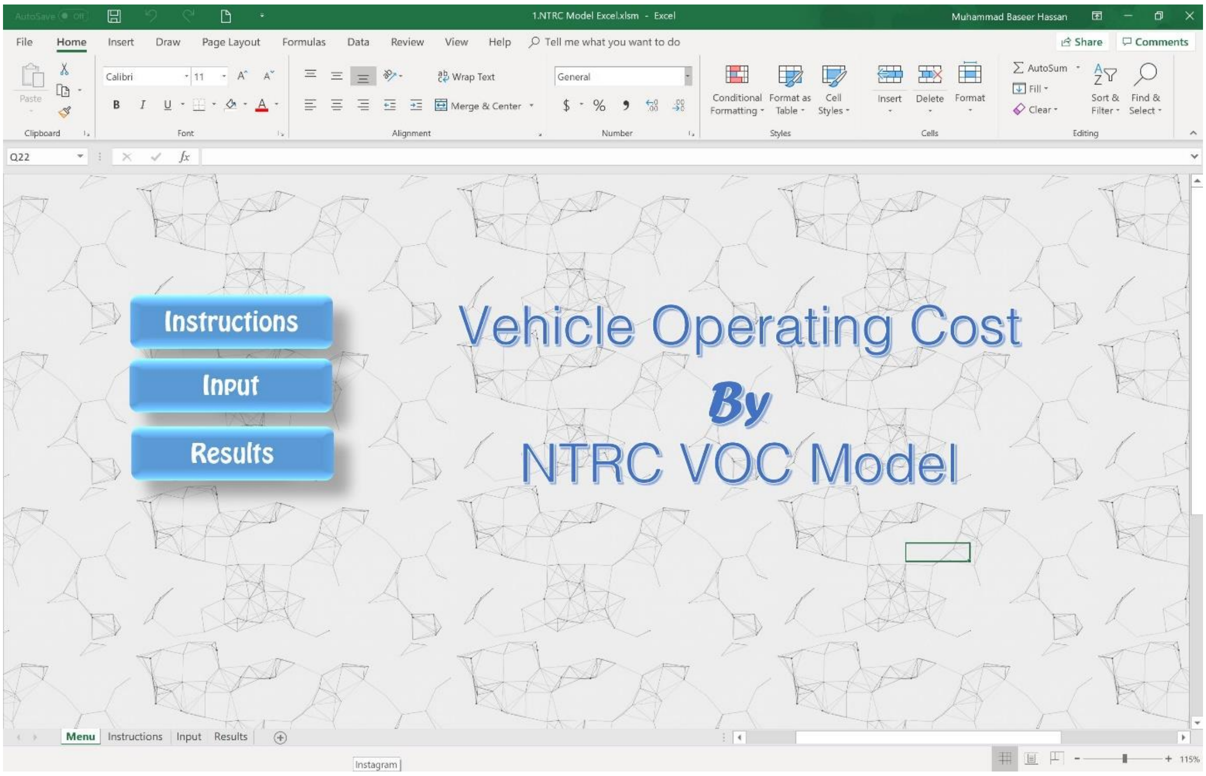


Figure 4.4 Excel Spreadsheet for the NTRC model

CHAPTER 5

ANALYSIS OF THE VOC ESTIMATES

5.1 ANALYSIS OF USER SURVEY FOR DIFFERENT VEHICLE CLASSES

In the following section, we are going to analyze the survey carried out from the Vehicle operators for different vehicle classes. Based on these analysis and calculations, we are going to carry out a VOC estimate for the three classes of vehicle.

Further the VOC estimates using the VOC models are shown in this section. Finally analysis of the sensitivity of the VOC to speed and roughness using HDM-4 model has been done.

5.1.1 Questionnaire Survey

A questionnaire consisting of 18 questions was prepared to conduct the survey from the vehicle operators limited to commercial vehicles. It was made sure that the questionairre addressed all the questions related to the consumption of vehicle operating cost components. The specimen of the questionnaire has been attached in Appedix.

5.1.2 Hi-aces:

14 Hiaces travelling from Islamabad to Mansehra were surveyed at G-9 Adda, Faizabad Adda and Pirwadaie Adda. The route followed by few of the vehicles was N-35 while few other vehicles used motorway and N-35 in combination. Half of the Hi-aces were petrol engines while others were using CNG. The average distance travelled from Islamabad to Mansehra was 163 km. The average travel time taken to cover this distance was 4 hours. The average fuel consumed to cover this distance was 24.25 liters worth Rs. 2700 at Rs. 113 per liter. It means that the distance per Liter was equal to 6.72 km/L. The total number of crew members included a driver only. Average remuneration paid for one-way trip was Rs. 1000. The number of working days was 26 with a one way trip each day. The tyres were changed after average 7.5 months. A pair of tyres costed Rs. 27000. The average maintenance cost per month accounted to Rs. 13000 while the vehicle travelled for an average 4000 vehicle kilometers. The Engine oil was changed after 3500 km which costed average Rs. 3500 for 5 liters. The Average Food/Accommodation Cost per day accounted to Rs. 300. A total of Rs. 300 toll was paid each way. The Adda charged Rs 600 for a one-way trip. The overhead costs included the Adda charges and the toll.

8 Hiaces travelling from Islamabad to Abbottabad were surveyed at G-9 Adda, Faizabad and Pirwadaie Adda. All the Hi-aces were using CNG as fuel. The average distance travelled from Islamabad to Abbottabad was 140 km. The average travel time taken to cover this distance was 3 hours. The average fuel consumed to cover this distance was 12.1 kilogram at Rs. 139 per kg at the time of survey. It means that the distance per kg was equal to 11.57 km/kg. The total number of crew members included a driver only. Average remuneration paid for one-way trip was Rs. 900. The number of working days was 26 with a one way trip each day. The tyres were changed after 10 months. A pair of tyres costed Rs. 28400. The average maintenance cost per month accounted to Rs. 13000. The Engine oil was changed after 3500 km which costed Rs. 3300. The Average Food/Accommodation Cost per day accounted to Rs. 300. A total of Rs. 300 toll was paid each way.

5.1.3 Buses:

7 Buses travelling from Islamabad to Quetta were surveyed at G-9 Adda, Pirwadaie Adda and Faizabad Adda. All the buses were having 2 axles and they were having diesel engines. The average distance travelled from Islamabad to Quetta was 900 km. The average travel time taken to cover this distance was 14 hours. The total fuel consumed to carry out this distance was equal to 550 Liters at 128.2 per liter (Price of Diesel fuel at the time of survey). It means that the distance per Liter was equal to 1.64 km/L. The total number of crew members were 2, which included 2 drivers or a driver and a helper. The salary for the driver was Rs. 1500 per one-way trip while it was Rs. 1000 for the helper. The average duration for changing the tyres was 2 months. On average a pair of tyres costed Rs. 70000. The Engine oil was changed after 4500 km and the engine oil capacity was approximately 20 liters.

8 Buses travelling from Rawapindi to Gilgit were surveyed at Pirwadaie Adda. All the buses were having 2 axles. The average distance travelled from Rawapindi to Gilgit was 610 km. The average travel time taken to cover this distance was 17 hours. The rough estimate of fuel consumption for this distance was 260.75 liters at 128.2 per liter (Price of Diesel fuel at the time of survey). It means that the distance per Liter was equal to 2.34 km/L. The total number of crew members were 2, which included 2 drivers or a driver and a helper. The salary for the driver was Rs 30000 per month while it was Rs. 20000 for the helper. The tyres were changed after an average 40000 km. On average a pair of tyres costed Rs. 70000. On average

the maintenance cost accounted to Rs.15000 per 1220 km (a trip). The Engine oil was changed after 3200 km and it was carried out for Rs. 10000.. A total of Rs. 900 toll was paid each way.

5.1.4 Trucks:

Multiple 2-axle Diesel Engine trucks were surveyed travelling from Rawalpindi to various destinations. They were surveyed at Sabzi Mandi, Mandi-Morr. The average distance travelled from Islamabad to Gawader was 2300 km. The average travel time taken to cover this distance was 4 days and 4 nights. The average fuel consumed to cover this distance was 500 liters worth Rs. 55,500 at Rs. 110.94 per liter at the time of survey. It means that the distance per Liter was equal to 4.6 km/L. The average capacity of the fuel tank varied from 200 liters. The total number of crew members included two drivers and a helper. Average monthly remuneration paid to the driver was Rs. 15000 and Rs. 10000 for helper. The average number of two-way trips carried out was 2 each month. The tyres were changed after 1 year. A pair of tyres costed Rs. 60000. The average maintenance cost per month was Rs. 25000-30000. The Engine oil was changed after 2 trips which amounts to Rs. 5000. The Average Food/Accommodation Cost per day accounted to Rs. 1500 for two drivers and a helper. A total of Rs. 3000 toll was paid per trip.

5.2 VOC CALCULATIONS BASED ON THE USER SURVEY DATA:

The calculations carried out for Hi-aces based on the User survey is as follow. Similar methodology was adopted for Trucks and Buses.

5.2.1 Hi-aces

Since, the total fuel consumed as per the survey for one-way trip from Rawalpindi to Mansehra consume an average 24.25 Liters petrol whereas, the distance from the origin to destination is approximately 163 km. Therefore,

Fuel Consumption per 1000 km = (24.25/163) * 1000 = 148.7730061 Litres

The tyres are changed after an average 7.5 months which is approximately 30000 km if a vehicle travels carries out a one way 163 km trip from Rawalpindi to Mansehra for 24 days.

Tyre Consumption per 1000 km = (4/30000) * 1000 = 0.1333333 units

Average Oil change for a Hi-ace according to the survey takes place at 3500 km. The engine oil capacity for a Toyota Hi-ace is approximately 5 litres according to vehicle specification. Therefore,

Engine Oil Consumption per 1000 km = (5/3500) * 1000 = 1.428571429 Litres

The above quantity if multiplied with the prices per unit/litre will give us the cost per 1000 km.

Therefore,

Cost of Fuel Consumed per 1000 km = 148.7730061 * 113 = Rs 16811.34969

Cost of Tyre per 1000 km = .1333333 * 13500 = Rs 1800

Cost of Engine Oil per 1000 km = 1.428571429 * 565 = Rs 807.1428571

Since average monthly maintenance expenditure are Rs 15000. A vehicle travelling for 24 days a month covering a distance of 163 km. Therefore,

Cost of Maintenance per 1000 km = = (15000/ (163*24)) * 1000 = Rs 3835

A driver getting a remuneration of Rs 1000 per trip and daily food cost incurred is equal to average Rs 300. Therefore,

Crew Cost per 1000 km = (1000/326) * 1000 + (300/163) * 1000 = Rs 4907.97546

Toll Paid per 1000 km = (300/163) * 1000 = Rs 1840.490798

Overhead Costs included in this case were the charges for using the bus stand or parking. An annual overhead cost has been assumed as an input parameter for all the models for Hi-aces. Therefore,

Overhead Charges per 1000 km = (64000/ (24*163*12)) * 1000 = Rs 1363.32652

Depreciation Charges per 1000 km

After calculating the depreciation values with the data gathered from the PakWheel website for different vehicles available for sale, it was determined that the depreciation cost for vehicle in Pakistan vary a little from the Depreciation cost determined by HDM-4. In the absence of the

Vehicles data for Trucks and Buses, it was decided to use the depreciation cost from HDM-4 model estimated in this study for all vehicles. Therefore,

The depreciation cost for Hi-aces per 1000 km = Rs 4822.49

5.3 ESTIMATE USING SMALL-SCALE SURVEY

Table 5-1 VOC estimate from the Small-scale survey carried out for this study

	Vehicle Speed (km/hr)	90	90	55	80
	VOC Component	**Car Large**	**Hi-ace**	**Truck 2-Axle**	**Bus Heavy**
Rs/1000 vehicle-km	Fuel		16,811	27,780	54,210
	Lubricants		807	1,104	1,846
	Tyre		1,800	1,163	3,500
	Maintenance Cost		3,835	26,139	12,295
	Toll		1,840	1,570	2,230
	Crew Cost		4,908	7,778	6,148
	Depreciation		4,822	2,857	7,254
	Overhead		1,363	1,590	1,650
Total VOC Rs/1000 km			36,188	69,980	86,508

5.4 VOC ESTIMATES FROM VOC MODELS

This section explains the input parameters considered to estimate the vehicle operating cost for different vehicle categories in Pakistan using the different VOC models and VOC estimation based on User survey. Further the results of estimation of vehicle operating cost (VOC) are also discussed and the comparison is made for the VOC estimates from the different models.

5.4.1 VOC Models Used

A number of VOC models were reviewed. Since most of the models were developed after the VOC studies carried out for the respective countries and the VOC estimated with these models for Pakistan would return either exaggerated or understated values. Furthermore, using such models for Pakistan will require calibration according to Pakistan's road conditions and vehicle types. The following VOC Models are used to estimate the vehicle operating costs.

- NTRC VOC model (1985)

- Nepal VOC model
- HDM-4 VOC model
- RED HDM-4

The input parameters used in different models were kept same to have consistency in the estimates for comparison purposes. The NTRC model was used since this was the only study carried out in Pakistan. The HDM-4 model is used worldwide across a number of countries since it was meant to be used in various countries and data from a number of counties was incorporated in modelling HDM-4.

5.4.2 Breakdown of Vehicle Cost and Fuel Cost

By using the factors mentioned in Tables 5.2 & 5.3 the market prices of vehicles (CBU or CKD), POL, parts and tires have been converted into Economic Cost. The economic cost calculated has been used to estimate vehicle operating cost by the different VOC models aforementioned.

Table 5-2 POL Cost

	Cost Rs. /Litre		Cost Rs. /Litre			
			FINANCIAL		ECONOMIC	
	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel
Ex-Refinary	71.89	82.06	71.89	82.06	71.89	82.06
Petroleum Development Levy	15	20	15	20		
(No. 1+2+3)	86.89	102.06				
Freight Charges	3.79	1.04	3.79	1.04	3.79	1.04
(No. 4+5)	90.68	103.1				
Distributor's Margin	2.64	2.64	2.64	2.64	2.64	2.64
Dealer's Margin	3.47	2.93	3.47	2.93	3.47	2.93
Price Before Sale (6+7+8)	96.79	108.67				
GST (17%)	16.45	18.47	16.45	18.47		
Max. Ex Depot Sale Price (9+10)	113.24	127.14	113.24	127.14	81.79	88.67

Table 5-3 Breakdown of Vehicle Cost

Vehicle Type & Cost	Charges Detail	Formula	**Rate**	**Remarks**
Motor Cycle, Car and Other Small Vehicles (CKD)				
a	Cost, Insurance and Freight		100%	CBU stands for Complete built-up Unit
b	Custom Duty		30%	
c	Port Charges		5%	
d	Sub-Total	(a+b+c)	135%	CKD stands for Complete Knock Down
e	Mark-ups	(20% of d)	27%	
f	Sub-Total	(d+e)	162%	
g	Sales Tax	(15% of f)	24%	
h	Factory Gate Price	(f+g)	186%	
i	ECONOMIC COST	(a+c+e) / h	**71%**	
j	Taxes	(100 - I)	**29%**	
WAGONS, MINI-BUS (16 SEATS) (CBU)				
a	Cost, Insurance and Freight		100%	
b	Custom Duty		60%	
c	Port Charges		5%	
d	Sub-Total	(a+b+c)	165%	
e	Mark-ups	(20% of d)	33%	
f	Sub-Total	(d+e)	206%	
g	Sales Tax	(17% of f)	35%	
h	Factory Gate Price	(f+g)	241%	
i	ECONOMIC COST	(a+c+e) / h	**57%**	
j	Taxes	(100 - I)	**43%**	
BUSES & TRUCKS (CKD)				
a	Cost, Insurance and Freight		100%	
b	Custom Duty		30%	
c	Port Charges		5%	
d	Sub-Total	(a+b+c)	135%	
e	Mark-ups	(40% of d)	54%	
f	Sub-Total	(d+e)	189%	
g	Sales Tax	(15% of f)	28%	
h	Factory Gate Price	(f+g)	217%	
I	ECONOMIC COST	(a+c+e) / h	**73%**	
J	Taxes	(100 - I)	**27%**	
ALL VEHICLES USING LOCAL PRODUCTS				
a	Cost and Mark-ups		100%	
b	Sales Tax		17%	
c	Factory Gate Price		117%	
d	ECONOMIC COST	(a / c)	**85%**	
e	Taxes	(100 - I)	**15%**	

Continued….

USING IMPORTED TYRES				
a	Cost, Insurance and Freight		100%	
b	Custom Duty		40%	
c	Port Charges		5%	
d	Sub-Total	(a+b+c)	145%	
e	Mark-ups	(20% of d)	29%	
f	Sub-Total	(d+e)	174%	
g	Sales Tax	(15% of f)	26%	
h	Factory Gate Price	(f+g)	203%	
i	ECONOMIC COST	(a+c+e) / h	**66%**	
j	Taxes	(100 - I)	**34%**	

5.5 VOC ESTIMATES RS/1000 KM

The following section consists of the estimates of the financial VOC (Rs/1000 km) carried out using the aforementioned VOC models. Conventional financial prices are required in to test general financial viability.

5.5.1 Financial VOC using NTRC VOC model

The financial VOC estimated for different vehicle classes using the NTRC model are given in Table 5-4 to 5-7.

Table 5-4 Financial VOC estimate carried out by NTRC model for Cars

	Speed km/hour	30	40	50	60	70	80	90
Rs/1000 vehicle-km	Fuel	9,859	9,203	10,130	11,170	12,731	15,686	20,508
	Lubricants	452	452	452	452	452	452	452
	Tyre	96	128	217	325	415	584	1,049
	Maintenance Labour	1,036	1,036	1,036	1,036	1,036	1,036	1,036
	Maintenance parts	1,993	1,993	1,993	1,993	1,993	1,993	1,993
	Depreciation	12,325	11,042	10,271	9,758	9,244	8,731	8,474
	Interest	11,942	9,909	8,639	7,622	6,860	6,352	5,844
	Time	1,111	625	400	278	204	156	123
Total VOC Rs/1000 km		38,814	34,388	33,138	32,633	32,935	34,990	39,479

Table 5-5 Financial VOC estimate carried out by NTRC model for Hi-ace

	Speed km/hour	30	40	50	60	70	80	90
Rs/1000 vehicle-km	Fuel	12,156	10,845	10,009	11,003	12,314	14,314	16,409
	Lubricants	808	808	808	808	808	808	808
	Tyre	149	189	326	447	583	860	16,099
	Maintenance Labour	6,816	6,816	6,816	6,816	6,816	6,816	6,816
	Maintenance parts	9,661	9,661	9,661	9,661	9,661	9,661	9,661
	Depreciation	13,479	12,085	11,155	10,690	9,761	9,761	9,296
	Interest	4,416	3,718	3,021	2,789	2,556	2,324	2,092
	Time	1,111	625	400	278	204	156	123
Total VOC Rs/1000 km		48,595	44,747	42,195	42,492	42,703	44,700	61,303

Table 5-6 Financial VOC estimate carried out by NTRC model for Buses

	Speed km/hour	30	40	50	60	70	80	90
Rs/1000 vehicle-km	Fuel	36,822	31,318	27,717	32,816	46,392	53,561	70,039
	Lubricants	3,136	3,136	3,136	3,136	3,136	3,136	3,136
	tyre	1,085	1,540	2,711	3,767	5,059	7,728	15,746
	Maintenance labour	10,769	10,769	10,769	10,769	10,769	10,769	10,769
	Maintenance parts	24,489	24,489	24,489	24,489	24,489	24,489	24,489
	Depreciation	32,200	29,400	26,600	25,200	23,800	22,400	22,400
	Interest	10,500	8,400	7,700	7,000	6,300	5,600	4,900
	Time	1,111	625	400	278	204	156	123
Total VOC Rs/1000 km		120,112	109,677	103,522	107,455	120,149	127,839	151,602

Table 5-7 Financial VOC estimate carried out by NTRC model for Trucks

	Speed km/hour	30	40	50	60	70	80	90
Rs/1000 vehicle-km	Fuel	36,909	32,344	29,360	26,327	30,120	41,552	N/A
	Lubricants	3,136	3,136	3,136	3,136	3,136	3,136	N/A
	Tyre	1,085	1,540	2,711	3,767	5,059	7,728	N/A
	Maintenance labour	10,265	10,265	10,265	10,265	10,265	10,265	N/A
	Maintenance parts	21,369	21,369	21,369	21,369	21,369	21,369	N/A
	Depreciation	19,317	17,452	16,154	15,163	14,455	13,865	N/A
	Interest	7,835	6,543	5,682	5,056	4,555	4,160	N/A
	Time	1,111	625	400	278	204	156	N/A
Total VOC Rs/1000 km		101,026	93,273	89,077	85,361	89,161	102,230	N/A

5.5.2 Economic VOC using NTRC VOC model

The economic VOC estimated for different vehicle classes using the NTRC model are given below.

Table 5-8 Economic VOC estimate carried out by NTRC model for Cars

	Speed km/hour	30	40	50	60	70	80	90
Rs/1000 vehicle-km	Fuel	7,136	6,661	7,332	8,085	9,215	11,354	14,844
	Lubricants	365	365	365	365	365	365	365
	Tyre	60	81	137	204	260	367	659
	Maintenance Labour	1,036	1,036	1,036	1,036	1,036	1,036	1,036
	Maintenance parts	1,701	1,701	1,701	1,701	1,701	1,701	1,701
	Depreciation	8,571	7,678	7,142	6,785	6,428	6,071	5,892
	Interest	8,304	6,890	6,007	5,300	4,770	4,417	4,064
	Time	1,111	625	400	278	204	156	123
Total VOC Rs/1000 km		28,285	25,038	24,121	23,755	23,980	25,467	28,685

Table 5-9 Economic VOC estimate carried out by NTRC model for Hi-aces

	Speed km/hour	30	40	50	60	70	80	90
Rs/1000 vehicle-km	Fuel	8,798	7,850	7,244	7,964	8,913	10,361	11,877
	Lubricants	622	622	622	622	622	622	622
	Tyre	95	121	208	286	373	550	10,303
	Maintenance Labour	6,816	6,816	6,816	6,816	6,816	6,816	6,816
	Maintenance parts	8,419	8,419	8,419	8,419	8,419	8,419	8,419
	Depreciation	7,594	6,808	6,285	6,023	5,499	5,499	5,237
	Interest	2,488	2,095	1,702	1,571	1,440	1,309	1,178
	Time	1,111	625	400	278	204	156	123
Total VOC Rs/1000 km		35,943	33,355	31,696	31,979	32,286	33,732	44,576

Table 5-10 Economic VOC estimate carried out by NTRC model for Buses

	Speed km/hour	30	40	50	60	70	80	90
Rs/1000 vehicle-km	Fuel	25,745	21,897	19,379	22,944	32,436	37,449	48,970
	Lubricants	1,848	1,848	1,848	1,848	1,848	1,848	1,848
	Tyre	694	986	1,735	2,411	3,237	4,946	10,077
	Maintenance Labour	10,769	10,769	10,769	10,769	10,769	10,769	10,769
	Maintenance parts	20,634	20,634	20,634	20,634	20,634	20,634	20,634
	Depreciation	23,153	21,140	19,127	18,120	17,113	16,107	16,107
	Interest	7,550	6,040	5,537	5,033	4,530	4,027	3,523
	Time	1,111	625	400	278	204	156	123
Total VOC Rs/1000 km		91,505	83,939	79,429	82,038	90,772	95,935	11,2052

Table 5-11 Economic VOC estimate carried out by NTRC model for Trucks

	Speed km/hour	30	40	50	60	70	80	90
Rs/1000 vehicle-km	Fuel	28,962	25,380	23,039	20,659	23,635	32,605	N/A
	Lubricants	1,102	1,102	1,102	1,102	1,102	1,102	N/A
	Tyre	694	986	1,735	2,411	3,237	4,946	N/A
	Maintenance Labour	10,857	10,857	10,857	10,857	10,857	10,857	N/A
	Maintenance parts	18,722	18,722	18722	18722	18722	18722	N/A
	Depreciation	13,683	12,362	11,443	10,741	10,239	9,821	N/A
	Interest	5,550	4,635	4,025	3,582	3,226	2,946	N/A
	Time	1,111	625	400	278	204	156	N/A
Total VOC Rs/1000 km		80,681	74,668	71,323	68,351	71,223	81,156	N/A

5.5.3 Financial Estimate using Nepal VOC model

The Financial VOC estimate was carried out with the equations developed as result from the Nepal VOC study. The VOC was estimated for Cars, Buses and Trucks. The detailed equations and calculations using Nepal model are given in the appendix at the end of the report.

Table 5-12 Financial VOC estimate carried out by Nepal model for Cars

	Round trip journey speed (km/hour)	**64**
Rs/1000 vehicle-km	Fuel	12,351
	Lubricants	877
	Tyre	832
	Maintenance Labour	1,734
	Maintenance parts	7,402
	Depreciation	5,536
	Crew cost	9,600
Total VOC Rs/1000 km		38,332

Table 5-13 Financial VOC estimate carried out by Nepal model for Buses

	Round trip journey speed (km/hour)	**51**
Rs/1000 vehicle-km	Fuel	25,141
	Lubricants	1,033
	Tyre	4,991
	Maintenance Labour	9,472
	Maintenance parts	6,526
	Depreciation	19,072
	Crew cost	13,078
Total VOC Rs/1000 km		79,313

Table 5-14 Financial VOC estimate carried out by Nepal model for trucks

	Round trip journey speed (km/hour)	53
Rs/1000 vehicle-km	Fuel	23,686
	Lubricants	1,033
	Tyre	4,293
	Maintenance Labour	14,526
	Maintenance parts	12,191
	Depreciation	7,061
	Crew cost	6,283
Total VOC Rs/1000 km		69,074

As compared to the estimate carried out by NTRC model, the values given by the Nepal VOC equations are lesser for all the vehicle classes. The same road condition values and vehicle prices were used for the calculations.

5.5.4 Economic Estimate using Nepal VOC model

The economic VOC estimate was carried out by the same equations developed as result from the Nepal VOC study. The VOC was estimated for Cars, Buses and Trucks.

Table 5-15 Economic VOC estimate carried out by Nepal model for Cars

	Round trip journey speed (km/hour)	63.52
Rs/1000 vehicle-km	Fuel	8,940
	Lubricants	675
	Tyre	523
	Maintenance Labour	1,206
	Maintenance parts	7,402
	Depreciation	3,850
	Crew cost	0
Total VOC Rs/1000 km		22,595

Table 5-16 Economic VOC estimate carried out by Nepal model for Buses

Rs/1000 vehicle-km	**Round trip journey speed (km/hour)**	**51.07**
	Fuel	17,578
	Lubricants	796
	Tyre	3,194
	Maintenance Labour	9,472
	Maintenance parts	4,693
	Depreciation	13,714
	Crew cost	13,078
Total VOC Rs/1000 km		62,524

Table 5-17 Economic VOC estimate carried out by Nepal model for Trucks

Rs/1000 vehicle-km	**Round trip journey speed (km/hour)**	**52.7**
	Fuel	1,6561
	Lubricants	796
	Tyre	2871
	Maintenance Labour	14,526
	Maintenance parts	8,635
	Depreciation	5,002
	Crew cost	6,283
Total VOC Rs/1000 km		54,674

5.5.5 Financial Estimate using HDM-4 VOC model

This section computes vehicle operating costs based on Free Flow Vehicle Operating Cost Model (**HDM-4**) of the World Bank. For analysis current market prices of vehicle, tires and Fuel & Lubricants etc. have been collected during September to December 2018. Typical market prices of vehicles are described at Table 5.12.

Table 5-18 Selected Vehicle Types and Market Prices

Vehicle	**Engine Power**	**Factory Gate Price**	**Remarks**
Type, Make & Model	**(cc)**	**(Rupees)**	
CAR			
Toyota Corolla XLI 1.3 MT	1299	2,076,000	CKD
Toyota Corolla Altis 1.6 (Automatic)	1598	2,607,500	CKD
Suzuki Cultus VXL (standard)	998	1,670,000	CKD
Suzuki Mehran Euro II (standard)	796	1,150,000	CKD
WAGON AND MINIBUS			
Hiace STD Dual A.C Petrol 2.7 L	2998	4,648,000	16 seats, CBU
Toyota Coaster Low Spec A.C	3661	6,650,000	26 seats, CBU
Toyota Coaster High Spec A.C	4198	7,700,000	30 seats, CKD
BUS			
HINO RN8JSKA Kazay Bus	8226	14,000,000	51 seats CKD
TRUCK 2-Axle with body			
Hino FM8JKKB Truck 4x2	7961	8,600,000	CKD
TRUCK 3-Axle with body			
Hino FM8JNKD Truck 6x4	7961	11,800,000	CKD
TRUCK TRACTOR with trailer			
Hino SG	10900	15,050,000	CKD

The market prices of vehicles, tires and POL have been converted into economic costs by deducting taxes, duties, transfer payment etc. Table 5.13 shows the tariff structure as applicable on these items.

Table 5-19 Market / Economic Costs of Cars

	Car			
DESCRIPTION	**Toyota Corrolla XE**	**Toyota Corrolla ALTIS 1.6**	**Suzuki Mehran (standard)**	**Suzuki Cultus (standard)**
BASIC SPECIFICATIONS				
Engine (cc)	1299	1299	796	993
Gross Vehicle Weight (kg)	1730	1730	620	800
Number of Axles	2	2	2	2
Types of Tyres	195-65-R14	195-65-R14	145-80-R12	165-80-R13
Seats	5	5	5	5
USAGE				
Life (years)	12	12	12	12
Hours Driven per year	450	450	400	400
Average Speed (km/hr)	50	50	50	50
Km Driven per year	22500	22500	20000	20000
COST (Rs)				
Vehicle Market Price	2,076,000	2,607,500	1,150,000	1,670,000
Market Price of Tyre	12,000	12,000	6,500	8,500
Market Price of Tyres in vehicle	48,000	48,000	26,000	34,000
Vehicle Market Price without Tyres	2,028,000	2,559,500	1,124,000	1,636,000
Duty / Tax Ratio	0.3	0.3	0.3	0.3
Economic Cost Ratio	0.7	0.7	0.7	0.7
Economic Cost	1,419,600	1,791,650	786,800	1,145,200
Tyre Cost (Rs)				
Market Price of Tyre	12000	12000	6500	8500
Tax Ratio on Tyre	0.37	0.37	0.37	0.37
Economic Cost Ratio	0.63	0.63	0.63	0.63
Economic Cost per Tyre	7560	7560	4095	5355

Table 5-20 Market / Economic Costs of Wagon

DESCRIPTION	Vehicle Types and Representative Model		
	WAGON & MINIBUS		
	Toyota Hiace Standard	**Toyota Coaster**	**Hino FB2WGKZ**
	CBU	CBU	CKD
BASIC SPECIFICATIONS			
Engine (cc)	2998	3661	4009
Gross Vehicle Weight (kg)	2850	5180	6200
Number of Axles	2	2	2
Types of Tyres	195R/15C	205-65-R16	265-65-R17
Seats	16	26	26
USAGE			
Life (years)	10	10	10
Hours Driven per year	1200	1200	1200
Average Speed (km/hr)	45	45	45
Km Driven per year	54000	54000	54000
COST (Rs)			
Vehicle Market Price	4,648,000	6,650,000	7,500,000
Market Price of Tyre	18,000	18,000	20,000
Market Price of Tyre in vehicle	72,000	72,000	80,000
Vehicle Market Price without Tyres	4,576,000	6,578,000	7,420,000
Duty / Tax Ratio	0.4	0.4	0.3
Economic Cost Ratio	0.6	0.6	0.7
Economic Cost of vehicle	2,745,600	3,946,800	5,194,000
Tyre Cost (Rs)			
Market Price of Tyre	20,000	25,000	35,000
Tax Ratio on Tyre	0.37	0.37	0.37
Economic Cost Ratio	0.63	0.63	0.63
Economic Cost per Tyre Set	12,600	15,750	22,050

Table 5-21 Market / Economic Costs of Bus & Trucks

DESCRIPTION	Vehicle Types and Representative Model				
	Bus	**Truck 2 - Axle**	**Truck 3 - Axle**	**Truck Articulated**	
	HINO RN8JSKA Kazay Bus	Hino FM8JKKB Truck 4x2	Hino FM8JNKD Truck 6x4	Hino SG	Hino FM
	CKD	CKD	CKD	CKD	CKD
BASIC SPECIFICATIONS					
Engine (cc)	8,226	7,961	7,961	8,500	10,520
Gross Vehicle Weight (kg)	14,000	18,000	27,500	35,000	45,000
Number of Axles	2	2	3	4	4
Types of Tyres	1200-20-20R	900 - 20-20R	900 - 20-20R	900 - 20-20R	900 - 20-20R
Seats	54	2	2	3	3
USAGE					
Life (years)	10	10	12	12	12
Hours Driven per year	1,200	1,750	1,750	1,750	1,750
Average Speed (km/hr.)	50	40	40	40	40
Km Driven per year	60,000	70,000	70,000	70,000	70,000
COST (Rs)					
Vehicle Market Price, chassis	14,000,000	8,600,000	11,800,000	15,050,000	16,215,000
Market Price of Tyre	33,000	33,000	33,000	33,000	33,000
Number of tyres	6	6	10	14	22
Market Price of Tyre in vehicle	198,000	198,000	330,000	462,000	726,000
Vehicle Market Price without Tyres	13,802,000	8,402,000	11,470,000	14,588,000	15,489,000
Duty / Tax Ratio	0.37	0.37	0.37	0.37	0.37
Economic Cost Ratio	0.63	0.63	0.63	0.63	0.63
Economic Cost of Chassis	8,695,260	5,293,260	7,226,100	9,190,440	9,758,070
Financial Cost of body	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000
Duty / Tax Ratio	0.15	0.15	0.15	0.15	0.15
Economic Cost Ratio	0.85	0.85	0.85	0.85	0.85
Economic Cost of Body	4,250,000	4,250,000	4,250,000	4,250,000	4,250,000
Economic Cost of Vehicle	13,695,260	9,543,260	11,476,100	13,440,440	14,008,070
Financial Cost of Vehicle	18,802,000	13,402,000	16,470,000	19,588,000	20,489,000

Continued….

Tyre Cost (Rs)					
Market Price of Tyre	33,000	33,000	33,000	33,000	33,000
Tax Ratio on Tyre	0.37	0.37	0.37	0.37	0.37
Economic Cost Ratio	0.63	0.63	0.63	0.63	0.63
Economic Cost per Tyre Set	20,790	20,790	20,790	20,790	20,790

Table 5-22 Crew Remuneration (Rs/hour)

Vehicle	**Crew**		**Cost per vehicle (Rs.)**	
	Type	Number	Monthly	Hourly
Wagon	Driver	1	15,000	
	Conductor	1	8,000	
	Sub-Total	2	23,000	80
Mini-bus				
	Driver	1	18,000	
	Conductor	1	10,000	
	Cleaner	1	7,000	
	Sub-Total	3	35,000	105
Bus				
	Driver	1	22,000	
	Conductor	1	10,000	
	Cleaner	1	5,000	
	Sub-Total	3	37,000	135
Truck Rigid				
	Driver	2	25,000	
	Cleaner	1	12,000	
	Sub-Total	4	370,000	100
Truck Multi-Axle				
	Driver	2	30,000	
	Cleaner	2	15,000	
	Sub-Total	4	45,000	105
Labour – All Vehicles	Mechanic	1	10000	100

Financial estimate carried out by the model designed to calculate unit road user costs adopting the Highway Development and Management Model (HDM-4) Version 2 relationships for speeds, travel times and vehicle operating costs.

Following steps were followed using the software to calculate the VOC.

Step 1: The Vehicle Fleet & Country Data worksheet was selected, and vehicle fleet unit costs and basic characteristics were entered. The Vehicle Fleet data was entered only for the vehicles that were intended to be evaluated and other tabs were left empty.

The yellow color represents the parameters that needed to be entered by the user of the model.

Vehicle Fleet Data

Vehicle Description	Economic or Financial Unit Costs ($)											Basic Vehicle Fleet Characteristics							
	New Vehicle ($/vehicle)	New Tire ($/tire)	Fuel ($/liter)	Lubricating Oil ($/liter)	Maintenance Labor ($/hour)	Crew Wages ($/hour)	Annual Overhead ($/year)	Annual Interest (%)	Passenger Working Time ($/hour)	Passenger Non-Working Time ($/hour)	Cargo Time ($/hour)	Annual km Driven (km)	Annual Working Hours (hours)	Service Life (years)	Private Use (%)	Numbe of Passengers (#)	Work Related Passengers Trips (%)	Gross Vehicle Weight (t)
Motorcycle	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Car Small	4,915	31.65	0.72	5.38	2.53	0.00	1.27	12.70	0.13	0.52	0.00	20,000	900	15	100	4	50	0.8
Car Medium	8,829	41.14	0.72	6.01	2.53	0.00	1.27	12.70	0.13	0.52	0.00	25,000	900	15	100	4	50	1.0
Delivery Vehicle	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Car Large	16,494	68	0.72	6.01	2.53	0.00	1.27	12.70	0.13	0.52	0.00	25,000	900	15	100	4	50	1.7
Hi-ace	29,418	85.44	0.72	6.01	2.53	0.73	316	12.70	0.13	0.52	0.10	54,000	1,200	15	0	10	50	4.5
Truck 2-Axle	54,430	212.03	0.80	3.48	3.29	0.66	380	12.70	0.13	0.52	0.10	100,000	1,750	25	0	0	0	17.5
Truck 3-Axle	74,684	212.03	0.80	3.48	3.29	0.66	380	12.70	0.13	0.52	0.10	100,000	1,750	25	0	0	0	29.5
Truck Articulated	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bus Light	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bus Medium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bus Heavy	88,608	221.52	0.80	3.48	3.48	0.82	316	12.70	0.13	0.52	0.00	80,000	1,200	20	0	35	50	16.2

Country and Currency

Country Name	Currency	Year
Pakistan	US$	2019

Emissions Unit Costs

Emissions Unit Costs ($ per ton)						
Carbon Dioxide	Carbon Monoxide	Hydrocarbon	Nitrous Oxide	Particulate	Sulfur Dioxide	Lead
0.00	0.00	0.00	0.00	0.00	0.00	0.00

Road Safety Costs

Road Safety Costs	
GDP per capita ($/person)	1,497
Factor to multiply GDP per capita to obtain fatality cost	60
Serious injuries cost as a percent of fatality cost	25%
Fatality cost ($/fatality)	89,838
Serious injury cost ($/serious injury)	22,460

Figure 5.1 Screenshot from the HDM-4 Model Version 2 "Vehicle Fleet Data Worksheet"

Step 2: The Road Characteristics worksheet was selected and the characteristics of the road to be evaluated were entered. At the end of the worksheet some, default values for typical road classes were suggested which were also adopted where data was unknown for local roads. Default values are represented by white colors in the screenshots given below.

Road Characteristics

Road Condition			Road Geometry				
Road Roughness (IRI, m/km)	Carriageway Width (m)	Surface Code (1-Paved / 2-Unpaved)	Rise & Fall (m/km)	Number of Rise & Fall per km (#)	Horizontal Curvature (degrees/km)	Super_ elevation (%)	Altitude (m)
1.5	10.5	1	10	2	100	0.01	500

Speed Adjustment Factors				Rolling Resistance Factors		
Speed Limit (km/hour)	Speed Limit Enforcement (#)	Roadside Friction (#)	Non Motorized Traffic Friction (#)	Percent Time Driven on Water (%)	Percent Time Driven on Snow (%)	Paved Roads Texture Depth (mm)
80	1.10	1.00	1.00	20	0	0.70

Road Traffic	
Vehicle Description	Average Annual Daily Traffic (AADT)
Motorcycle	0
Car Small	3699
Car Medium	8500
Delivery Vehicle	0
Car Large	12500
Hi-ace	3645
Truck 2-Axle	2108
Truck 3-Axle	1143
Truck Articulated	0
Bus Light	0
Bus Medium	0
Bus Heavy	232
Total	31826

Vehicle Fleet Accident Rates		
	Fatality	Serious Injury
Number per 100 million vehicle-km	3	30

Traffic Flow Pattern									
Percentage of Annual Traffic on Each Period					Number of Hours Per Year on Each Period				
Period 1 (%)	Period 2 (%)	Period 3 (%)	Period 4 (%)	Period 5 (%)	Period 1 (#)	Period 2 (#)	Period 3 (#)	Period 4 (#)	Period 5 (#)
2.17	7.59	11.64	40.24	38.36	87.6	350.4	613.2	2978.4	4730.4
100					8760				

Speed Flow Type					Desired Speed Adjustment Factor (#)	Acceleration Noise Parameters		Operating Speed Adjustment Factor (#)	Acceleration Effects (1-Yes, 0-No)
Ultimate Capacity (pcse/hour/lane)	Free-Flow Capacity (pcse/hour/lane)	Nominal Capacity (pcse/hour/lane)	Jam Speed at Capacity (km/hour)	Number of Lanes (#)		zadral (m/s2)	zamaxr (m/s2)		
1400	140	1260	25	2	1	0.10	0.65	1.0	0

HDM-4 Recommended Default Values

Paved Roads Roughness (IRI, m/km)			
Road Condition	Primary Roads	Secondary Roads	Tertiary Roads
Good	2	3	4
Fair	4	5	6
Poor	6	7	8
Bad	8	9	10

Road Geometry	Rise & Fall (m/km)	Number of Rise & Fall per km (#)	Horizontal Curvature (deg/km)	Super_ elevation (%)	Altitude (m)	Speed Limit (km/hour)	Speed Limit Enforcement (#)	Roadside Friction (#)	NMT Friction (#)
Straight and level	1	1	3	2.0	0	110	1.10	1.00	1.00
Mostly straight and gently undulating	10	2	15	2.5	0	100	1.10	1.00	1.00
Bendy and generally level	3	2	50	2.5	0	100	1.10	1.00	1.00
Bendy and gently undulating	15	2	75	3.0	0	80	1.10	1.00	1.00
Bendy and severely undulating	25	3	150	5.0	0	70	1.10	1.00	1.00
Winding and gently undulating	20	3	300	5.0	0	60	1.10	1.00	1.00
Winding and severely undulating	40	4	500	7.0	0	50	1.10	1.00	1.00

Figure 5.2 Screenshot from the HDM-4 Model Version 2 Interface “Road Characteristics Worksheet”

Step 3: After entering the input values, the Menu tab was selected and "Calculate Road User Costs" button was pressed. A message appeared after few moments indicating that the calculations were done.

Step 4: Results were available at the Road User Costs worksheet, the resulting unit road user costs and speeds. Since the currency for the model is model, the estimate given was represented in $/km. The final estimate was converted to Rs/1000 km. The table below shows the results.

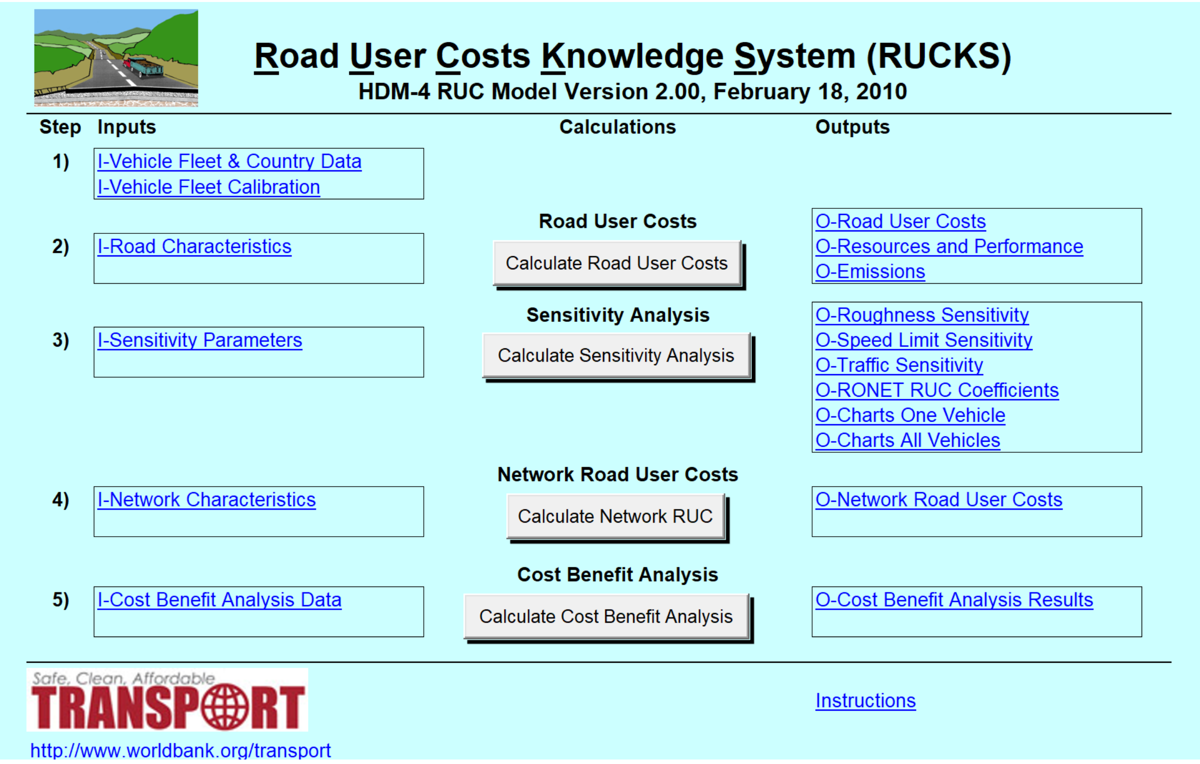


Figure 5.3 Screenshot from the HDM-4 Model Version 2 Interface "Main Menu worksheet"

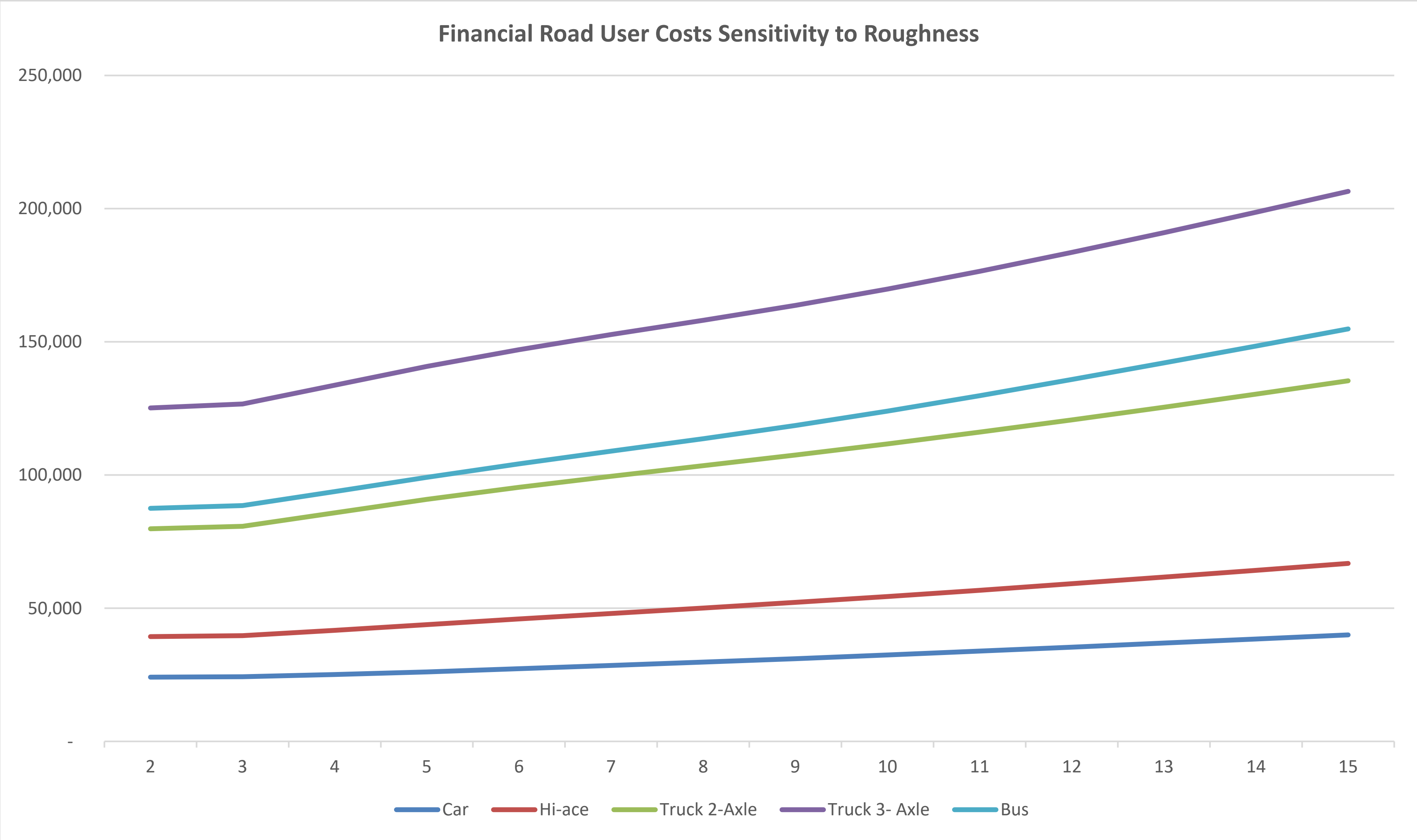
5.5.6 RESULTS OF FINANCIAL ANALYSIS

	Vehicle Speed (km/hour)	67	68	67	65	64	67	66
	VOC Component	Car Small	Car Medium	Car Large	Hi-ace	Truck 2-Axle	Truck 3-Alxe	Bus Heavy
Rs/1000 vehicle-km	Fuel	8,367	9,624	9,665	13,515	29,820	59,544	36,012
	Lubricants	343	361	514	1,160	1,023	2,247	2,309
	Tyre	221	287	542	688	2,100	3,332	2,910
	Maintenance Parts	1,694	3,260	3,810	9,043	32,159	44,125	20,172
	Maintenance Labour	1,081	1,122	868	3,793	6,921	8,620	5,481
	Crew Time	-	-	-	1,776	1,638	1,567	1,957
	Depreciation	2,143	3,103	5,812	4,822	2,857	3,899	7,254
	Interest	906	1,623	3,041	4,196	5,365	7,117	12,396
	Overhead	-	-	-	711	589	570	697
	Value of Time Cost	3,052	3,043	3,054	8,199	247	236	27,140
	Passenger Time	3,052	3,043	3,054	7,955	-	-	27,140
Total VOC Rs/1000 km		14,756	19,380	24,252	39,705	82,472	131,083	88,630

5.5.7 Unit Road User Costs Sensitivity to Roughness (Rs/ 1000 vehicle-km)

Total VOC per 1000 km (Financial) on Rupees					
IRI	**Car**	**Hi-ace**	**Truck 2-Axle**	**Truck 3- Axle**	**Bus**
2	24,486	39,860	81,021	128,603	88,435
3	24,631	40,204	81,936	130,018	89,452
4	25,441	42,170	86,944	136,978	94,645
5	26,386	44,214	91,847	143,619	99,856
6	27,449	46,191	96,101	148,964	104,532
7	28,546	48,099	99,932	153,584	108,907
8	29,716	50,033	103,641	158,282	113,437
9	30,989	52,085	107,530	163,675	118,417
10	32,385	54,309	111,659	169,761	123,918
11	33,852	56,664	116,051	176,437	129,758
12	35,359	59,113	120,658	183,545	135,830
13	36,887	61,628	125,434	190,971	142,064
14	38,426	64,188	130,343	198,636	148,414
15	39,968	66,781	135,354	206,483	154,848

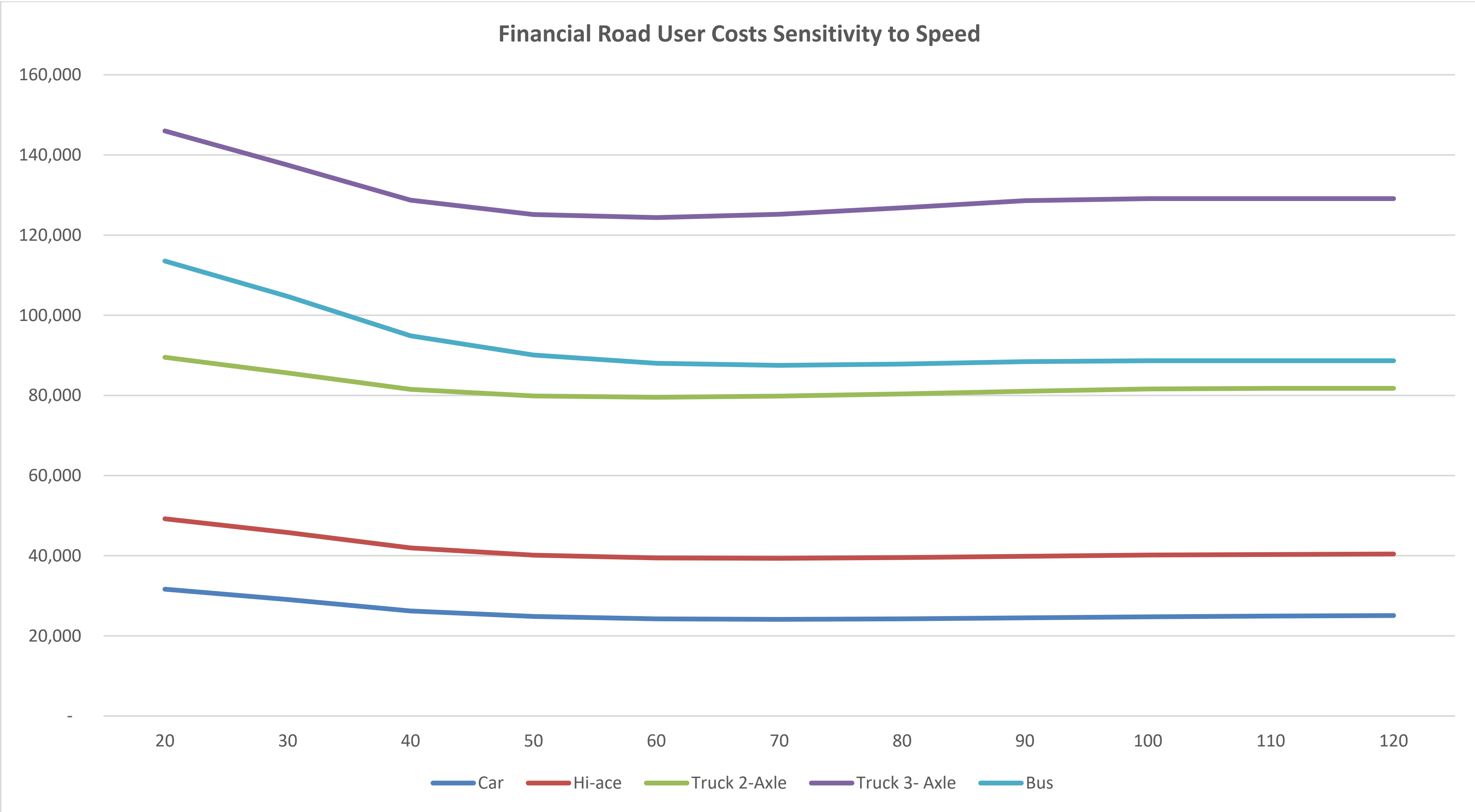
5.5.8 Financial Road User Costs Sensitivity to Roughness



5.5.9 Unit Road User Costs Sensitivity to Speed Limit (Rs/vehicle-km)

Total VOC per 1000 km (Financial) on Rupees					
Speed	**Car**	**Hi-ace**	**Truck 2-Axle**	**Truck 3- Axle**	**Bus**
20	31,642	49,212	89,504	145,990	113,528
30	29,057	45,771	85,589	137,492	104,689
40	26,222	41,940	81,500	128,708	94,864
50	24,845	40,146	79,874	125,142	90,079
60	24,251	39,441	79,525	124,376	88,004
70	24,114	39,342	79,816	125,186	87,496
80	24,236	39,544	80,377	126,809	87,821
90	24,486	39,860	81,021	128,603	88,435
100	24,756	40,157	81,607	129,087	88,652
110	24,928	40,305	81,761	129,104	88,657
120	25,057	40,413	81,761	129,104	88,657

5.5.10 Financial Road User Costs Sensitivity to Speed



5.5.11 RESULTS OF ECNOMIC ANALYSIS

	VOC Component	Car Small	Car Medium	Car Large	Hi-ace	Truck 2-Axle	Truck 3-Alxe	Bus Heavy
Rs/1000 vehicle-km	Fuel	6,056	6,966	6,996	9,782	20,849	41,632	25,179
	Lubricants	264	278	396	788	893	1,778	1,347
	Tyre	221	287	542	688	2,100	3,332	2,910
	Maintenance Parts	1,172	2,272	2,661	5,094	22,562	31,297	14,505
	Maintenance Labour	1,081	1,122	868	3,793	6,921	8,620	5,481
	Crew Time	-	-	-	1,776	1,638	1,567	1,957
	Depreciation	1,465	2,144	4,029	2,692	1,984	2,733	5,164
	Interest	626	1,131	2,123	2,364	3,764	5,048	8,913
	Overhead	-	-	-	711	589	570	697
	Value of Time Cost	3,052	3,043	3,054	8,199	247	236	27,140
	Passenger Time	3,052	3,043	3,054	7,955	-	-	27,140
Total Vehicle Operating Cost		10,886	14,200	17,615	27,689	61,301	96,576	66,154

CHAPTER 6

CONCLUSION & RECOMMENDATIONS

Vehicle Operating Costs need to be updated regularly since they are used in the cost benefit analysis for investment in transportation projects. When transportation improvements are made, the vehicle operating costs along a facility can change due to changes in number of kilometers driven or due to the reduction in the number of stops or changes in speed cycles

This study is an effort to estimate vehicle operating costs for Pakistan which were carried out by the National transportation Research Center about two decades ago. The VOC estimates were carried out using the NTRC VOC model, (based on the Kenya VOC model and the studies carried out by Ministry of Communication, Pakistan), the Nepal VOC model and the HDM-4 VOC model. A small-scale user survey was also carried out from the vehicle operators and drivers for Hi-ace, Buses and Trucks at Islamabad and Rawalpindi.

Following are the conclusion derived from this study:

- VOC estimates carried out by the NTRC VOC model are a little exaggerated.
- VOC estimates carried out by the Nepal VOC model are understated.
- The VOC estimates using the HDM-4 models are the best estimate to be used in Pakistan for the project's appraisal.
- The VOC estimates from the small-scale survey in Rawalpindi and Islamabad validates the VOC estimate from the HDM-4 model.
- The improvement of pavements causes substantial reduction in the VOC since VOC is sensitive to pavement roughness and vehicle speed.
- The final financial and economical VOC estimates using HDM-4 VOC model for different vehicle types per 1000 km are as follows:

Vehicle Type		Car Small	Car Medium	Car Large	Hi-ace	Truck 2-Axle	Truck 3-Alxe	Bus Heavy
Total VOC Rs/1000 vehicle-km	**Financial**	14,756	19,380	24,252	39,705	82,472	131,083	88,630
	Economical	10,886	14,200	17,615	27,689	61,301	96,576	66,154

This study was an effort towards estimation of vehicle operating cost (VOC) in Pakistan, since the last detailed study carried out was three decades ago in which fuel consumption measurements were made for level tangent road in Pakistan specifically. While the intermediate studies carried out by JICA updated the prices for different components only. The recommendations are stated as follows:

- Significant research can be carried out in this specific domain. It is recommended that research should be carried out for each individual VOC component consumption according to Pakistan's road conditions and vehicle types. An attempt to study VOC in a single research by a researcher will not cover all the components comprehensively.
- This study has been supported by a small-scale survey. It is recommended that the experimental surveys to work out the vehicle speed, fuel consumption on the different National Highways of Pakistan varying according to the gradient, curvature and road roughness may be conducted.
- It is recommended to carry out a comprehensive survey from the vehicle driver/operator by hiring vehicle drivers who travel on day to day basis who could keep a record of their activities for at least a year. The trend in other VOC components consumption could only be then justified for a specific vehicle type and the VOC components consumption relations could be established for Pakistan.
- The institution should play major role in acquiring data related to different VOC components. It has been experienced through this study that both private and government departments were both reluctant and the concerned officials were hurdle in acquiring necessary data.

- It is further recommended that an attempt should be made to develop a theoretical model according to regional and environmental conditions of Pakistan, which should not be limited to just carrying out fuel consumption experiments but also the various other VOC components should be modelled based on surveys.

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Appendix

Questionnaire Sample

Vehicle Operating Cost for Pakistan
(User Survey)

Date: ____ Location: ____

Time: ____ Name: ____

1. Vehicle Type: ____
2. Axle Configuration ____
3. Fuel type: ____
4. Distance per Trip: ____ Fuel consumed per trip: ____

   Trip Origin: ____ Trip Destination: ____
5. Capacity of fuel Tank (gallons or Liters): ____
6. Average Load carried per trip: ____ Commodity: ____
7. Charges per Trip / Tonnage: ____
8. Number of hours travelled each day: ____
9. Distance per Liter (km/ Liter): ____
10. Total crew members: Drivers: ____ Helpers: ____
11. Monthly Salary: Driver: ____ Helper: ____
12. Toll Paid per trip: ____
13. Non- Travelling hours (Rest hours) per trip: ____
14. Average Food/Accommodation Cost per day: ____
15. Tyre change after (km or duration): ____ Cost of Tyres: ____
16. Number of trips made each month: ____
17. Average Engine oil change after (km): ____

    Cost of Oil change: ____
18. Average Maintenance Cost per month: ____