RESULT AND APPLICATIONS OF DETERIORATION MODEL IN ROAD ASSET MANAGEMENT – A CASE STUDY, ETHIOPIA

Rajeev Kumar Makhija
Intercontinental Consultants and Technocrats Pvt. Ltd., New Delhi, India
makhija@ictonline.com

ABSTRACT

In order to properly manage the increasing quality road asset on account of huge investments on rehabilitation, upgrading, widening and new construction of roads and highways in the last decade, a road deterioration model was established during the study in Ethiopia as per the actual maintenance requirement on the principles of life cycle cost analysis, based on traffic loading, road geometry, pavement type and condition, terrain, and climate for different road types and thus, ensuring adequate road maintenance strategies and standards, i.e. timely and proper maintenance interventions to an acceptable level of service in view of ensuring uninterrupted, sustainable, efficient, effective and safe road transport system in the country.

Accordingly, this paper highlights the result and applications of deterioration model in road asset management to preserve the national assets as well as bringing down the overall transport system cost in the country.

There are various applications of the road deterioration model, which can, inter alia, be applied to determine and rationalize a number of road user charges, such as, estimation of the overloading fines/fees on account of damages caused by the overloaded vehicles in the country, and determining the rational road user charges, to cover the extent of road deterioration, e.g. Mass Distance Charges (MDCs) to be adopted for the paved road network in various developing and developed countries.

KEYWORDS

RSDP, MDCs, ETB, HDM-4, IRI, NPV, ORF.

1. INTRODUCTION

Last decade most of the developing countries witnessed a huge investment on rehabilitation, upgrading, widening and new construction of national/state highways and other category roads; which has significantly increased the mobility of the people; but also created a challenge before the road agencies to preserve and manage the fast growing quality road asset.

Management of the upgraded road network requires undertaking timely and proper maintenance in view of ensuring uninterrupted, efficient, effective and safe road transport system during its design life; well-maintained road network would also reduce the total transport cost. It is known that funds allocation for road maintenance in developing countries is generally based on resource and capacity available, and not on the actual maintenance requirement of the network. Maintenance is not performed on the optimal basis as there remains a tendency by the road agencies to apply adhoc cuts in the face of resource constraints and as expected, and consequences are the premature deterioration of road network, which is not a healthy sign for developing economies.

In order to manage the road asset with a proper assessment of maintenance requirement, a road deterioration model was established during the study in Ethiopia ensuring adequate road maintenance strategies and standards, i.e. timely and proper maintenance interventions, to be setup related to traffic loading, terrain, and climate for different road types for maintaining the network to an acceptable level of service on the principles of life cycle cost analysis in view of ensuring uninterrupted, efficient, effective and safe road transport system.

2. STUDY AREA

Ethiopia is a landlocked country with the varied geographical terrains and scattered settlement pattern. Ethiopia is Africa's third most populated country, with 82 million inhabitants and is renowned for its distinctive cultural heritage and varied topography. For transportation of goods and services, road system plays an important role. As per Road Sector Development Program (RSDP 2011), the classified road network in Ethiopia comprised 48,793 km, of which 21,849 km were Federal Roads. About 95% of Ethiopia's passenger and freight traffic uses the road system and it is the only means of access to the widely scattered rural communities. But despite ongoing efforts to expand the road network, the country still has one of the lowest road densities in Africa with 44 km/’000 km^2 as per 2011 estimates, compared with other Sub-Saharan African countries, which have an average of 54 km/’000 km^2 of area. Moreover, the road network in Ethiopia is dominated by unpaved roads (>83%); there were 7,476 km paved roads under Ethiopian Roads Authority (ERA), and 1,285 km under Municipal Roads Authority (MRA). The entire road network of 26,944 km under the Regional Roads Authority (RRA) was unpaved.

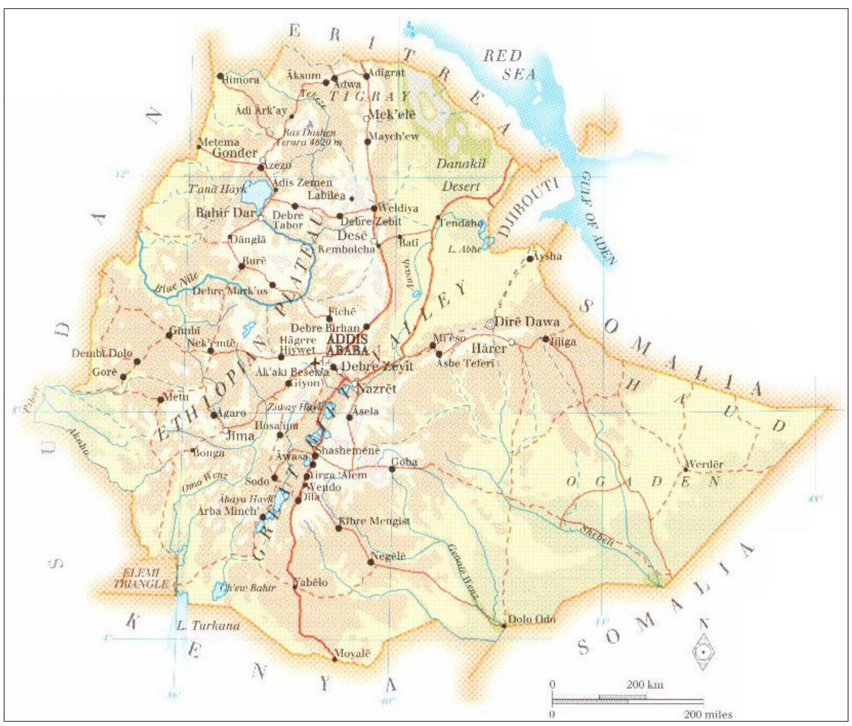

FIGURE 1 Road Map of Ethiopia

As per the records (2011), about 52% of the classified roads in the country were observed as very good / good, 28% as fair and 20% as poor / very poor.

3. ROAD MAINTENANCE IN ETHIOPIA

It does not require emphasis that an adequate and timely maintenance is required for all types of road surfaces to keep the roads in good level of serviceability, and also to preserve the national road assets which have been developed over a long period of time with heavy investments. Like other developing countries, in Ethiopia also, due to lack of resources maintenance of roads usually does not receive adequate attention of the authorities responsible. The consequences of this practice are the premature deterioration of road network in the country. Hence, in order to have proper assessment of maintenance requirement, there was a need for formulating adequate road maintenance strategies and standards, i.e. timely and proper maintenance interventions, to be setup related to traffic, terrain, and climate for different road types for maintaining the network to an acceptable level of service.

For a quick appreciation, the fund requirements for carrying out the road maintenance activities and to preserve the asset as well as offering quality road system to its users, the study made the estimates for ten years (i.e. 2011-20); which shows that for the classified road network in Ethiopia including the additional roads planned to be constructed during the period, the road agencies would be requiring annualized maintenance cost ranging from ETB 2.9 billion to ETB 3.2 billion (i.e. US$ 163 million to US$ 180 million) depending on different maintenance strategies. It is mentioned that in the year 2012, US$ 1 was equal to about ETB 18.

4. ROAD DETERIORATION MODEL

The Road Deterioration Model was developed based on the HDM-4 analysis carried out during the study. The Model covers the entire maintainable classified road networks administered by different road agencies, which would help in developing proper strategies and policies of preserving the road assets in the country.

The Deterioration Model, inter alia, was used to assess the year-wise requirement of maintenance interventions to keep the maintainable classified road network on a satisfactory level of service for 10 years. The Model’s results have also been used for estimating the overloading charges in order to meet the incremental maintenance cost caused by the heavily loaded vehicles due to damages made by the overloaded vehicles, and to estimate the probable Mass Distance Charges (MDCs), i.e. one of the potential sources of revenue to the Road Fund in Ethiopia. The MDCs may be introduced as an additional source of revenue to cover part of the variable costs for maintenance.

4.1 Road Maintenance Strategies & Standards

The major factors responsible for road deterioration are age, traffic and construction material quality and workmanship for paved roads, and traffic, quality of materials, terrain and climate for unpaved roads. From the road users’ point of view, for paved roads roughness and for unpaved roads roughness and all weather pass-ability are the important characteristics of a road. These are the key factors also influencing vehicle operating costs and ability to use the road.

The International Roughness Index (IRI), a measure for road roughness, is considered to be an indicator of pavement condition of any road. For example, a new asphalt concrete road can have a roughness (IRI) as low as 2 - 2.5. This level of IRI provides smooth riding quality. A newly constructed gravel road of good materials can have a roughness (IRI) of nearly 5. Over the time, increase in roughness, among others, may be observed due to the traffic, terrain and weather.

In Ethiopia, where there is substantial use of natural aggregates, the newly constructed gravel roads could have roughness value of around 5.5 IRI for higher standard roads, and 6.5-7.5 IRI for lower standard roads. As per the prevailing practices, according to the ERA's Pavement Management System of categorizing roads according to riding quality, gravel roads with less than 11 IRI and paved roads with less than 4.5 IRI are classified as being in good condition.

4.2 Optimum Maintenance Interventions

Optimum Maintenance Interventions based on the maximizing net present value (NPV) were worked out using HDM-4 by specifying a series of maintenance alternatives including ranges of traffic level, pavement condition for different pavement types, for different regions with varied terrains and climate, and proposed for next 10 years for the road networks under the road agencies. Though, in reality, a true optimum level of maintenance interventions is difficult to achieve without intensive investigations, due to the level of interaction of the numerous deterioration parameters and works standards effects, the Study adopted intervention levels based on internationally accepted standards to set a deterioration model for the country. The exercise was carried out as per availability of the relevant data.

4.3 Recommended Maintenance Strategies & Standards for the Study

4.3.1 Routine Maintenance

Paved Roads: For paved roads, routine maintenance includes patch repairs, crack sealing, edge repair, cleaning of road side drains/cross drainage structures, repairing of shoulders, painting of highway signs and km-stones, arboriculture and turfing, road markings, removal of litter, debris, replacement of damaged signs and maintenance of culverts, etc.

For paved roads, the critical parameters influencing the performance and the maintenance effort are the existing pavement condition in terms of roughness (IRI) and level of patching/cracking, traffic loading in terms of equivalent standard axles, and pavement strength in terms of structural number (SN). HDM-4 analysis was undertaken in the Study to assess the quantum of routine maintenance (repairing potholes, sealing cracks, edge breaks, etc.) and periodicity of resealing for maintaining the roads under different levels of serviceability in terms of IRI.

Unpaved Roads: Routine maintenance for unpaved roads includes filling up of depressions, making up rain cuts, removal of rock falls, slips and other obstructions, cleaning of drains/cross-drainage, etc., along with grading and spot graveling, whereas periodic maintenance consists of resurfacing and re-gravelling.

In the present Study, HDM-4 analysis was carried out for different traffic levels for two levels of serviceability for unpaved roads, i.e. basic level ($IRI<11$) and the most desirable (ideal) level ($IRI<8$) and the periodicity of such operations was determined and used in assessing the road maintenance needs in the country for next 10 years.

4.3.2 Periodic Maintenance

Periodic maintenance activities involve provision of renewal coat to the wearing surface at a predetermined frequency based on the treatment type, to safeguard the road crust and keeping the pavement for better riding surface.

For paved roads, the development of set of "optimum" economic based standards, as a matrix of intervention levels for different traffic levels, pavement type, climate and terrain was developed. The analysis has been carried out for Asphalt Mix on Granular Base (AMGB) and Surface Treatment on Granular Base (STGB). Various maintenance alternatives tested for AMGB and STGB for different combinations of maintenance strategies as per the existing practices of maintenance activities in Ethiopia are given in Table 1.

The analysis shows that for AMGB, the maintenance strategy of Overlay when Roughness>= 4.5 IRI and reconstruction/rehabilitation when Roughness >=8 IRI yields the highest NPV with the interval between overlays varying for different traffic levels and terrains. And that for STGB, the maintenance strategy (high) of reseal, when total cracked area >=15% and reconstruction/rehabilitation when Roughness >=8 IRI gives the highest NPV with the interval between resealing and reconstruction varying for different traffic levels and terrains.

TABLE 1 Treatment Alternatives Considered for AMGB & STGB

Maintenance Strategy	Resealing	Overlay	Reconstruction
Low Level	Total Carriageway Cracked >=30%	Roughness>=6 IRI	Roughness>=10 IRI
Medium Level	Total Carriageway Cracked >=20%	Roughness>=5 IRI	Roughness>=9 IRI
High Level	Total Carriageway Cracked >=15%	Roughness>=4.5 IRI	Roughness>=8 IRI

Alternative maintenance interventions, as presented in Table 1, ensure that roughness of the roads with asphaltic pavement in the country assumed to be less than 6, 5 and 4.5 IRI during the entire analysis period of the Study, i.e. up to 2020, based on the suggested level of maintenance strategy, viz. low, medium and high. So the periodic maintenance is recommended whenever the roughness of the pavement exceeds the IRI as indicated in Table 1.

Average roughness assumed for the analysis period for paved roads under different road maintenance strategies has been graphically presented in Figure 2.

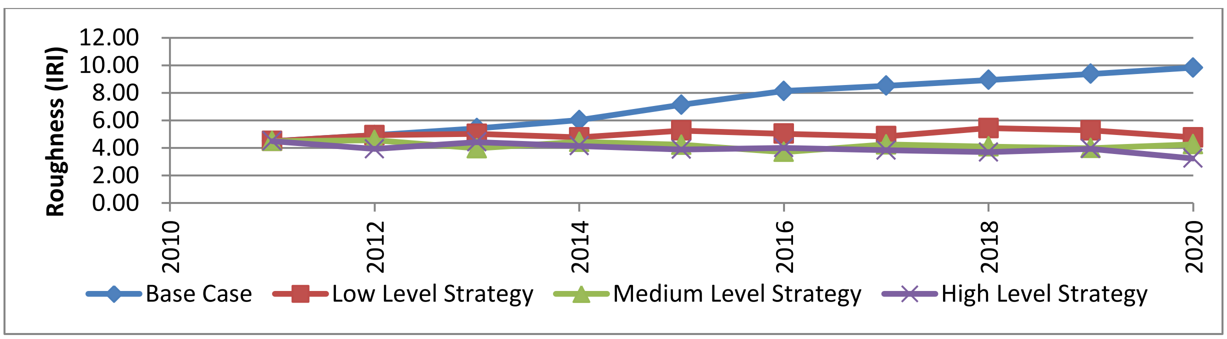

FIGURE 2 Average roughness for different maintenance strategies for paved roads

Unpaved Roads: Working out the optimum maintenance strategy (Table 4) for unpaved roads involved using HDM-4 Strategic Analysis Tool and creating a large number of alternatives for grading at intervals of between 1 and 14 times per year, spot gravelling with various percentages of material loss to replace and re-gravelling. Five traffic levels (very low, low, medium, high and very high AADT), starting road condition as "good" was selected for the analysis period. The analysis was carried out to evolve optimum maintenance standards for unpaved roads. In finalizing the optimum maintenance strategies, which maximize the NPV, two levels of serviceability, viz. basic level and ideal level was considered:

- basic level of maintenance to keep the network below roughness of 11 IRI; and
- ideal level of maintenance to keep the network below roughness of 8 IRI.

The outcome of the analysis is shown in Table 2 and Table 3 for unpaved roads as a set of optimum grading frequencies for each operation, with the optimum level derived on the basis of maximizing NPV.

TABLE 2 Unpaved Roads - Basic Level of Maintenance/year (Roughness <11 IRI)

Traffic Category (vpd)	Plain	Rolling	Mountainous
Very Low (<75)	2 gradings	2 gradings	2 gradings
Low (75-150)	4 gradings	4 gradings	4 gradings
Medium (150-300)	7 gradings	7 gradings	7 gradings
High (300-500)	12 gradings	12 gradings	12 gradings
Very High (>500)	14 gradings	14 gradings	14 gradings

TABLE 3 Federal Unpaved Roads - Ideal Level of Maintenance/year (Roughness <8 IRI)

Traffic Category (vpd)	Plain	Rolling	Mountainous
Very Low (<75)	4 gradings	4 gradings	4 gradings
Low (75-150)	6 gradings	6 gradings	6 gradings
Medium (150-300)	8 gradings	8 gradings	8 gradings
High (300-500)	12 gradings	12 gradings	12 gradings
Very High (>500)	14 gradings	14 gradings	14 gradings

TABLE 4 Maintenance Strategies for Unpaved Roads

Level of Service	Activity Requirement	Intervention Level
Acceptable	Spot graveling @ Gravel Thickness	<=100 mm (up to 25% annual material loss to replace)
	Re-graveling @ Gravel Thickness	<=75 mm
	Routine Maintenance	Every Year
Desirable (Ideal)	Spot graveling @ Gravel Thickness	<=125 mm (up to 25% annual material loss to replace)
	Re-graveling @ Gravel Thickness	<=100 mm
	Routine Maintenance	Every Year

The graphical representation of average roughness for the Base Case, Acceptable Case and Ideal Case during the analysis period is given in Figure 3.

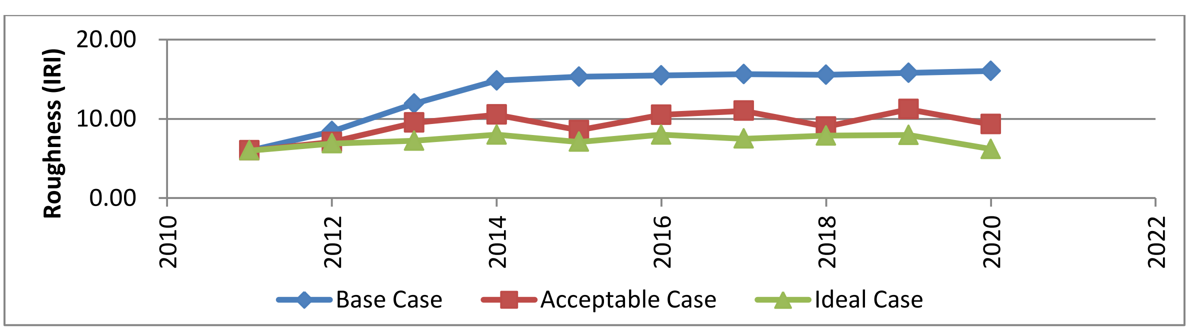

FIGURE 3 Average roughness for different maintenance strategies for gravel roads

4.4 Multiyear Analysis

The approach and methodology used for carrying out the multiyear maintenance need analysis and estimating the cost implications for the classified road network in the country are mainly based on the Road Deterioration Model developed during the present Study. It is important to mention that the maintenance interventions were proposed only on the "maintainable roads", as per the eligibility criteria set for the maintenance activities. While conducting the multiyear analysis, the following issues and considerations were kept in view:

The road networks under different road agencies, identified as very good/good, fair and poor condition, were categorized as "Maintainable Roads", which need to remain in good/fair condition for next 10 years. This approach would preserve the road assets;

Establish the extent and magnitude of maintenance needs of the total classified road network under the roads agencies, viz. ERA, RRAs and MRAs in the country for next 10 years for varied terrains in different regions. This exercise considers the RSDP IV projections, i.e. up to 2020, the expected growth in the road network in the country in view of the past trend and requirements for the socio-economic development of the country; and

The effects of varied traffic levels on the road networks on varied terrains and regional distribution on the maintenance needs assessment of the road network for next 10 years, i.e. up to 2020.

Table 5 presents projected classified road network up to the year 2020. This is based on the RSDP IV document for the future years i.e. 2020 on the basis of addition of new roads which are to be included in the network under road agencies. Also it is assumed that the road network in Ethiopia would increase by 4.8% pa during 2015-20.

TABLE 5 Projected Classified Road Network in km (2015-20)

Particular	2010	2015-16	2016-17	2017-18	2018-19	2019-20
Addition in the ERA's Network	-	806	845	885	928	972
Planned ERA's Network	21,849	26,986	27,831	28,716	29,643	30,615
Addition in the RRAs Network	-	2,125	2,227	2,334	2,446	2,564
Planned RRAs Network	26,944	40,281	42,508	44,842	47,288	49,852
MRAs Network	4,556	5,440	5,603	5,771	5,945	6,123
Total Network (incl. MRAs)	53,349	72,707	75,942	79,329	82,877	86,591
Total Network (excl. MRAs)	48,793	67,267	70,340	73,559	76,932	80,468
Road Density /'000 km^2 of Area (excl. MRAs)	44.40	61.21	64.00	66.93	70.00	73.22

4.4.1 Maintenance Needs Assessment required for Multiyear Analysis

The maintenance needs assessment for the classified road network was carried out for future years, i.e. up to 2020 using the Road Deterioration Model based on HDM-4. It is assumed that after the maintenance of the road network in the base year, the entire network is brought to be in good condition (with roughness between 6 and 11 IRI for the gravel roads, and between 4.5 and 6.0 IRI for paved roads), and predicted pavement condition of the roads, i.e. in future, would be in good condition as illustrated in the following sections.

For Paved Roads: As illustrated earlier, the analysis has been carried out for the paved roads in three maintenance strategies, i.e. low (IRI=<6.0), medium (IRI=<5.0) and high (IRI=<4.5), so that during the analysis period of 10 years, roads under different road agencies are likely to work on a satisfactory level of service and also ensure preserving the road assets.

For Unpaved Roads: Two types of maintenance strategies were proposed for unpaved roads, i.e. (i) Acceptable Level of Maintenance, where the roughness level of <11 IRI is likely to be attained; and (ii) Desirable (Ideal) Level of Maintenance, where the roughness level is likely to remain <8 IRI, throughout the analysis period.

In view of estimating Road Maintenance Costs, latest traffic details required for the HDM-4 analysis were collected from ERA. Length of the stretches with various traffic levels were sorted out and per km maintenance cost in each maintenance strategy, i.e. low, medium and high, by varying traffic levels for paved and unpaved roads under ERA, RRAs and MRAs were calculated as per the actual road deterioration in next 10 years.

It may be noted that the annualized maintenance cost was derived using the HDM-4 Model; the Model calculates the maintenance needs and costs based on the defined maintenance interventions and the unit rates of different maintenance activities; requirements of the maintenance in future years on the particular roads are based on the previous years' pavement condition and the maintenance tasks undertaken, i.e. type and extent of maintenance: routine and periodic and accordingly annualized maintenance cost was estimated during the analysis.

For an illustration, to repair "area under cracking" is one of the major components in routine maintenance, which requires much higher cost that may not be required in next or subsequent years. Therefore, the cost incurred on the above account may not repeatedly feature in years to come. Also, the maintenance costs are worked out for entire maintainable road network, which is further categorized with different traffic level groups influencing the maintenance interventions, etc.; accordingly, HDM-4 analysis was carried out with the responsive option in the model. Further, the above exercise was carried out on a macro level aggregate for planning and policy formulation purposes.

The total maintenance cost of projected road network in Ethiopia is shown in Table 6.

TABLE 6 Total Road Maintenance Cost of the Projected Road Network (2011-20)

Year	**Strategy**		
	Low Level	**Medium Level**	**High Level**
			(US$ million)
Total	1631.33	1720.99	1801.33
Cost/Year	163.13	172.10	180.13

Table 6 shows that in order to maintain and preserve the classified road network in Ethiopia including the additional roads, which are planned to be constructed during the analysis period, the road agencies would be requiring annual budget as on present prices on an average about US$ 163 million to US$ 180 million based on the adaptation of maintenance strategy, i.e. low, medium and high.

4.5 Overloading Charges

4.5.1 General

The "overloading charges" are levied on those vehicles carrying load more than the permitted limits, which could be termed as overloaded vehicles. The fines/fees are principally to be imposed as a deterrent to overloading practices though the estimates address the issue of the charging for the damage caused to the pavement due to overloading. It is usually observed that the fines are too low to act as a serious deterrent or to compensate for the additional damage caused to the road pavement due to overloading. It is generally argued that the damage caused by an overloaded vehicle is much higher than the fine imposed.

The damage that vehicles do to road pavements increases exponentially at the "4.5 power of the axle load"; e.g. a 16-tonne axle does about 20 times more damage to a road pavement than 8-tonne axle.

Conceptually, in context of the Road Fund, overloading fines cannot be taken as source of revenue, rather deterrent to restrict the road users not to overload their vehicles.

As the degree of overloading increases, major safety issues are raised in addition to the non-recovery from the road users of damage to the infrastructure. These issues include:

- Increased severity of road accidents when overloaded vehicles are involved;
- Reduced grade climbing capability and acceleration;
- Greater loss of lateral stability;
- Increased breaking distance required for overloaded vehicles; and
- Increased vehicle emissions, noise and ground–borne vibrations.

The severity of road accidents in Africa is extremely high that is estimated to be some 30-50 times higher than the U.K. or the USA. Many of these accidents are caused by overloaded commercial vehicles. The cost of overloading is estimated to consume about 2% of GNP in Africa as per the TRL study entitled, Towards Safer Roads for Developing Countries, 1991.

Comparison of permissible limit of gross vehicle mass also known as combined mass of various axles for different vehicle types in some of the African countries including Ethiopia is shown in Table 7.

TABLE 7 Maximum Permissible Vehicle/Combination Mass/Weight in Select Countries (tons)

Vehicle / Combination Type	Kenya	Tanzania	Uganda	Ethiopia
Vehicle with 2 Axles	18	18	18	18
Vehicle with 3 Axles	24	26	24	24
Vehicle with 4 Axles	28	28	30	32
Vehicle + Semitrailer with 3 Axles	28	28	28	28
Vehicle + Semitrailer with 4 Axles	34	36	32	34
Vehicle + Semitrailer with 5 Axles	42	44	40	42
Vehicle + Semitrailer with 6 Axles	48	50	48	50
Vehicle + Drawbar Trailer with 4 Axles	36	37	38	38
Vehicle + Drawbar Trailer with 5 Axles	42	45	42	44

Vehicle / Combination Type	Kenya	Tanzania	Uganda	Ethiopia
Vehicle + Drawbar Trailer with 6 Axles	48	53	50	50
Vehicle + Drawbar Trailer with 7 Axles	--	56	56	56

Source: Study for the Harmonization of Vehicle Overload Control in the East African Community (April 2011).

4.5.2 Overloading Practices & Charges in Ethiopia

Overloading fine is part of the Road Fund Proclamation, Ethiopia (66/1997), and identified as one of the sources of the revenue. The basic concept behind imposing the "Overloading Fines" is not necessarily for generating revenues, rather it is used as a deterrent, so that the road users do not overload their vehicles, and also do not make severe damages to the road surface. For observing traffic discipline and also to protect the road pavement, the overloading fines are imposed on the vehicles carrying more loads than the permitted limits. In fact, the overloaded vehicles make the damages to the road surface much more than what they pay as overloading fines.

4.5.3 Road Deterioration & Overloading Fines

In order to estimate the road deterioration caused by overloaded vehicles and the overloading fines commensurate with damage to the roads, the Road Deterioration Model using HDM-4 was used in the analysis as discussed in the following sections:

4.5.4 Determination of Road Deterioration & Overloading Fines

With the help of HDM-4 model, the exercise estimated the difference of road deterioration under the scenarios "with" and "without" overloading and also difference of total maintenance cost. Under the scenarios "with overloading" a typical overloading situation in Ethiopia as depicted from the traffic data obtained from ERA was used. For the case of "without overloading", calculations were made by assuming overloading vehicles be replaced by fully loaded vehicles with GVM at the legal limit, resulting in less per vehicle payload and additional number of vehicles. The difference of maintenance cost in both the scenarios is illustrated in Table 8.

TABLE 8 Difference of Maintenance Cost – With & Without Overloading

Particular	Cost (US$) per		
	'00 km	Veh-km	Veh/ton-km
Maintenance Cost "with Overloading" (Present)	1,052,999	-	-
Maintenance Cost "without Overloading" (Ideal)	911,839	-	-
Difference (Present and Ideal Situation)	141,160	9.16	0.01

Source: The Consultant's Estimates.

Results of the above exercise show that in order to cover the additional maintenance cost due to the overloading, the overloaded goods vehicles would be required to pay US$ 0.01/veh/ton-km. Revenue generated by the overloading fines may be expected in the range of US$ 1.8 million pa with the assumption that only 50% of overloaded vehicles are likely to be tapped, and other reasons, like, sampling procedure, improper enforcement, inadequate number of weighbridges in the country, change of route by the vehicles, etc.

Though the revenue generated through the overloading fines should be treated as deterrent, it should be diverted to the Office of the Road Fund (ORF) account for having the additional burden of road maintenance due to overloading as well as enforcement purposes and road safety.

4.6 Mass Distance Charges

The concept behind imposing the Mass Distance Charges (MDCs), i.e. also known as Weight Distance Charges is based on reducing the inequality among road users by ensuring that heavy vehicle owners/operators pay their fair share for the maintenance of roads in the country, as the road consumption increases more sharply with the increase in gross vehicle mass (GVM) than it does with the level of fuel consumption. The MDCs contribute to the variable costs component of the road maintenance cost.

The Mass Distance Charges for different types of heavy goods and passenger vehicles for Ethiopia were worked out in the Study based on the actual road deterioration caused by the heavy vehicles travelling on the road networks in the country. The exercise was carried out using the multiple runs of HDM-4 model by using different types of additional heavy vehicles in the present traffic scenario on the federal paved road network (trunk) of ERA. HDM-4 analysis was carried out "with" and "without" additional heavy vehicles with the existing traffic on the federal roads, and the incremental impact of heavy vehicles on the additional maintenance needs and, hence, the additional maintenance cost was derived considering both the scenarios.

It is learnt that the road deterioration rate increases exponentially with the increase in vehicle weight, the difference of maintenance cost, as per the concept of the MDCs should be borne by none other than these heavy vehicles. Hence, the increased maintenance cost was distributed on various vehicle types depending on their share of annual vehicle utilization on the main road network in the country. The MDCs, thus, estimated in five levels for accommodating different vehicles are presented in Table 9.

TABLE 9 Vehicle-wise Estimated MDCs in Ethiopia

Level of Charges	Vehicle Type	Rate/Vehicle	
		(ETB/100 km)	(US$/100 km)
Level 1	Mini Bus / Small Truck	7.1	0.39
Level 2	Large Bus / Medium Truck	16.6	0.92
Level 3	Heavy Truck	19.6	1.09
Level 4	Very Heavy Truck	23.5	1.31
Level 5	Over dimensional/abnormally Heavy Vehicle	50.0	2.78

Source: The Consultant's Estimates.

The practice of MDCs has been successfully operational in a number of developing and developed countries, such as, New Zealand, Switzerland, Iceland, CAR, Zimbabwe, etc. The MDCs, as one of the sources of the Road Fund, is already introduced in Namibia. For the purpose of analysis and appreciation, a comparison of the rates estimated for MDCs in Ethiopia with the prevailing rates in Namibia in Africa, is presented in Table 10.

TABLE 10 Comparison of Estimated MDCs in Ethiopia with Prevailing Charges in Namibia

Level of Charges	Vehicle		MDCs (US$/'00 veh-km)	
	Type	Description	Estimated for Ethiopia	Prevailing rates in Namibia
1	Mini Bus	V Value: >3,500 kg or <=7,000 kg	0.39	0.59
	Small Truck			
2	Medium Bus	V Value: >7,000 kg or <=16,000 kg	0.92	0.75
	Medium Truck			
3	Large Bus	V Value: >16,000 kg	1.09	1.45
	Heavy Truck	V Value: >16,000 kg or <=34,000 kg		
	Trailers	D Value: >16,000 kg or <=34,000 kg		
4	Trailers	D Value: >34,000 kg or <=44,000 kg	1.31	2.90
5	Trailers	D Value: >44,000 kg	2.78	4.35

V Value – maximum legally allowed mass of vehicle, not equipped to drawing unit, D Value – maximum permissible drawing vehicle mass of a power unit.

Table 10 shows that MDCs proposed for different vehicles in Ethiopia are comparable, rather slightly on the lower side as per the prevailing rates in Namibia. It may be noted that the contribution of MDCs in Namibia is accounted for 2-3% of the total revenue of Road Fund.

If implemented, the proposed MDCs may contribute to the Road Fund up to 4-5% with the assumed level of traffic with composition of vehicles.

5. SUM UP

The present paper has highlighted the result and applications of a need based road deterioration model developed to assess the multiyear requirement of maintenance interventions for the roads in the country with the principle that maintenance of the asset is more important than new construction as negligence may deteriorate the road asset considerably or even completely. Results of the road deterioration model were used for determination of various road user charges including estimating the overloading charges and mass distance charges in order to meet the incremental maintenance cost caused due to damages made by the overloaded vehicles in the country.

ACKNOWLEDGEMENT

This paper has been written based on the results and recommendations of the IRF's award winning Study entitled, "Maintenance Needs Assessment and Update of Road Financing Study, Ethiopia" undertaken during 2010-2012, in which the author was involved as one of the Key Professionals. Author is thankful to all the personnel's directly or indirectly involved in the preparation of this paper.