Truck Overload Fine Rationalization on Ethiopian Primary Roads

A Case Study on Addis Ababa – Adama Expressway

Kibret Gebremedhin
Lecturer at Wolkite University Civil Engineering Department
Master of Science in Civil Engineering (Road and Transport Engineering)
Mobile; +251-09 13 65 77 09 e-mail; kibretgmedhin@yahoo.com October 2015

Abstract

The relationship between overloaded trucks and corresponding economic impact on flexible pavement was investigated using HDM-4 model. Accordingly, a rational overload fine structure was prepared using optimum maintenance standards. Comparison was then made between developed rational and existing court imposed overload fines. It is believed that results of this study can help road management agencies in improving overload management.

Key Words

Overload cases, HDM-4 , Optimized Maintenance Standards, Rational and Court Imposed Overload Fine.

Introduction

Road infrastructure represents huge investment for any country. To protect these assets against overloading, individual countries have regulations for permissible axle load and vehicle dimensions. However, transporters tend to overload to reduce their running cost and overhead for freight transport regardless of damaging impacts of overloading.

Overloading is criminalized in Ethiopia (Ethiopian Council of minister's regulation № 11, 1990). Overloaded truck operators pay a certain amount of fee specified by a local court nearby a weighing station based on cumulative of extra weight of overloaded axles of overloaded vehicle measured in quintals. Usually, extra weight is also adjusted or unloaded at weighing stations to legal limit prior to allowing overloaded trucks continue their trip. In Ethiopia, there are several problems associated with overload management; however, the main focus of this study is regarding two problems associated with overload fines.

I. Overload charges imposed by court of law are laid based on factors that have no relation to the damage to road infrastructure and benefits to haulers. The lack of justification and consistency would make overload fines ineffective in preventing overloading.

II. All overload fines are paid to a local court account and revenue collected is not used as a cost recovery to the road fund, which would negatively affect sustainability of road infrastructure.

The rational overload fine structure (Fee per axle overload per kilometer) that takes in to account rate of overloading and its economic impact is unknown in Ethiopia. Therefore, this paper deals with determination of rational overload fine structure by analyzing economic impact of overloading using HDM-4 (Highway Development and Management Model).

Objective

The following are the key objectives of the study

- To determine rationalised overload fine structure (Fine per axle overload per km) for Ethiopia.
- To Compare rational overload fine with current court-imposed overloading fee in Ethiopia.

Summary of Literature

Vehicle operators' lack of awareness regarding pavement damage due to overloading and reluctance to self regulate due to their desire to make more profit from extra loading is taken as primary cause of overloading (EGIS, 2010). The weak road management system in developing countries is also another reason for increased overloading activity (Chuan, 2008). Overload fines imposed by courts are usually insufficient and ineffective in preventing overloading because they are unrealistic and low compared with the damage done by the vehicle on the road and the higher profit made by the hauler (Michael lan Pinard, 2010).

The best alternative recommended for governments to deal with overloading and its impacts is maintaining roads to desired level of service combined with strict law enforcement (Chuan, 2008). The importance of efficient road management system was also given more emphasis in overload control. Literatures show that importance of enforcement or penalty is similar in terms of overload prevention. However, increasing overload fine supplemented by enforcement is considered cost effective mechanism of overload control (Strathman, 2001).

Determination of a rational overload fine that commensurate the actual damage to the pavement requires analyzing damage related with overloaded truck. Overloading has several impacts on economy, and efficiency of road infrastructure. Overloading has also impact on environment, safety and fair trade (Chuan, 2008). Economic impacts of overloading include; increase in vehicle operating costs, increase in maintenance costs and reduced pavement life (Africon Ltd, 2011). However, these effects are interdependent and need to consider their combined effects instead of separate analysis. Computer software, a pavement management system (PMS) can be developed to assist decision makers in finding optimum strategies for providing, evaluating, and maintaining pavements in a serviceable condition over a given period of time (Huang, 2004).

Study Area

The selected study area is Addis Ababa – Adama Expressway. The road link located along the Addis Ababa - Djibouti Road, which is a major gateway of Ethiopia's import-export logistic. It is expected that heavy vehicles will remain a common sight on the expressway in the future. The project selection is also rational due to its recent nature and availability of road design documents.

Considering similarity of traffic, topography and Subgrade soil characteristics, and five road sections were established (see Figure 1). The two directions of study road link were also considered separately due to their differences in traffic volume and terrain. The road sections are:

- Section 1: Addis Ababa – North Debre Zeit [AA-DZ] [K2+800 - K17+000]
- Section 2: North Debre Zeit – Modjo [DZ-MO] [K17+000 - K52+200]
- Section 3:Modjo –Adama West [MO-AW] [K52+200 - K60+500]
- Section 4: Adama West – Asela Road [AW-AR] [K60+500 - K71+700]
- Section 5: Asela Road – Adama [AR-AD] [K71+700 - K78+000]

Uphill and Dow Hill

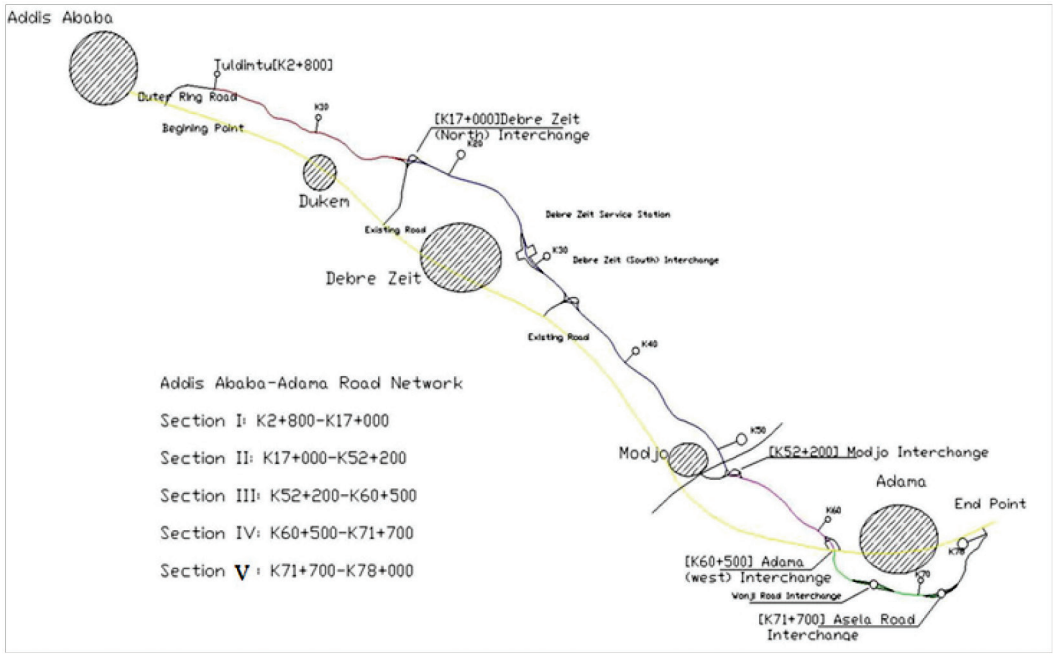


Figure 1. Addis Ababa Adama Road Link and Study Sections (No Scale)

Methodology

In order to analyse the economic impact of overloaded trucks, which is the base for determining overload fine structure, overloaded trucks were ideally allowed to use the road. Statistical analysis of axle load data of Modjo weighing and field axle load survey was performed to determine overload pattern. Five overload cases were then identified to levy different overload fines based on the severity of overloading per axle. These five cases are truck traffic comprising overloading per axle of 10%, 20%, 30%, 40% and 50% as listed in Table 1. Percent of overloading per axle was used due to the same relative damage for front and rear axles relative to their legal limit.

Table 1 Overload cases used for the study

Overloading per axle	Overloading Cases					
	Case 0	Case1	Case 2	Case 3	Case 4	Case 5
≤≤0 % (no Overloading)	√	√	√	√	√	√
0-10%	×	√	√	√	√	√
11-20%	×	×	√	√	√	√
21-30%	×	×	×	√	√	√
31-40%	×	×	×	×	√	√
41-50%	×	×	×	×	×	√

Note:√√: Truck can use the road

××: Truck has to unload extra weight to the nearest limit before using the road

Traffic and vehicle fleets, and general data requirements applicable in study area is obtained from as built documents of Ethiopian Toll Road Enterprise office (ETRE).

Routine and periodic Maintenance standards that are common in Ethiopia were considered for the study. Non-pavement routine maintenance works were applied annually. Pavement related routine maintenance and periodic maintenance works were applied based on condition of pavement. Roughness (IRI) values in the range of 3m/km-5m/km at 0.5m/km interval was used as a trigger values for periodic maintenance (Refer Table-2). Optimized maintenance standard for particular road section under particular overload case was then selected using life cycle programme analysis.

Table 2. Alternative Maintenance Standards used for the Study

Periodic Maintenance Options	**Trigger Points [IRI(m/km)] and 15%**				
	IRI=3	IRI=3.5	IRI=4	IRI=4.5	IRI=5
	3 [1]	**3.5 [2]**	**4 [3]**	**4.5 [4]**	**5 [5]**
RM+30 mm Asphalt Concrete Overlay [A]	A1	A2	A3	A4	A5
RM+40 mm Asphalt Concrete Overlay [B]	B1	B2	B3	B4	B5
RM+50 mm Asphalt Concrete Overlay [C]	C1	C2	C3	C4	C5
RM+60 mm Asphalt Concrete Overlay [D]	D1	D2	D3	D4	D5
RM+70 mm Asphalt Concrete Overlay [E]	E1	E2	E3	E4	E5
RM+80 mm Asphalt Concrete Overlay [F]	F1	F2	F3	F4	F5

Note: RM=Routine Maintenance [Pavement and Non Pavement Routine Maintenance

Economic impact of overloaded trucks considered in the study are increase in pavement roughness (IRI) and associated Vehicle Operating Costs (VOC), travel time cost and optimum maintenance interventions cost. The combined effect in terms of change in cost and benefits were then analyzed using HDM-4 (Version 1.1) and converted into a common unit or Net Present Value (NPV), which is used as an indicator of economic impact due to overloading. Economic impact due to overloading was then distributed sequentially to overloaded axles.

On the other hand, Weighing stations cost including initial investment and running cost was predicted and distributed equally to all overloaded trucks over analysis period of 20 years (2015-2034). The rational overload fine structure was finally determined as the sum of cumulative of overload fine on overloaded axles and weighing station cost per vehicle as it is given in Equation 1.

$$Fx = \sum_{i=0}^{i=n} L * Yxi + WcFx = \sum_{i=0}^{i=n} L * Yxi + Wc$$

…….....(1)

Where Fx = Rationalized Overload Fine of vehicle x

L = Total distance travelled by the vehicle (distance between origin and weighing station)

Yxi = Overload fine on i^{th} axle determined by Equation 2 and 3

i = i^{th} axle of vehicle x

n = total number of axles in vehicle x

Wc= Weighing Station Cost (in ETB=Ethiopian Birr)

A 186 sample court imposed overload fines were finally re-evaluated and compared with rationalized overload fine. Based on these results, discussion, conclusion and recommendation were provided. The flow chart of methodology can be seen in Figure 2.

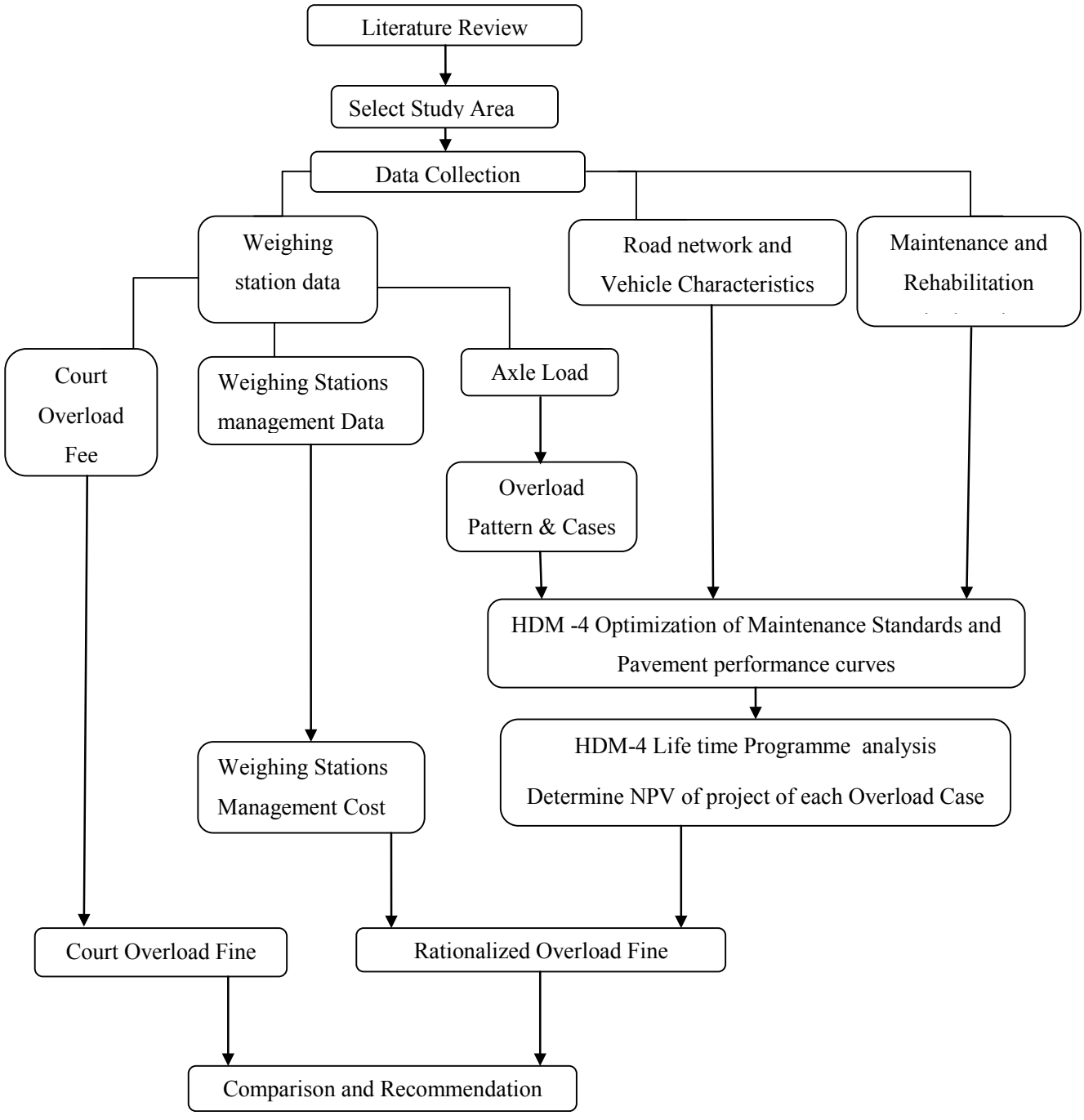


Figure 2. Summary of Methodology Used for the Study

Results

The economic impact caused by overloaded trucks was estimated by comparing NPV of different overloaded cases against the base case (Case 0). The change in NPV, was then distributed to the NPV of overloaded axles over analysis period of 20 years to determine economic impact per axle per kilometre. As shown in Table 3, the economic impact was higher in most road sections for uphill direction (Adama to Addis Ababa) than the downhill direction. This result is expected as pavement damage would be higher in uphill direction due to the fact that fully loaded slow moving heavy vehicles are more damaging than otherwise.

On the other hand, the road section V (Asela - Adama) did not show any change in NPV on both directions. The pavement of this road section is overdesigned for low traffic and it has good subgrade strength which made it capable of carrying traffic under all overload cases. Hence, no economic impact was detected on this road section. This also shows that, if pavements are designed to accommodate the anticipated practical loading conditions of trucks, the impact due to overloading may be minimized.

Table 3. Economic cost per overloaded axle per kilometer (ETB)

Road Section	Overloading per axle					
	0%	10%	20%	30%	40%	50%
Addis Ababa - Debre Zeit (Uphill)	0.00	0.27	0.58	1.29	1.39	1.62
Addis Ababa - Debre Zeit (Downhill)	0.00	0.28	0.57	1.27	1.41	3.49
Debre Zeit - Modjo (Uphill)	0.00	0.75	1.27	2.39	2.66	3.36
Debre Zeit - Modjo (Downhill)	0.00	0.29	0.58	1.25	1.91	2. 03
Modjo - Adama West (Uphill)	0.00	0.22	0.47	0.92	1.06	1.12
Modjo - Adama West (Downhill)	0.00	0.18	0.40	0.83	0.92	0.99
Adama West - Asela Road (Uphill)	0.00	0.02	0.18	0.29	1.17	1.44
Adama West - Asela Road (Downhill)	0.00	0.05	0.19	0.5	0.57	1.75
Asela Road - Adama (Uphill)	0.00	0.00	0.00	0.00	0.00	0.00
Asela Road - Adama (Downhill)	0.00	0.00	0.00	0.00	0.00	0.00

Weighing station cost per vehicle is analyzed considering initial investment of ETB 20 million and annual running cost of ETB 717,600. Estimated weighing stations cost is then distributed equally to NPV of overloaded trucks over analysis period which resulted in ETB 14.67 per overloaded vehicle.

The rational overload fine of 186 overloaded trucks (whose court imposed fine is known) was then calculated using Equation 1.

In order to simplify overload fine analysis, the overload charges listed in Table 3 were combined based on principle of weighted average of road fine and corresponding road length. In order to allow easier prediction of costs in between specified overload cases, best fitting curves were developed (see Figure 3). Equation 2 and 3 were then developed to determine Overload fine on i^{th} axle (**Yxi of** Equation 1).

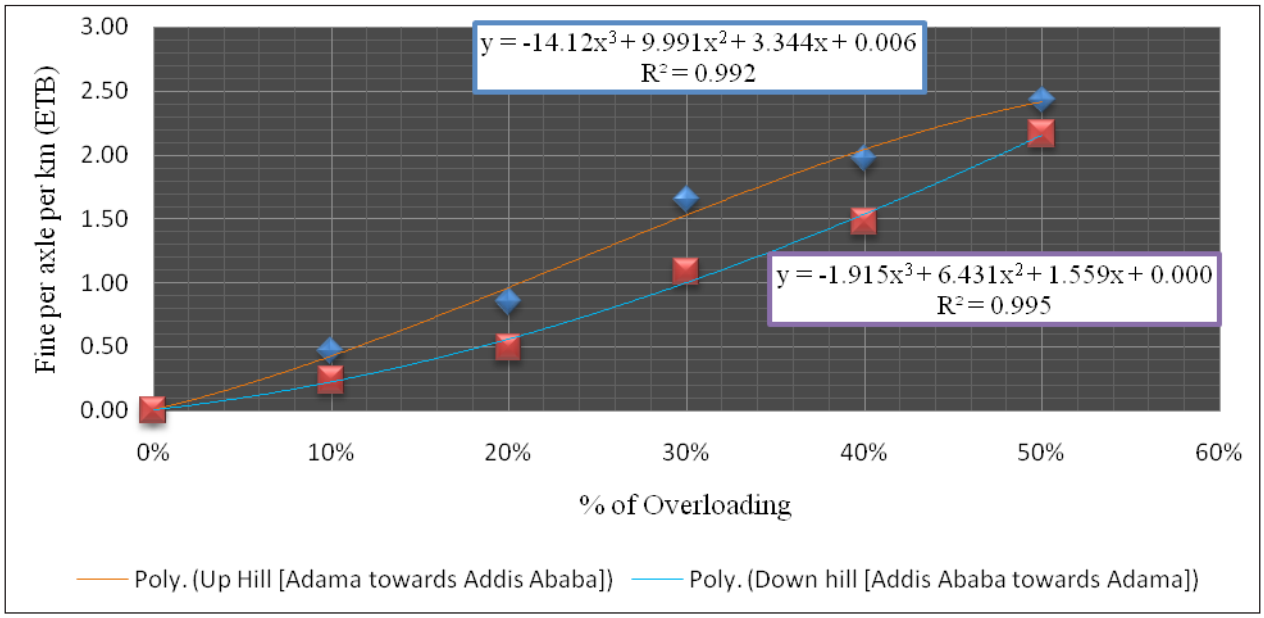


Figure 3. Best fit curves and equations used for comparison of overload fines

For Uphill direction

$$Yx_i = a * (-14.12Xi^3 + 9.991Xi^2 + 3.344Xi + 0.006)$$

.....(1)

$$Yx_i = a * (-14.12Xi^3 + 9.991Xi^2 + 3.344Xi + 0.006)$$

.....(2)

For Downhill direction

$$Yx_i = -1.915Xi^3 + 6.431Xi^2 + 1.559Xi$$

$$Yx_i = -1.915Xi^3 + 6.431Xi^2 + 1.559Xi \text{ .....}$$

.....(3)

Where; $Yx_i = Yx_i =$ overload fine on i^{th} axle in ETB

Xi = Percent of overload per axle

a is a dummy variable used to set zero cost or zero overloading a = 0 if Xi ≤ 0%≤ 0% a = 1 if Xi > 0%

Note: Extrapolation of Equation 2 & 3 to overloading beyond 50% is unreliable (not recommended).

Results of statistical comparison between court imposed overload charges and rationalized ones showed that nearly a quarter (24.68%) of overloaded trucks have paid on average ETB 1098.03 (-55.23%) below rationalized ones. While the remaining (75.32%) overloaded vehicles have paid on average ETB 280.82 (+186.08%) above rationalized one. In terms of gross revenue collected from sample overloaded trucks, the actual collected revenue is 8.53 % less than what is expected in terms of rationalized fines.

Conclusion

With optimum maintenance interventions, the economic impact of overloading was higher for higher overload cases. Statistical comparison between rationalized and court imposed overload fines showed a significant variation in terms individual fines. The gross revenue collected from sample court imposed overload fines was also less than what could have been collected in terms of rationalized fines.

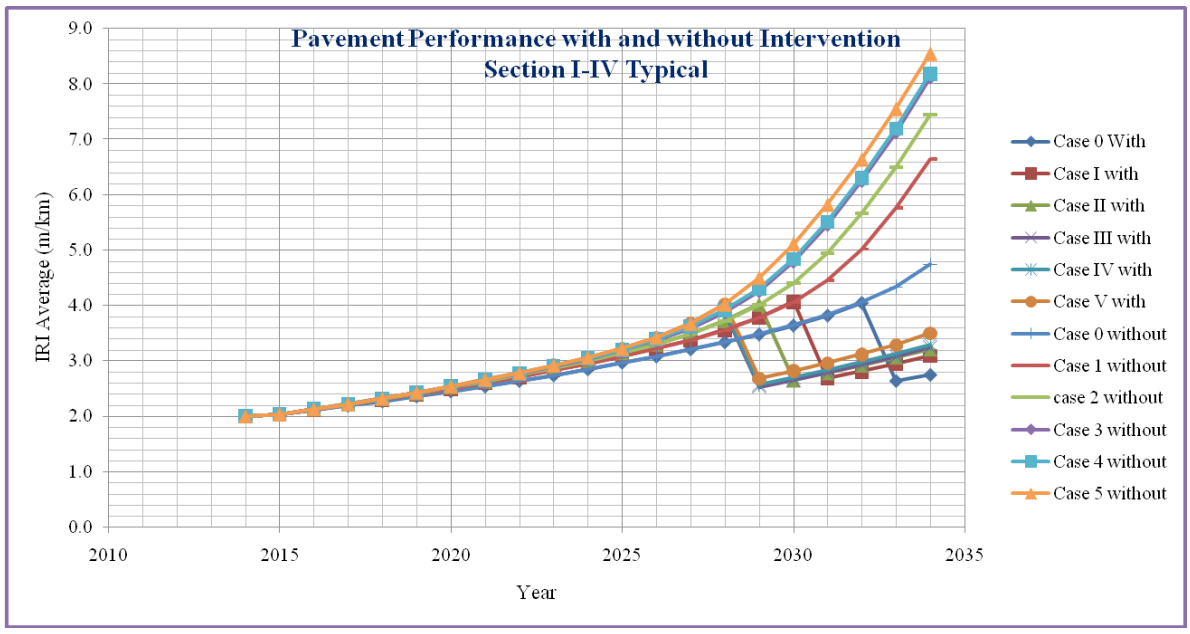
This study is expected to lay a foundation for scientific approach of determining overload charges in Ethiopia and beyond. The procedure could also be used in special permits considering economic impact, including bridge damage cost and any other service

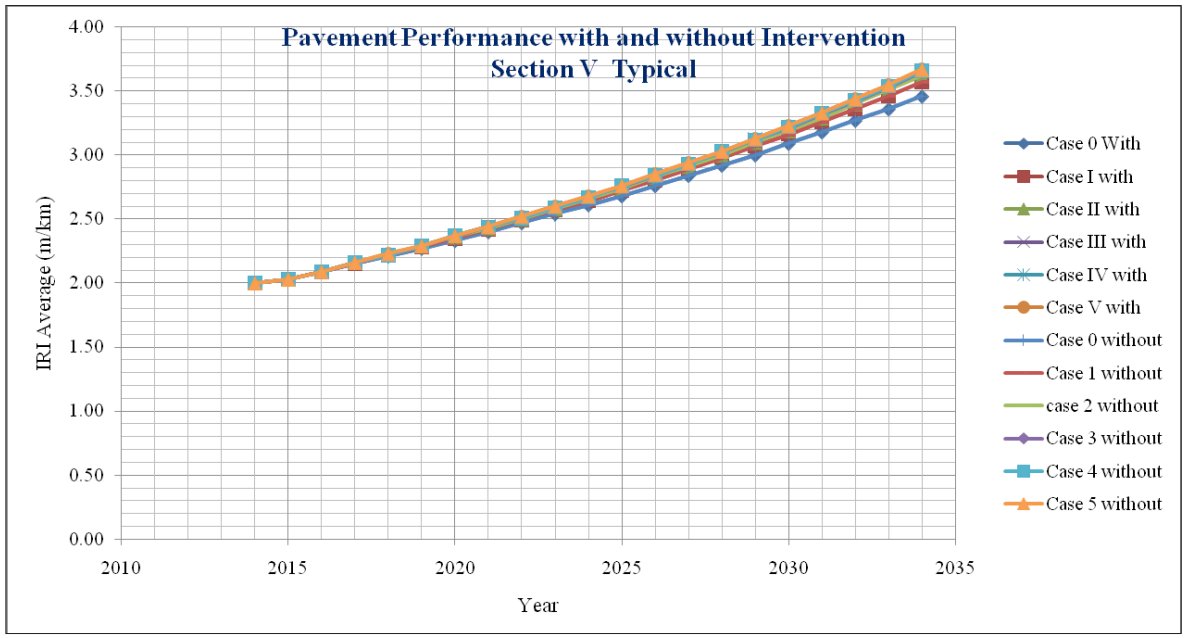
charges. However overload fine structures must updated regularly considering up to date data and other overload impacts which were not considered in this study.

Acknowledgment

I would like to express my deepest gratitude to my advisor, Dr. Alemayehu Ambo, for providing insight, expertise and direction that greatly assisted my study. I also place on record, my sense of gratitude to one and all, who directly or indirectly, have lent their hand during the study. My special thanks goes to W/ro. Konjit Alemu, Monitoring and Evaluation Team Leader of ERA, Mr. Tesfaye Hageru, Manager of Modjo Weighing Station, for their open discussion on important ideas and open data sharing and Dr. Bikila Teklu his positive feedbacks and assistance. I would like also to thank Engineer Afework and Ethiopian Association of Civil Engineers (EACE) for editing and publishing my study.

Appendix A Typical Pavement performance curves under optimum maintenance intervention for different overload cases & road sections of study Addis Ababa - Adama Road Link.





EACE Journal Vol. 8 No. 6, October 2015

Appendix B: Selected optimum maintenance intervention and NPV for each overload cases & each road sections of study Addis Ababa - Adama Road Link

Road Section I [Addis Ababa-Debre Zeit]; Direction Down Hill						
Case	Case 0	Case 1	Case 2	Case 3	Case 4	Case 5
Intervention	A3 in 2032	A3 in 2030	A3+ Preparatory Patching in 2029	A3 + Preparatory Patching in 2028	A3 + Preparatory Patching in 2028	A3 + Preparatory Patching in 2028, Crack sealing in 2027
NPV (Millions)	10.51	49.00	72.04	95.49	96.93	106.65

Road Section I [Addis Ababa-Debre Zeit]; Direction Up Hill						
Intervention	A3 in 2032	A3+ Preparatory Patching in 2030	A3+ Preparatory Patching in 2029	A3 + Preparatory Patching in 2028	A3 + Preparatory Patching in 2028	A3 + Preparatory Patching in 2028
NPV (Millions)	12.56	51.84	73.62	97.54	98.56	99.62
Note; A3; 30mm Asphalt Concrete Overlay at 4m/km (IRI)			Non Pavement Routine Maintenance is required every year			

Road Section II [Debre Zeit - Modjo]; Direction Down Hill						
Overload	Case 0	Case 1	Case 2	Case 3	Case 4	Case 5
Intervention	A3 in 2031	A3 + Preparatory Patching in 2029 , Crack Sealing in 2028	A3+ Preparatory Patching in 2028 , Crack Sealing in 2027	A3 + Preparatory Patching in 2027, Crack Sealing in 2026	B3+ Preparatory Patching in 2027. Crack Sealing in 2026	B3 + Preparatory Patching in 2027, Crack Sealing in 2026
NPV (Millions)	45.12	172.17	242.6	314.54	336.2	337.91

Road Section II [Debre Zeit - Modjo]; Direction Up Hill						
Intervention	A3 + Preparatory Patching in 2030	A3 +Preparatory Patching in 2027, Crack sealing in 2026	B3 + Preparatory Patching in 2026, Crack Sealing in 2025	C3 + Preparatory Patching in 2025, Crack Sealing in 2024	C3 + Preparatory Patching in 2025, Crack Sealing in 2025	C3 + Preparatory Patching in 2025, Crack Sealing in 2024
NPV (Millions)	165.52	570.45	736.38	886.35	897.38	910.28
Note; A3; 30mm Asphalt Concrete Overlay at 4m/km (IRI)				B3; 40mm Asphalt Concrete Overlay at 4m/km (IRI)		
and C3; 50mm Asphalt Concrete Overlay at 4m/km (IRI)				Non Pavement Routine Maintenance is required every year		

Road Section III [Modjo - Adama West]; Direction Down Hill						
Case	Case 0	Case 1	Case 2	Case 3	Case 4	Case 5
Intervention	A3 in 2033	A3 in 2030	A3+ Preparatory Patching in 2029	A3 + Preparatory Patching in 2028	A3 + Preparatory Patching in 2028	A3 + Preparatory Patching in 2028
NPV (Millions)	0.14	13.97	24.46	32.93	33.51	33.71
Road Section III [Modjo - Adama West]; Direction Up Hill						
Intervention	A3 in 2033	A3 in 2030	A3 + Preparatory Patching in 2029	A3 + Preparatory Patching in 2028	A3 + Preparatory Patching in 2028	A3+Preparatory Patching in 2028
NPV (Millions)	0.83	17.64	29.19	38.12	38.96	39.13
Note; A3; 30mm Asphalt Concrete Overlay at 4m/km (IRI)				Non Pavement Routine Maintenance is required every year		

Road Section IV [Adama West - Asela Road]; Direction Down Hill						
Overload Case	Case 0	Case 1	Case 2	Case 3	Case 4	Case 5
Intervention	No Intervention	A3 in 2032	A3 + Preparatory Patching in 2031	A3 + Preparatory Patching in 2030	A3 + Preparatory Patching in 2030	A3 + Preparatory Patching in 2030, Crack Sealing in 2029
NPV (Millions)	0	5.69	14.96	24.17	24.76	29.46
Road Section IV [Adama West - Asela Road]; Direction Up Hill						
Intervention	No Intervention	A3 in 2033	A3 in 2031	A3 + Preparatory Patching in 2031	A3 + Preparatory Patching in 2030	A3+Preparatory Patching in 2030
NPV (Millions)	0	5.69	14.96	24.17	24.76	29.46
Note; A3; 30mm Asphalt Concrete Overlay at 4m/km (IRI)				Non Pavement Routine Maintenance is required every year		

Road Section V [Asela Road-Adama]; Direction Down Hill						
Case	Case 0	Case 1	Case 2	Case 3	Case 4	Case 5
Intervention	No Intervention	No Intervention	No Intervention	No Intervention	No Intervention	No Intervention
Road Section V [Asela Road-Adama]; Direction Up Hill						
Intervention	No Intervention	No Intervention	No Intervention	No Intervention	No Intervention	No Intervention
Note; No Intervention; No need of intervention within 20 years as the pavement wouldn't reach 4m/km (IRI)						

Reference

1. Africon Ltd (2011) *EAC Transport Strategy and Regional Road Sector Development Program*, part III, 03_2011-11-15.
2. Austret.P and Broussee, J.L (1992), *Computer aided method of Estimating road network maintenance needs (VIZR),* Paris, France
3. CSIR, Roads and Transport Technology, Department of Transport Directorate (1997), *The damaging effects of overloaded heavy vehicles on roads*, ISBN: 1-86844-285-3, Pretoria -Republic of South Africa.
4. EGIS International Consultant (2010), *Strategic Review of Ethiopian Road Sector Development Assessment of Road Development and Maintenance Needs,* ERA, Ethiopia
5. Fiker Alebachew (2005), *Pavement distress on Addis Ababa city arterial roads, causes and maintenance options*, MSc thesis, Addis Ababa Institute Technology of Technology, Addis Ababa
6. Greg Morosiuk, mike J Riley, J B Odoki (2004), *HDM-4 volume six Structural Design of Pavements, Modeling road deterioration and work effects,* www.worldbank.org
7. James G. Strathman (2001), *Economics of Overloading and the Effect of Weight Enforcement*, Research Note, center for urban studies college of urban and public affairs Portland state University, Portland
8. Khan M.U (2011), A*nalysis to set long term strategy for Bangladesh*, Journal of Civil Engineering (IEB), Institution of Engineers, Bangladesh
9. Michael lan Pinard (2010), *Overload control Practice in Eastern and Sothern Africa,* Main Lessons learned, SSATP Working Paper Nº.91, www.worldbank.org/afr/ssatp.
10. Misbah Uddin Khan and Jennaro B.Odoki (2005), *Development optimal maintenance standards for Bangladesh, School of Civil Engineering*, MS Phil Thesis, University of Birmingham, UK
11. Nagawoo Abdissa (2008), *Commercialization of roads in Ethiopia, a case study on Addis Ababa- Adama road*, MSc thesis. Addis Ababa Institute of Technology, Addis Ababa Ethiopia
13. Yang H. Huang (2004), *Pavement Analysis and Design*, 2nd edition, University of Kentucky, United States of America, Pearson Prentice Hall.
14. Ying Chuen Chan (2008), *Truck Overloading Study in developing countries and strategies to minimize its impact*, Masters in Engineering thesis, Queensland University of Technology