Appendices

Appendix A Regional Economic Benefits from Harmonization of Axle Load Regulations in the East African Community

This appendix quantifies the economic benefits due to regional harmonization of axle load regulations in the East African Community (EAC), specifically focusing on transport fixed cost savings accruing from decreases in weighbridge crossing times.

The regional truck transport cost for a 40-foot freight container vehicle (at an average of 26 tonnes of freight per container) can be summarized as follows:

Total Transport Costs = (Variable Cost x *Travel Km*) + (Fixed Cost x *Travel Days*)

Variable costs include costs for fuel, lubricants, tyres, and other incidentals. Fixed costs consist of salary and equipment costs related to the operation of the vehicle. Table A-1 summarizes the variable costs (in USD/km) and fixed costs (USD/day) for the various corridors in the four regions of Sub-Saharan Africa.

Table A-1: Truck[1] Operating Costs along Four African Corridors (2008)

Corridor	Route Gateway / Destination	Variable Cost (USD/km)	Fixed Cost (USD/Day)
West Africa (Burkina Faso and Ghana)	Tema/Accra – Ouagandougou (Burkina Faso)	1.51	30
	Tema/Accra – Bamako (Mali)	1.67	36
Central Africa (Cameroon and Chad)	Douala – N'Djamena (Chad)	1.31	49
	Doula – Bangui (Central African Republic)	1.22	73
	Ngaoundere – N'Djamena (Chad)	1.83	22
	Ngaoundere – Moundou (Chad)	2.49	21
East Africa (Uganda and Kenya)	Mombasa – Kampala (Uganda)	0.98	61
	Kampala – Kigali (Rwanda)	1.47	40
Southern Africa (Zambia)	Lusaka – Johannesburg (South Africa)	1.54	55
	Lusaka – Dar es Salaam (Tanzania)	1.34	71

Source: Africa Infrastructure Country Diagnostic, *Transport Prices and Costs in Africa: A Review of the Main International Corridors*, 2008.

The fixed and variable costs for East Africa Region (with respect to the Northern Corridor originating from Mombasa Port) can be attributed to the transport kilometers and transport days summarized in Table A-2.

[1] It is assumed that the term "heavy truck" in the AICD report and the 40-foot container (26 tonnes) vehicle are the same.

Table A-2: Freight Transport Time through the Northern Corridor (Mombasa Port–Kampala/Kigali) by a 40-foot Container Vehicle (2008)

Freight Destination (Originating from Mombasa Port)	Kampala	Kigali
Distance (km)	1,119	1,683
Number of Borders	1	2
Port Dwell Time (days)	14	12
Land Transport Time (days)[2]	5	7
Driving Time (hours)	41	62
Border Crossing Time (hours)	8	10
Weighbridge Crossing Time (hours)	11	12
Clearance Time at ICD (days)	4	4
Total Transport Time (days)	23	23

Source: JICA and PADECO, *The Research on the Cross-Border Transport Infrastructure Phase 3*. Based on information from the Kenya Ports Authority (KPA), 2008; *Annual Review and Bulletin of Statistics*, 2007; East African Trade and Transport Facilitation Project (EATTFP), 2008; *Report on Inspection Tour on Northern Corridor*; and KPA, *A Study of the Central Corridor*, 2008

Combining the information from Tables A-1 and A-2, the average fixed and variable transport cost along the entire Northern Corridor is summarized in Table A-3.

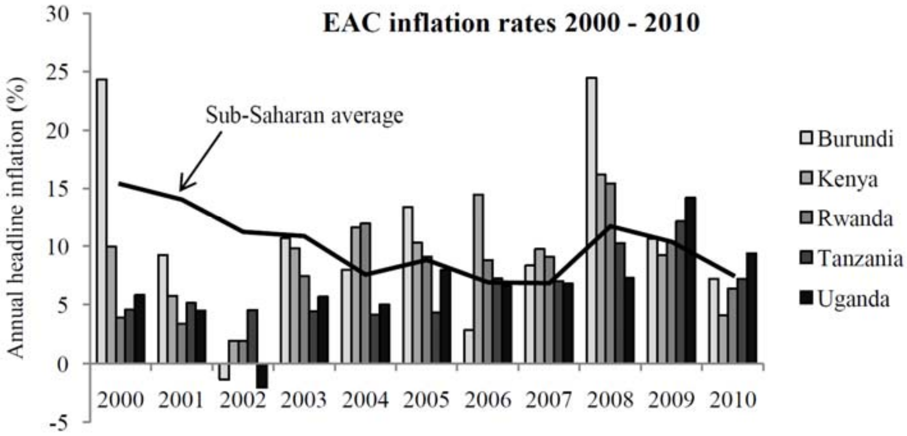
Table A-3: Fixed and Variable Cost for a 40-foot Container Vehicle (2008)

Variable Costs	**Mombasa–Kampala**	**Kampala–Kigali**
Distance (km)	1,119 km	562 km*
Variable Cost (USD/km)	USD 0.98/km	USD 1.47/km
Average Variable Cost Along the Entire Northern Corridor	USD 1.14/km **	
Fixed Costs (Land Tranpsort)* **	**Mombasa–Kampala**	**Kampala–Kigali**
Driving Time (hours)	41	21
Border Crossing Time (hours)	8	2
Weighbridge Crossing Time (hours)	11	1
Fixed Cost (USD/day)	61	41
Fixed Cost (USD/hour)****	5.1	3.4
Average Fixed Cost Along the Entire Northern Corridor (USD/hour)	USD 4.61/hour *****	

Note: * Calculated as 1,683 km – 1,119 km = 562 km;
** Calculated as [(1,119 km x USD 0.98/km) + (562 km x USD 1.47/km)] / 1,683 km;
*** Port/ICD Dwell Time omitted
****Truck Operation is assumed to be 12 hours/day;
***** Calculated as [(Total Land Transport 60hrs x USD 5.1/hr) + (24 hrs x USD 3.4/hr)] / 84 hrs
Source: JICA Study Team

As Table A-3 is based on information derived from publications and traffic surveys from 2008, the weighted average inflation rate for the five EAC countries shown in Figure A-1 was applied to establish the current fixed and variable costs.

[2] The total land transport time is defined as the sum of driving time, border crossing time, and the time spent at weighbridge stations. An hour-to-day conversion was undertaken, assuming truck operations of 12 hours a day.



Source: Ministry of Finance, Planning and Economic Development, Republic of Uganda

Figure A-1: EAC Weighted Average Inflation Rate

An average inflation rate from 2008-2010 was applied to the 2008 costs to derive the fixed and variable costs for 2011 as summarized in Table A-4.

Table A-4: Fixed and Variable Cost for a 40-foot Container Vehicle (2011)

Costs	
Average Variable Cost along the Northern Corridor (USD/km)	1.5
Average Fixed Cost along the Northern Corridor (USD/hour)	6.0

Source: JICA Study Team

As Table A-3 suggests, regional harmonization of axle load regulations in the East African Community would directly lower the fixed costs of truck transport by specifically decreasing the land transport time attributed to weighbridge crossing time. As summarized in Table A-5, for the case of the route from Mombasa to Kampala, the fixed cost attributed to weighbridge crossing time is USD 66 per trip, and constitutes approximately 18.6% of total fixed costs for land transport (omitting Port/ICD dwell time). By harmonization of axle load regulation in the EAC, this cost of weighbridge crossing could be substantially thereby generating economic benefits due to lower regional transport costs, which will facilitate regional trade.

Table A-5: Fixed Land Transport Costs for a 40-foot Container Vehicle

Fixed Costs (Land Tranpsort)	Mombasa–Kampala USD (hrs)	Kampala–Kigali USD (hrs)
Driving Time	240 (41)	126 (21)
Border Crossing Time	48 (8)	12 (2)
Weighbridge Crossing Time	66 (11)	6 (1)
Average Fixed Cost along the Northern Corridor (USD/hour)	6.0[3]	

Source: JICA Study Team

[3] This value is also in the same range as the fixed costs derived from the JICA Cross-Border Transport Infrastructure Phase 3 Report (2008), in which the total fixed costs for forward land transport of a 40-foot container from Mombasa Port to Kamala is 400 USD for a 60 hours of transport time, which roughly equates to USD 6.7/hour/40-foot container.

Tables A-6 and A-7 show that the total annual volume of goods transported by road transport along the Northern and Central Corridors are 20.3 million tonnes and 7.1 million tonnes, respectively. These values roughly equate to 780,770 trips [assuming that one trip equals one 40-foot (26-tonne) container traveling from Mombasa to Kigali[4]] along the Northern Corridor road per year, and 273,080 trips along the Central Corridor [assuming that one trip equals one 40-foot (26 tonne) container travelling from Dar es Salaam to Kampala]. Within the EAC, weighbridges have been used mainly along the Northern and Central Corridors, thus economic benefits from harmonization of axle load regulations is speculated to affect traffic along the Northern and Central Corridors specifically.

Table A-6: Northern Corridor Road Traffic (2009)

Type of Traffic	**Traffic Volume (000 tonnes)**
Transit	5,509
Regional	2,974
Domestic	11,817
Total	**20,300**

Source: USAID, *Corridor Diagnostic Study of the Northern and Central Corridors of East Africa*, by Nathan Associates Inc.

Table A-7: Central Corridor Road Traffic (2009)

Type of Traffic	**Traffic Volume (000 tonnes)**
Transit	357
Regional	658
Domestic	5,617
Total	**6,632**

Source: USAID, *Corridor Diagnostic Study of the Northern and Central Corridors of East Africa*, by Nathan Associates Inc.

Assuming that the Central Corridor will experience the same USD/time rate of savings as the Northern Corridor, the cost savings from weighbridge time savings would be as shown in Table A-8. **A 10-minute decrease in weighbridge crossing time amounts to USD 1 cost saving per trip with an annual economic benefit calculated to USD 1 million within the EAC.[5] Furthermore, a one-hour reduction in weighbridge crossing time amounts to USD 6 cost saving per trip with an annual economic benefit calculated to be USD 6.2 million within the EAC.**

[4] JICA and PADECO, *The Research on the Cross-Border Transport Infrastructure Phase 3.* Based on information from the Kenya Ports Authority (KPA), 2008; *Annual Review and Bulletin of Statistics*, 2007; East African Trade and Transport Facilitation Project (EATTFP), 2008; *Report on Inspection Tour on Northern Corridor*; and KPA, *A Study of the Central Corridor*, 2008.

[5] As explained earlier, economic benefits from reductions in weighbridge crossing time in the EAC will mainly affect traffic along the Northern and Central Corridors.

Table A-8: Economic Benefits from Savings from Weighbridge Crossing Time

Corridor	10 Minute Decrease	1 Hour Decrease
Northern Corridor	780,770	4,684,620
Central Corridor	273,080	1,638,460
EAC Total	**1,053,850**	**6,323,080**

Note: This calculation does not include benefits from time savings in the empty backhaul truck operation.
Source: JICA Study Team

Table A-9 shows that small physical improvements (e.g., computerization, increased versatile portable weighing machines, an increased number of lanes) at weighbridges result in time savings ranging from 10 minutes to a few hours. Axle load harmonization within the EAC (and in the future with SADC and COMESA) would most likely contribute to more than a 10-minute decrease in weighbridge crossing time. This finding suggests that economic benefits resulting from transport savings from decreased weighbridge crossing times will be of the order of a few million USD annually, furthermore leading to greater implications in terms of regional trade facilitation.

Table A-9: Improvements in EAC Weighbridge Crossing Times

Weighbridges	Baseline	Dec 07	May 08	Jul 09	Improvements
Mariakani	6 hrs	10 hrs	8 hrs	5 hrs	Additional lane, computerization
Athi River (Mlolongo)	–	8 hrs	8 hrs	3 hrs	Increased number of weighing machines, computerization
Maai Mahiu	–	2 hrs	1 hrs	40 min	Only escorted trucks pass through March
Gilgil	–	3 hrs	1 hrs	1.5 hrs	Only escorted trucks pass through weighbridge
Eldoret	–	50 min	20 min	30 min	Versatile portable weighing machine as been introduces
Webuye					
Amagoro (Malaba)	–	50 min	20 min	30 min	Only verification of documents take place
Busia	–	–	–	–	–
Kisumu		–	–	–	–
Busitema	–	30 min	20 min	20 min	Versatile portable weighing machine is easing operations
Masaka (Lukaya)	–	–	–	–	–
Mbarara	–	20 min	10 min	10 min	360 degree turn to weighbridge may increase process time
Mubende	–	–	–	–	–

Source: East Africa Trade and Transport Facilitation Project (EATTFP), *Report on Inspection Tour of Northern Corridor From Mombasa – Malaba – Kigali by the Seamless Transport Committee 4–12 July 2008.*

Appendix B Regional Saving in Maintenance Cost from Eliminating Overloading

In Section 4.4 the methodology adopted in this study for estimating maintenance cost with or without overloading was described. It was based on the distribution of axle loads actually measured at a limited number of points in the road network are limited. Although overloading is said to be rampant in the region, and while actual records do show some overloading, the majority of loads are under the limit. Generally, there are fewer violations on roads with high traffic volumes and more violations on roads with low traffic volumes. Two traffic types were taken as axle load distribution patterns: Type T with high traffic volumes and low violation rates and Type UB with low traffic volumes and high violation rates. Table 4-25 shows the results of HDM-4 model runs. For Type T the ratio of maintenance cost with and without overloading turned out to be 1.21, i.e., maintenance cost for the without case was 82.6% of the case with overloading. Similarly, for Type UB the without overloading case resulted in a maintenance cost 89.3% of that in the with-overloading case. The third type, a medium-traffic type, was defined as the average of the two, which gives a maintenance cost without overloading of 86.2% of the case with overloading. As explained in Section 4.4, the case of without overloading was defined assuming that all cargo on the overloaded vehicles would be transferred to vehicles at the maximum axle load limit, i.e., “ideal” loading. The number of vehicles thus would be larger than in the overloading case since the total amount of cargo must be divided into smaller individual payloads.

Road networks of each Partner State were divided into three types: high, medium, and low traffic carrying sections. Table B-1 shows the distribution of road lengths that fall into the three types by country. Applying the above-mentioned reduction factors by traffic type to the distribution of traffic type for each country, overall cost reduction factors for each country were obtained as shown in the table.

Table B-1: Average Maintenance Cost Reduction Factor by Country Due to No Overloading

Country	High Traffic %	Medium Traffic %	Low Traffic %	Average Cost Reduction Factor
Burundi	25	38	67	0.865
Kenya	6	31	63	0.879
Rwanda	31	31	38	0.862
Tanzania	1	9	90	0.889
Uganda	0	10	90	0.890

Source: JICA Study Team

The HDM-4 model was run for each country with overloading to yield the maintenance cost for each country with existing, i.e., overloading conditions. The model was run for 20 years starting from the existing conditions and assuming 3% annual traffic growth. The model determines necessary maintenance activities to achieve a given road condition level (in this case an IRI of 4.0) and calculates maintenance cost. Maintenance cost under the ideal condition, i.e., without overloading, can be obtained by applying the cost reduction factor shown above to the maintenance cost for each country. Table B-2 shows the results.

Table B-2: Maintenance Cost by Country

(USD million)

Country	Estimated Maintenance Cost for 2011–2030	Estimated Maintenance Cost without Overloading (Ideal Loading)
Burundi	20.38	17.62
Kenya	1,511.33	1,328.66
Rwanda	100.68	86.38
Tanzania	1,268.54	1,128.23
Uganda	1,306.23	1,162.20
Total	4,207.15	3,723.55

Source: JICA Team

In 20 years the elimination of overloading would save USD 484 million for the EAC region, or USD 24 million per year.

As Table A-3 was based on information derived from publications and traffic surveys from 2008, the weighted average inflation rate for the five EAC countries shown in Figure A-1 was applied to establish the current fixed and variable costs.

Appendix C EAC Trunk Road Network Data

C.1 Traffic Volume Data

Table C-1: Tanzania Traffic Data

Road	Link	Length	Traffic Volume			
			Light	Medium	Heavy	Total
T1	1	1	26280	6251	9	32540
T1	10	2	36943	3579	0	40522
T1	15	2	29693	14741	29	44463
T1	20	1	41215	5750	221	47186
T1	30	1	17841	6270	818	24929
T1	35	1	28517	4962	235	33714
T1	40	1	28930	5816	270	35016
T1	45	2	17841	6271	823	24935
T1	47	5	20116	5799	755	26670
T1	50	3	11755	4187	615	16557
T1	55	3	10659	4497	555	15711
T1	70	2	7370	4039	678	12087
T1	87	1	3988	2513	1023	7524
T1	90	2	3633	1950	1230	6813
T1	92	1	4198	3189	1422	8809
T1	96	1	1218	953	368	2539
T1	100	15	1251	1646	1053	3950
T1	105	21	1964	1098	1005	4067
T1	110	21	1888	1179	761	3828
T1	112	7	1718	1339	827	3884
T3	605	43	1783	775	468	3026
T3	607	20	1013	459	395	1867
T3	610	3	318	243	125	686
T3	612	36	281	342	243	866
T3	615	33	300	198	111	609
	Total	228				
		Weighted Average	3248.4	1297.7	511.6	5057.7
T3	620	14	272	316	181	769
T3	625	10	283	318	185	786
T3	630	14	272	320	192	784
T3	635	18	349	352	214	915
T3	640	17	511	300	217	1028
T3	641	1	431	258	170	859
T3	645	18	368	342	185	895
T3	650	12	505	575	231	1311
T3	653	0	965	311	260	1536
T3	654	1	6462	1309	381	8152

T3	655	26	240	218	181	639
T3	660	19	156	272	222	650
T3	665	22	194	179	364	737
T3	670	10	181	266	211	658
T3	675	0	69	77	164	310
T3	680	0	162	268	227	657
T3	685	27	122	179	385	686
T3	690	38	246	216	269	731
T3	695	2	67	100	145	312
T3	698	27	289	278	251	818
T3	700	33	179	233	222	634
T3	705	7	169	230	229	628
T3	715	19	1614	1272	2943	5829
T3	720	17	117	134	116	367
T3	725	26	57	89	184	330
T3	730	46	128	128	140	396
T3	735	9	280	201	349	830
T3	740	1	219	166	314	699
T3	745	21	216	238	299	753
T3	760	31	298	250	267	815
	Total	486				
Weighted Average			297.3	277.6	337.5	912.4
T3	765	21	330	259	278	867
T3	770	21	445	391	343	1179
T3	775	7	227	175	188	590
T3	780	79	310	234	180	724
T3	790	47	709	437	311	1457
T3	792	8	230	117	193	540
T3	795	18	185	186	186	557
T3	800	16	300	159	195	654
	Total	217				
Weighted Average			394.7	279.9	236.0	910.5
T3	805	32	139	146	159	444
T3	810	38	192	75	74	341
T3	815	5	373	101	122	596
T3	820	19	140	83	144	367
	Total	94				
Weighted Average			173.1	102.2	119.6	394.9

Source: Data from Tanzania

Table C-2: Kenya Traffic Data

Region	Province	District	RoadID	Chainage	Distance	Traffic Volume			
						Light	Medium	Heavy	Total
3	Western	Teso	A104	2.20	6.12	971	364	219	5134
3	Western	Nakuru	A104	10.04	7.33	8879	5646	871	51626
3	Western	Bungoma	A104	16.86	3.48	786	607	330	5764
3	Western	Bungoma	A104	16.99	8.21	904	576	340	6086
3	Western	Bungoma	A104	33.28	8.24	1298	879	641	9595
3	Western	Bungoma	A104	33.48	0.90	735	233	99	3463
3	Western	Bungoma	A104	35.08	1.02	2123	591	299	9783
3	Western	Bungoma	A104	35.51	2.99	2005	574	300	9366
3	Western	Bungoma	A104	41.05	2.89	1417	460	168	6609
3	Western	Bungoma	A104	41.30	8.37	1450	398	107	6273
3	Western	Bungoma	A104	57.80	8.33	2092	744	227	9820
3	Western	Bungoma	A104	57.96	0.63	1999	853	326	10294
3	Western	Bungoma	A104	59.05	3.29	1483	337	47	5941
3	Western	Bungoma	A104	64.53	2.97	1841	589	286	8811
3	Western	Lugari	A104	64.99	1.25	1044	509	286	6069
3	Western	Lugari	A104	67.02	1.16	1785	577	156	8062
3	Western	Lugari	A104	67.30	2.09	1963	738	256	9591
3	Western	Lugari	A104	71.20	2.07	885	164	77	3621
3	Western	Lugari	A104	71.44	7.30	1550	499	173	7123
3	Western	Lugari	A104	85.80	7.28	1041	555	315	6340
3	Western	Lugari	A104	85.99	5.23	1770	882	509	10466
				Total Length	91.13				
					Weighted Average	2051.2	975.8	343.1	3370.1
2	Rift Valley	Uasin Gishu	A104	96.26	5.92	1633	570	299	8186
2	Rift Valley	Uasin Gishu	A104	97.84	5.43	2678	841	420	12799
2	Rift Valley	Uasin Gishu	A104	107.11	4.93	3115	1706	487	17087
2	Rift Valley	Uasin Gishu	A104	107.69	3.27	2117	1256	395	12184
2	Rift Valley	Uasin Gishu	A104	113.64	3.15	2163	813	358	10844
2	Rift Valley	Uasin Gishu	A104	114.00	5.76	1481	651	342	8128
2	Rift Valley	Uasin Gishu	A104	125.16	6.99	6971	1435	568	28787
2	Rift Valley	Uasin Gishu	A104	127.97	1.65	1333	742	461	8484
2	Rift Valley	Uasin Gishu	A104	128.47	2.64	5447	1266	684	24022
2	Rift Valley	Uasin Gishu	A104	133.25	2.81	3282	817	385	14523
2	Rift Valley	Uasin Gishu	A104	134.09	5.72	3058	801	390	13798
2	Rift Valley	Uasin Gishu	A104	144.70	5.69	5873	1537	610	25806
2	Rift Valley	Uasin Gishu	A104	145.48	2.50	3997	1292	494	18658
2	Rift Valley	Uasin Gishu	A104	149.70	2.42	1853	738	293	9348
2	Rift Valley	Uasin Gishu	A104	150.32	10.15	1648	537	298	8132
2	Rift Valley	Uasin Gishu	A104	170.01	10.08	1672	882	358	9513
2	Rift Valley	Uasin Gishu	A104	170.47	3.76	1912	813	410	10279
2	Rift Valley	Uasin Gishu	A104	177.52	3.84	1349	581	288	7266
2	Rift Valley	Uasin Gishu	A104	178.15	5.88	1081	815	433	7797
2	Rift Valley	Uasin Gishu	A104	189.28	5.86	1120	806	302	7277
2	Rift Valley	Uasin Gishu	A104	189.87	2.58	1145	522	232	6208
2	Rift Valley	Koibatek	A104	194.45	4.02	2578	1531	485	14800
2	Rift Valley	Koibatek	A104	197.91	10.73	1622	1268	502	11114
2	Rift Valley	Koibatek	A104	215.91	9.92	2106	630	286	9822
2	Rift Valley	Nakuru	A104	217.75	7.68	1381	659	287	7627
2	Rift Valley	Nakuru	A104	231.27	6.99	1414	692	260	7703
2	Rift Valley	Nakuru	A104	231.72	0.85	3383	1545	655	18235
2	Rift Valley	Nakuru	A104	232.96	0.81	3736	2130	789	21787
2	Rift Valley	Nakuru	A104	233.35	2.88	3733	2132	789	21782
2	Rift Valley	Nakuru	A104	238.72	3.24	6084	1822	619	27504
2	Rift Valley	Nakuru	A104	239.83	0.76	3179	1307	483	16236
2	Rift Valley	Nakuru	A104	240.25	7.34	3502	1378	501	17526
2	Rift Valley	Nakuru	A104	254.51	7.45	2502	1623	555	15277
2	Rift Valley	Nakuru	A104	255.15	5.74	2198	1522	553	13987
2	Rift Valley	Nakuru	A104	265.99	5.71	6725	2095	718	30665

2	Rift Valley	Nakuru	A104	266.57	5.34	5909	1928	579	26999
2	Rift Valley	Nakuru	A104	276.67	5.40	6003	2083	833	28908
2	Rift Valley	Nakuru	A104	277.37	4.00	7762	2441	870	35661
2	Rift Valley	Nakuru	A104	284.67	3.88	34228	3647	853	122397
2	Rift Valley	Nakuru	A104	285.14	2.48	22853	3848	890	87469
2	Rift Valley	Nakuru	A104	289.62	2.55	18181	3548	977	72238
2	Rift Valley	Nakuru	A104	290.23	1.22	2053	940	442	11209
2	Rift Valley	Nakuru	A104	292.06	1.16	13509	3250	1063	57009
2	Rift Valley	Nakuru	A104	292.55	12.36	9580	2116	760	39929
2	Rift Valley	Nakuru	A104	316.78	12.38	4259	2288	666	23274
2	Rift Valley	Nakuru	A104	317.31	1.80	6994	2332	667	32031
2	Rift Valley	Nakuru	A104	320.38	1.77	3342	1342	492	16882
2	Rift Valley	Nakuru	A104	320.84	8.75	3422	1360	497	17205
2	Rift Valley	Nakuru	A104	337.88	8.68	5724	3063	950	31348
2	Rift Valley	Nakuru	A104	338.21	2.35	5758	3055	890	31161
2	Rift Valley	Nakuru	A104	342.57	4.78	8378	3076	871	39441
2	Rift Valley	Nakuru	A104	347.77	2.93	5196	1067	60	19879
2	Rift Valley	Nakuru	A104	348.43	2.47	10004	3564	948	46358
2	Rift Valley	Nakuru	A104	352.71	2.57	394	226	3	1907
2	Rift Valley	Nakuru	A104	353.57	9.22	778	285	6	3328
2	Rift Valley	Nakuru	A104	371.14	9.05	5812	1336	58	22573
1	Central	Nyandarua	A104	371.67	1.69	14228	2403	60	52378
1	Central	Nyandarua	A104	374.52	1.54	3585	656	53	13510
1	Central	Nyandarua	A104	374.74	3.15	3567	662	61	13508
1	Central	Kiambu	A104	380.81	3.58	3602	649	46	13509
1	Central	Kiambu	A104	381.90	4.39	3534	676	75	13511
1	Central	Kiambu	A104	389.59	4.07	3669	622	17	13506
1	Central	Kiambu	A104	390.03	3.85	3400	730	133	13517
1	Central	Kiambu	A104	397.30	4.06	3585	933	246	15186
1	Central	Kiambu	A104	398.16	3.22	3216	526	20	11845
1	Central	Kiambu	A104	403.74	3.03	4328	487	15	15204
1	Central	Kiambu	A104	404.21	1.19	9606	2080	794	39978
1	Central	Kiambu	A104	406.12	1.48	3400	730	133	13517
1	Central	Kiambu	A104	407.17	6.05	3308	628	77	12682
1	Central	Kiambu	A104	418.22	5.56	7868	1936	798	34108
1	Central	Kiambu	A104	418.29	2.95	11525	2968	777	48587
1	Nairobi	Nairobi	A104	424.11	3.87	9570	1060	277	34615
1	Nairobi	Nairobi	A104	426.02	7.32	42375	5610	874	154093
1	Nairobi	Nairobi	A104	438.76	6.40	100361	2652	709	327965
1	Nairobi	Nairobi	A104	438.82	0.76	116234	4613	749	383386
1	Nairobi	Nairobi	A104	440.28	0.79	2889	880	195	12626
1	Nairobi	Nairobi	A104	440.40	5.10	85560	4232	741	285408
1	Nairobi	Nairobi	A104	450.49	5.46	7140	947	142	25924
1	Nairobi	Nairobi	A104	451.32	6.06	9135	2762	928	41051
				Total Length	365.83				
					Weighted Average	9027.3	1687.1	503.7	11218.1
4	Eastern	Machakos	A109	0.33	0.91	6157	3671	1162	35344
4	Coast	Mombasa	A109	1.49	6.75	12426	2933	1558	54847
4	Eastern	Machakos	A109	13.84	6.58	1458	2081	1617	18017
4	Eastern	Machakos	A109	14.65	3.77	1432	2074	1614	17902
4	Eastern	Machakos	A109	21.37	4.17	4553	2671	1042	26841
4	Eastern	Machakos	A109	22.98	7.66	2312	1799	1041	17282
4	Eastern	Machakos	A109	36.70	6.86	941	809	478	7530
4	Eastern	Machakos	A109	36.71	0.01	2512	1873	1121	18485
4	Eastern	Machakos	A109	36.72	4.75	2482	941	320	12060
4	Eastern	Machakos	A109	46.21	4.96	2676	1825	888	17798
4	Eastern	Makueni	A109	46.64	6.64	3004	2134	1056	20495
4	Eastern	Makueni	A109	59.48	6.66	4225	3307	1794	31329
4	Eastern	Makueni	A109	59.96	4.90	2685	1910	825	17911
4	Eastern	Makueni	A109	69.29	4.88	1896	2247	1657	20070
4	Eastern	Makueni	A109	69.72	7.79	1868	2129	1558	19193
4	Eastern	Makueni	A109	84.86	8.02	2320	1914	1136	18059
4	Eastern	Makueni	A109	85.76	6.70	5382	1765	1076	27018
4	Eastern	Makueni	A109	98.26	6.50	8442	1615	1015	35969
4	Eastern	Makueni	A109	98.76	0.68	2164	1593	1042	16240
4	Eastern	Makueni	A109	99.62	0.87	1510	2097	1622	18252
4	Eastern	Makueni	A109	100.50	22.69	1408	2066	1611	17791

4	Eastern	Makueni	A109	144.99	33.66	1677	1638	1120	15196
4	Eastern	Makueni	A109	167.82	11.63	1859	1537	968	14781
4	Eastern	Makueni	A109	168.26	19.58	1555	1770	1270	15881
4	Eastern	Makueni	A109	206.99	19.86	1408	1529	1032	13627
4	Eastern	Makueni	A109	207.99	23.89	1689	1687	1207	15774
4	Eastern	Makueni	A109	254.76	23.72	652	1085	713	8494
4	Eastern	Makueni	A109	255.43	5.41	1152	1624	1236	14046
4	Eastern	Makueni	A109	265.57	5.41	1339	1985	1118	15132
4	Coast	Taita Taveta	A109	266.24	8.72	1183	1579	1117	13464
4	Coast	Taita Taveta	A109	283.01	8.73	1090	1873	1351	15105
4	Coast	Taita Taveta	A109	283.69	7.63	1122	1861	1340	15121
4	Coast	Taita Taveta	A109	298.27	7.85	1016	1669	1222	13653
4	Coast	Taita Taveta	A109	299.39	1.90	1243	1737	1254	14731
4	Coast	Taita Taveta	A109	302.07	1.68	1427	1381	930	12789
4	Coast	Taita Taveta	A109	302.75	1.12	823	1200	856	9986
4	Coast	Taita Taveta	A109	304.30	1.15	1336	1498	1169	13886
4	Coast	Taita Taveta	A109	305.05	1.40	1321	470	253	6704
4	Coast	Taita Taveta	A109	307.10	1.54	1173	1220	834	11084
4	Coast	Taita Taveta	A109	308.14	12.63	851	1483	813	10660
4	Coast	Taita Taveta	A109	332.36	29.40	1671	1403	950	13741
4	Coast	Kwale	A109	366.93	18.46	1799	1424	917	14059
4	Coast	Kwale	A109	369.29	14.27	1797	1473	906	14160
4	Coast	Kwale	A109	395.48	13.97	673	737	546	6771
4	Coast	Kwale	A109	397.23	10.05	1577	1009	685	11067
4	Coast	Kwale	A109	415.57	9.82	1277	1484	1060	13185
4	Coast	Kilifi	A109	416.86	3.29	1442	1509	1060	13778
4	Coast	Kilifi	A109	422.16	3.47	1888	1455	806	13866
4	Coast	Kilifi	A109	423.80	4.61	2523	1409	921	16279
4	Coast	Kilifi	A109	431.38	3.89	3128	1014	325	14344
4	Coast	Kilifi	A109	431.59	3.07	2284	1262	693	14061
4	Coast	Kilifi	A109	437.51	3.22	1889	1655	1052	15587
4	Coast	Kilifi	A109	438.02	0.26	3508	2137	1226	22957
				Total Length	438.02				
					Weighted Average	1964.8018	1629.8736	1066.8527	4661.5281

Source: Data from Kenya

Table C-3: Uganda Traffic Data

Station	Traffic Count Station No	Road No	Traffic Volume			
			Light	Medium	Heavy	Total
Kampala	2	A001	13950	2494	913	17357
Kampala	5	A001	5634	1431	797	7862
Jinja	120	A001	3403	977	716	5096
Jinja	118	A001	2321	810	683	3814
Tororo	126	A001	910	317	456	1683
Tororo	128	A001	810	104	546	1460
		Average	4504.7	1022.2	685.2	6212.0
Mpigi	6	A002	7362	1917	202	9481
Mpigi	8	A002	1456	940	128	2524
Masaka	25	A002	1763	772	154	2689
		Average	3527	1210	161	4898
Masaka	26	A002	891	520	135	1546
Kabale	62	A002	1051	422	144	1617
		Average	971	471	140	1582

Source: Data from Uganda

Table C-4: Rwanda Traffic Data

Rd ID	Section	Type	Length (km)	Small	Medium	Large
RN1	GITIKINYONI-GITARAMA	Rural	42.343	1903	445	38
RN1	GITARAMA-NYANZA	Rural	41.587	1153	183	32
RN1	NYANZA-BUTARE	Rural	34.871	919	144	34
RN1	BUTARE-MUKONI	Urban	3.59	2865	144	10
RN1	MUKONI-AKANYARU	Rural	29.582	69	19	10
		Total Length	151.973			
		Weighted Average		1138	214	29
RN2	GATSATA- NYACYONGA	Urban	7.817	1969	948	121
RN2	NYACYONGA-GASEKE	Rural	16.179	691	211	109
RN2	GASEKE- RUKOMO	Rural	22.968	527	208	100
RN2	RUKOMO-GATUNA	Rural	28.378	272	184	107
		Total Length	75.342			
		Weighted Average		616	276	107
RN3	KIGALI-KANOMBE	Urban	9.25	3857	386	89
RN3	KANOMBE-RUGENDE	Urban	16.56	3857	386	89
RN3	RUGENDE-GISHARI	Rural	31.183	1633	378	82
RN3	GISHARI-RWAMAGANA	Urban	3.373	1343	164	1
RN3	RWAMAGANA-KAYONZA	Rural	14.026	1312	230	89
RN3	KAYONZA-KIBUNGO	Rural	31.792	685	168	90
RN3	KIBUNGO-KIBAYA	Rural	10.662	316	106	87
RN3	KIBAYA-CYUNUZI	Rural	10.022	272	54	61
RN3	CYUNUZI-RUSUMO	Rural	38.831	85	13	44
		Total Length	165.699			
		Weighted Average		1235	199	74

Source: Data from Rwanda

Table C-5: Burundi Traffic Data

Route	Location		Length (km)	Traffic Volume			
	CH.P	Station		Small	Medium	Large	Total
RN 1	**0**						
RN 1	6	Kamenge	28.5	1089	689	57	1836
RN 1	51	Bukeye	44	488	114	34	636
RN 1	94	Kayanza	42.38	235	57	19	311
RN 1	114.88						
Weighted Average				543.8	235.7	34.0	813.5

Source: Data from Burundi

C.2 Axle Load Distribution Data

Table C-6: Axle Load Distribution Data in Tanzania

Category		Number of Axles							
Low (kg)	High (kg)	Total	1 Axle	2 Axles	3 Axles	4 Axles	5 Axles	6 Axles	7 Axles
0	1000	2	0	1	1	0	0	0	0
1000	2000	0	0	0	0	0	0	0	0
2000	3000	9	1	1	1	2	2	2	0
3000	4000	30	8	6	3	5	5	3	0
4000	5000	49	12	12	9	4	4	6	2
5000	6000	147	64	38	20	7	9	9	0
6000	7000	284	149	53	45	16	11	10	0
7000	8000	556	203	43	51	91	82	79	7
8000	9000	386	17	117	100	54	45	48	5
9000	10000	190	0	144	30	5	7	3	1
10000	11000	38	0	38	0	0	0	0	0
11000	12000	2	0	0	0	1	1	0	0
12000	13000	0	0	0	0	0	0	0	0
13000	14000	0	0	0	0	0	0	0	0
14000	15000	0	0	0	0	0	0	0	0
15000	16000	0	0	0	0	0	0	0	0
16000	17000	0	0	0	0	0	0	0	0
17000	18000	1	0	1	0	0	0	0	0
18000	19000	0	0	0	0	0	0	0	0
19000	20000	0	0	0	0	0	0	0	0
20000	21000	0	0	0	0	0	0	0	0
21000	22000	0	0	0	0	0	0	0	0
22000	23000	0	0	0	0	0	0	0	0
23000	24000	0	0	0	0	0	0	0	0
24000	25000	0	0	0	0	0	0	0	0
25000	26000	0	0	0	0	0	0	0	0
Total		1694	454	454	260	185	166	160	15

Source: Axle load data from Tanzania (Sample N = 454 vehicles)

Table C-7: Axle Load Distribution Data in Kenya

Category		Number of Axles						
Low (kg)	High (kg)	Total	1 Axle	2 Axles	3 Axles	4 Axles	5 Axles	6 Axles
0	1000	829	10	505	142	87	85	0
1000	2000	749	11	388	191	52	48	59
2000	3000	1251	23	581	371	96	74	106
3000	4000	2640	203	1199	637	236	175	190
4000	5000	8788	2535	3514	1126	680	420	513
5000	6000	28147	14993	6762	2009	1939	1005	1439
6000	7000	38699	18491	4185	3685	5334	3106	3898
7000	8000	55969	4562	5948	10878	11719	12320	10542
8000	9000	73600	925	12147	14630	13032	18174	14692
9000	10000	25377	34	3598	5705	5213	4168	6659
10000	11000	4910	10	1757	1498	1288	355	2
11000	12000	1628	0	665	527	353	82	1
12000	13000	630	1	301	201	110	17	0
13000	14000	249	0	136	79	25	9	0
14000	15000	105	0	64	23	16	2	0
15000	16000	44	0	33	8	2	1	0
16000	17000	10	0	8	1	1	0	0
17000	18000	7	0	4	1	1	1	0
18000	19000	4	0	3	0	1	0	0
19000	20000	0	0	0	0	0	0	0
20000	21000	0	0	0	0	0	0	0
21000	22000	0	0	0	0	0	0	0
22000	23000	0	0	0	0	0	0	0
23000	24000	0	0	0	0	0	0	0
24000	25000	0	0	0	0	0	0	0
25000	26000	0	0	0	0	0	0	0
Total		243636	41798	41798	41712	40185	40042	38101

Source: Axle load data from Kenya (Sample N = 41,798 vehicles)

Table C-8: Axle Load Distribution Data in Uganda

Category		Number of Axles							
Low (kg)	High (kg)	Total	1 Axle	2 Axles	3 Axles	4 Axles	5 Axles	6 Axles	7 Axles
0	1000	180	2	147	13	12	3	3	0
1000	2000	152	8	54	30	34	17	9	0
2000	3000	524	77	124	77	116	61	59	10
3000	4000	1447	374	309	166	280	156	145	17
4000	5000	3483	1275	563	326	666	329	303	21
5000	6000	6968	3080	796	795	1025	718	515	39
6000	7000	9598	3634	979	1318	1316	1197	1035	119
7000	8000	11559	2216	2396	2484	1123	1678	1475	187
8000	9000	7181	624	1854	1958	715	974	1020	36
9000	10000	3160	167	1232	832	325	294	300	10
10000	11000	2065	75	1140	433	156	119	134	8
11000	12000	1199	12	675	281	79	76	68	8
12000	13000	589	6	289	176	36	31	40	11
13000	14000	501	6	234	144	39	34	36	8
14000	15000	343	1	195	91	16	13	17	10
15000	16000	272	1	145	75	25	11	9	6
16000	17000	190	0	119	38	8	11	13	1
17000	18000	154	2	107	23	12	3	5	2
18000	19000	112	1	82	14	4	5	5	1
19000	20000	64	1	42	8	10	2	1	0
20000	21000	37	0	24	11	2	0	0	0
21000	22000	13	0	6	4	3	0	0	0
22000	23000	5	0	0	4	1	0	0	0
23000	24000	7	0	2	0	4	0	1	0
24000	25000	4	0	3	0	1	0	0	0
25000	26000	0	0	0	0	0	0	0	0
Total		49807	11562	11517	9301	6008	5732	5193	494

Source: Axle load data from Uganda (Sample N = 11,525 vehicles)

Table C-9: Axle Load Distribution Data in Burundi

Category		Number of Axles							
Low (kg)	High (kg)	Total	1 Axle	2 Axles	3 Axles	4 Axles	5 Axles	6 Axles	7 Axles
0	1000	3	1	2	0	0	0	0	0
1000	2000	48	21	22	1	2	1	1	0
2000	3000	198	118	53	8	8	8	3	0
3000	4000	152	69	45	16	7	9	4	2
4000	5000	99	43	36	12	3	1	3	1
5000	6000	79	38	29	5	2	2	2	1
6000	7000	83	29	34	13	4	1	1	1
7000	8000	80	24	30	10	5	6	5	0
8000	9000	63	8	28	7	8	7	3	2
9000	10000	54	4	15	6	5	9	9	6
10000	11000	49	4	18	9	5	5	5	3
11000	12000	37	2	13	3	8	4	6	1
12000	13000	22	0	9	2	1	4	6	0
13000	14000	16	0	9	3	2	0	0	2
14000	15000	18	0	9	5	2	1	0	1
15000	16000	6	0	1	3	1	0	1	0
16000	17000	4	0	2	1	0	0	1	0
17000	18000	5	0	4	1	0	0	0	0
18000	19000	1	0	1	0	0	0	0	0
19000	20000	0	0	0	0	0	0	0	0
20000	21000	1	0	1	0	0	0	0	0
21000	22000	0	0	0	0	0	0	0	0
22000	23000	0	0	0	0	0	0	0	0
23000	24000	0	0	0	0	0	0	0	0
24000	25000	0	0	0	0	0	0	0	0
25000	26000	0	0	0	0	0	0	0	0
Total		1018	361	361	105	63	58	50	20

Source: Axle load data in Burundi (Sample N = 361 vehicles)

Appendix D Japanese Design Standards

D.1 Japanese Pavement Design Standards

Items	Japan
Design Standards	Manual for Asphalt Pavement (1998)
Principle of Design Method	Method based on the AASHO Road Test and experiments in Japan
Outline of Design Method	(i) Evaluate subgrade using the California Bearing Ratio (CBR). (ii) Total thickness of asphalt concrete called T_A, which assumes that necessary thickness of pavement is composed of only asphalt concrete, is determined by accumulated heavy traffic volume and the strength of subgrade. (iii) Thickness of each layer is determined utilizing coefficients of relative strengths of each layer's material based on AASHO Road Test and the above T_A value.
Traffic Volume for Design	(i) Design traffic volume for pavement is determined by calculating average traffic volume of heavy vehicle in the design period utilizing the growth factor and the latest traffic volume data. (ii) Above T_A is calculated by converting the design traffic volume for pavement into accumulated number of standard axle loads of which standard is equivalent to 49 kN.

Source: Japan Road Association, *Manual for Asphalt Pavement*, 1998

D.2 Japanese Bridge Design Standards

Items	Japan
Design Standard	Specifications For Highway Bridges
Design Method	Permissible Stress Design Method
Design Period	Not specified
Live Load	A loading and B loading
Loading Carriageway Width: B(m)	Not specified
Uniformly Distributed Load (UDL)	@3.5 kN/m^2 + @10 kN/m^2 on 10 m of length
Truck Load	200 kN × k (1 axle) k: Extra coefficient k = 1.0 (L < 4m), k = L/32 + 7/8 (4 m < L)
Impact Load	Impact factor
Live Load for Slab Design	2@100 kN (Wheel load, 20 cm × 50 cm)

Source: Japan Road Association, *Specifications for Highway Bridges*

Appendix E Maintenance Cost Estimates, Input Data, and Modelling Results

E.1 Funding Needs Estimation using HDM-4

E.1.1 Common Maintenance Configuration for the HDM-4 Model

Maintenance Options and Scenarios

	Condition	Economic cost	Type 1	Type 2	Type 3	Type 4
Crack seal	Apply >10% of surface	5 USD/sqm	v			
Patch	Apply 10 potholes per km	12 USD/sqm	v	v	v	v
Reseal	Apply >20% damaged	34 USD/sqm		v		v
Overlay	Apply when IRI>5	45 USD/sqm			v	
Reconstruct	Apply when IRI>8	86 USD/sqm				v

Note: These unit rates are based on to the prices in Rwanda, where all of unit rates for maintenance work were collected.

Economic Cost Configuration by Country

	Condition	Rwanda, Uganda, Burundi	Kenya and Tanzania
Crack seal	Apply >10 % of surface	5 USD/sqm	3.5 USD/sqm
Patch	Apply 10 potholes per km	12 USD/sqm	9 USD/sqm
Reseal	Apply >20% damaged	34 USD/sqm	24 USD/sqm
Overlay	Apply when IRI>5	45 USD/sqm	31 USD/sqm
Reconstruct	Apply when IRI>8	86 USD/sqm	60 USD/sqm

Basic Configurations of Vehicles

Type UB loading

Motorised Vehicle Types

Name	Base Type	PCSE	No. of Wheels	No. of Axles	Tyre Type	Tyre Base Recaps	Tyre Retread Cost (%)	Annual Km	Annual Work Hours	Avg Life	Private Use (%)	Pass-engers	Work Related Trips (%)	ESALF	Oper Weight (t)	Life Model
1_6 axle(Present)	Articulated Truck	3.00	22	6	Bias ply	1.30	15.00	86,000	2,050	14	0	0	0.00	5.85	42.71	Optimal
1_4-5 axle(Present)	Articulated Truck	2.50	16	4	Bias ply	1.30	15.00	86,000	2,050	14	0	0	0.00	4.84	33.47	Optimal
1_3 axle(Present)	Heavy Truck	1.60	10	3	Bias ply	1.30	15.00	86,000	2,050	14	0	0	0.00	5.88	24.25	Optimal
1_2 axle(Present)	Medium Truck	1.40	6	2	Bias ply	1.30	15.00	40,000	1,200	12	0	0	0.00	4.28	15.89	Optimal
0_Cars	Medium Car	1.00	4	2	Radial ply	1.30	15.00	23,000	550	10	100	1	75.00	0.00	1.20	Constant
0_Pickup	Light Goods	1.00	4	2	Bias ply	1.30	15.00	30,000	1,300	8	0	0	0.00	0.01	1.50	Optimal
0_SmallBus	Mini Bus	1.20	4	2	Radial ply	1.30	15.00	30,000	750	8	0	10	75.00	0.01	1.50	Optimal
0_Bus	Heavy Bus	1.60	10	3	Bias ply	1.30	15.00	70,000	1,750	12	0	40	75.00	0.80	10.00	Optimal

Type T Loading

Motorised Vehicle Types

Name	Base Type	PCSE	No. of Wheels	No. of Axles	Tyre Type	Tyre Base Recaps	Tyre Retread Cost (%)	Annual Km	Annual Work Hours	Avg Life	Private Use (%)	Pass-engers	Work Related Trips (%)	ESALF	Oper Weight (t)	Life Model
1_6 axle(Present)	Articulated Truck	3.00	22	6	Bias ply	1.30	15.00	86,000	2,050	14	0	0	0.00	4.56	44.00	Optimal
1_4-5 axle(Present)	Articulated Truck	2.50	16	4	Bias ply	1.30	15.00	86,000	2,050	14	0	0	0.00	2.86	29.67	Optimal
1_3 axle(Present)	Heavy Truck	1.60	10	3	Bias ply	1.30	15.00	86,000	2,050	14	0	0	0.00	2.49	22.46	Optimal
1_2 axle(Present)	Medium Truck	1.40	6	2	Bias ply	1.30	15.00	40,000	1,200	12	0	0	0.00	2.57	16.47	Optimal
0_Cars	Medium Car	1.00	4	2	Radial ply	1.30	15.00	23,000	550	10	100	1	75.00	0.00	1.20	Constant
0_Pickup	Light Goods	1.00	4	2	Bias ply	1.30	15.00	30,000	1,300	8	0	0	0.00	0.01	1.50	Optimal
0_SmallBus	Mini Bus	1.20	4	2	Radial ply	1.30	15.00	30,000	750	8	0	10	75.00	0.01	1.50	Optimal
0_Bus	Heavy Bus	1.60	10	3	Bias ply	1.30	15.00	70,000	1,750	12	0	40	75.00	0.80	10.00	Optimal

E.1.2 Dataset for HDM-4 Analysis for Burundi

<u>Traffic volume/composition, length, and pavement condition for the target network</u>

Location		Length														Total	Condition		
CH.P	Station	(km)														Vehicle	Good	Fair	Poor
0																			
6	Kamenge	28.5	438	399	252	54	497	136	2	0	3	0	2	29	23	1836	22.3	6.2	0.0
			438	399	252	54	497	137		5				52					
			23.9%	21.7%	13.7%	3.0%	27.1%	7.5%		0.3%				2.8%					
51	Bukeye	44	183	189	116	25	78	12	0	1	1	0	1	29	3	636	44.0	0.0	0.0
			183	189	116	25	78	12		3				32					
			28.7%	29.7%	18.2%	3.9%	12.2%	1.9%		0.5%				5.0%					
94	Kayanza	42.38	152	73	10	19	29	7	2	1	1	1	0	13	3	311	40.1	2.3	0.0
			152	73	10	19	29	9		3				16					
			48.9%	23.5%	3.2%	6.1%	9.4%	2.8%		1.0%				5.2%					
114.88																			
		114.88	234.8	198.4	110.6	30.0	163.9	40.9	0.9	0.5	1.1	0.5	0.8	23.1	8.0	813.7	106	9	0

<u>Result of optimized maintenance programme (with Type UB Loading)</u>

HDM-4
HIGHWAY DEVELOPMENT & MANAGEMENT

Work Programme Unconstrained by Year

Study Name: **6. Burundi Present Case**
Run Date: **04-04-2011**

All costs are expressed in: US Dollar (millions)

Year	Section	Road Class	Length (km)	AADT	Surface Class	Work Description	NPV/CAP	Financia Costs	Cum Costs
2012	01_RN1-1-2 Fair Condition	Primary or Trunk	6.2	1947	Bituminous	Overlay 50mm at 6 IRI	0.443	2.170	2.170
2014	02_RN1-2	Primary or Trunk	44.0	715	Bituminous	Reseal at 30% surface d	-0.703	1.540	3.710
	03_RN1-3-2 Fair Condition	Primary or Trunk	2.3	350	Bituminous	Overlay 50mm at 6 IRI	-0.819	0.805	4.515
2015	03_RN1-3-1 Good Condition	Primary or Trunk	40.1	360	Bituminous	Reseal at 30% surface d	-0.863	1.404	5.919
2021	01_RN1-1-1 Good Condition	Primary or Trunk	22.3	2541	Bituminous	Overlay 50mm at 6 IRI	0.049	7.805	13.724
2024	02_RN1-2	Primary or Trunk	44.0	962	Bituminous	Reseal at 30% surface d	-0.703	1.540	15.264
	03_RN1-3-1 Good Condition	Primary or Trunk	40.1	470	Bituminous	Reseal at 30% surface d	-0.863	1.404	16.667
2025	01_RN1-1-2 Fair Condition	Primary or Trunk	6.2	2860	Bituminous	Overlay 50mm at 6 IRI	0.443	2.170	18.837
2029	02_RN1-2	Primary or Trunk	44.0	1115	Bituminous	Reseal at 30% surface d	-0.703	1.540	20.377

Year	Cost	NPV
2011	0	0.496488
2012	2.17	
2013	0	
2014	2.345	
2015	1.4035	
2016	0	
2017	0	
2018	0	
2019	0	
2020	0	
2021	7.805	
2022	0	
2023	0	
2024	2.9435	
2025	2.17	
2026	0	
2027	0	
2028	0	
2029	1.54	
2030	0	
Total	20.38	
annual	1.02	

Result of optimized maintenance programme (with Type T Loading)

H D M - 4
HIGHWAY DEVELOPMENT & MANAGEMENT

Work Programme Unconstrained by Year

Study Name: **6. Burundi TKmodel**
Run Date: **02-08-2011**

All costs are expressed in: US Dollar (millions)

Year	Section	Road Class	Length (km)	AADT	Surface Class	Work Description	NPV/CAP	Financia Costs	Cum Costs
2013	01_RN1-1-2 Fair Condition	Primary or Trunk	6.2	2006	Bituminous	Overlay 50mm at 6 IRI	0.294	2.170	2.170
2014	02_RN1-2	Primary or Trunk	44.0	715	Bituminous	Reseal at 30% surface dan	-0.658	1.540	3.710
	03_RN1-3-2 Fair Condition	Primary or Trunk	2.3	350	Bituminous	Overlay 50mm at 6 IRI	-0.821	0.805	4.515
2015	03_RN1-3-1 Good Condition	Primary or Trunk	40.1	360	Bituminous	Reseal at 30% surface dan	-0.900	1.404	5.919
2024	01_RN1-1-1 Good Condition	Primary or Trunk	22.3	2777	Bituminous	Overlay 50mm at 6 IRI	-0.246	7.805	13.724
	02_RN1-2	Primary or Trunk	44.0	962	Bituminous	Reseal at 30% surface dan	-0.658	1.540	15.264
2025	03_RN1-3-1 Good Condition	Primary or Trunk	40.1	484	Bituminous	Reseal at 30% surface dan	-0.900	1.404	16.667
2029	01_RN1-1-2 Fair Condition	Primary or Trunk	6.2	3219	Bituminous	Overlay 50mm at 6 IRI	0.294	2.170	18.837
2030	03_RN1-3-1 Good Condition	Primary or Trunk	40.1	561	Bituminous	Reseal at 30% surface dan	-0.900	1.404	20.241

Year	Cost	NPV
2011	0.00	0.441472
2012	0.00	
2013	2.17	
2014	2.35	
2015	1.40	
2016	0.00	
2017	0.00	
2018	0.00	
2019	0.00	
2020	0.00	
2021	0.00	
2022	0.00	
2023	0.00	
2024	9.35	
2025	1.40	
2026	0.00	
2027	0.00	
2028	0.00	
2029	2.17	
2030	1.40	
Total	20.24	
annual	1.01	

E.1.3 Dataset for HDM-4 Analysis for Kenya

<u>Traffic volume/composition</u>

	Car	Pick-up - Utility	4WD - Jeep	Minibus - Matatu	Small Bus	Large Bus	Medium Truck	Heavy Truck	Articulated Truck
Low	21.5%	10.6%	12.2%	18.6%	2.8%	2.0%	11.9%	11.3%	9.1%
Medium	23.7%	6.5%	9.4%	12.1%	4.7%	2.6%	9.1%	16.8%	15.0%
High	36.7%	8.0%	13.0%	25.5%	2.9%	1.6%	7.1%	3.1%	2.1%

<u>Result of optimized maintenance programme with Type UB loading</u>

HDM-4
HIGHWAY DEVELOPMENT & MANAGEMENT

Work Programme Unconstrained by Year

Study Name: **4. Kenya present case**
Run Date: **04-04-2011**

All costs are expressed in: US Dollar (millions)

Year	Section	Road Class	Length (km)	AADT	Surface Class	Work Description	NPV/CAP	Financial Costs	Cum. Costs
2011	02_AM_Paved High Traffic Fair	Primary or Trunk	12.0	36726	Bituminous	Overlay 50mm at 5 IRI	42.703	4.200	4.200
	06_AM_Paved Middle Traffic P	Primary or Trunk	271.0	5972	Bituminous	Reconstruct at 9 IRI	15.380	0.027	4.227
	05_AM_Paved Middle Traffic F	Primary or Trunk	39.0	5972	Bituminous	Overlay 50mm at 5.5 IRI	8.622	13.650	17.877
	09_AM_Paved Low Traffic Poor	Primary or Trunk	1,048.0	1030	Bituminous	Overlay 50mm at 6 IRI	1.597	366.800	384.677
2013	01_AM_Paved High Traffic Goo	Primary or Trunk	32.0	38963	Bituminous	Overlay 50mm at 5 IRI	35.186	11.200	395.877
	08_AM_Paved Low Traffic Fair	Primary or Trunk	92.0	1092	Bituminous	Overlay 50mm at 6 IRI	0.023	32.200	428.077
2015	04_AM_Paved Middle Traffic G	Primary or Trunk	276.0	6722	Bituminous	Overlay 50mm at 5.5 IRI	9.050	96.600	524.677
2017	02_AM_Paved High Traffic Fair	Primary or Trunk	12.0	43853	Bituminous	Overlay 50mm at 5 IRI	42.703	4.200	528.877
	06_AM_Paved Middle Traffic P	Primary or Trunk	271.0	7132	Bituminous	Overlay 50mm at 5.5 IRI	15.380	94.850	623.727
	05_AM_Paved Middle Traffic F	Primary or Trunk	39.0	7132	Bituminous	Overlay 50mm at 5.5 IRI	8.622	13.650	637.377
2019	01_AM_Paved High Traffic Goo	Primary or Trunk	32.0	46524	Bituminous	Overlay 50mm at 5 IRI	35.186	11.200	648.577
2021	04_AM_Paved Middle Traffic G	Primary or Trunk	276.0	8027	Bituminous	Overlay 50mm at 5.5 IRI	9.050	96.600	745.177
2023	02_AM_Paved High Traffic Fair	Primary or Trunk	12.0	52363	Bituminous	Overlay 50mm at 5 IRI	42.703	4.200	749.377
	06_AM_Paved Middle Traffic P	Primary or Trunk	271.0	8516	Bituminous	Overlay 50mm at 5.5 IRI	15.380	94.850	844.227
	05_AM_Paved Middle Traffic F	Primary or Trunk	39.0	8516	Bituminous	Overlay 50mm at 5.5 IRI	8.622	13.650	857.877
2024	01_AM_Paved High Traffic Goo	Primary or Trunk	32.0	53934	Bituminous	Overlay 50mm at 5 IRI	35.186	11.200	869.077
	07_AM_Paved Low Traffic Goo	Primary or Trunk	65.0	1512	Bituminous	Overlay 50mm at 6 IRI	-0.449	22.750	891.827
2025	09_AM_Paved Low Traffic Poor	Primary or Trunk	1,048.0	1557	Bituminous	Overlay 50mm at 6 IRI	1.597	366.800	1,258.627
2027	04_AM_Paved Middle Traffic G	Primary or Trunk	276.0	9584	Bituminous	Overlay 50mm at 5.5 IRI	9.050	96.600	1,355.227
2028	02_AM_Paved High Traffic Fair	Primary or Trunk	12.0	56451	Bituminous	Overlay 50mm at 5 IRI	42.703	4.200	1,359.427
2029	01_AM_Paved High Traffic Goo	Primary or Trunk	32.0	56451	Bituminous	Overlay 50mm at 5 IRI	35.186	11.200	1,370.627
	06_AM_Paved Middle Traffic P	Primary or Trunk	271.0	10168	Bituminous	Overlay 50mm at 5.5 IRI	15.380	94.850	1,465.477
	08_AM_Paved Low Traffic Fair	Primary or Trunk	92.0	1753	Bituminous	Overlay 50mm at 6 IRI	0.023	32.200	1,497.677
2030	05_AM_Paved Middle Traffic F	Primary or Trunk	39.0	10473	Bituminous	Overlay 50mm at 5.5 IRI	8.622	13.650	1,511.327

Year	Cost	NPV
2011	384.7	40.0
2012	0.0	
2013	43.4	
2014	0.0	
2015	96.6	
2016	0.0	
2017	112.7	
2018	0.0	
2019	11.2	
2020	0.0	
2021	96.6	
2022	0.0	
2023	112.7	
2024	33.9	
2025	366.8	
2026	0.0	
2027	96.6	
2028	4.2	
2029	138.3	
2030	13.6	
Total	1511.3	
annual	75.6	

<u>Result of optimized maintenance programme with Type T loading</u>

HDM-4
HIGHWAY DEVELOPMENT & MANAGEMENT

Work Programme Unconstrained by Year

Study Name: **4-2. Kenya present case with Tk model**
Run Date: **02-08-2011**

All costs are expressed in: US Dollar (millions)

Year	Section	Road Class	Length (km)	AADT	Surface Class	Work Description	NPV/CAP	Financia Costs	Cum Costs
2011	02_AM_Paved High Traffic Fair Con	Primary or Trunk	12.0	36726	Bituminous	Overlay 50mm at 5 IRI	44.391	4.200	4.200
	06_AM_Paved Middle Traffic Poor C	Primary or Trunk	271.0	5972	Bituminous	Reconstruct at 9 IRI	23.471	0.027	4.227
	05_AM_Paved Middle Traffic Fair C	Primary or Trunk	39.0	5972	Bituminous	Overlay 50mm at 5.5 IRI	11.300	13.650	17.877
	09_AM_Paved Low Traffic Poor Co	Primary or Trunk	1,048.0	1030	Bituminous	Overlay 50mm at 6 IRI	1.492	366.800	384.677
2012	04_AM_Paved Middle Traffic Good (	Primary or Trunk	276.0	6152	Bituminous	Reseal at 30% surface dan	11.936	9.660	394.337
2013	08_AM_Paved Low Traffic Fair Con	Primary or Trunk	92.0	1092	Bituminous	Overlay 50mm at 6 IRI	0.688	32.200	426.537
	07_AM_Paved Low Traffic Good C	Primary or Trunk	65.0	1092	Bituminous	Reseal at 30% surface dan	0.136	2.275	428.812
2014	01_AM_Paved High Traffic Good C	Primary or Trunk	32.0	40132	Bituminous	Overlay 50mm at 5 IRI	47.294	11.200	440.012
2017	02_AM_Paved High Traffic Fair Con	Primary or Trunk	12.0	43853	Bituminous	Overlay 50mm at 5 IRI	44.391	4.200	444.212
	04_AM_Paved Middle Traffic Good (	Primary or Trunk	276.0	7132	Bituminous	Reseal at 30% surface dan	11.936	9.660	453.872
2018	06_AM_Paved Middle Traffic Poor C	Primary or Trunk	271.0	7346	Bituminous	Overlay 50mm at 5.5 IRI	23.471	94.850	548.722
2019	05_AM_Paved Middle Traffic Fair C	Primary or Trunk	39.0	7566	Bituminous	Overlay 50mm at 5.5 IRI	11.300	13.650	562.372
2020	01_AM_Paved High Traffic Good C	Primary or Trunk	32.0	47920	Bituminous	Overlay 50mm at 5 IRI	47.294	11.200	573.572
2022	04_AM_Paved Middle Traffic Good (	Primary or Trunk	276.0	8267	Bituminous	Overlay 50mm at 5.5 IRI	11.936	96.600	670.172
2023	02_AM_Paved High Traffic Fair Con	Primary or Trunk	12.0	52363	Bituminous	Overlay 50mm at 5 IRI	44.391	4.200	674.372
	07_AM_Paved Low Traffic Good C	Primary or Trunk	65.0	1468	Bituminous	Reseal at 30% surface dan	0.136	2.275	676.647
2025	01_AM_Paved High Traffic Good C	Primary or Trunk	32.0	55552	Bituminous	Overlay 50mm at 5 IRI	47.294	11.200	687.847
	06_AM_Paved Middle Traffic Poor C	Primary or Trunk	271.0	9034	Bituminous	Overlay 50mm at 5.5 IRI	23.471	94.850	782.697
	05_AM_Paved Middle Traffic Fair C	Primary or Trunk	39.0	9034	Bituminous	Overlay 50mm at 5.5 IRI	11.300	13.650	796.347
2028	04_AM_Paved Middle Traffic Good (	Primary or Trunk	276.0	9872	Bituminous	Overlay 50mm at 5.5 IRI	11.936	96.600	892.947
	09_AM_Paved Low Traffic Poor Co	Primary or Trunk	1,048.0	1702	Bituminous	Overlay 50mm at 6 IRI	1.492	366.800	1,259.747
	07_AM_Paved Low Traffic Good C	Primary or Trunk	65.0	1702	Bituminous	Reseal at 30% surface dan	0.136	2.275	1,262.022
2029	02_AM_Paved High Traffic Fair Con	Primary or Trunk	12.0	56451	Bituminous	Overlay 50mm at 5 IRI	44.391	4.200	1,266.222

Year	Cost	NPV
2011	4.2	29.8
2012	9.7	
2013	48.1	
2014	378.0	
2015	0.0	
2016	0.0	
2017	13.9	
2018	94.9	
2019	13.7	
2020	11.2	
2021	0.0	
2022	96.6	
2023	6.5	
2024	0.0	
2025	119.7	
2026	0.0	
2027	0.0	
2028	465.7	
2029	4.2	
2030	0.0	
Total	1266.2	
annual	63.3	

E.1.4 Dataset for HDM-4 Analysis for Rwanda

Sections, length, traffic volume, vehicle composition, and initial pavement condition

Length (km)	Cars	Pick up	Minibus& Jeep4x4	Bus	2 Axles Truck	3 Axles Truck	Trailer-Truck	Trailer	TOTAL without Motorcycles	Good	Fair	Poor
42.343	250	61	1592	32	366	47	14	24	2386	42.343	0	0
	10.5%	2.6%	66.7%	1.3%	15.3%	2.0%	0.6%	1.0%				
41.587	151	28	974	15	147	21	15	17	1368	41.587	0	0
	11.0%	2.0%	71.2%	1.1%	10.7%	1.5%	1.1%	1.2%				
34.871	101	15	803	16	111	17	15	19	1097	34.871	0	0
	9.2%	1.4%	73.2%	1.5%	10.1%	1.5%	1.4%	1.7%				
3.59	954	123	1788	9	120	15	4	6	3020	3.59	0	0
	31.6%	4.1%	59.2%	0.3%	4.0%	0.5%	0.1%	0.2%				
29.582	21	3	45	6	4	9	3	7	104	27.982	1.6	0
	21.4%	3.1%	45.9%	6.1%	4.1%	9.2%	3.1%	7.1%				
7.817	480	97	1392	30	763	155	74	47	3038	7.817	0	0
	15.8%	3.2%	45.8%	1.0%	25.1%	5.1%	2.4%	1.5%				
16.179	106	88	497	29	130	52	60	49	1012	16.179	0	0
	10.5%	8.7%	49.2%	2.9%	12.9%	5.1%	5.9%	4.8%				
22.968	93	73	361	30	122	56	55	45	836	22.968	0	0
	11.1%	8.7%	43.2%	3.6%	14.6%	6.7%	6.6%	5.4%				
28.378	67	5	200	32	95	57	60	47	561	26.578	0	1.8
	11.9%	0.9%	35.5%	5.7%	16.9%	10.1%	10.7%	8.3%				
9.25	784	416	2657	133	237	16	82	7	4334	9.25	0	0
	18.1%	9.6%	61.3%	3.1%	5.5%	0.4%	1.9%	0.2%				
16.56	784	416	2657	133	237	16	82	7	4334	16.56	0	0
	18.1%	9.6%	61.3%	3.1%	5.5%	0.4%	1.9%	0.2%				
31.183	251	91	1291	44	317	17	76	6	2093	31.183	0	0
	12.0%	4.3%	61.7%	2.1%	15.1%	0.8%	3.6%	0.3%				
3.373	198	48	1097	38	124	2	1	0	1506	3.373	0	0
	13.1%	3.2%	72.7%	2.5%	8.2%	0.1%	0.1%	0.0%				
14.026	167	254	891	96	127	7	82	7	1632	14.026	0	0
	10.2%	15.6%	54.6%	5.9%	7.8%	0.4%	5.0%	0.4%				
31.792	90	37	558	1	164	3	85	5	944	24.792	7	0
	9.5%	3.9%	59.2%	0.1%	17.4%	0.3%	9.0%	0.5%				
10.662	28	14	274	3	99	4	82	5	509	10.662	0	0
	5.5%	2.8%	53.8%	0.6%	19.4%	0.8%	16.1%	1.0%				
10.022	26	8	238	1	50	3	56	5	387	8.922	1.1	0
	6.7%	2.1%	61.5%	0.3%	12.9%	0.8%	14.5%	1.3%				
38.831	12	4	69	0	7	6	39	5	365	27.231	11.6	0
	8.5%	2.8%	48.6%	0.0%	4.9%	4.2%	27.5%	3.5%				
26.501	61	38	413	31	61	6	10	8	628	24.901	1.6	0
	9.7%	6.1%	65.8%	4.9%	9.7%	1.0%	1.6%	1.3%				
26.228	32	10	319	6	81	8	12	10	479	26.228	0	0
	6.7%	2.1%	66.7%	1.3%	16.9%	1.7%	2.5%	2.1%				
62.645	17	6	106	7	25	11	8	5	184	27.945	23.6	11.1
	9.2%	3.2%	57.3%	3.8%	13.5%	5.9%	4.3%	2.7%				
25.765	37	8	288	15	86	18	14	16	481	4.665	13.6	7.5
	7.7%	1.7%	59.8%	3.1%	17.8%	3.7%	2.9%	3.3%				
4.79	186	26	285	0	91	6	10	11	616	4.79	0	0
	30.2%	4.2%	46.3%	0.0%	14.8%	1.0%	1.6%	1.8%				

HDM analysis results (work programme for Rwanda and cumulative cost for maintenance with Type UB loading)

HDM-4 – [Work Programme Unconstrained by Year]

Workspace View Report/Chart Window Help

1 of 3 | 92% | Total:1 | 100% | 1 of 1

Preview

Unconstrained

HDM-4 HIGHWAY DEVELOPMENT & MANAGEMENT

Work Programme Unconstrained by Year

Study Name: **5. Rwanda Present Case**

Run Date: **04-04-2011**

All costs are expressed in: US Dollar (millions)

Year	Section	Road Class	Length (km)	AADT	Surface Class	Work Description	NPV/CAP	Financia Costs	Cum. Costs
2011	09_RN2-4-2 Poor Condition	Primary or Trunk	1.8	577	Bituminous	Overlay 50mm at 6 IRI	0.106	0.630	0.630
	22_RN6-4-3 Poor Condition	Primary or Trunk	7.5	495	Bituminous	Overlay 50mm at 6 IRI	-0.196	2.625	3.255
	21_RN6-3-3 Poor Condition	Primary or Trunk	11.1	189	Bituminous	Overlay 50mm at 6 IRI	-0.722	3.885	7.140
2012	11_RN3-2	Primary or Trunk	16.6	4597	Bituminous	Reseal at 30% surface d	8.869	0.580	7.720
	10_RN3-1	Primary or Trunk	9.3	4597	Bituminous	Reseal at 30% surface d	8.867	0.324	8.043
	04_RN1-4	Primary or Trunk	3.6	3203	Bituminous	Reseal at 30% surface d	0.342	0.126	8.169
2013	14_RN3-5	Primary or Trunk	14.0	1783	Bituminous	Reseal at 30% surface d	0.045	0.491	8.660
	07_RN2-2	Primary or Trunk	16.2	1105	Bituminous	Reseal at 30% surface d	-0.028	0.566	9.226
	15_RN3-6-2 Fair Condition	Primary or Trunk	7.0	1031	Bituminous	Overlay 50mm at 6 IRI	-0.268	2.450	11.676
	02_RN1-2	Primary or Trunk	41.6	1494	Bituminous	Reseal at 30% surface d	-0.292	1.456	13.132
	13_RN3-4	Primary or Trunk	3.4	1645	Bituminous	Reseal at 30% surface d	-0.300	0.118	13.250
	03_RN1-3	Primary or Trunk	34.9	1198	Bituminous	Reseal at 30% surface d	-0.457	1.220	14.470
	18_RN3-9-2 Fair Condition	Primary or Trunk	11.6	398	Bituminous	Overlay 50mm at 6 IRI	-0.597	4.060	18.530
	22_RN6-4-2 Fair Condition	Primary or Trunk	13.6	525	Bituminous	Overlay 50mm at 6 IRI	-0.627	4.760	23.290
2014	09_RN2-4-1 Good Condition	Primary or Trunk	26.6	631	Bituminous	Reseal at 30% surface d	-0.310	0.931	24.221
	15_RN3-6-1 Good Condition	Primary or Trunk	24.8	1062	Bituminous	Reseal at 30% surface d	-0.316	0.868	25.089
	16_RN3-7	Primary or Trunk	10.7	572	Bituminous	Reseal at 30% surface d	-0.495	0.375	25.464
	19_RN6-1-2 Fair Condition	Primary or Trunk	1.6	706	Bituminous	Overlay 50mm at 6 IRI	-0.596	0.560	26.024
	18_RN3-9-1 Good Condition	Primary or Trunk	27.2	410	Bituminous	Reseal at 30% surface d	-0.674	0.952	26.976
	17_RN3-8-2 Fair Condition	Primary or Trunk	1.1	435	Bituminous	Overlay 50mm at 6 IRI	-0.675	0.385	27.361
	19_RN6-1-1 Good Condition	Primary or Trunk	24.9	706	Bituminous	Reseal at 30% surface d	-0.678	0.872	28.232
	20_RN6-2	Primary or Trunk	26.2	539	Bituminous	Reseal at 30% surface d	-0.710	0.917	29.149
	22_RN6-4-1 Good Condition	Primary or Trunk	4.7	541	Bituminous	Reseal at 30% surface d	-0.726	0.165	29.314
	23_RN6-5	Primary or Trunk	4.8	693	Bituminous	Reseal at 30% surface d	-0.759	0.168	29.482
	21_RN6-3-2 Fair Condition	Primary or Trunk	23.6	207	Bituminous	Overlay 50mm at 6 IRI	-0.856	8.260	37.742
	05_RN1-5-2 Fair Condition	Primary or Trunk	1.6	117	Bituminous	Overlay 50mm at 6 IRI	-0.914	0.560	38.302
2015	17_RN3-8-1 Good Condition	Primary or Trunk	8.9	448	Bituminous	Reseal at 30% surface d	-0.805	0.312	38.613
	21_RN6-3-1 Good Condition	Primary or Trunk	27.9	213	Bituminous	Reseal at 30% surface d	-0.927	0.977	39.590

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HDM-4 – [Work Programme Unconstrained by Year]

Workspace View Report/Chart Window Help

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Preview

Unconstrained

HDM-4 Work Programme Unconstrained by Year

2019	06_RN2-1	Primary or Trunk	7.8	3963	Bituminous	Overlay 50mm at 6 IRI	0.965	2.737	42.327
2021	11_RN3-2	Primary or Trunk	16.6	5999	Bituminous	Reseal at 30% surface d	8.869	0.580	42.907
	10_RN3-1	Primary or Trunk	9.3	5999	Bituminous	Reseal at 30% surface d	8.867	0.324	43.230
2022	04_RN1-4	Primary or Trunk	3.6	4305	Bituminous	Reseal at 30% surface d	0.342	0.126	43.356
	07_RN2-2	Primary or Trunk	16.2	1442	Bituminous	Reseal at 30% surface d	-0.028	0.566	43.922
	09_RN2-4-1 Good Condition	Primary or Trunk	26.6	799	Bituminous	Reseal at 30% surface d	-0.310	0.931	44.853
	15_RN3-6-1 Good Condition	Primary or Trunk	24.8	1345	Bituminous	Reseal at 30% surface d	-0.316	0.868	45.721
2023	14_RN3-5	Primary or Trunk	14.0	2396	Bituminous	Reseal at 30% surface d	0.045	0.491	46.212
	01_RN1-1	Primary or Trunk	42.3	3503	Bituminous	Overlay 50mm at 6 IRI	-0.080	14.819	61.031
	02_RN1-2	Primary or Trunk	41.6	2008	Bituminous	Reseal at 30% surface d	-0.292	1.456	62.487
	13_RN3-4	Primary or Trunk	3.4	2211	Bituminous	Reseal at 30% surface d	-0.300	0.118	62.605
	03_RN1-3	Primary or Trunk	34.9	1610	Bituminous	Reseal at 30% surface d	-0.457	1.220	63.825
	16_RN3-7	Primary or Trunk	10.7	747	Bituminous	Reseal at 30% surface d	-0.495	0.375	64.200
2024	12_RN3-3	Primary or Trunk	31.2	3165	Bituminous	Overlay 50mm at 6 IRI	-0.269	10.913	75.113
	18_RN3-9-1 Good Condition	Primary or Trunk	27.2	552	Bituminous	Reseal at 30% surface d	-0.674	0.952	76.065
	19_RN6-1-1 Good Condition	Primary or Trunk	24.9	949	Bituminous	Reseal at 30% surface d	-0.678	0.872	76.936
	20_RN6-2	Primary or Trunk	26.2	724	Bituminous	Reseal at 30% surface d	-0.710	0.917	77.853
	22_RN6-4-1 Good Condition	Primary or Trunk	4.7	727	Bituminous	Reseal at 30% surface d	-0.726	0.165	78.018
	23_RN6-5	Primary or Trunk	4.8	931	Bituminous	Reseal at 30% surface d	-0.759	0.168	78.186
	17_RN3-8-1 Good Condition	Primary or Trunk	8.9	585	Bituminous	Reseal at 30% surface d	-0.805	0.312	78.497
2025	08_RN2-3	Primary or Trunk	23.0	1302	Bituminous	Overlay 50mm at 6 IRI	-0.686	8.050	86.547
	21_RN6-3-1 Good Condition	Primary or Trunk	27.9	286	Bituminous	Reseal at 30% surface d	-0.927	0.977	87.524
2026	11_RN3-2	Primary or Trunk	16.6	6954	Bituminous	Reseal at 30% surface d	8.869	0.580	88.103
	10_RN3-1	Primary or Trunk	9.3	6954	Bituminous	Reseal at 30% surface d	8.867	0.324	88.427
	22_RN6-4-3 Poor Condition	Primary or Trunk	7.5	771	Bituminous	Reseal at 40% surface d	-0.196	0.263	88.690
2027	09_RN2-4-2 Poor Condition	Primary or Trunk	1.8	927	Bituminous	Overlay 50mm at 6 IRI	0.106	0.630	89.320
	07_RN2-2	Primary or Trunk	16.2	1672	Bituminous	Reseal at 30% surface d	-0.028	0.566	89.886
	21_RN6-3-3 Poor Condition	Primary or Trunk	11.1	304	Bituminous	Reseal at 40% surface d	-0.722	0.389	90.274
2028	06_RN2-1	Primary or Trunk	7.8	5171	Bituminous	Overlay 50mm at 6 IRI	0.965	2.737	93.011
	14_RN3-5	Primary or Trunk	14.0	2778	Bituminous	Reseal at 30% surface d	0.045	0.491	93.503
	02_RN1-2	Primary or Trunk	41.6	2328	Bituminous	Reseal at 30% surface d	-0.292	1.456	94.958
	03_RN1-3	Primary or Trunk	34.9	1867	Bituminous	Reseal at 30% surface d	-0.457	1.220	96.179
2029	09_RN2-4-1 Good Condition	Primary or Trunk	26.6	983	Bituminous	Reseal at 30% surface d	-0.310	0.931	97.110
	15_RN3-6-1 Good Condition	Primary or Trunk	24.8	1655	Bituminous	Reseal at 30% surface d	-0.316	0.868	97.978
	18_RN3-9-1 Good Condition	Primary or Trunk	27.2	640	Bituminous	Reseal at 30% surface d	-0.674	0.952	98.930
	22_RN6-4-1 Good Condition	Primary or Trunk	4.7	843	Bituminous	Reseal at 30% surface d	-0.726	0.165	99.094
	23_RN6-5	Primary or Trunk	4.8	1080	Bituminous	Reseal at 30% surface d	-0.759	0.168	99.262

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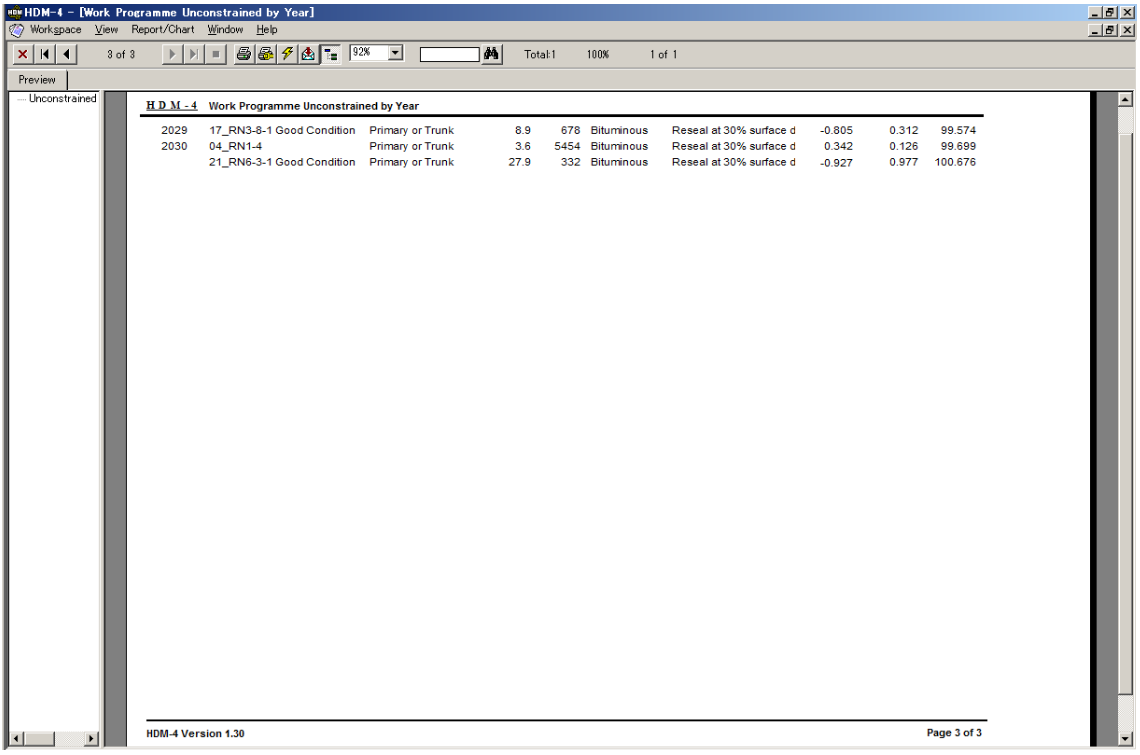

Year	Cost	NPV
2011	7.14	2.60
2012	1.03	
2013	15.12	
2014	15.01	
2015	1.29	
2016	0.00	
2017	0.00	
2018	0.00	
2019	2.74	
2020	0.00	
2021	0.90	
2022	2.49	
2023	18.48	
2024	14.30	
2025	9.03	
2026	1.17	
2027	1.58	
2028	5.90	
2029	3.40	
2030	1.10	
Total	100.68	
annual	5.03	

<u>HDM analysis results (work programme for Rwanda and cumulative cost for maintenance with Type T loading)</u>

HDM - 4
HIGHWAY DEVELOPMENT & MANAGEMENT

Work Programme Unconstrained by Year

Study Name: 5. Rwanda Present Case(Tmodel)
Run Date: 02-08-2011

All costs are expressed in: US Dollar (millions)

Year	Section	Road Class	Length (km)	AADT	Surface Class	Work Description	NPV/CAP	Financial Costs	Cum. Costs
2011	09_RN2-4-2 Poor Condition	Primary or Trunk	1.8	577	Bituminous	Overlay 50mm at 6 IRI	0.098	0.630	0.630
	22_RN6-4-3 Poor Condition	Primary or Trunk	7.5	495	Bituminous	Overlay 50mm at 6 IRI	-0.214	2.625	3.255
	21_RN6-3-3 Poor Condition	Primary or Trunk	11.1	189	Bituminous	Overlay 50mm at 6 IRI	-0.718	3.885	7.140
2012	11_RN3-2	Primary or Trunk	16.6	4597	Bituminous	Reseal at 30% surface dar	6.964	0.580	7.720
	10_RN3-1	Primary or Trunk	9.3	4597	Bituminous	Reseal at 30% surface dar	6.963	0.324	8.043
	01_RN1-1	Primary or Trunk	42.3	2531	Bituminous	Reseal at 30% surface dar	0.837	1.482	9.525
	12_RN3-3	Primary or Trunk	31.2	2220	Bituminous	Reseal at 30% surface dar	0.370	1.091	10.617
	04_RN1-4	Primary or Trunk	3.6	3203	Bituminous	Reseal at 40% surface dar	0.350	0.126	10.742
2013	14_RN3-5	Primary or Trunk	14.0	1783	Bituminous	Reseal at 30% surface dar	-0.128	0.491	11.233
	07_RN2-2	Primary or Trunk	16.2	1105	Bituminous	Reseal at 30% surface dar	-0.236	0.566	11.800
	02_RN1-2	Primary or Trunk	41.6	1494	Bituminous	Reseal at 30% surface dar	-0.256	1.456	13.255
	15_RN3-6-2 Fair Condition	Primary or Trunk	7.0	1031	Bituminous	Overlay 50mm at 6 IRI	-0.307	2.450	15.705
	13_RN3-4	Primary or Trunk	3.4	1645	Bituminous	Reseal at 30% surface dar	-0.398	0.118	15.823
	03_RN1-3	Primary or Trunk	34.9	1198	Bituminous	Reseal at 30% surface dar	-0.421	1.220	17.044
2014	08_RN2-3	Primary or Trunk	23.0	940	Bituminous	Reseal at 30% surface dar	-0.167	0.805	17.849
	09_RN2-4-1 Good Condition	Primary or Trunk	26.6	631	Bituminous	Reseal at 30% surface dar	-0.303	0.931	18.780
	15_RN3-6-1 Good Condition	Primary or Trunk	24.8	1062	Bituminous	Reseal at 30% surface dar	-0.481	0.868	19.648
	16_RN3-7	Primary or Trunk	10.7	572	Bituminous	Reseal at 30% surface dar	-0.572	0.375	20.022
	18_RN3-9-2 Fair Condition	Primary or Trunk	11.6	410	Bituminous	Overlay 50mm at 6 IRI	-0.603	4.060	24.082
	19_RN6-1-2 Fair Condition	Primary or Trunk	1.6	706	Bituminous	Overlay 50mm at 6 IRI	-0.607	0.560	24.642
	18_RN3-9-1 Good Condition	Primary or Trunk	27.2	410	Bituminous	Reseal at 30% surface dar	-0.626	0.952	25.594
	22_RN6-4-2 Fair Condition	Primary or Trunk	13.6	541	Bituminous	Overlay 50mm at 6 IRI	-0.630	4.760	30.354
	17_RN3-8-2 Fair Condition	Primary or Trunk	1.1	435	Bituminous	Overlay 50mm at 6 IRI	-0.685	0.385	30.739
	21_RN6-3-2 Fair Condition	Primary or Trunk	23.6	207	Bituminous	Overlay 50mm at 6 IRI	-0.859	8.260	38.999
	05_RN1-5-2 Fair Condition	Primary or Trunk	1.6	117	Bituminous	Overlay 50mm at 6 IRI	-0.915	0.560	39.559
2015	22_RN6-4-1 Good Condition	Primary or Trunk	4.7	557	Bituminous	Reseal at 40% surface dar	-0.762	0.165	39.724
	17_RN3-8-1 Good Condition	Primary or Trunk	8.9	448	Bituminous	Reseal at 30% surface dar	-0.771	0.312	40.035
	19_RN6-1-1 Good Condition	Primary or Trunk	24.9	728	Bituminous	Reseal at 40% surface dar	-0.772	0.872	40.907

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H D M - 4 Work Programme Unconstrained by Year

2015	23_RN6-5	Primary or Trunk	4.8	714	Bituminous	Reseal at 40% surface dar	-0.796	0.168	41.075
	20_RN6-2	Primary or Trunk	26.2	555	Bituminous	Reseal at 40% surface dar	-0.805	0.917	41.992
2021	11_RN3-2	Primary or Trunk	16.6	5999	Bituminous	Reseal at 30% surface dar	6.964	0.580	42.571
	10_RN3-1	Primary or Trunk	9.3	5999	Bituminous	Reseal at 30% surface dar	6.963	0.324	42.895
	06_RN2-1	Primary or Trunk	7.8	4205	Bituminous	Overlay 50mm at 6 IRI	1.119	2.736	45.631
	01_RN1-1	Primary or Trunk	42.3	3302	Bituminous	Reseal at 30% surface dar	0.837	1.482	47.113
2022	12_RN3-3	Primary or Trunk	31.2	2984	Bituminous	Reseal at 30% surface dar	0.370	1.091	48.204
	04_RN1-4	Primary or Trunk	3.6	4305	Bituminous	Reseal at 40% surface dar	0.350	0.126	48.330
2023	14_RN3-5	Primary or Trunk	14.0	2396	Bituminous	Reseal at 30% surface dar	-0.128	0.491	48.821
	08_RN2-3	Primary or Trunk	23.0	1227	Bituminous	Reseal at 30% surface dar	-0.167	0.805	49.626
	07_RN2-2	Primary or Trunk	16.2	1486	Bituminous	Reseal at 30% surface dar	-0.236	0.566	50.192
	02_RN1-2	Primary or Trunk	41.6	2008	Bituminous	Reseal at 30% surface dar	-0.256	1.456	51.648
	09_RN2-4-1 Good Condition	Primary or Trunk	26.6	823	Bituminous	Reseal at 30% surface dar	-0.303	0.931	52.579
	13_RN3-4	Primary or Trunk	3.4	2211	Bituminous	Reseal at 30% surface dar	-0.398	0.118	52.697
	03_RN1-3	Primary or Trunk	34.9	1610	Bituminous	Reseal at 30% surface dar	-0.421	1.220	53.917
2024	15_RN3-6-1 Good Condition	Primary or Trunk	24.8	1427	Bituminous	Reseal at 30% surface dar	-0.481	0.868	54.785
	16_RN3-7	Primary or Trunk	10.7	769	Bituminous	Reseal at 30% surface dar	-0.572	0.375	55.160
	18_RN3-9-1 Good Condition	Primary or Trunk	27.2	552	Bituminous	Reseal at 30% surface dar	-0.626	0.952	56.112
	17_RN3-8-1 Good Condition	Primary or Trunk	8.9	585	Bituminous	Reseal at 30% surface dar	-0.771	0.312	56.423
2025	22_RN6-4-1 Good Condition	Primary or Trunk	4.7	749	Bituminous	Reseal at 40% surface dar	-0.762	0.165	56.588
	19_RN6-1-1 Good Condition	Primary or Trunk	24.9	978	Bituminous	Reseal at 40% surface dar	-0.772	0.872	57.459
	23_RN6-5	Primary or Trunk	4.8	959	Bituminous	Reseal at 40% surface dar	-0.796	0.168	57.627
	20_RN6-2	Primary or Trunk	26.2	746	Bituminous	Reseal at 40% surface dar	-0.805	0.917	58.544
2026	22_RN6-4-3 Poor Condition	Primary or Trunk	7.5	771	Bituminous	Reseal at 40% surface dar	-0.214	0.263	58.807
2027	12_RN3-3	Primary or Trunk	31.2	3459	Bituminous	Reseal at 30% surface dar	0.370	1.091	59.898
2028	11_RN3-2	Primary or Trunk	16.6	7378	Bituminous	Reseal at 30% surface dar	6.964	0.580	60.478
	10_RN3-1	Primary or Trunk	9.3	7378	Bituminous	Reseal at 30% surface dar	6.963	0.324	60.802
	01_RN1-1	Primary or Trunk	42.3	4062	Bituminous	Reseal at 30% surface dar	0.837	1.482	62.284
	14_RN3-5	Primary or Trunk	14.0	2778	Bituminous	Reseal at 30% surface dar	-0.128	0.491	62.774
	07_RN2-2	Primary or Trunk	16.2	1722	Bituminous	Reseal at 30% surface dar	-0.236	0.566	63.341
2029	09_RN2-4-2 Poor Condition	Primary or Trunk	1.8	983	Bituminous	Overlay 50mm at 6 IRI	0.098	0.630	63.971
	15_RN3-6-1 Good Condition	Primary or Trunk	24.8	1655	Bituminous	Reseal at 30% surface dar	-0.481	0.868	64.839

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Year	Cost	NPV
2011	7.1	2.0
2012	3.6	
2013	6.3	
2014	22.5	
2015	2.4	
2016	0.0	
2017	0.0	
2018	0.0	
2019	0.0	
2020	0.0	
2021	5.1	
2022	1.2	
2023	5.6	
2024	2.5	
2025	2.1	
2026	0.3	
2027	1.1	
2028	3.4	
2029	1.5	
2030	0.0	
Total	64.8	
annual	3.2	

E.1.5 Dataset for HDM-4 Analysis for Tanzania

Traffic composition

	Cars	PUs Vans	Small Buses	Large Buses	Light Lorries	Med. Lorries	Heavy Lorries	V.H. Lorries
Low	16.6%	20.7%	11.0%	14.1%	8.4%	10.0%	12.7%	6.6%
Medium	19.0%	24.7%	22.2%	8.1%	6.3%	6.9%	5.7%	7.1%
High	35.2%	21.7%	21.1%	13.1%	4.6%	2.6%	1.3%	0.5%

HDM analysis results (work programme for Tanzania and cumulative cost for maintenance with Type UB loading)

HDM-4 – [Work Programme Unconstrained by Year]

Workspace View Report/Chart Window Help

1 of 1 92% Total:1 100% 1 of 1

Preview

Unconstrained

H D M - 4
HIGHWAY DEVELOPMENT & MANAGEMENT

Work Programme Unconstrained by Year

Study Name: **7. Tanzania**
Run Date: **04-04-2011**

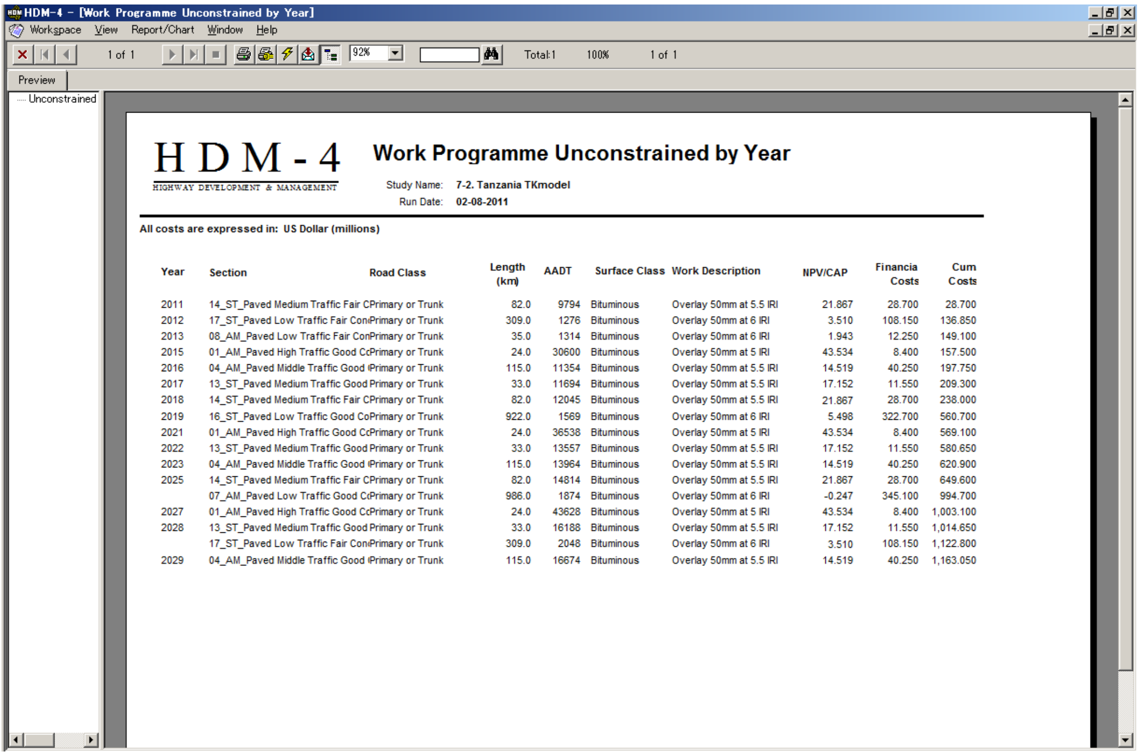
All costs are expressed in: US Dollar (millions)

Year	Section	Road Class	Length (km)	AADT	Surface Class	Work Description	NPV/CAP	Financia Costs	Cum Costs
2011	14_ST_Paved Medium Traffic F	Primary or Trunk	82.0	9794	Bituminous	Overlay 50mm at 5.5 IRI	16.473	28.700	28.700
2012	17_ST_Paved Low Traffic Fair (	Primary or Trunk	309.0	1276	Bituminous	Overlay 50mm at 6 IRI	3.517	108.150	136.850
2013	16_ST_Paved Low Traffic Good	Primary or Trunk	922.0	1314	Bituminous	Reseal at 40% surface d	4.752	32.270	169.120
	08_AM_Paved Low Traffic Fair (	Primary or Trunk	35.0	1314	Bituminous	Overlay 50mm at 6 IRI	0.949	12.250	181.370
2014	01_AM_Paved High Traffic Goo	Primary or Trunk	24.0	29708	Bituminous	Overlay 50mm at 5 IRI	43.720	8.400	189.770
2015	04_AM_Paved Middle Traffic G	Primary or Trunk	115.0	11023	Bituminous	Overlay 50mm at 5.5 IRI	15.139	40.250	230.020
2016	13_ST_Paved Medium Traffic G	Primary or Trunk	33.0	11354	Bituminous	Overlay 50mm at 5.5 IRI	17.364	11.550	241.570
2017	14_ST_Paved Medium Traffic F	Primary or Trunk	82.0	11694	Bituminous	Overlay 50mm at 5.5 IRI	16.473	28.700	270.270
2020	01_AM_Paved High Traffic Goo	Primary or Trunk	24.0	35474	Bituminous	Overlay 50mm at 5 IRI	43.720	8.400	278.670
	16_ST_Paved Low Traffic Good	Primary or Trunk	922.0	1616	Bituminous	Reseal at 40% surface d	4.752	32.270	310.940
2021	13_ST_Paved Medium Traffic G	Primary or Trunk	33.0	13162	Bituminous	Overlay 50mm at 5.5 IRI	17.364	11.550	322.490
	04_AM_Paved Middle Traffic G	Primary or Trunk	115.0	13162	Bituminous	Overlay 50mm at 5.5 IRI	15.139	40.250	362.740
2022	07_AM_Paved Low Traffic Goo	Primary or Trunk	986.0	1715	Bituminous	Overlay 50mm at 6 IRI	0.211	345.100	707.840
2023	14_ST_Paved Medium Traffic F	Primary or Trunk	82.0	13964	Bituminous	Overlay 50mm at 5.5 IRI	16.473	28.700	736.540
2025	16_ST_Paved Low Traffic Good	Primary or Trunk	922.0	1874	Bituminous	Overlay 50mm at 6 IRI	4.752	322.700	1,059.240
2026	01_AM_Paved High Traffic Goo	Primary or Trunk	24.0	42357	Bituminous	Overlay 50mm at 5 IRI	43.720	8.400	1,067.640
	17_ST_Paved Low Traffic Fair (	Primary or Trunk	309.0	1930	Bituminous	Overlay 50mm at 6 IRI	3.517	108.150	1,175.790
2027	13_ST_Paved Medium Traffic G	Primary or Trunk	33.0	15716	Bituminous	Overlay 50mm at 5.5 IRI	17.364	11.550	1,187.340
	04_AM_Paved Middle Traffic G	Primary or Trunk	115.0	15716	Bituminous	Overlay 50mm at 5.5 IRI	15.139	40.250	1,227.590
	08_AM_Paved Low Traffic Fair (	Primary or Trunk	35.0	1988	Bituminous	Overlay 50mm at 6 IRI	0.949	12.250	1,239.840
2029	14_ST_Paved Medium Traffic F	Primary or Trunk	82.0	16674	Bituminous	Overlay 50mm at 5.5 IRI	16.473	28.700	1,268.540

Type UB

Year	Cost	NPV
2011	28.7	28.0
2012	108.2	
2013	44.5	
2014	8.4	
2015	40.3	
2016	11.6	
2017	28.7	
2018	0.0	
2019	0.0	
2020	40.7	
2021	51.8	
2022	345.1	
2023	28.7	
2024	0.0	
2025	322.7	
2026	116.6	
2027	64.1	
2028	0.0	
2029	28.7	
2030	0.0	
Total	1268.5	
annual	63.4	

HDM analysis results (work programme for Tanzania and cumulative cost for maintenance with Type T loading)



HDM-4 — Work Programme Unconstrained by Year

Study Name: 7-2. Tanzania TKmodel

Run Date: 02-08-2011

All costs are expressed in: US Dollar (millions)

Year	Section	Road Class	Length (km)	AADT	Surface Class	Work Description	NPV/CAP	Financia Costs	Cum Costs
2011	14_ST_Paved Medium Traffic Fair C	Primary or Trunk	82.0	9794	Bituminous	Overlay 50mm at 5.5 IRI	21.867	28.700	28.700
2012	17_ST_Paved Low Traffic Fair Con	Primary or Trunk	309.0	1276	Bituminous	Overlay 50mm at 6 IRI	3.510	108.150	136.850
2013	08_AM_Paved Low Traffic Fair Con	Primary or Trunk	35.0	1314	Bituminous	Overlay 50mm at 6 IRI	1.943	12.250	149.100
2015	01_AM_Paved High Traffic Good C	Primary or Trunk	24.0	30600	Bituminous	Overlay 50mm at 5 IRI	43.534	8.400	157.500
2016	04_AM_Paved Middle Traffic Good	Primary or Trunk	115.0	11354	Bituminous	Overlay 50mm at 5.5 IRI	14.519	40.250	197.750
2017	13_ST_Paved Medium Traffic Good	Primary or Trunk	33.0	11694	Bituminous	Overlay 50mm at 5.5 IRI	17.152	11.550	209.300
2018	14_ST_Paved Medium Traffic Fair C	Primary or Trunk	82.0	12045	Bituminous	Overlay 50mm at 5.5 IRI	21.867	28.700	238.000
2019	16_ST_Paved Low Traffic Good Co	Primary or Trunk	922.0	1569	Bituminous	Overlay 50mm at 6 IRI	5.498	322.700	560.700
2021	01_AM_Paved High Traffic Good C	Primary or Trunk	24.0	36538	Bituminous	Overlay 50mm at 5 IRI	43.534	8.400	569.100
2022	13_ST_Paved Medium Traffic Good	Primary or Trunk	33.0	13557	Bituminous	Overlay 50mm at 5.5 IRI	17.152	11.550	580.650
2023	04_AM_Paved Middle Traffic Good	Primary or Trunk	115.0	13964	Bituminous	Overlay 50mm at 5.5 IRI	14.519	40.250	620.900
2025	14_ST_Paved Medium Traffic Fair C	Primary or Trunk	82.0	14814	Bituminous	Overlay 50mm at 5.5 IRI	21.867	28.700	649.600
	07_AM_Paved Low Traffic Good C	Primary or Trunk	986.0	1874	Bituminous	Overlay 50mm at 6 IRI	-0.247	345.100	994.700
2027	01_AM_Paved High Traffic Good C	Primary or Trunk	24.0	43628	Bituminous	Overlay 50mm at 5 IRI	43.534	8.400	1,003.100
2028	13_ST_Paved Medium Traffic Good	Primary or Trunk	33.0	16188	Bituminous	Overlay 50mm at 5.5 IRI	17.152	11.550	1,014.650
	17_ST_Paved Low Traffic Fair Con	Primary or Trunk	309.0	2048	Bituminous	Overlay 50mm at 6 IRI	3.510	108.150	1,122.800
2029	04_AM_Paved Middle Traffic Good	Primary or Trunk	115.0	16674	Bituminous	Overlay 50mm at 5.5 IRI	14.519	40.250	1,163.050

Type T

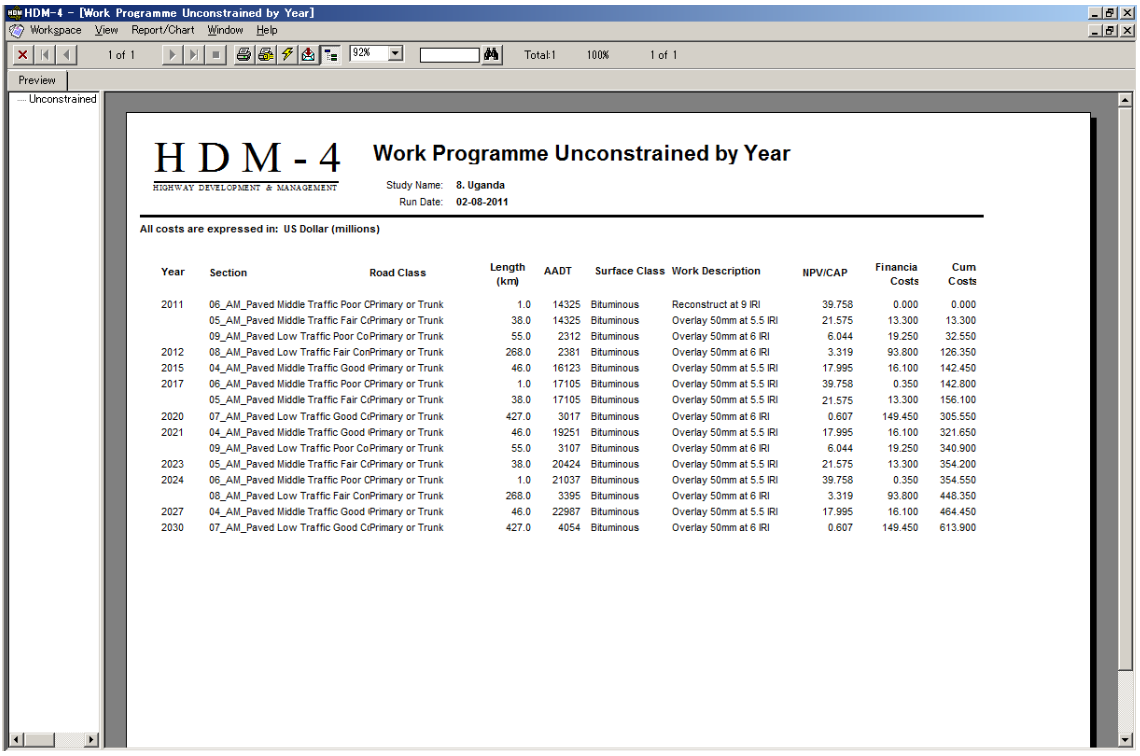
Year	Cost	NPV
2011	28.7	26.3
2012	108.2	
2013	12.3	
2014	0.0	
2015	8.4	
2016	40.3	
2017	11.6	
2018	28.7	
2019	322.7	
2020	0.0	
2021	8.4	
2022	11.6	
2023	40.3	
2024	0.0	
2025	373.8	
2026	0.0	
2027	8.4	
2028	119.7	
2029	40.3	
2030	0.0	
Total	1163.0	
annual	58.2	

E.1.6 Dataset for HDM-4 Analysis for Uganda

<u>Traffic Composition</u>

	Saloon cars and Taxies	Light Goods	Small Buses	Buses	Light Single Unit Truck	Medium/Large Single Unit Truck	Truck Trailer and Semi Trailer
Low	18.4%	22.2%	22.6%	4.3%	8.1%	12.7%	11.7%
Medium	27.5%	23.6%	29.1%	1.2%	6.8%	7.7%	4.0%

<u>HDM Analysis results (work programme for Uganda and cumulative cost of maintenance with Type UB loading)</u>



HDM-4 – [Work Programme Unconstrained by Year]

H D M - 4
HIGHWAY DEVELOPMENT & MANAGEMENT

Work Programme Unconstrained by Year

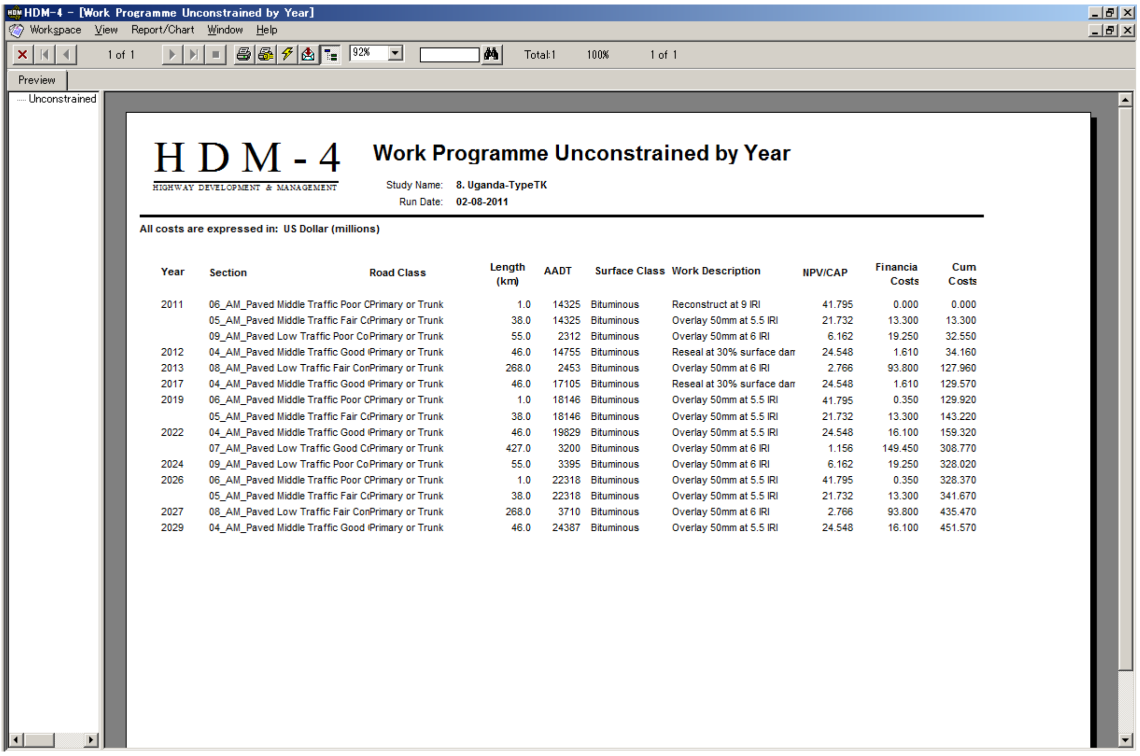
Study Name: **8. Uganda**
Run Date: **02-08-2011**

All costs are expressed in: US Dollar (millions)

Year	Section	Road Class	Length (km)	AADT	Surface Class	Work Description	NPV/CAP	Financia Costs	Cum Costs
2011	06_AM_Paved Middle Traffic Poor C	Primary or Trunk	1.0	14325	Bituminous	Reconstruct at 9 IRI	39.758	0.000	0.000
	05_AM_Paved Middle Traffic Fair C	Primary or Trunk	38.0	14325	Bituminous	Overlay 50mm at 5.5 IRI	21.575	13.300	13.300
	09_AM_Paved Low Traffic Poor Co	Primary or Trunk	55.0	2312	Bituminous	Overlay 50mm at 6 IRI	6.044	19.250	32.550
2012	08_AM_Paved Low Traffic Fair Con	Primary or Trunk	268.0	2381	Bituminous	Overlay 50mm at 6 IRI	3.319	93.800	126.350
2015	04_AM_Paved Middle Traffic Good	Primary or Trunk	46.0	16123	Bituminous	Overlay 50mm at 5.5 IRI	17.995	16.100	142.450
2017	06_AM_Paved Middle Traffic Poor C	Primary or Trunk	1.0	17105	Bituminous	Overlay 50mm at 5.5 IRI	39.758	0.350	142.800
	05_AM_Paved Middle Traffic Fair C	Primary or Trunk	38.0	17105	Bituminous	Overlay 50mm at 5.5 IRI	21.575	13.300	156.100
2020	07_AM_Paved Low Traffic Good C	Primary or Trunk	427.0	3017	Bituminous	Overlay 50mm at 6 IRI	0.607	149.450	305.550
2021	04_AM_Paved Middle Traffic Good	Primary or Trunk	46.0	19251	Bituminous	Overlay 50mm at 5.5 IRI	17.995	16.100	321.650
	09_AM_Paved Low Traffic Poor Co	Primary or Trunk	55.0	3107	Bituminous	Overlay 50mm at 6 IRI	6.044	19.250	340.900
2023	05_AM_Paved Middle Traffic Fair C	Primary or Trunk	38.0	20424	Bituminous	Overlay 50mm at 5.5 IRI	21.575	13.300	354.200
2024	06_AM_Paved Middle Traffic Poor C	Primary or Trunk	1.0	21037	Bituminous	Overlay 50mm at 5.5 IRI	39.758	0.350	354.550
	08_AM_Paved Low Traffic Fair Con	Primary or Trunk	268.0	3395	Bituminous	Overlay 50mm at 6 IRI	3.319	93.800	448.350
2027	04_AM_Paved Middle Traffic Good	Primary or Trunk	46.0	22987	Bituminous	Overlay 50mm at 5.5 IRI	17.995	16.100	464.450
2030	07_AM_Paved Low Traffic Good C	Primary or Trunk	427.0	4054	Bituminous	Overlay 50mm at 6 IRI	0.607	149.450	613.900

Year	Cost	NPV
2011	0.0	14.0
2012	107.1	
2013	19.3	
2014	0.0	
2015	16.1	
2016	0.0	
2017	0.4	
2018	13.3	
2019	0.0	
2020	149.5	
2021	16.1	
2022	19.3	
2023	13.3	
2024	0.4	
2025	93.8	
2026	0.0	
2027	16.1	
2028	0.0	
2029	0.0	
2030	149.5	
Total	613.9	
annual	30.7	

<u>HDM Analysis results (work programme for Uganda and cumulative cost of maintenance with Type T loading)</u>



HDM-4 – [Work Programme Unconstrained by Year]

HDM-4 HIGHWAY DEVELOPMENT & MANAGEMENT

Work Programme Unconstrained by Year

Study Name: **8. Uganda-TypeTK**

Run Date: **02-08-2011**

All costs are expressed in: US Dollar (millions)

Year	Section	Road Class	Length (km)	AADT	Surface Class	Work Description	NPV/CAP	Financia Costs	Cum Costs
2011	06_AM_Paved Middle Traffic Poor C	Primary or Trunk	1.0	14325	Bituminous	Reconstruct at 9 IRI	41.795	0.000	0.000
	05_AM_Paved Middle Traffic Fair C	Primary or Trunk	38.0	14325	Bituminous	Overlay 50mm at 5.5 IRI	21.732	13.300	13.300
	09_AM_Paved Low Traffic Poor Co	Primary or Trunk	55.0	2312	Bituminous	Overlay 50mm at 6 IRI	6.162	19.250	32.550
2012	04_AM_Paved Middle Traffic Good (	Primary or Trunk	46.0	14755	Bituminous	Reseal at 30% surface dam	24.548	1.610	34.160
2013	08_AM_Paved Low Traffic Fair Con	Primary or Trunk	268.0	2453	Bituminous	Overlay 50mm at 6 IRI	2.766	93.800	127.960
2017	04_AM_Paved Middle Traffic Good (	Primary or Trunk	46.0	17105	Bituminous	Reseal at 30% surface dam	24.548	1.610	129.570
2019	06_AM_Paved Middle Traffic Poor C	Primary or Trunk	1.0	18146	Bituminous	Overlay 50mm at 5.5 IRI	41.795	0.350	129.920
	05_AM_Paved Middle Traffic Fair C	Primary or Trunk	38.0	18146	Bituminous	Overlay 50mm at 5.5 IRI	21.732	13.300	143.220
2022	04_AM_Paved Middle Traffic Good (	Primary or Trunk	46.0	19829	Bituminous	Overlay 50mm at 5.5 IRI	24.548	16.100	159.320
	07_AM_Paved Low Traffic Good C	Primary or Trunk	427.0	3200	Bituminous	Overlay 50mm at 6 IRI	1.156	149.450	308.770
2024	09_AM_Paved Low Traffic Poor Co	Primary or Trunk	55.0	3395	Bituminous	Overlay 50mm at 6 IRI	6.162	19.250	328.020
2026	06_AM_Paved Middle Traffic Poor C	Primary or Trunk	1.0	22318	Bituminous	Overlay 50mm at 5.5 IRI	41.795	0.350	328.370
	05_AM_Paved Middle Traffic Fair C	Primary or Trunk	38.0	22318	Bituminous	Overlay 50mm at 5.5 IRI	21.732	13.300	341.670
2027	08_AM_Paved Low Traffic Fair Con	Primary or Trunk	268.0	3710	Bituminous	Overlay 50mm at 6 IRI	2.766	93.800	435.470
2029	04_AM_Paved Middle Traffic Good (	Primary or Trunk	46.0	24387	Bituminous	Overlay 50mm at 5.5 IRI	24.548	16.100	451.570

Year	Cost	NPV
2011	32.6	11.0
2012	1.6	
2013	93.8	
2014	0.0	
2015	0.0	
2016	0.0	
2017	1.6	
2018	0.0	
2019	13.7	
2020	0.0	
2021	0.0	
2022	165.6	
2023	0.0	
2024	19.3	
2025	0.0	
2026	13.7	
2027	93.8	
2028	0.0	
2029	16.1	
2030	0.0	
Total	451.6	
annual	22.6	

E.2 Analysis of Overloading Measurement Records by Country

E.2.1 Uganda

The recorded axle loads of each axle of all passing traffic at two weighbridge stations, Mbaraba and Masaka, located along the Central Corridor, shown as below, were recorded in the following format.

Figure E-1: Location of Measurement

Table E-1: Measurement Record Format for Uganda

Items	Actual record as example	Notes by the study team
Ticket_No	28	
Axle_Format		
Units_Measure	kg	
Axle 1	6900	Recorded by each axle, no group measurement. For this case, Axle 2,3,4 and 6 are overloading
Axle 2	8400	
Axle 3	8250	
Axle 4	8350	
Axle 5	7700	
Axle 6	8200	
Axle 7		
Axle 8		
Axle 9		
Axle_Groups	4,5,6	Just shows the number of axle
GVW(Kgs)	47800	
OverWeight_(Kgs)	250	
PGOW_(%)	1.04	
Mobile Station	LUKAYA	
Cargo_Type	FUEL	Over 250 kinds of goods are recorded; there is no standardized manner in record.
Permit_No	J594***	(The asterisks are for protection of personal information)
Driver's_Signature	MWEBAZE***	
WB_Operator's_Name	SOOXXX	
WB_Controller's_Name		
Action Taken	SM-S2T8T12 (1*12-222)	
WB_Controller's_Signature		

The measurements covered the period from June to August 2010, measured 11,572 freight vehicles, and detected about 57% of freight traffic exceeding axle load and/or GVM limits. The following tables summarize the measurements.

Table E-2: Summary of Freight Vehicle Overloading Measurements in Uganda

# of Axles	# of Measured Vehicles	# of Overloading Vehicles	Share of Overloading	ESAL per vehicle	GVM per Vehicle
2	2271	1462	64.4%	4.28	15887.1
3	3293	1782	54.1%	5.88	24245.0
4	276	121	43.8%	3.13	27495.5
5	539	289	53.6%	5.73	36532.9
6	4699	2606	55.5%	5.76	42707.0
7	494	317	64.2%	13.85	56167.3

Source: JICA Study Team and Uganda National Road Authority

Table E-3: Overloading Measurement Results by Weighbridge Stations

Summary of GVM and ESAL data (Mbarara Weighbridge, Uganda)

	Total			Overweight Vehicle			Non-Overweight Vehicle		
	# of Vehi.	Ave. GMV	Ave. ESAL	# of Vehi.	Ave. GMV	Ave. ESA	# of Vehi.	Ave. GMV	Ave. ESAL
2 Axle	632	14382.6	3.13	312	16870.2	5.06	320	11912.3	1.23
3 Axle	1459	22717.5	3.85	562	26024.4	7.16	897	20645.7	1.77
4 Axle	183	27509.0	3.15	81	29477.8	4.37	102	25945.6	2.22
5 Axle	366	35715.7	5.17	172	39517.4	7.72	194	32345.1	2.91
6 Axle	2313	41119.3	4.55	1045	44933.0	6.52	1268	37976.3	2.93
7 Axle	71	48758.5	5.20	43	52007.0	6.40	28	43769.6	3.36

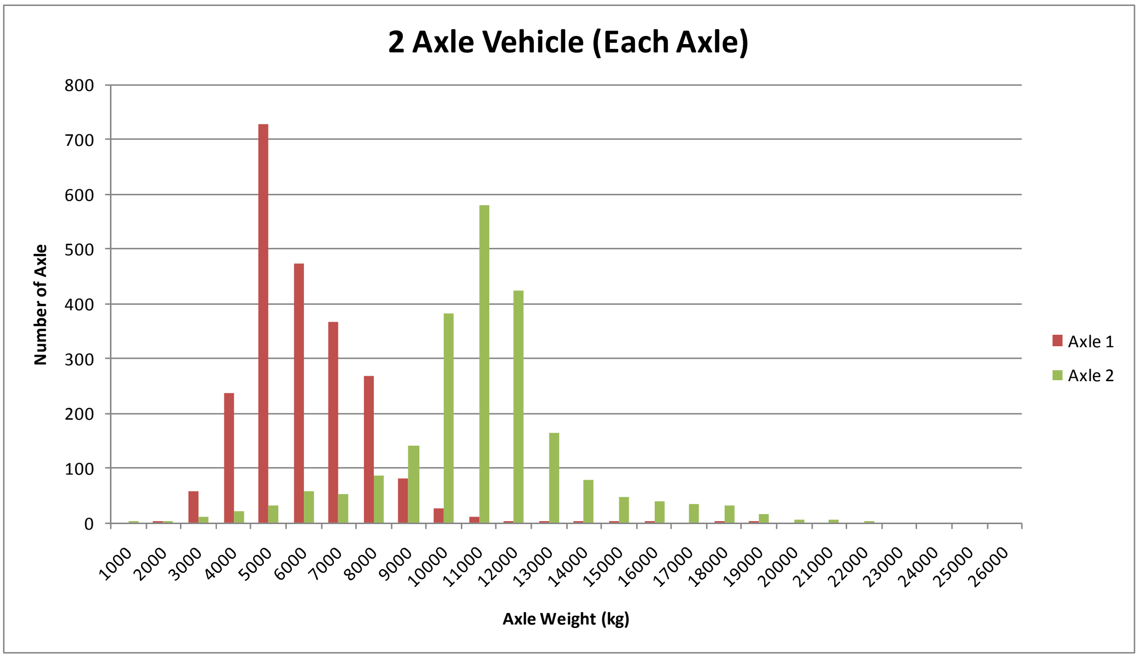
Summary of GVM and ESAL data (Masaka Weighbridge, Uganda)

	Total			Overweight Vehicle			Non-Overweight Vehicle		
	# of Vehi.	Ave. GMV	Ave. ESAL	# of Vehi.	Ave. GMV	Ave. ESA	# of Vehi.	Ave. GMV	Ave. ESAL
2 Axle	1639	16467.2	4.72	1150	17742.9	6.03	489	13467.2	1.66
3 Axle	1834	25460.2	7.49	1220	27802.2	10.20	614	20806.6	2.12
4 Axle	93	27468.8	3.09	40	29586.3	4.22	53	25870.8	2.23
5 Axle	173	38261.8	6.92	117	41248.3	8.80	56	32022.3	2.99
6 Axle	2386	44246.1	6.93	1561	47340.0	8.84	825	38392.1	3.32
7 Axle	423	57410.9	15.30	274	62140.3	20.50	149	48713.8	5.73

Source: JICA Study Team and Uganda National Road Authority

	Overload	Total	Share
GVM	801	2261	35%
1 axle	128	2261	6%
2 axle	1428	2261	63%

The following chart presents a summary of loading per axle by vehicle type. For example, examining the axle loading of 2-axle vehicles, it was found that 63% of vehicles exceeded its rear axle weight limits (10 tonnes), but only 6% of the front axles exceeded the limit (8 tonnes), and 35% of vehicles violated the GVM regulation. This suggests that 30% of overloaded freight is caused by overloading of the rear axle, and damage to pavement by overloading can be alleviated by improving the loading distribution.



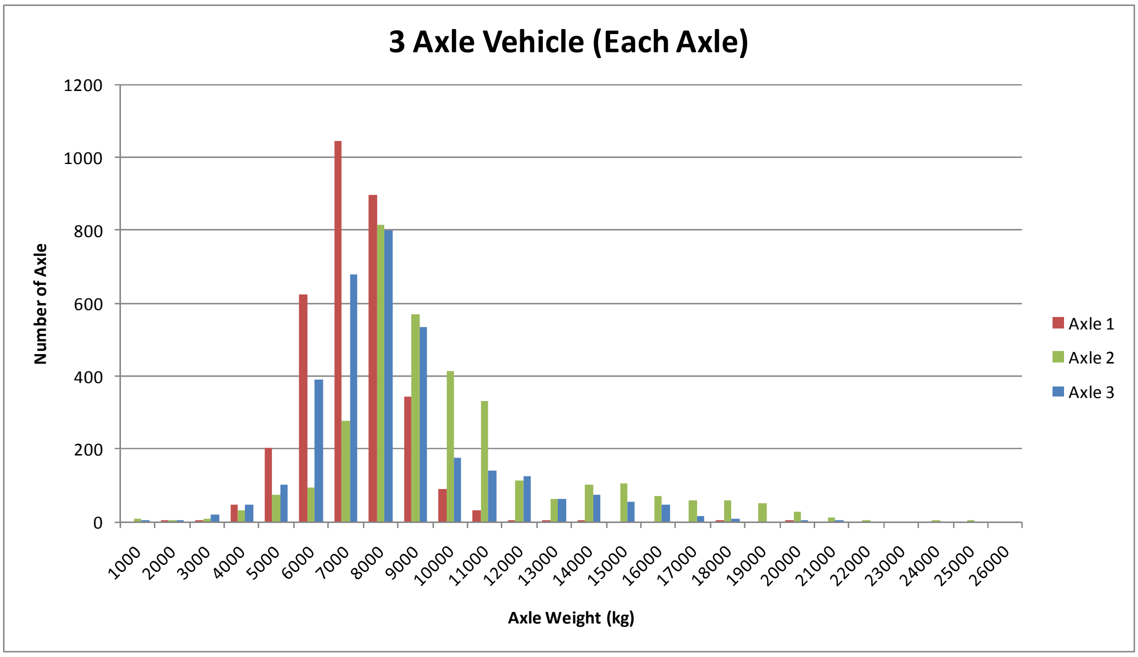
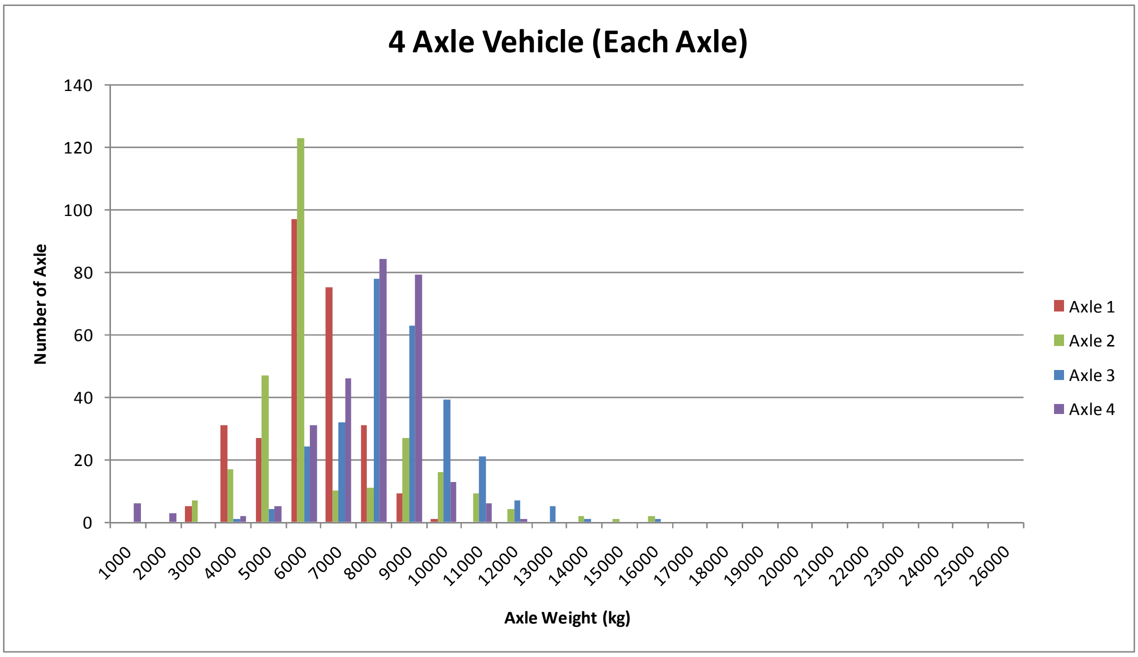


Figure E-2: Axle Load Distribution by Freight Vehicle Types (UGANDA)



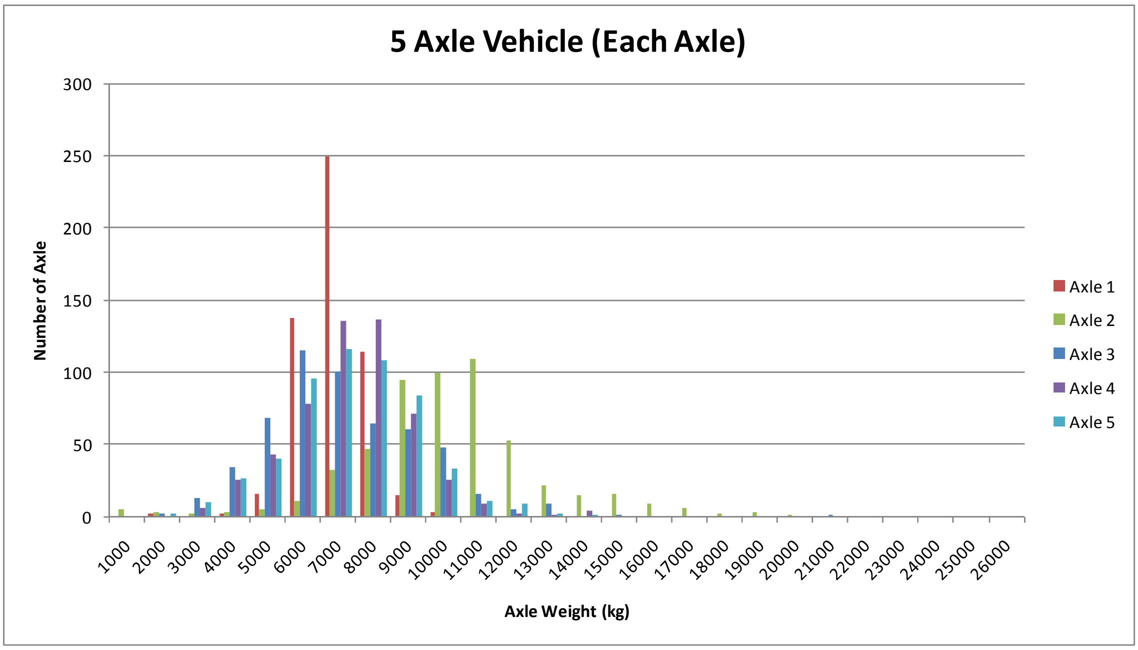
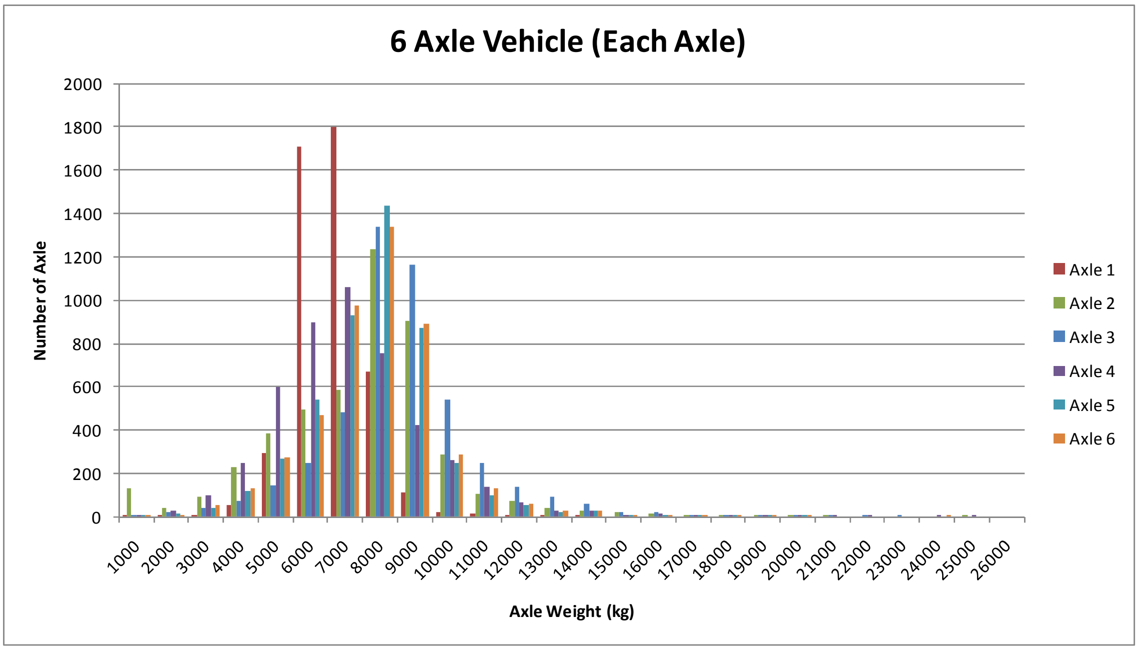


Figure E-2: Axle Load Distribution by Freight Vehicle Types (UGANDA) (continued)



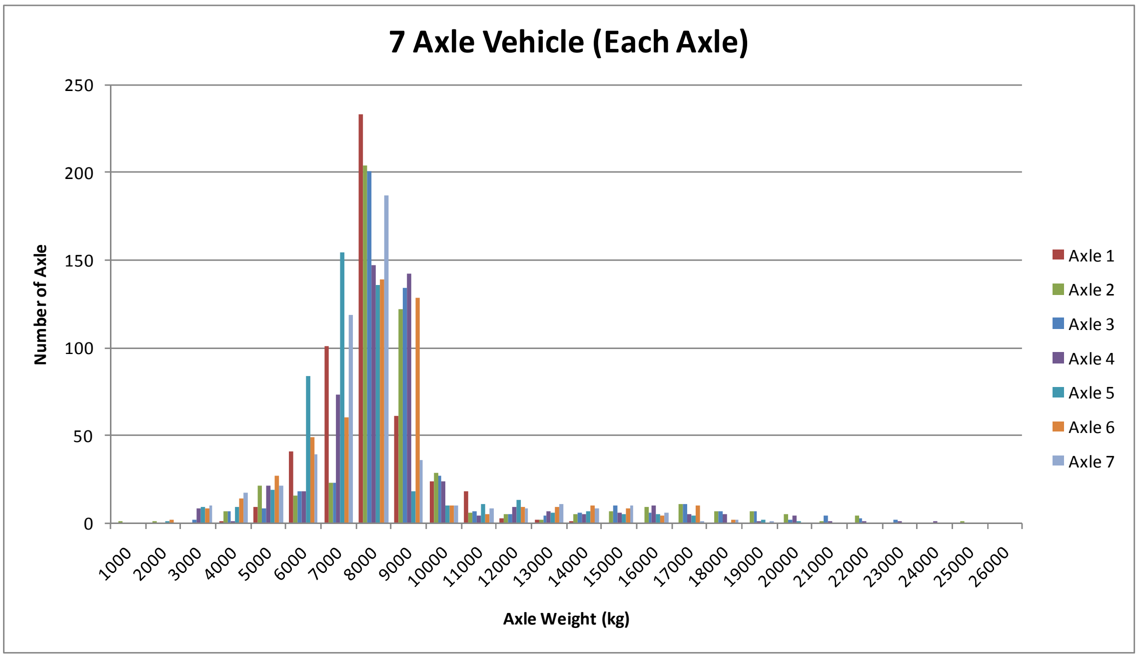


Figure E-2: Axle Load Distribution by Freight Vehicle Types (UGANDA) (continued)

The JICA Study Team also examined the types of goods involved in overloading as shown in the following table, which lists the top goods groups involved at each location. Overloading is higher in Masaka. Major overloading items at Masaka are fuel, cement, beer, matoke, and coffee. The rate of overloading exceeds 50% for several goods types, e.g., coffee, cassava, bitumen, and salt. For Mbaraba, the major overloaded goods are fuel and construction materials (e.g., cement, limestone). Also, the rate of overloading is high among transporters of construction materials.

This set of measurement records is extensive, which suggests strengthening of measurement by industry. It covers only freight movements over months; however, other seasonal agro products should be been monitored.

Table E-4: State of Overloading by Goods (Masaka)

Masaka	Not OL	OL	Total	OL rate
Fuel	769	436	1205	36%
Cement	409	170	579	29%
Beer	320	132	452	29%
Assorted	193	136	329	41%
Matooke	139	89	228	39%
Coffee	54	126	180	70%
Soda	91	58	149	39%
Soap	93	43	136	32%
Timber	60	59	119	50%
Steel	50	57	107	53%
Water	43	54	97	56%
Sugar	34	49	83	59%
Posho	35	38	73	52%
Beans	37	33	70	47%
Oil	26	32	58	55%
Salt	20	33	53	62%
Cassava	10	37	47	79%
Bitumen	16	26	42	62%
Tea	20	21	41	51%

Table E-5: State of Overloading by Goods (Mbaraba)

Mbalaba	Not OL	OL	Total	OL rate
Cement	1093	302	1395	22%
Pozzolana	714	178	892	20%
Fuel	241	84	325	26%
Limestone	105	136	241	56%
Beer	132	54	186	29%
Salt	98	34	132	26%
Assorted Goods	98	26	124	21%
Food	56	15	71	21%
Millet	36	7	43	16%
Maize	67	7	74	9%
Coffee	26	5	31	16%
Soda	44	11	55	20%
Sand	10	15	25	60%
Tyres	19	5	24	21%
Empty	22		22	0%
Plastics	18	2	20	10%
Rice	19	1	20	5%

E.2.2 Tanzania

Tanzania's overloading measurements were collected at the Kibaha weighbridge on 12 July 2010 (Monday), located along the A7 central corridor, 30 km from the Dar es Salaam. The records were collected in the following format, by stopping all freight vehicles in both directions. A total of 454 records were collected.

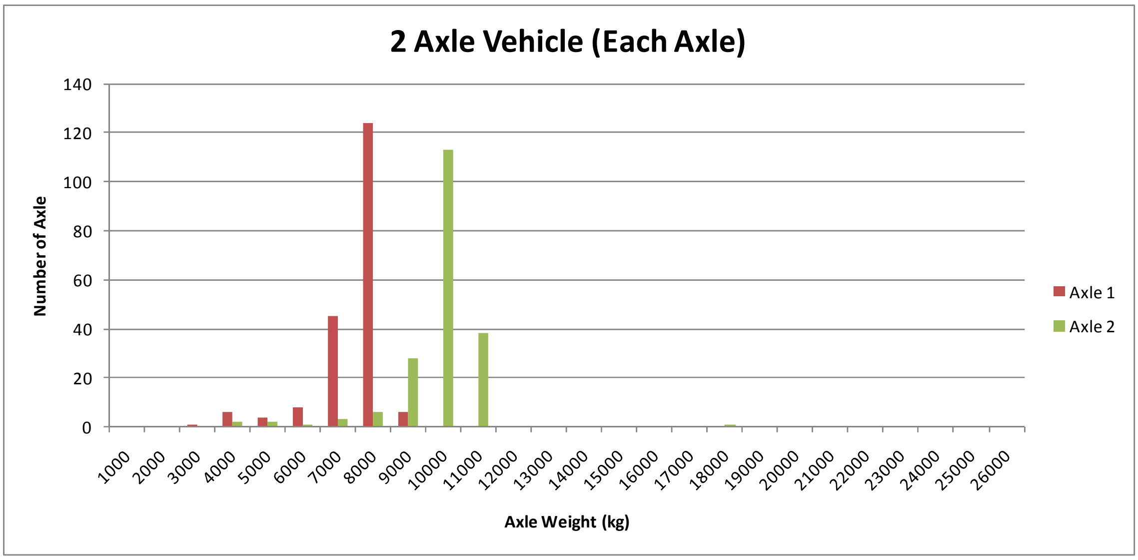
Item	1	2	Notes
Date	12/07/2010	12/07/2010	
Weighbridge Station	SOUTH	SOUTH	
Ticket Number	1304186	1304187	
Time	0:01	0:05	Showing 24-hour operation
Vehicle Reg.No.	T 153 XXX	T 190 XXX	
Axle Configuration	1-22+2-22	1-22-222	
Axle Grp.Wt1 (Kg)	6500	6600	Measured by axle group, and the JICA Study Team estimated weight per axle.
Axle Grp.Wt2 (Kg)	18050	11650	
Axle Grp.Wt3 (Kg)	8550	17600	
Axle Grp.Wt4 (Kg)	17950		
Total GVM (Kg)	51050	35850	

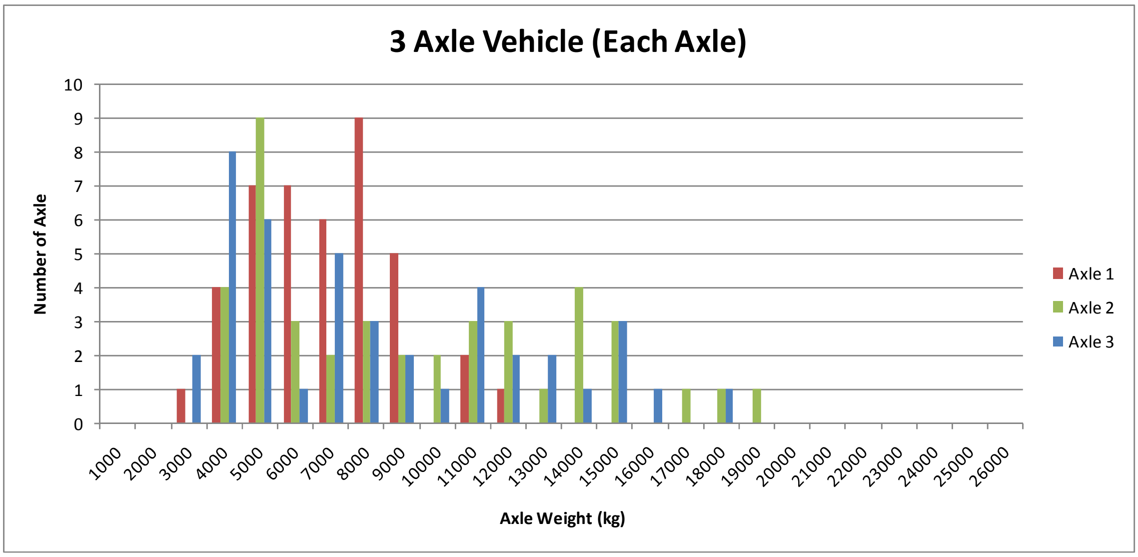
The following table is a summary of measurement records. This shows that 29.1% of freight vehicles are overloaded, and heavier vehicles had a high ratio of overloading.

Table E-6: Summary of Freight Vehicle Overloading Measurement in Tanzania

	Total			Overweight Vehicle			Non-Overweight Vehicle			OL Ratio
	# of Vehi.	Ave. GVM	Ave. ESAL	# of Vehi.	Ave. GVM	Ave. ESAL	# of Vehi.	Ave. GVM	Ave. ESAL	
2 Axle	194	16470.9	2.57	45	17475.6	3.44	149	16167.4	2.31	23.2%
3 Axle	75	22456.0	2.49	16	24465.6	3.33	59	22456.0	2.27	21.3%
4 Axle	19	26881.6	2.14	6	27416.7	2.23	13	26634.6	2.10	31.6%
5 Axle	6	38500.0	5.12	3	41950.0	7.43	3	35050.0	2.82	50.0%
6 Axle	145	44033.8	4.56	56	47508.0	5.81	89	41847.8	3.77	38.6%
7 Axle	15	49690.0	5.06	6	53541.7	6.05	9	47122.2	4.40	40.0%
	454			132			322			29.1%

The distribution of load per axle is illustrated in the following charts. Compared with Uganda, the records show good compliance to the limit value. Figures for 4 and 5 axles have been omitted due to the small number of samples.





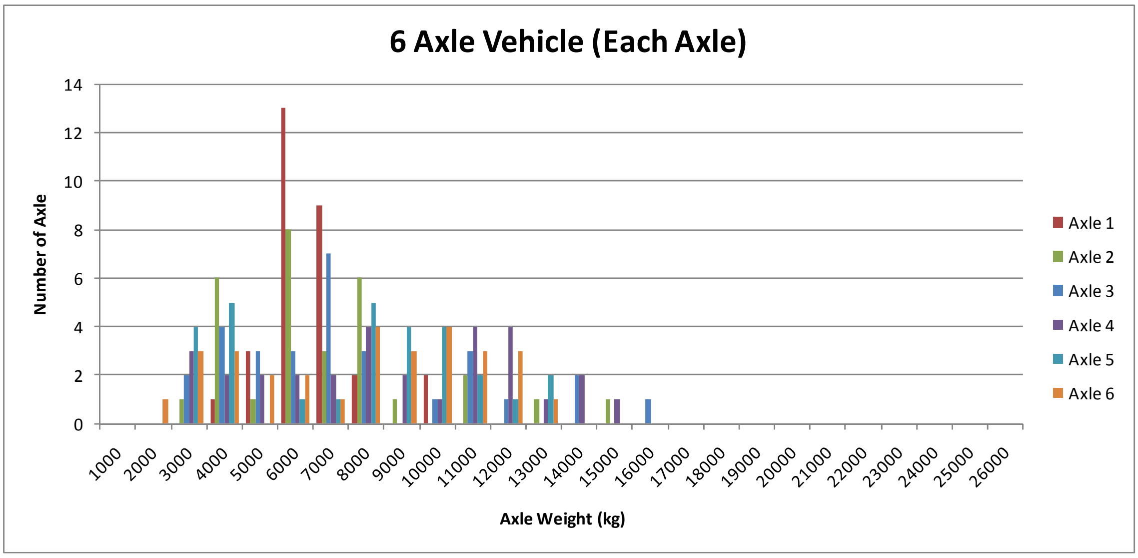


Figure E-3: Axle Loading Distribution by Freight Vehicle Types (Tanzania)

E.2.3 Burundi

Overloading measurement results were collected from several weighbridges in the country, without information on the location of weighbridges. A total of 361 records were collected. The following summary shows that the overloading rate was 28%, and heavier vehicles particularly those of 6 and 7 axles, had a higher overloading tendency.

Table E-7: Summary of Freight Vehicle Overloading Measurement in Burundi

	Total			Overweight Vehicle			Non-Overweight Vehicle			OL Ratio
	# of Vehi.	Ave. GVM	Ave. ESAL	# of Vehi.	Ave. GVM	Ave. ESAL	# of Vehi.	Ave. GVM	Ave. ESAL	
2 Axle	256	9172.1	0.87	38	18185.8	2.77	218	7601.0	0.29	14.8%
3 Axle	42	23050.2	7.23	22	30284.1	13.21	20	15093.0	0.65	52.4%
4 Axle	4	27310.0	7.03	2	39070.0	13.78	2	15550.0	0.27	50.0%
5 Axle	9	21504.4	1.29	1	38920.0	7.97	8	19327.5	0.46	11.1%
6 Axle	30	42313.2	7.83	20	50837.8	11.35	10	25264.0	0.78	66.7%
7 Axle	20	63319.5	19.03	18	67097.2	21.06	2	29320.0	0.71	90.0%
	361			101			260			28.0%

The distribution of load per axle is illustrated in the following charts. The records for 2-axle vehicles show compliance with the limit value. The figures for 4 and 5 axles have been omitted due to the small sample size.

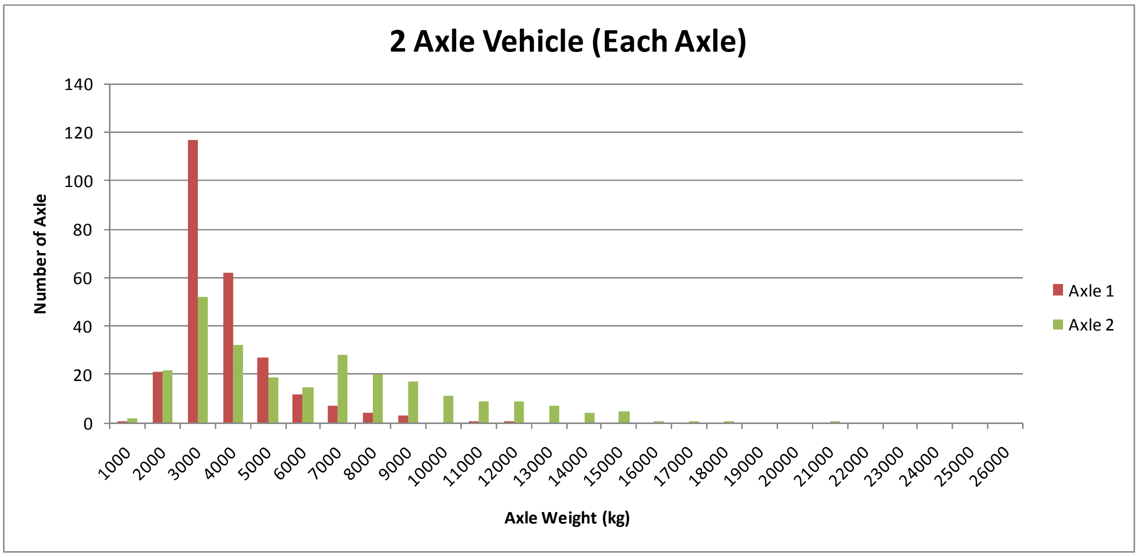
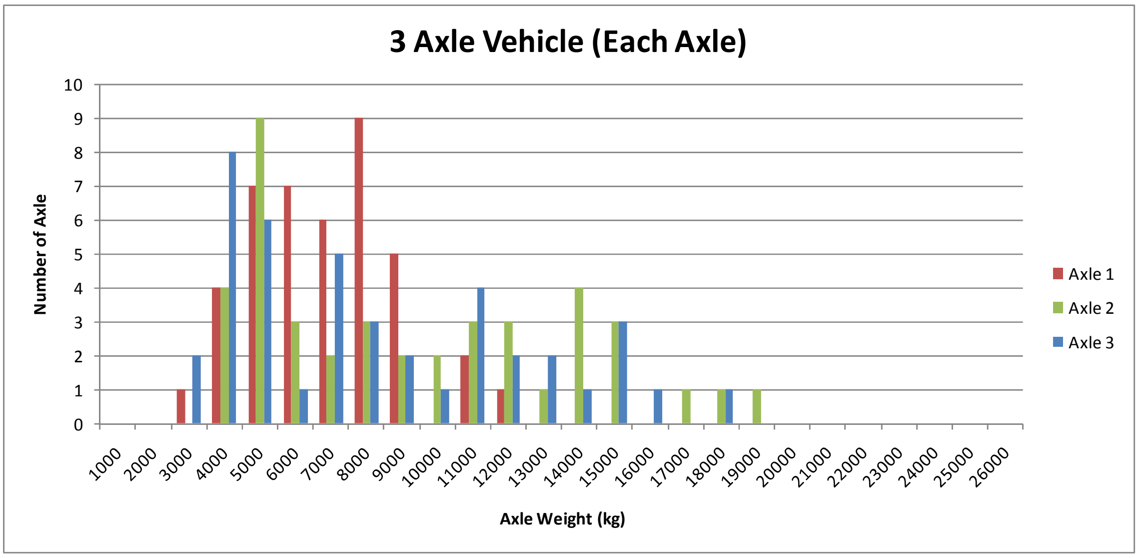


Figure E-4: Axle Loading Distribution by Freight Vehicle Types (Burundi)



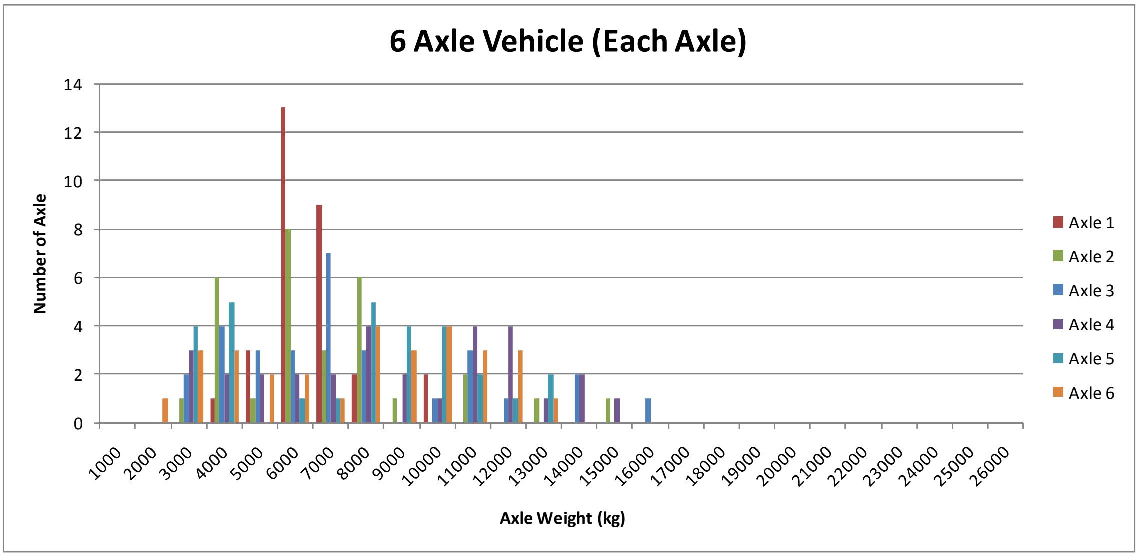


Figure E-4: Axle Loading Distribution by Freight Vehicle Types (Burundi) (continued)

E.2.4 Kenya

Over 40,000 measurement results were provided by the Kenyan authority without information on the location of weighbridges. The following summary shows the overloading rate as 61%, which is the highest among the countries. Note that the data for 6-axle freight vehicle accounts for over 90% of measurements, and the JICA Study Team requested an explanation of background for this occurrence.

Table E-8: Summary of Freight Vehicle Overloading Measurement in Kenya

	Total			Overweight Vehicle			Non-Overweight Vehicle			
	# of Vehi.	Ave. GVM	Ave. ESAL	# of Vehi.	Ave. GVM	Ave. ESAL	# of Vehi.	Ave. GVM	Ave. ESAL	OL Ratio
2 Axle	86	14348.9	2.33	35	16770.9	3.81	51	12686.8	1.31	41%
3 Axle	1,527	23431.3	2.89	741	23718.6	3.21	786	23718.6	3.21	49%
4 Axle	143	29484.7	3.73	70	30829.4	4.34	73	28195.1	3.15	49%
5 Axle	1,941	39179.2	6.03	1,359	39611.7	6.54	582	38169.2	4.82	70%
6 Axle	38,101	45006.9	5.40	23,098	45298.5	5.76	15,003	44557.9	4.83	61%
7 Axle	-	-	-	-	-	-	-	-	-	
	41,798			25,303						61%

The distribution of load per axle is illustrated in the following charts. The records for 2-axle vehicle show its compliance to the limit value.

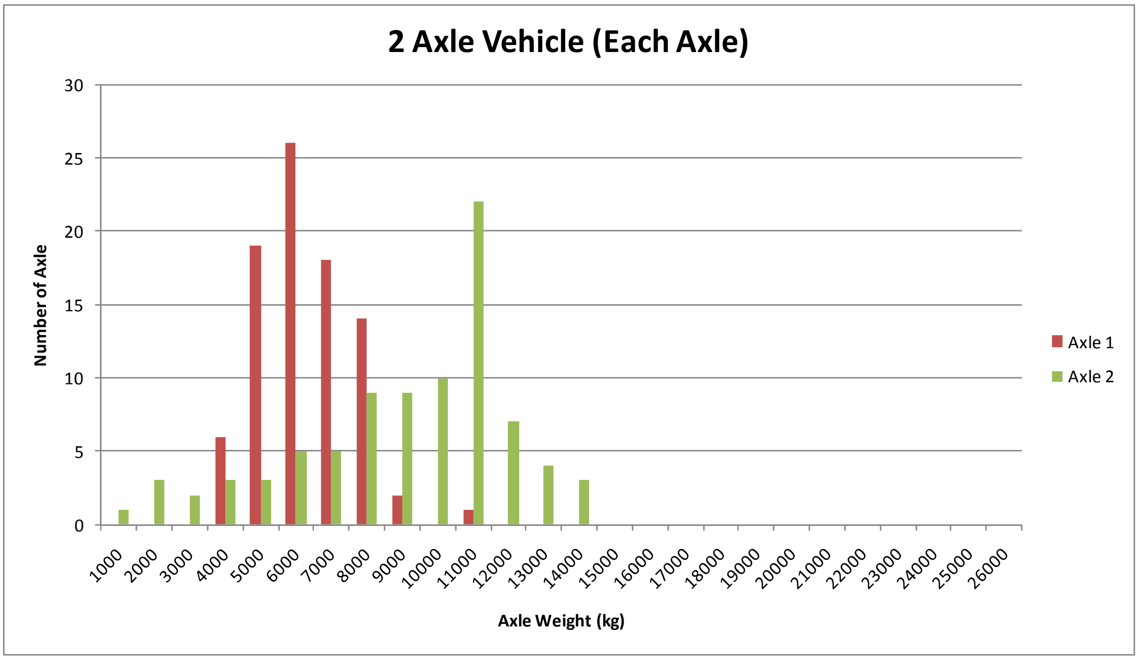
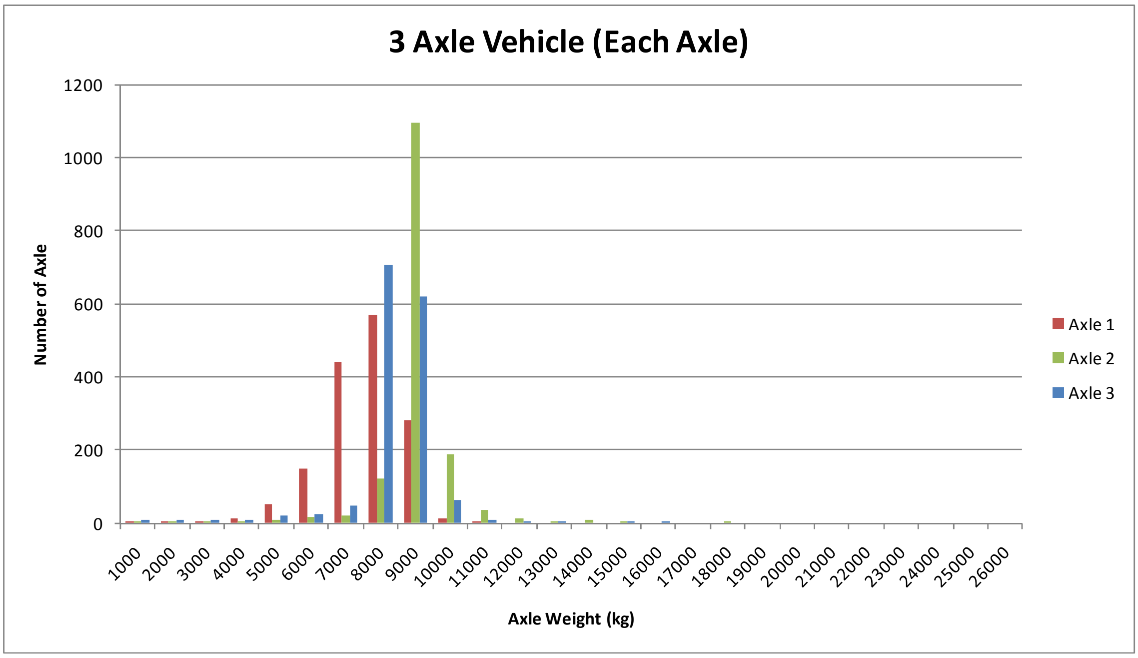


Figure E-5: Axle Loading Distribution by Freight Vehicle Types (Kenya)



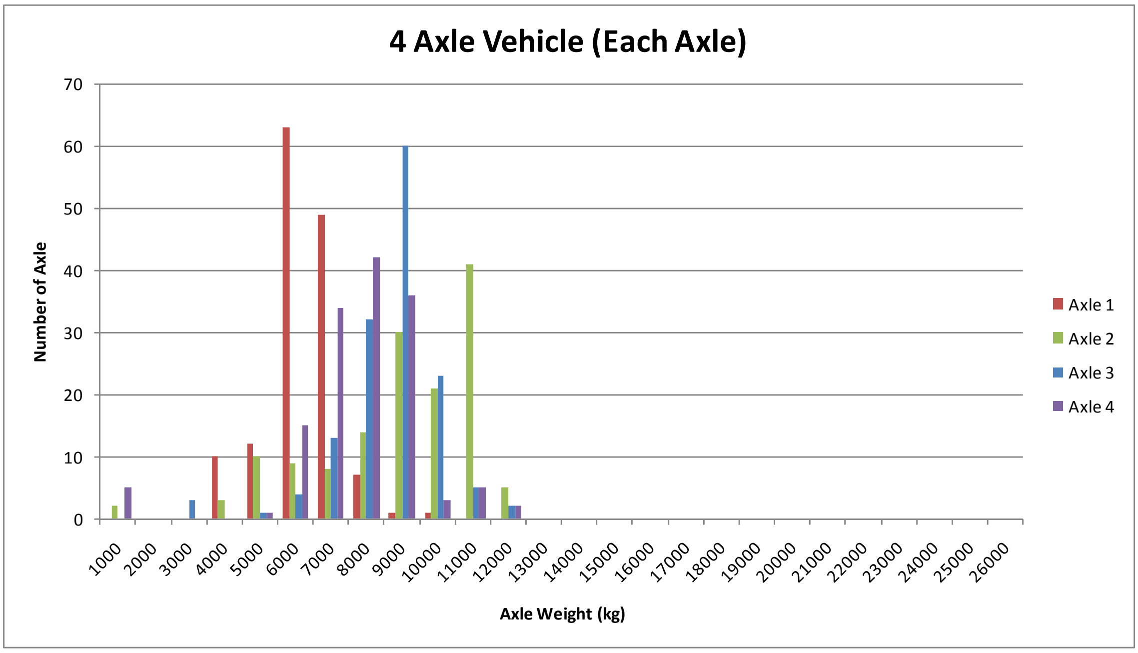
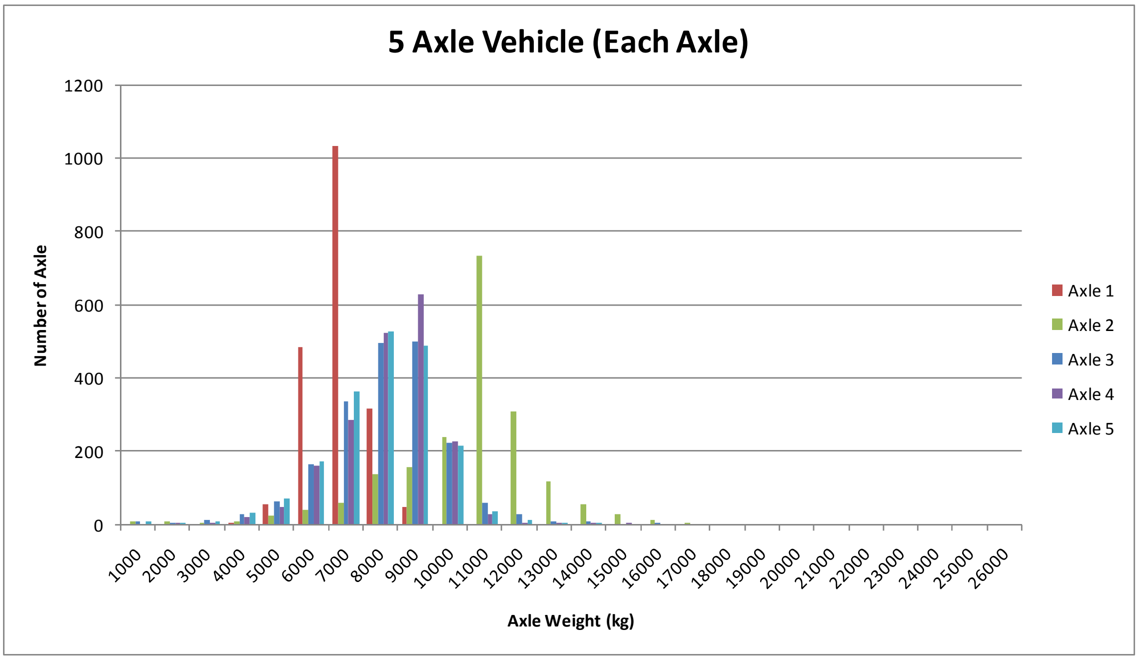


Figure E-5: Axle Loading Distribution by Freight Vehicle Types (Kenya) (continued)



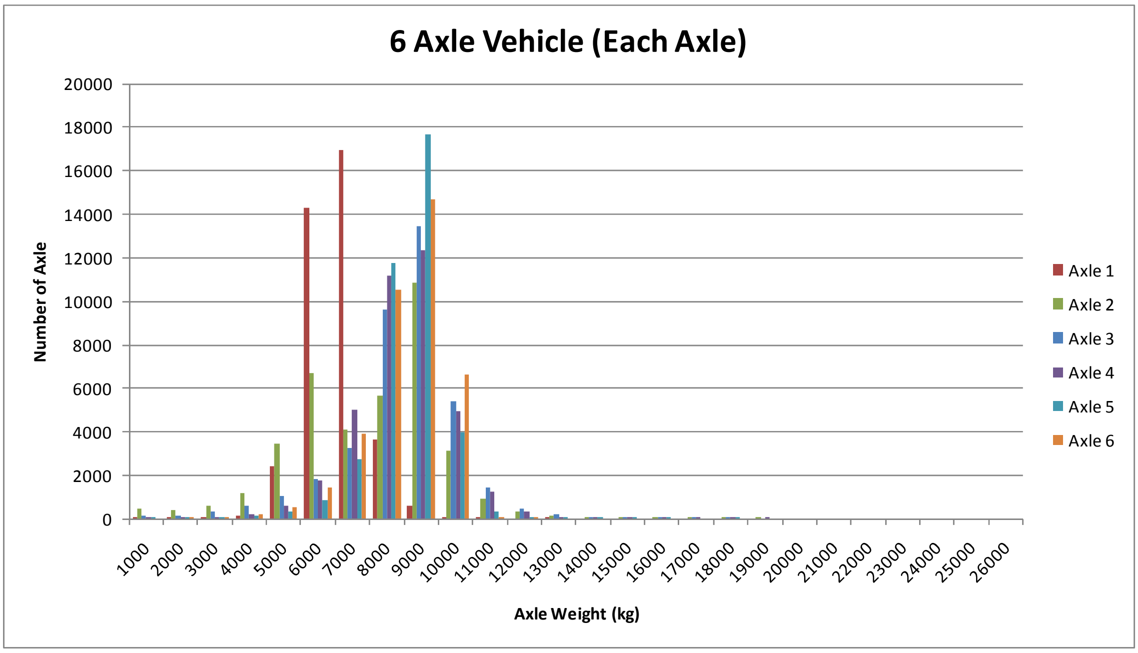


Figure E-5: Axle Loading Distribution by Freight Vehicle Types (Kenya) (continued)

E.3 Assumptions in the Analysis With/Without Overloading

E.3.1 Input Data

(1) Sample Network for Analysis

Name	Condition Year	Length (km)	Roughness IRI (m/km)	Total Cracking Area (%)	Ravelled Area (%)	Edge Break (m^2/km)	Rut Depth (mm)	ADT (veh.)
01_AM_Paved High Traffic Good Condition	2010	32.00	3.00	1.00	1.00	0.00	0.00	10,000
02_AM_Paved High Traffic Fair Condition	2010	12.00	5.50	5.00	5.00	8.00	5.00	10,000
03_AM_Paved High Traffic Poor Condition	2010	80.00	8.00	10.00	15.00	50.00	10.00	10,000

(2) Traffic Composition

		TYPE TK (%)		TYPE UB (%)	
		with OL	without OL	with OL	without OL
Common for both cases (passenger traffic)	Cars	35.1	35.1	35.1	35.1
	Pick up	21.7	21.7	21.7	21.7
	Minibus	21.1	21.1	21.1	21.1
	Bus	13.1	13.1	13.1	13.1
Composition for overloading cases referring to actual status	2 Axles Truck	3.8		1.8	
	3 Axles Truck	1.5		2.6	
	Trailer	0.5		0.6	
	Trailer-Truck	3.2		4.0	
Composition for non-overloaded vehicles	2 Axles Truck		3.0		0.6
	3 Axles Truck		1.2		1.1
	Trailer		0.3		0.3
	Trailer-Truck		2.0		1.8
Composition of ideal loading vehicles replacing overloading amount	2 Axles Truck		0.9		1.1
	3 Axles Truck		0.3		1.5
	Trailer		0.2		0.3
	Trailer-Truck		1.2		2.2

(due to rounding)

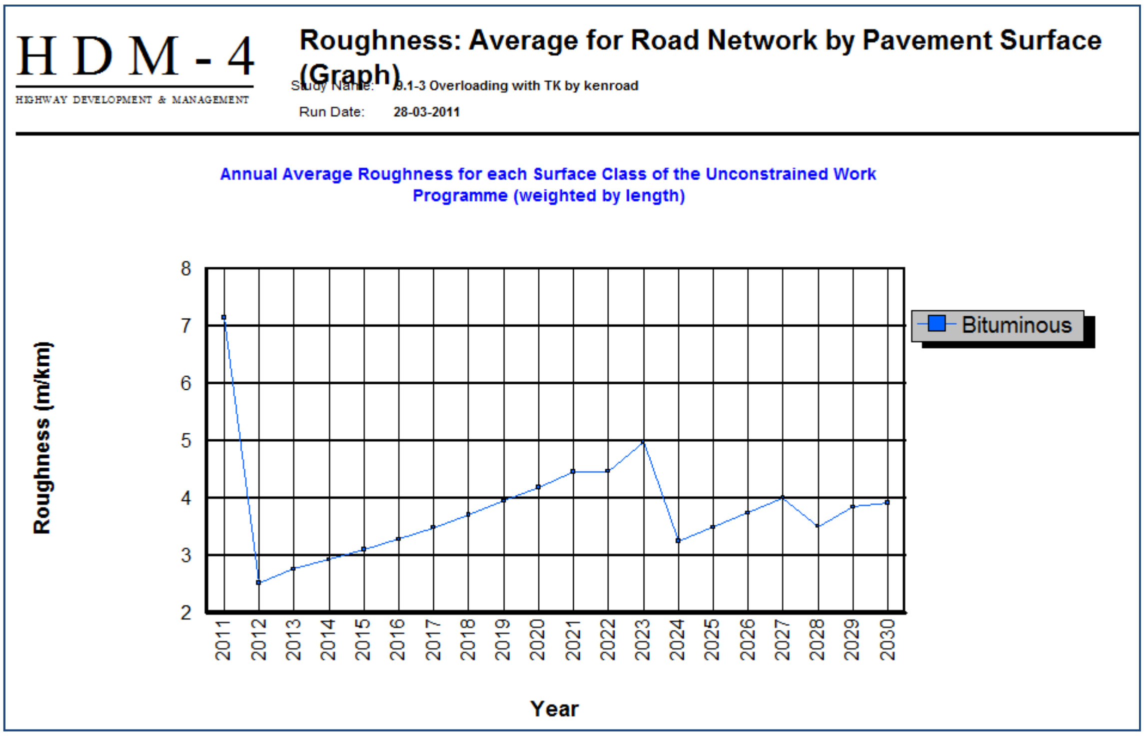
(3) Specification for ESAL and GVM

		TYPE T		TYPE UB	
		GVM (kg)	ESAL	GVM (kg)	ESAL
Overloading cases referring to actual status	2 Axles Truck	17,475	3.44	19,735	4.28
	3 Axles Truck	24,465	3.33	28,953	5.88
	Trailer	29,670	2.86	34,244	4.85
	Trailer-Truck	47,508	5.81	48,455	5.76
Non-overloaded vehicles	2 Axles Truck	16,167	2.31	15,162	1.49
	3 Axles Truck	22,456	2.27	21,865	1.91
	Trailer	28,212	2.24	29,462	2.66
	Trailer-Truck	41,847	3.77	41,452	3.09
Ideally loaded vehicles	2 Axles Truck	18,000	3.18	18,000	3.18
	3 Axles Truck	24,000	2.77	24,000	2.77
	Trailer	35,000	4.19	35,000	4.19
	Trailer-Truck	48,000	5.54	48,000	5.54

E.3.2 Analysis Results

(1) With Overloading Case for Type T

1. Progress of IRI during the project period



2. Optimized Work Programme and Cumulative Maintenance Expenditure

HDM-4 HIGHWAY DEVELOPMENT & MANAGEMENT

Work Programme Unconstrained by Year

Study Name: **9.1-3 Overloading with TK by kenroad**
Run Date: **04-04-2011**

All costs are expressed in: US Dollar (millions)

Year	Section	Road Class	Length (km)	AADT	Surface Class	Work Description	NPV/CAP	Financia Costs	Cum Costs
2011	03_AM_Paved High Traffic Poo	Primary or Trunk	80.0	10300	Bituminous	Reconstruct at 8 IRI	18.975	56.000	56.000
	02_AM_Paved High Traffic Fair	Primary or Trunk	12.0	10300	Bituminous	Overlay 50mm at 5 IRI	14.936	4.200	60.200
2012	01_AM_Paved High Traffic Goo	Primary or Trunk	32.0	10609	Bituminous	Reseal at 20% surface d	27.130	1.120	61.320
2018	01_AM_Paved High Traffic Goo	Primary or Trunk	32.0	12667	Bituminous	Reseal at 20% surface d	27.130	1.120	62.440
2021	02_AM_Paved High Traffic Fair	Primary or Trunk	12.0	13842	Bituminous	Overlay 50mm at 5 IRI	14.936	4.200	66.640
2023	01_AM_Paved High Traffic Goo	Primary or Trunk	32.0	14685	Bituminous	Reseal at 20% surface d	27.130	1.120	67.760
	03_AM_Paved High Traffic Poo	Primary or Trunk	80.0	14685	Bituminous	Overlay 50mm at 5 IRI	18.975	28.000	95.760
2027	01_AM_Paved High Traffic Goo	Primary or Trunk	32.0	16528	Bituminous	Overlay 50mm at 5 IRI	27.130	11.200	106.960
2029	02_AM_Paved High Traffic Fair	Primary or Trunk	12.0	17535	Bituminous	Overlay 50mm at 5 IRI	14.936	4.200	111.160

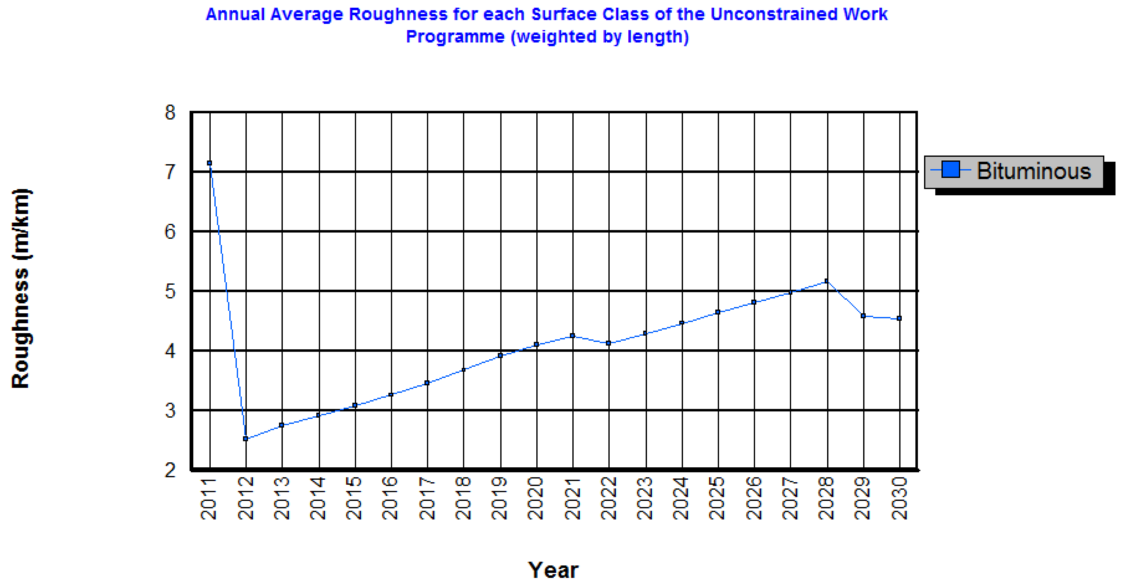
(2) Without Overloading Case for Type T

1. Progress of IRI during the project period

H D M - 4
HIGHWAY DEVELOPMENT & MANAGEMENT

Roughness: Average for Road Network by Pavement Surface (Graph)

Study Name: 9.2-3 non-Overloading with TK by Kenroad
Run Date: 28-03-2011



2. Optimized Work Programme and Cumulative Maintenance Expenditure

H D M - 4
HIGHWAY DEVELOPMENT & MANAGEMENT

Work Programme Unconstrained by Year

Study Name: 9.2-3 non-Overloading with TK by Kenroad
Run Date: 04-04-2011

All costs are expressed in: US Dollar (millions)

Year	Section	Road Class	Length (km)	AADT	Surface Class	Work Description	NPV/CAP	Financia Costs	Cum. Costs
2011	02_AM_Paved High Traffic Fair	Primary or Trunk	12.0	10300	Bituminous	Reseal at 20% surface d	106.907	0.420	0.420
	03_AM_Paved High Traffic Poo	Primary or Trunk	80.0	10300	Bituminous	Reconstruct at 8 IRI	24.509	56.000	56.420
2017	02_AM_Paved High Traffic Fair	Primary or Trunk	12.0	12298	Bituminous	Reseal at 20% surface d	106.907	0.420	56.840
2019	03_AM_Paved High Traffic Poo	Primary or Trunk	80.0	13047	Bituminous	Reseal at 20% surface d	24.509	2.800	59.640
2023	02_AM_Paved High Traffic Fair	Primary or Trunk	12.0	14685	Bituminous	Reseal at 20% surface d	106.907	0.420	60.060
2024	03_AM_Paved High Traffic Poo	Primary or Trunk	80.0	15125	Bituminous	Reseal at 20% surface d	24.509	2.800	62.860
2028	02_AM_Paved High Traffic Fair	Primary or Trunk	12.0	17024	Bituminous	Reseal at 20% surface d	106.907	0.420	63.280
2029	03_AM_Paved High Traffic Poo	Primary or Trunk	80.0	17535	Bituminous	Reseal at 20% surface d	24.509	2.800	66.080

(3) With Overloading Case for Type UB

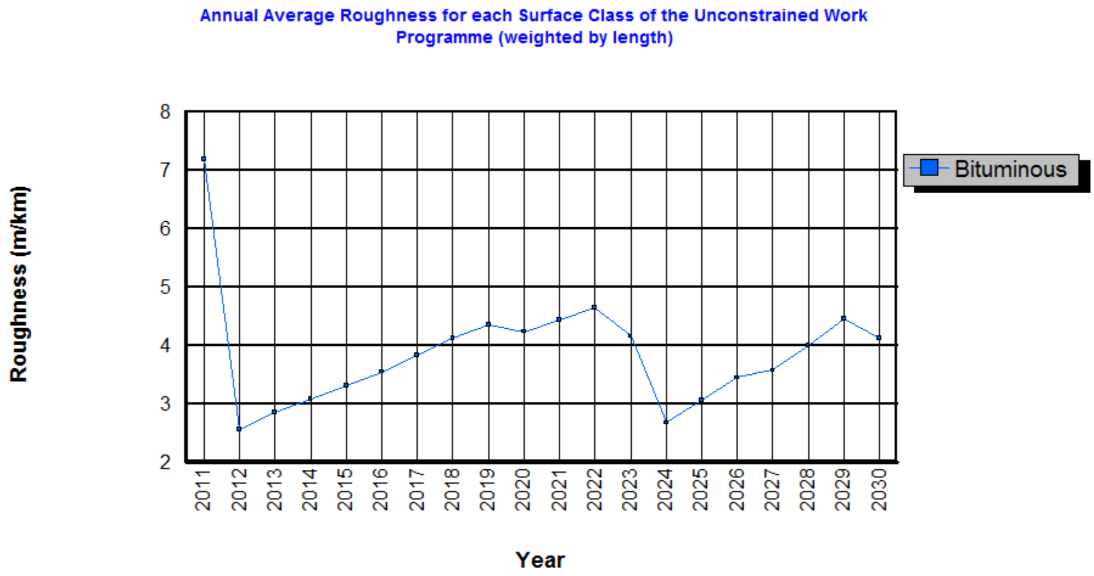
1. Progress of IRI during the project period

HDM-4
HIGHWAY DEVELOPMENT & MANAGEMENT

Roughness: Average for Road Network by Pavement Surface (Graph)

Study Name: 9.1-2 Overloading with UBR by kenroad

Run Date: 22-03-2011



2. Optimized Work Programme and Cumulative Maintenance Expenditure

HDM-4
HIGHWAY DEVELOPMENT & MANAGEMENT

Work Programme Unconstrained by Year

Study Name: 9.1-2 Overloading with UBR by kenroad

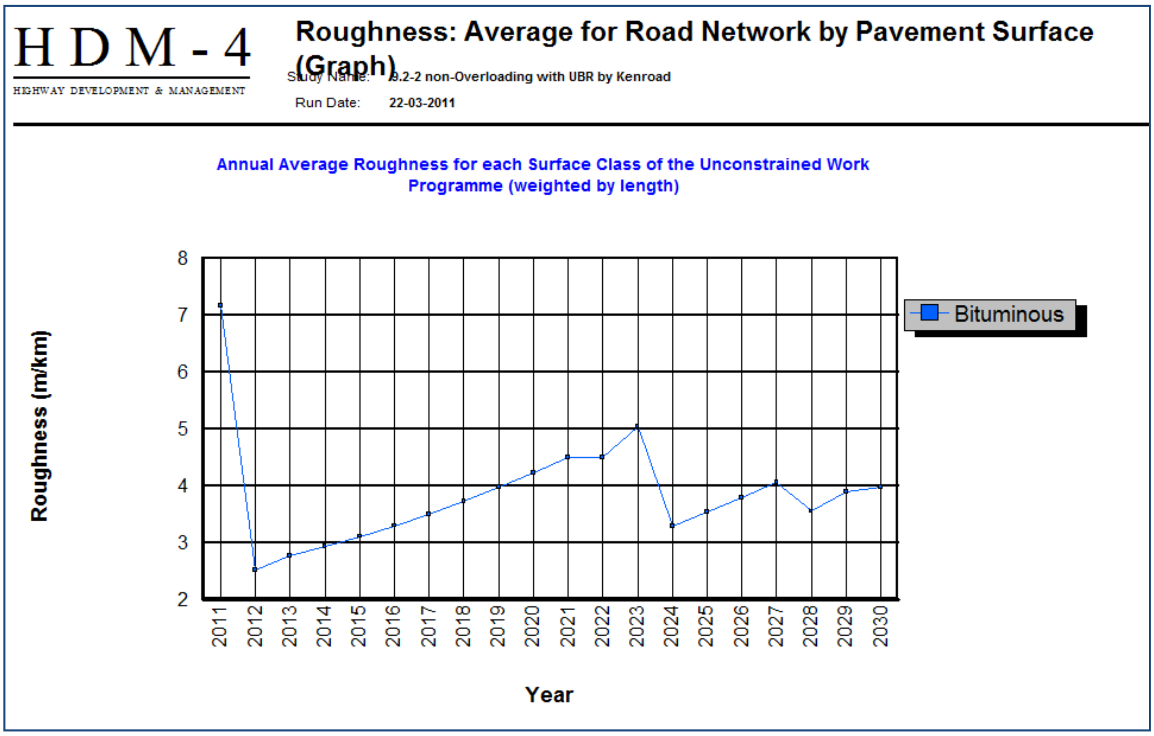
Run Date: 04-04-2011

All costs are expressed in: US Dollar (millions)

Year	Section	Road Class	Length (km)	AADT	Surface Class	Work Description	NPV/CAP	Financia Costs	Cum Costs
2011	03_AM_Paved High Traffic Poo	Primary or Trunk	80.0	10300	Bituminous	Reconstruct at 8 IRI	19.020	56.000	56.000
	02_AM_Paved High Traffic Fair	Primary or Trunk	12.0	10300	Bituminous	Overlay 50mm at 5 IRI	15.574	4.200	60.200
2012	01_AM_Paved High Traffic Goo	Primary or Trunk	32.0	10609	Bituminous	Reseal at 20% surface d	16.662	1.120	61.320
2017	01_AM_Paved High Traffic Goo	Primary or Trunk	32.0	12298	Bituminous	Reseal at 20% surface d	16.662	1.120	62.440
2018	03_AM_Paved High Traffic Poo	Primary or Trunk	80.0	12667	Bituminous	Reseal at 20% surface d	19.020	2.800	65.240
2019	02_AM_Paved High Traffic Fair	Primary or Trunk	12.0	13047	Bituminous	Overlay 50mm at 5 IRI	15.574	4.200	69.440
2022	01_AM_Paved High Traffic Goo	Primary or Trunk	32.0	14257	Bituminous	Overlay 50mm at 5 IRI	16.662	11.200	80.640
2023	03_AM_Paved High Traffic Poo	Primary or Trunk	80.0	14685	Bituminous	Overlay 50mm at 5 IRI	19.020	28.000	108.640
2026	02_AM_Paved High Traffic Fair	Primary or Trunk	12.0	16047	Bituminous	Overlay 50mm at 5 IRI	15.574	4.200	112.840
2029	01_AM_Paved High Traffic Goo	Primary or Trunk	32.0	17535	Bituminous	Overlay 50mm at 5 IRI	16.662	11.200	124.040

(4) Without Overloading Case for Type UB

1. Progress of IRI during the project period



2. Optimized Work Programme and Cumulative Maintenance Expenditure

HDM-4
HIGHWAY DEVELOPMENT & MANAGEMENT

Work Programme Unconstrained by Year

Study Name: 9.2-2 non-Overloading with UBR by Kenroad
Run Date: 05-04-2011

All costs are expressed in: US Dollar (millions)

Year	Section	Road Class	Length (km)	AADT	Surface Class	Work Description	NPV/CAP	Financia Costs	Cum Costs
2011	03_AM_Paved High Traffic Poo	Primary or Trunk	80.0	10300	Bituminous	Reconstruct at 8 IRI	19.637	56.000	56.000
	02_AM_Paved High Traffic Fair	Primary or Trunk	12.0	10300	Bituminous	Overlay 50mm at 5 IRI	15.539	4.200	60.200
2012	01_AM_Paved High Traffic Goo	Primary or Trunk	32.0	10609	Bituminous	Reseal at 20% surface d	28.227	1.120	61.320
2018	01_AM_Paved High Traffic Goo	Primary or Trunk	32.0	12667	Bituminous	Reseal at 20% surface d	28.227	1.120	62.440
2021	02_AM_Paved High Traffic Fair	Primary or Trunk	12.0	13842	Bituminous	Overlay 50mm at 5 IRI	15.539	4.200	66.640
2023	01_AM_Paved High Traffic Goo	Primary or Trunk	32.0	14685	Bituminous	Reseal at 20% surface d	28.227	1.120	67.760
	03_AM_Paved High Traffic Poo	Primary or Trunk	80.0	14685	Bituminous	Overlay 50mm at 5 IRI	19.637	28.000	95.760
2027	01_AM_Paved High Traffic Goo	Primary or Trunk	32.0	16528	Bituminous	Overlay 50mm at 5 IRI	28.227	11.200	106.960
2029	02_AM_Paved High Traffic Fair	Primary or Trunk	12.0	17535	Bituminous	Overlay 50mm at 5 IRI	15.539	4.200	111.160

Appendix F Overloading Charge Estimates, Input Data, and Calculation Results

F.1 Estimation using the Results of the Funding Needs Estimation

Using the input data of the HDM Model for the Funding Needs Estimation by applying Type T loading (low rate of overloading), described in Section 4.3 and Appendix D.1, the sum of the number of ESALs per day at each section and the length of each section (km) of the model road network in this HDM analysis was calculated, which was converted to the total number of ESALs per day for the model road network. Then, assuming 3% annual traffic growth, the total number of ESALs over the 20-year analysis period for each model road network was estimated. The level of responsibility of a vehicle axle for road maintenance cost per ESAL per km was estimated from the road maintenance cost for the analysis period per km calculated in Section 4.3 and the average ESAL for that period. This estimation was conducted for both Power 4.0 Case and Power 4.5 Case as described in Section 4.5.

The data used for this calculation and the calculation results for both the Power 4.0 Case and Power 4.5 Case are presented on the following pages.

F.1.1 Power 4.0 Case (Type T)

Common Assumption of Average ESAL

Vehicle Type	Cars	Pickup	Small Bus	Bus	2 Axle	2.5 Axle	3 Axle	4.5 Axle	6 Axle
ESAL	0.00	0.01	0.01	0.80	2.57	2.55	2.49	2.86	4.56

Calculation Result of the Total Number of ESALs*km per Day (2010) and Input Data of HDM Model Used for this Calculation

		Traffic Composition									Road Length (km)				ESALs* km/day (2010)
Country	Traffic Volume	Cars	Pickup	Small Bus	Bus	2 Axle	2.5 Axle	3 Axle	4.5 Axle	6 Axle	Good	Fair	Poor	Total	
Kenya	35,657	36.7%	21.0%	28.4%	1.6%	-	7.1%	-	3.1%	2.1%	32	12	80	124	1,696,081
	5,799	23.7%	15.9%	16.8%	2.6%	-	9.1%	-	16.8%	15.0%	276	39	271	586	4,835,055
	1,000	21.5%	22.8%	21.4%	2.0%	-	11.9%	-	11.3%	9.1%	65	92	1,048	1,205	1,281,548
Tanzania	26,396	35.2%	21.7%	21.1%	13.1%	4.6%	-	2.6%	1.3%	0.5%	24	-	-	24	221,565
	9,509	19.0%	24.7%	22.2%	8.1%	6.3%	-	6.9%	5.7%	7.1%	148	82	-	230	1,944,682
	1,203	16.6%	20.7%	11.0%	14.1%	8.4%	-	10.0%	12.7%	6.6%	1,908	344	-	2,252	3,370,676
Burundi	1,836	23.9%	21.7%	13.7%	3.0%	27.1%	-	7.5%	0.3%	2.8%	22	6	0	29	54,797
	636	28.7%	29.7%	18.2%	3.9%	12.2%	-	1.9%	0.5%	5.0%	44	0	0	44	17,854
	311	48.9%	23.5%	3.2%	6.1%	9.4%	-	2.8%	1.0%	5.2%	40	2	0	42	8,294
Rwanda	2,386	10.5%	2.6%	66.7%	1.3%	15.3%	-	2.0%	0.6%	1.0%	42	0	0	42	52,918
	1,368	11.0%	2.0%	71.2%	1.1%	10.7%	-	1.5%	1.1%	1.2%	42	0	0	42	23,817
	1,097	9.2%	1.4%	73.2%	1.5%	10.1%	-	1.5%	1.4%	1.7%	35	0	0	35	16,677
	3,020	31.6%	4.1%	59.2%	0.3%	4.0%	-	0.5%	0.1%	0.2%	4	0	0	4	1,476
	104	21.4%	3.1%	45.9%	6.1%	4.1%	-	9.2%	3.1%	7.1%	28	2	0	30	2,464
	3,038	15.8%	3.2%	45.8%	1.0%	25.1%	-	5.1%	2.4%	1.5%	8	0	0	8	21,989
	1,012	10.5%	8.7%	49.2%	2.9%	12.9%	-	5.1%	5.9%	4.8%	16	0	0	16	14,379
	836	11.1%	8.7%	43.2%	3.6%	14.6%	-	6.7%	6.6%	5.4%	23	0	0	23	19,409
	561	11.9%	0.9%	35.5%	5.7%	16.9%	-	10.1%	10.7%	8.3%	27	0	2	28	22,617
	4,334	18.1%	9.6%	61.3%	3.1%	5.5%	-	0.4%	1.9%	0.2%	9	0	0	9	9,743
	4,334	18.1%	9.6%	61.3%	3.1%	5.5%	-	0.4%	1.9%	0.2%	17	0	0	17	17,442
	2,093	12.0%	4.3%	61.7%	2.1%	15.1%	-	0.8%	3.6%	0.3%	31	0	0	31	35,896
	1,506	13.1%	3.2%	72.7%	2.5%	8.2%	-	0.1%	0.1%	0.0%	3	0	0	3	1,241
	1,632	10.2%	15.6%	54.6%	5.9%	7.8%	-	0.4%	5.0%	0.4%	14	0	0	14	9,805

		Traffic Composition									Road Length (km)				ESALs* km/day (2010)
Country	Traffic Volume	Cars	Pickup	Small Bus	Bus	2 Axle	2.5 Axle	3 Axle	4.5 Axle	6 Axle	Good	Fair	Poor	Total	
	944	9.5%	3.9%	59.2%	0.1%	17.4%	-	0.3%	9.0%	0.5%	25	7	0	32	22,334
	509	5.5%	2.8%	53.8%	0.6%	19.4%	-	0.8%	16.1%	1.0%	11	0	0	11	5,620
	387	6.7%	2.1%	61.5%	0.3%	12.9%	-	0.8%	14.5%	1.3%	9	1	0	10	3,229
	365	8.5%	2.8%	48.6%	0.0%	4.9%	-	4.2%	27.5%	3.5%	27	12	0	39	16,770
	628	9.7%	6.1%	65.8%	4.9%	9.7%	-	1.0%	1.6%	1.3%	25	2	0	27	7,054
	479	6.7%	2.1%	66.7%	1.3%	16.9%	-	1.7%	2.5%	2.1%	26	0	0	26	8,310
	184	9.2%	3.2%	57.3%	3.8%	13.5%	-	5.9%	4.3%	2.7%	28	24	11	63	8,978
	481	7.7%	1.7%	59.8%	3.1%	17.8%	-	3.7%	2.9%	3.3%	5	14	8	26	10,128
	616	30.2%	4.2%	46.3%	0.0%	14.8%	-	1.0%	1.6%	1.8%	5	0	0	5	1,587
Uganda	13,908	27.5%	23.6%	29.1%	1.2%	6.8%	-	7.7%	0.5%	3.5%	46	38	1	84	653,432
	2,245	18.4%	22.2%	22.6%	4.3%	8.1%	-	12.7%	1.6%	10%	427	268	55	750	1,801,684

Calculation Result of the Total Number of ESALs for the Model Road Network for 20 years (2010-2030)

	Total ESALs for 20 Years				
Year	Kenya	Tanzania	Burundi	Rwanda	Uganda
2010	1,489,102	806,455	257,180	226,124	1,074,239
2011	1,533,775	830,649	264,895	232,908	1,106,466
2012	1,579,788	855,568	272,842	239,895	1,139,660
2013	1,627,181	881,235	281,027	247,092	1,173,850
2014	1,675,997	907,672	289,458	254,505	1,209,066
2015	1,726,277	934,903	298,142	262,140	1,245,338
2016	1,778,065	962,950	307,086	270,004	1,282,698
2017	1,831,407	991,838	316,299	278,104	1,321,179
2018	1,886,349	1,021,593	325,788	286,447	1,360,814
2019	1,942,940	1,052,241	335,561	295,041	1,401,638
2020	2,001,228	1,083,808	345,628	303,892	1,443,688
2021	2,061,265	1,116,323	355,997	313,009	1,486,998
2022	2,123,103	1,149,812	366,677	322,399	1,531,608
2023	2,186,796	1,184,307	377,677	332,071	1,577,556
2024	2,252,400	1,219,836	389,007	342,033	1,624,883

Year	Total ESALs for 20 Years				
	Kenya	**Tanzania**	**Burundi**	**Rwanda**	**Uganda**
2025	2,319,972	1,256,431	400,678	352,294	1,673,630
2026	2,389,571	1,294,124	412,698	362,863	1,723,838
2027	2,461,258	1,332,948	425,079	373,749	1,775,554
2028	2,535,096	1,372,936	437,831	384,961	1,828,820
2029	2,611,149	1,414,124	450,966	396,510	1,883,685
Total (20 years)	**40,012,715**	**21,669,755**	**6,910,515**	**6,076,037**	**28,865,207**

<u>Responsibility of a Vehicle Axle per ESAL for Road Maintenance Cost</u>

Country	M. Cost ($) ('10-'30)	Road Length (km)	M. Cost (US$)/ km ('10-'30)	ESALs*km/day (2010)	Total ESALs/day (2010)	Total ESALs ('10-'30) with 3% annual traffic growth	M. Cost (US$)/ ESAL/km)	M. Cost (US$)/ ESAL/100 km
Kenya	1,266,200,000	1,915	661201.04	7,812,683	4,080	40,012,715	0.0165	1.65
Tanzania	1,163,000,000	2,506	464086.19	5,536,923	2,209	21,669,755	0.0214	2.14
Burundi	20,200,000	115	175835.65	80,945	705	6,910,515	0.0254	2.54
Rwanda	64,800,000	539	120235.35	333,885	620	6,076,037	0.0198	1.98
Uganda	451,600,000	834	541364.78	2,455,116	2,943	28,865,207	0.0188	1.88
Average	**-**	**-**	**392,544.60**	3,243,910	**2,111**	**20,706,846**	**0.0204**	**2.04**

F.1.2 Power 4.5 Case (Type T)

Common Assumption of Average ESAL

Vehicle Type	Cars	Pickup	Small Bus	Bus	2 Axle	2.5 Axle	3 Axle	4.5 Axle	6 Axle
ESAL	0.00	0.01	0.01	0.68	2.76	2.68	2.49	2.85	4.49

Calculation Result of the Total Number of ESALs*km per Day (2010) and Input Data of HDM Model Used for this Calculation

		Traffic Composition									Road Length (km)				ESALs* km/day (2010)
Country	Traffic Volume	Cars	Pickup	Small Bus	Bus	2 Axle	2.5 Axle	3 Axle	4.5 Axle	6 Axle	Good	Fair	Poor	Total	
Kenya	35,657	36.7%	21.0%	28.4%	1.6%	-	7.1%	-	3.1%	2.1%	32	12	80	124	1,710,391
	5,799	23.7%	15.9%	16.8%	2.6%	-	9.1%	-	16.8%	15.0%	276	39	271	586	4,820,430
	1,000	21.5%	22.8%	21.4%	2.0%	-	11.9%	-	11.3%	9.1%	65	92	1,048	1,205	1,286,470
Tanzania	26,396	35.2%	21.7%	21.1%	13.1%	4.6%	-	2.6%	1.3%	0.5%	24	-	-	24	215,128
	9,509	19.0%	24.7%	22.2%	8.1%	6.3%	-	6.9%	5.7%	7.1%	148	82	-	230	1,932,229
	1,203	16.6%	20.7%	11.0%	14.1%	8.4%	-	10.0%	12.7%	6.6%	1,908	344	-	2,252	3,346,105
Burundi	1,836	23.9%	21.7%	13.7%	3.0%	27.1%	-	7.5%	0.3%	2.8%	22	6	0	29	57,031
	636	28.7%	29.7%	18.2%	3.9%	12.2%	-	1.9%	0.5%	5.0%	44	0	0	44	18,196
	311	48.9%	23.5%	3.2%	6.1%	9.4%	-	2.8%	1.0%	5.2%	40	2	0	42	8,364
Rwanda	2386	10.5%	2.6%	66.7%	1.3%	15.3%	-	2.0%	0.6%	1.0%	42	0	0	42	55,197
	1368	11.0%	2.0%	71.2%	1.1%	10.7%	-	1.5%	1.1%	1.2%	42	0	0	42	24,612
	1097	9.2%	1.4%	73.2%	1.5%	10.1%	-	1.5%	1.4%	1.7%	35	0	0	35	17,135
	3020	31.6%	4.1%	59.2%	0.3%	4.0%	-	0.5%	0.1%	0.2%	4	0	0	4	1,517
	104	21.4%	3.1%	45.9%	6.1%	4.1%	-	9.2%	3.1%	7.1%	28	2	0	30	2,442
	3038	15.8%	3.2%	45.8%	1.0%	25.1%	-	5.1%	2.4%	1.5%	8	0	0	8	22,971
	1012	10.5%	8.7%	49.2%	2.9%	12.9%	-	5.1%	5.9%	4.8%	16	0	0	16	14,600
	836	11.1%	8.7%	43.2%	3.6%	14.6%	-	6.7%	6.6%	5.4%	23	0	0	23	19,710
	561	11.9%	0.9%	35.5%	5.7%	16.9%	-	10.1%	10.7%	8.3%	27	0	2	28	22,866
	4334	18.1%	9.6%	61.3%	3.1%	5.5%	-	0.4%	1.9%	0.2%	9	0	0	9	9,845
	4334	18.1%	9.6%	61.3%	3.1%	5.5%	-	0.4%	1.9%	0.2%	17	0	0	17	17,625
	2093	12.0%	4.3%	61.7%	2.1%	15.1%	-	0.8%	3.6%	0.3%	31	0	0	31	37,297
	1506	13.1%	3.2%	72.7%	2.5%	8.2%	-	0.1%	0.1%	0.0%	3	0	0	3	1,284
	1632	10.2%	15.6%	54.6%	5.9%	7.8%	-	0.4%	5.0%	0.4%	14	0	0	14	9,870

Country	Traffic Volume	Traffic Composition									Road Length (km)				ESALs* km/day (2010)
		Cars	Pickup	Small Bus	Bus	2 Axle	2.5 Axle	3 Axle	4.5 Axle	6 Axle	Good	Fair	Poor	Total	
	944	9.5%	3.9%	59.2%	0.1%	17.4%	-	0.3%	9.0%	0.5%	25	7	0	32	23,154
	509	5.5%	2.8%	53.8%	0.6%	19.4%	-	0.8%	16.1%	1.0%	11	0	0	11	5,780
	387	6.7%	2.1%	61.5%	0.3%	12.9%	-	0.8%	14.5%	1.3%	9	1	0	10	3,298
	365	8.5%	2.8%	48.6%	0.0%	4.9%	-	4.2%	27.5%	3.5%	27	12	0	39	16,779
	628	9.7%	6.1%	65.8%	4.9%	9.7%	-	1.0%	1.6%	1.3%	25	2	0	27	7,177
	479	6.7%	2.1%	66.7%	1.3%	16.9%	-	1.7%	2.5%	2.1%	26	0	0	26	8,621
	184	9.2%	3.2%	57.3%	3.8%	13.5%	-	5.9%	4.3%	2.7%	28	24	11	63	9,151
	481	7.7%	1.7%	59.8%	3.1%	17.8%	-	3.7%	2.9%	3.3%	5	14	8	26	10,421
	616	30.2%	4.2%	46.3%	0.0%	14.8%	-	1.0%	1.6%	1.8%	5	0	0	5	1,656
Uganda	13,908	27.5%	23.6%	29.1%	1.2%	6.8%	-	7.7%	0.5%	3.5%	46	38	1	84	660,697
	2,245	18.4%	22.2%	22.6%	4.3%	8.1%	-	12.7%	1.6%	10%	427	268	55	750	1,803,071

Calculation Result of the Total Number of ESALs for the Model Road Network for 20 years (2010–2030)

Year	Total ESALs for 20 Years				
	Kenya	Tanzania	Burundi	Rwanda	Uganda
2010	1,489,980	800,125	265,586	232,301	1,078,025
2011	1,534,679	824,129	273,553	239,270	1,110,366
2012	1,580,720	848,853	281,760	246,448	1,143,677
2013	1,628,141	874,318	290,213	253,841	1,177,987
2014	1,676,985	900,548	298,919	261,456	1,213,327
2015	1,727,295	927,564	307,887	269,300	1,249,726
2016	1,779,114	955,391	317,123	277,379	1,287,218
2017	1,832,487	984,053	326,637	285,701	1,325,835
2018	1,887,462	1,013,574	336,436	294,272	1,365,610
2019	1,944,086	1,043,982	346,529	303,100	1,406,578
2020	2,002,408	1,075,301	356,925	312,193	1,448,775
2021	2,062,481	1,107,560	367,633	321,558	1,492,239
2022	2,124,355	1,140,787	378,662	331,205	1,537,006
2023	2,188,086	1,175,011	390,022	341,141	1,583,116
2024	2,253,728	1,210,261	401,722	351,376	1,630,609

	Total ESALs for 20 Years				
Year	**Kenya**	**Tanzania**	**Burundi**	**Rwanda**	**Uganda**
2025	2,321,340	1,246,569	413,774	361,917	1,679,528
2026	2,390,980	1,283,966	426,187	372,774	1,729,914
2027	2,462,710	1,322,485	438,973	383,958	1,781,811
2028	2,536,591	1,362,159	452,142	395,476	1,835,265
2029	2,612,689	1,403,024	465,706	407,341	1,890,323
Total (20 years)	**40,036,315**	**21,499,660**	**7,136,390**	**6,242,006**	**28,966,934**

Responsibility of a Vehicle Axle per ESAL for Road Maintenance Cost

Country	M. Cost ($) ('10-'30)	Road Length (km)	M. Cost (US$)/km ('10-'30)	ESALs*km/day (2010)	Total ESALs/ day (2010)	Total ESALs ('10-'30) with 3% annual traffic growth	M. Cost (US$)/ ESAL/km)	M. Cost (US$)/ ESAL/100km
Kenya	1,266,200,000	1,915	661201.04	7,817,291	4,082	40,036,315	0.0165	1.65
Tanzania	1,163,000,000	2,506	464086.19	5,493,461	2,192	21,499,660	0.0216	2.16
Burundi	20,200,000	115	175835.65	83,590	728	7,136,390	0.0246	2.46
Rwanda	64,800,000	539	120235.35	343,005	636	6,242,006	0.0193	1.93
Uganda	451,600,000	834	541364.78	2,463,768	2,953	28,966,934	0.0187	1.87
Average	**-**	**-**	**392,544.60**	**3,240,223**	**2,118**	**20,776,261**	**0.0201**	**2.01**

F.2 Estimation Using the Results of the Analysis With/Without Overloading

For both Types T (low rate of overloading) and UB (high rate overloading), overloaded axles were extracted from the axles of all vehicles weighed at sample weighbridge stations, and the sum of the overloaded proportion of ESALs of those overloaded axles (i.e., the sum of the difference between the ESALs of overloaded axles and ESALs at the axle load limits) by number of axles by vehicle type were calculated. Then, adapting the sum of the overloaded proportion of ESALs to the number of vehicles weighed, the sum of the overloaded proportion of ESALs per day under the assumptions of with/without HDM-4 analysis, described in Section 4.4 and Appendix D.2, was estimated. Converting the total overloaded proportion of ESALs per day to a 20-year period with 3% annual traffic growth, the overloaded proportion of ESALs of the “target” section of 124 km in the analysis period was calculated. Finally, the level of responsibility of an overloaded axle for road maintenance cost per overloaded proportion of ESAL per km was estimated from the difference of the road maintenance cost between the with and without cases, and the total overloaded proportion of ESALs of overloaded axles described above.

The data used for this calculation and calculation results for both Types T and UB are as follows.

F.2.1 Type T

Sum of Overloaded Portion of ESALs of Overloaded Axles (Actual Data from Tanzania)

Vehicle	Configuration	Axle 1	Axle 2	Axle 3	Axle 4	Axle 5	Axle 6	Total	# of Vehicles Weighted
2 Axle	1*2	5.88	116.81	-	-	-	-	122.69	194
3 Axle	1*22	7.03	14.39	14.39	-	-	-	35.80	75
4 Axle	11*22	1.94	3.63	0.00	0.00	-	-	5.58	19
5 Axle	1*2-222	0.00	0.00	1.53	7.78	7.78		17.10	6
6 Axle	1*22-222	2.04	32.29	32.29	49.40	48.26	48.26	212.55	145
Total	-	-	-	-	-	-	-	**393.71**	**439**

Sum of Overloaded Proportion of ESALs of Overloaded Axles per Day (2010) under the Assumption of With/Without Analysis

Vehicle	Configuration	Axle 1	Axle 2	Axle 3	Axle 4	Axle 5	Axle 6	Total	ADT by Vehicle Category
2 Axle	1*2	0.65	56.33	-	-	-	-	56.98	380
3 Axle	1*22	1.11	12.13	12.13	-	-	-	25.37	150
4 Axle	11*22	0.96	3.75	0.00	0.00	-	-	4.72	38
5 Axle	1*2-222	0.00	0.00	1.21	10.02	10.02	-	21.25	12
6 Axle	1*22-222	0.43	30.45	30.45	15.14	14.67	14.67	105.80	320
Total	-	-	-	-	-	-	-	**214.11**	**900**

Sum of Overloaded Proportion of ESALs of Overloaded Axles for 20 years (2010-2029) under the Assumption of With/Without Analysis

Year	Overloaded ESALs (with 3% annual traffic growth)
2010	78,150
2011	80,494
2012	82,909
2013	85,397
2014	87,958
2015	90,597
2016	93,315
2017	96,115
2018	98,998
2019	101,968
2020	105,027
2021	108,178
2022	111,423
2023	114,766
2024	118,209
2025	121,755
2026	125,408
2027	129,170
2028	133,045
2029	137,036
Total (20 years)	**2,099,919**

Responsibility of Overloaded Proportion of ESALs for Road Maintenance Cost

Maintenance Cost for 20 years (US$)			Responsibility per Overloaded Axle	
With Case	Without Case	With - Without	(US$/124km/ESAL)	(US$/km/ESAL)
111,160,000	91,560,000	19,600,000	9.333694095	0.075271727

F.2.2 Type UB

Sum of Overloaded Proportion of ESALs of Overloaded Axles (Actual Data from Mbarara and Masaka Weighbridges)

Vehicle	Configuration	Axle 1	Axle 2	Axle 3	Axle 4	Axle 5	Axle 6	Total	# of Vehicles Weighted
2 Axle	1*2	275.48	7,852.28	-	-	-	-	8,127.76	2,271
3 Axle	1*22	712.55	10,503.30	4,213.53	-	-	-	15,429.38	3,293
4 Axle	11*22	35.71	110.22	213.42	107.25	-	-	466.60	276
5 Axle	1*2-222	22.24	1,271.12	290.47	166.69	189.23	-	1,939.75	539
6 Axle	1*22-222	238.58	3,444.38	5,694.74	2,957.85	2,363.29	2,491.09	17,189.93	4,699
Total	-	-	-	-	-	-	-	**43,153.42**	**11,078**

Sum of Overloaded Proportion of ESAL of Overloaded Axles per Day (2010) under the Assumption of With/Without Analysis

Vehicle	Configuration	Axle 1	Axle 2	Axle 3	Axle 4	Axle 5	Axle 6	Total	ADT by Vehicle Category
2 Axle	1*2	12.53	368.45	-	-	-	-	380.98	180
3 Axle	1*22	21.72	715.97	252.80	-	-	-	990.50	260
4 Axle	11*22	1.19	7.40	8.56	2.65	-	-	19.81	20
5 Axle	1*2-222	0.41	54.52	13.28	5.94	6.92	-	81.07	40
6 Axle	1*22-222	7.95	188.11	320.95	186.21	117.97	129.48	950.67	400
Total	-	-	-	-	-	-	-	**2,423.02**	**900**

Sum of Overloaded Proportion of ESALs of Overloaded Axles for 20 years (2010–2029) under the Assumption of With/Without Analysis

Year	Overloaded ESAL (with 3% annual traffic growth)
2010	884,403
2011	910,936
2012	938,264
2013	966,412
2014	995,404
2015	1,025,266
2016	1,056,024
2017	1,087,705
2018	1,120,336
2019	1,153,946
2020	1,188,564
2021	1,224,221
2022	1,260,948
2023	1,298,776
2024	1,337,740
2025	1,377,872
2026	1,419,208
2027	1,461,784
2028	1,505,638
2029	1,550,807
Total (20 years)	**23,764,253**

Responsibility of Overloaded Proportion of ESALs for Road Maintenance Cost

Maintenance Cost for 20 years (US$)			Responsibility per Overloaded Axle	
With Case	**Without Case**	**With - Without**	**(US$/ 124km/ ESAL)**	**(US$/ km/ ESAL)**
124,040,000	111,160,000	12,880,000	0.541990535	0.004370891

Appendix G Axle Load Limit Analysis, Input Data, and Modelling Results

(1) Axle Load and GVM Specifications of an "Ideal" Vehicle for a Various ESALs

1) ESAL=6

Vehicle	Configurati	No.1	No.2	No.3	No.4	No.5	No.6	No.7	GVW	ESAL	GVM	ESAL	total carryin	vehicle number		ratio
2 Axle	1*2	6000	8000						14000	1.22	12908	1.025008	3195350	248	2axle	41.5%
3 Axle	1*22	6000	6000	6000					18000	0.88	16596	0.739101	1684200	101	3axle	17.0%
4 Axle	11*22	4000	4000	6000	6000				20000	0.70	18440	0.590064	510750	28	4-5axle	6.0%
5 Axle	1*2-222	6000	8000	6000	6000	6000			32000	2.10	29504	1.764108	231000	8	6axle	35.5%
6 Axle	1*22-222	6000	6000	6000	6000	6000	6000		36000	1.76	33192	1.478201	6384900	192		
7 Axle	1*22+22*2	6000	6000	6000	6000	6000	6000	6000	42000	2.05	38724	1.724568	745350	19		

2) ESAL=8

Vehicle	Configurati	No.1	No.2	No.3	No.4	No.5	No.6	No.7	GVW	ESAL	GVM	ESAL	total carryin	vehicle number		ratio
2 Axle	1*2	8000	10000						18000	3.18	16596	2.67962	3195350	193	2axle	42.5%
3 Axle	1*22	8000	8000	8000					24000	2.77	22128	2.335923	1684200	76	3axle	16.8%
4 Axle	11*22	6000	6000	8000	8000				28000	2.43	25816	2.050016	510750	20	4-5axle	5.7%
5 Axle	1*2-222	8000	10000	8000	8000	8000			42000	5.96	38724	5.015543	231000	6	6axle	35.0%
6 Axle	1*22-222	8000	8000	8000	8000	8000	8000		48000	5.55	44256	4.671846	6384900	144		
7 Axle	1*22+22*2	8000	8000	8000	8000	8000	8000	8000	56000	6.47	51632	5.450487	745350	14		

3) ESAL=10

Vehicle	Configurati	No.1	No.2	No.3	No.4	No.5	No.6	No.7	GVW	ESAL	GVM	ESAL	total carryin	vehicle number		ratio
2 Axle	1*2	10000	12000						22000	6.94	20284	5.842849	3195350	158	2axle	43.1%
3 Axle	1*22	10000	10000	10000					30000	6.77	27660	5.702937	1684200	61	3axle	16.7%
4 Axle	11*22	8000	8000	10000	10000				36000	6.36	33192	5.35924	510750	15	4-5axle	5.5%
5 Axle	1*2-222	10000	12000	10000	10000	10000			52000	13.71	47944	11.54579	231000	5	6axle	34.7%
6 Axle	1*22-222	10000	10000	10000	10000	10000	10000		60000	13.55	55320	11.40587	6384900	115		
7 Axle	1*22+22*2	10000	10000	10000	10000	10000	10000	10000	70000	15.80	64540	13.30685	745350	12		

4) ESAL=12

Vehicle	Configurati	No.1	No.2	No.3	No.4	No.5	No.6	No.7	GVW	ESAL	GVM	ESAL	total carryin	vehicle number		ratio
2 Axle	1*2	12000	14000						26000	13.35	23972	11.24467	3195350	133	2axle	43.5%
3 Axle	1*22	12000	12000	12000					36000	14.04	33192	11.82561	1684200	51	3axle	16.6%
4 Axle	11*22	10000	10000	12000	12000				44000	13.88	40568	11.6857	510750	13	4-5axle	5.4%
5 Axle	1*2-222	12000	14000	12000	12000	12000			62000	27.40	57164	23.07028	231000	4	6axle	34.5%
6 Axle	1*22-222	12000	12000	12000	12000	12000	12000		72000	28.09	66384	23.65122	6384900	96		
7 Axle	1*22+22*2	12000	12000	12000	12000	12000	12000	12000	84000	32.77	77448	27.59309	745350	10		

5) ESAL=14

Vehicle	Configurati	No.1	No.2	No.3	No.4	No.5	No.6	No.7	GVW	ESAL	GVM	ESAL	total carryin	vehicle number		ratio
2 Axle	1*2	14000	16000						30000	23.47	27660	19.76106	3195350	116	2axle	43.8%
3 Axle	1*22	14000	14000	14000					42000	26.02	38724	21.9084	1684200	43	3axle	16.5%
4 Axle	11*22	12000	12000	14000	14000				52000	26.71	47944	22.48934	510750	11	4-5axle	5.4%
5 Axle	1*2-222	14000	16000	14000	14000	14000			72000	49.49	66384	41.66946	231000	3	6axle	34.4%
6 Axle	1*22-222	14000	14000	14000	14000	14000	14000		84000	52.04	77448	43.8168	6384900	82		
7 Axle	1*22+22*2	14000	14000	14000	14000	14000	14000	14000	98000	60.71	90356	51.1196	745350	8		

(2) HDM Results for the ADT 10,000 Case

1. IRI 4 ESAL 6 case
2. IRI 4 ESAL 8 case
3. IRI 4 ESAL 10 case
4. IRI 4 ESAL 12 case
5. IRI 4 ESAL 14 case
6. IRI 7 ESAL 6 case
7. IRI 7 ESAL 8 case
8. IRI 7 ESAL 10 case
9. IRI 7 ESAL 12 case
10. IRI 7 ESAL 14 case

(3) HDM Results for the ADT 10,000 Case

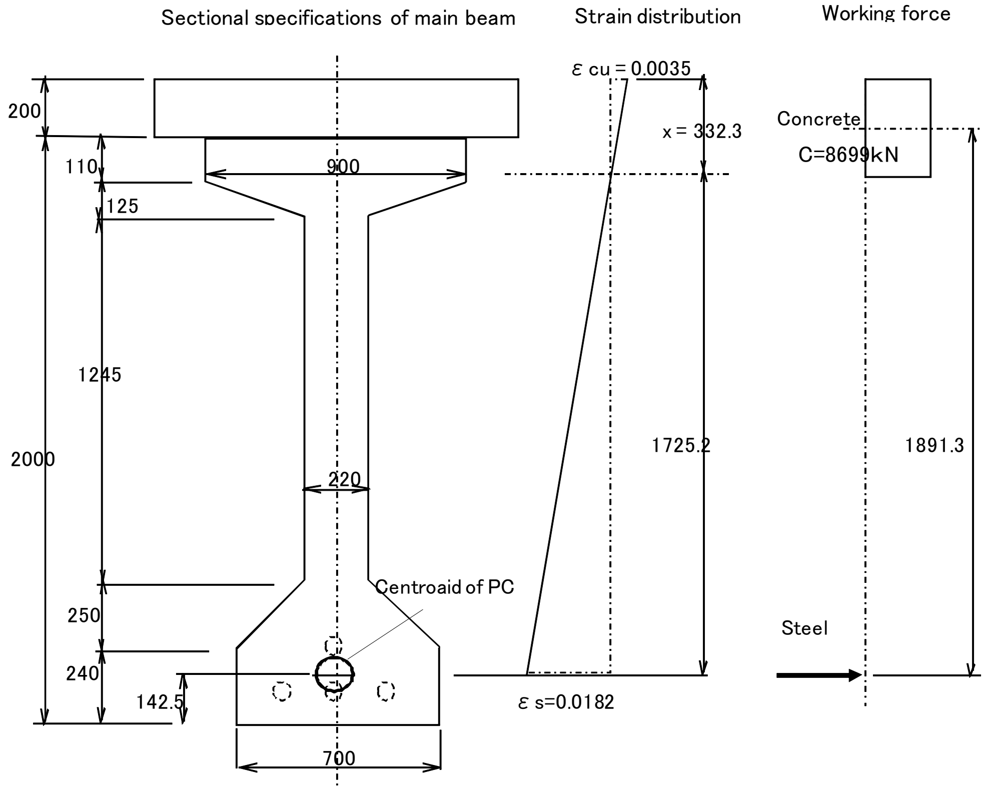
1. IRI 4 ESAL 6 case
2. IRI 4 ESAL 8 case
3. IRI 4 ESAL 10 case
4. IRI 4 ESAL 12 case
5. IRI 4 ESAL 14 case
6. IRI 7 ESAL 6 case
7. IRI 7 ESAL 8 case
8. IRI 7 ESAL 10 case
9. IRI 7 ESAL 12 case
10. IRI 7 ESAL 14 case

(4) HDM Results for the ADT 10,000 Case

1. IRI 4 ESAL 6 case
2. IRI 4 ESAL 8 case
3. IRI 4 ESAL 10 case
4. IRI 4 ESAL 12 case
5. IRI 4 ESAL 14 case
6. IRI 7 ESAL 6 case
7. IRI 7 ESAL 8 case
8. IRI 7 ESAL 10 case
9. IRI 7 ESAL 12 case
10. IRI 7 ESAL 14 case

Appendix H Bridge Strength Evaluation Data

Consideration on the ultimate limit state (main beam at the center of bridge span) was based on the following:



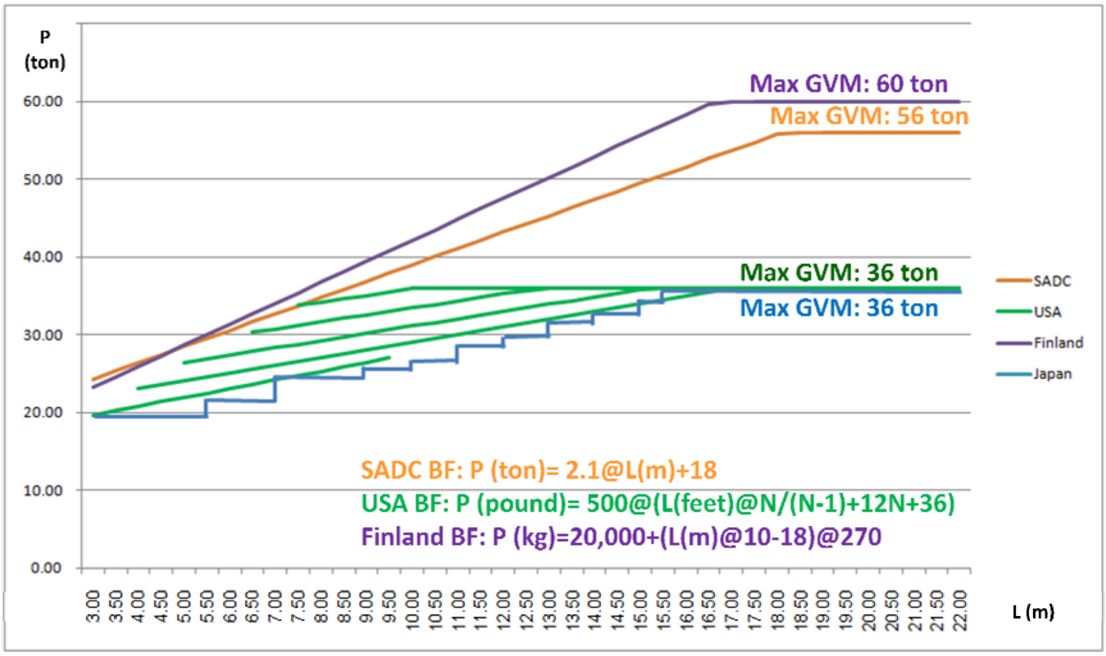
Calculation of resisting bending moment

d	Effective Hight	mm	2057.5
W1	Compression Flunge	mm	2450
t1	Thickness of Slab	mm	200
W2	Thickness of Web	mm	220
x	Neutral Axis from Top	mm	332.3
σck	Concrete Slab	N/mm2	30
σck	Concrete Beam	N/mm2	40
εcu	Stress Limitation of Conc		0.0035
A	Resistance area	mm2	609070
C=0.67/1.5*fcu*A			
=0.447fcu*A		kN	8699.9
Ep	Young Modulous Steel	N/mm2	200000
Ap	Area of PC tendon	mm2	5376
εs	(Traial calculation)		0.182
	σpu	N/mm2	1860
T	T=0.87σpu*Ap	kN	8699.44
	Z=d-0.5x	mm	1891.35
Mr	Mrc=C*Z	kNm	16454.6
	Mrt=T*Z	kNm	16453.7

Appendix I Comparison of Bridges Formulas in the World and Historical Course of Events Leading to SADC Axle Load Limits

I.1 Comparison of Bridge Formulas in the World

Figure I-1 presents a comparison of bridge formulas in the world.



P: GVM limit; L: extreme axle spacing; N: number of axles
* Japan does not have a bridge formula but stipulates GVM limits for ranges of max wheelbase.

Figure I-1: Comparison of Bridge Formulas in the World

I.2 Historical Course of Events Leading to SADC Axle Load Limits and the Bridge Formula

Generally axle mass limits in Africa are low in relation to international practice, while gross vehicle/combination mass limits are higher. The historical development of these limits is set out in this appendix.

(1) Origins of Single, Tandem, and Tridem Axle Mass Limits

For many years in South Africa, the single axle mass limit for an axle with dual tyres was set at 8.2 tonnes,[1] while limit for a tandem axle unit was set at 16.4 tonnes (i.e., 8.2 tonnes × 2). Also, historically (i.e., prior to the introduction of a bridge formula in South Africa in the early 1970s), the tridem axle unit was 24.6 tonnes (i.e., 8.2 tonnes × 3). With the application of the bridge formula, the axle load limit for the tridem axle unit with an extreme axle spacing of 2.72 m was set at 20.9 tonnes.[2]

[1] The limit for the rear axle of a bus was set higher at 10.2 tonnes, perhaps because the government owned railway buses.
[2] However, in many parts of South Africa, the bridge formula was not applied and a load limit of 24.6 tonnes was applied for the tridem axle unit.

Early international studies showed that an axle with air suspension caused 15% less road wear than an axle with a steel suspension, presupposing (of course) that the shock absorbers in the air suspension were working efficiently. Furthermore, on average, under dynamic conditions, single axle loadings varied by plus or minus 25% of the static load, while axles in tandem axle units varied by 15%. Axles in tridem axle units generally caused less road deterioration than axles in tandem axle units. In fact, it was shown that axles in a well-designed tridem axle unit caused less road wear than single axles.[3]

A number of significant studies, working group reports, and symposia relating to axle mass limits were undertaken in Africa and globally between 1986 and 1993 as summarized below:

<u>C.R. Freeme, Simplification of Regulations, June[4] 1986</u>

High tyre pressures (around 1,000 kilopascals) can reduce pavement life by 60%–70%.

<u>Canadian Vehicle Weights and Dimensions Study, 1986</u>

Recommendations were limits of 10 tonnes for single, 17 tonnes for tandem, and 24 tonnes for tridem axle units.

<u>Council of Ministers, Canada, 1988</u>

Noted the following existing regulations:

(i) steering 5.5 tonnes (long nose);
(ii) single with duals, 9.1 tonnes;
(iii) tandem with duals, 17.0 tonnes (1.2–1.85 m spacing); and
(iv) tridem with duals, 21.0 tonnes (2.4–3.0 m) spacing, 23.0 tonnes (3.0–3.6m), and 24.0 tonnes (3.6–3.7m).

<u>South African Technical Working Group, May 1991</u>

The recommendations from this Working Group were to:

(i) increase the articulated vehicle length from 17.0 to 18.5 m, for increased efficiency without causing any real detriment; and
(ii) increase the vehicle combination length from 20 m to 22 m, for increased efficiency without causing any real detriment.

<u>Van Wyk & Louw Inc., Consequences in the Increases of Legal Axle Loads, September 1991</u>

Recommendations from this study were as follows:

(i) There was economic justification to increase the legal load limits.
(ii) Although limits of 10.2 tonnes (single), 20.4 tonnes (tandem), and 24 tonnes (tridem) offered the highest benefit/cost ratios, load limits of 10 tonnes, 18 tonnes, and 21 tonnes, respectively, were recommended.

<u>South African Department of Transport Working Group on Dimensions and Loads, February 1992</u>

The road transport industry recommended load limits of 10 tonnes (single), 18 tonnes (tandem), 24 tonnes (tridem), and 56 tonnes (gross vehicle/combination mass), as it could be shown that

[3] NITRR Technical Note TP/39/86, Council for Scientific and Industrial Research (CSIR), 1986.
[4] Months cited where available.

there would be a financial net benefit to the country if mass limits were increased. A regulation was drafted that would increase axle mass limits on the condition that overloading was being reduced and additional funds were being appropriated for increased road maintenance. The increases agreed were 9, 18 and 21 tonnes, respectively. The Working Group agreed that these limits would be reviewed with long-term application the ultimate goal.

Third International Symposium on Heavy Vehicle Weights, United Kingdom, August 1992

Most delegates at this symposium spoke of 24 tonnes as the optimum for a tridem axle unit, irrespective of other axle limitations. The United Kingdom was undertaking a bridge strengthening program to allow for a 24-tonne tridem.

Carl Bro International, Axle Load Study for Southern Africa, May 1993

The objective was to harmonize load limits in Southern Africa. The main outcome was an estimated optimum mass limit for the single axle with dual tyres of 13 tonnes; however, allowing a safety margin, 12 tonnes was recommended. Since the Highway Design and Maintenance Standards Model (HDM-III) assumed that 15.1 tonnes on a tandem axle was equivalent to 2 equivalent standard axles (ESAs)[5] for road wear, 24/15.1 for a tandem axle unit was found to be roughly equal to 13/8.16 for a single axle. Hence, 24 tonnes was estimated as the correct loading for a tandem axle unit. The optimum single, tandem, and tridem limits varied from 12, 17, and 24 tonnes, to 12, 22, and 33 tonnes. The consultants recommended a compromise between the two, presumably 12, 19.5, and 28.5 tonnes, although no figures were given.

(2) Origins of the SADC Bridge Formula

The origins of the bridge formula may be traced from the 1970s to the 1990s, as below. It is on this basis that SADC has been guiding the region forward, as also described at the end of this subsection.

Origin of the 1.8 × L + 16,000 Bridge Formula, 1970–71

In 1970–71 the South African Department of Transport formed a committee chaired by E.B. Cloete to update existing load regulations to protect the nation’s bridges. While the committee found that South Africa needed to follow act to protect its bridges as did overseas countries, the committee also found that the overseas systems were very complex. For example, the United States formula was $W = 500 \times (L \times N/(N - 1) + 12N + 36)$, where L was the spacing in feet, N being the number of axles, and W the weight in pounds. Therefore, a simpler formula was required and N.O. Marriott of the Cape Provincial Administration and a member of the committee came up with a solution. He placed two reference points on a graph of allowable mass (y axis) against distance between axles (x axis). A tandem axle unit was allowed to be loaded to 16 tonnes and so he placed the first reference point at zero distance and 16 tonnes.

At the other end of the scale, a 20 m long vehicle combination should be allowed a gross combination mass (GCM) of 50 tonnes. Since the extreme axle spacing for a 20 m vehicle combination was about 18.5 m, he placed the reference point at 18.5 m extreme axle spacing, with a GCM of 50 tonnes. A straight line was drawn between the two reference points and this line was defined by the equation $1.8 \times L + 16$. This formula was subsequently introduced into South Africa’s regulations as the bridge formula. Figure I-2 illustrates this derivation of the South African bridge formula graphically.

[5] An ESA refers to the number of standard axle loads that are equivalent in damaging effect on a pavement to a given vehicle or axle loading.

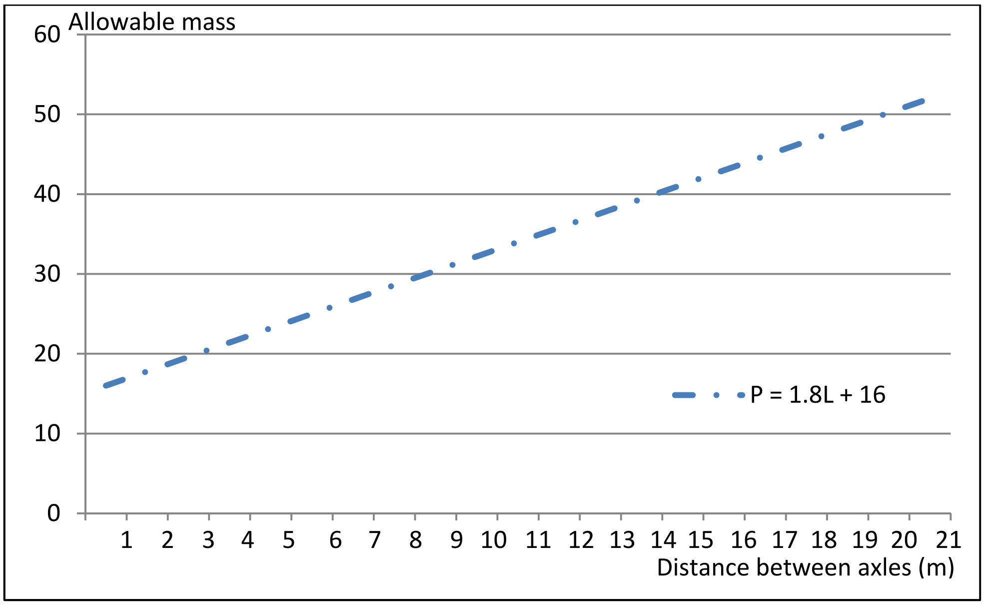


Figure I-2: Derivation of the South African Bridge Formula

<u>Canadian Vehicle Weights and Dimensions Study, 1986, and Council of Ministers Decision, Canada, 1988</u>

Based on the 1986 study,[6] in 1988 the Canadian Council of Ministers of Transportation agreed on certain vehicle configurations and mass limits. Included was a B-double or B-Train double (equivalent to the interlink), with a GCM limit of 62.5 tonnes. The minimum extreme axle spacing was set at 18.75 m. Applying the 1.8 L + 16 bridge formula, the 18.75 m extreme axle spacing gives a GCM limit of 49.75 tonnes. Using the 2.1 L + 18 bridge formula proposed for East and Southern Africa, the 18.75 m extreme axle spacing gives a GCM limit of 57.4 tonnes, less than the Canadian limit of 62.5 tonnes.

<u>South African Technical Working Group. May 1991</u>

The recommendations from this Working Group were to (i) increase the articulated vehicle length from 17.0 to 18.5 m, for increased efficiency without any detriment; and (ii) increase the vehicle combination length from 20 m to 22 m, for increased efficiency and again with no detriment. The increased length of a vehicle combination meant an increase in the GCM to around 52 tonnes.

<u>Peter Buckland, North American and British Long-Span Bridge Mass, Journal of Structural Engineering, October 1991</u>[7]

Buckland showed that the British Standard BS5400 1978 (to which many of the bridges in East and Southern Africa were designed) allowed higher loadings than the American AASHTO 1983 and the Canadian CAN/CSA-S6-88 1988 standards. Yet, as indicated above, the Canadians allowed their B-Double a higher bridge loading than what is being proposed for East and Southern Africa even though there bridges were designed for a lesser loading.

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[6] The study found that "[a]mong the B-doubles [i.e., interlinks], the eight-axle variety, with tridem centre-group, offers the greatest productivity advantages while suffering no significant loss in dynamic performance relative to the five-axle truck tractor semi-trailer. Recognizing the safety benefits of the reduced exposure which accompanies increased payload capacity plus high performance, yet simplicity, of this vehicle combination, the eight-axle B-doubles (interlink) is looked upon as the closest to ideal configuration of the overall group of vehicles."

[7] http://cedb.asce.org/cgi/WWWdisplay.cgi?73321.

For a tandem axle unit in South Africa, using the original bridge formula of 1.8L + 16 and an axle spacing of 1.36 m, the mass limit would be 18.5 tonnes, which is in excess of the original 16 tonnes and the proposed 18 tonnes. However, the 1.8L + 16 bridge formula limited the tridem axle unit (spacing 2.72 m) to 20.9 tonnes. Retaining this formula meant that the transporters and trailer manufactures would spread the tridem axle unit out to over 4 m to achieve the 24-tonne mass limit (i.e., the sum of 3 × 8 tonne axles). Such a wide-spaced axle unit would be legal (as it was not considered an axle unit), but it would not be desirable because: (i) it would create considerable scuffing unless expensive and complex steering axles were included; and (ii) it would be very difficult to retain equal massing on the three axles. This was one justification to upgrade the original bridge formula.

Technical Methods for Highways (TMH) 7 Code of Practice, 1981, assumes a constant limiting value of 3.6 tonnes per m (36 kN/m).[8] As shown in Figure I-3 below, with an extreme axle spacing of around 9.5 m, the original bridge formula gave higher mass limits, while the gross vehicle mass/gross combination mass was controlled by the sum of the axle mass limits. Above an extreme axle spacing of around 9.5 m, and for the heavy vehicle combinations, the original bridge formula reduced the bridge loading below that of TMH7.

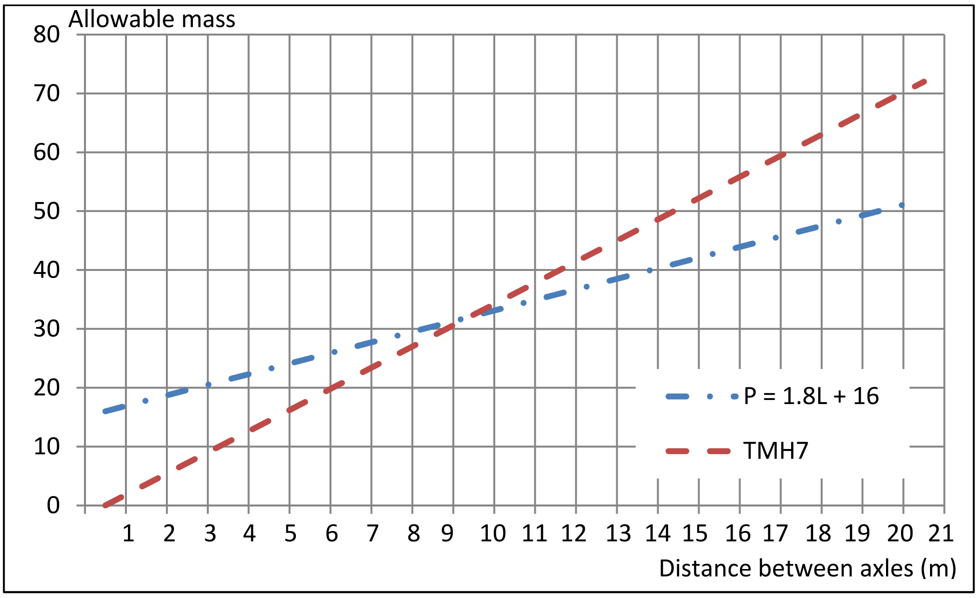


Figure I-3: Comparison of TMH 7 and the Original Bridge Formula

It can be shown that a line of jam-packed 4 × 2 trucks results in a bridge loading of around 4.2 tonnes per m while a line of jam-packed 6 × 4 trucks results in a bridge loading of around 3.6 tonnes per m. However, this does not consider the practical situation where: (i) other vehicle types of vehicles are interspersed, (ii) vehicles are partly laden or empty, and (iii) there is a reasonable distance between moving vehicles. It can be seen from Figure I-3 above that a 7-axle vehicle combination (truck and trailer, or interlink) of 20 m length is controlled by the bridge formula and therefore causes considerably less wear to the roads than does smaller heavy vehicles.

[8] BS5400 takes into consideration high mass per unit length. It also considers impact massing.

Van Wyk & Louw Inc, Consequences of Increases in the Legal Axle Mass Limits, September 1991

Three studies were carried out as inputs to this document. Study 1 showed that increased axle masses would give net gains to South Africa, but that no increases should be given until additional maintenance funds were made available. Study 2 recommended the bridge formula 2L + 15 and limits of 10.2 tonnes for a single axle, 20.4 tonnes for a tandem axle unit, and 24 tonnes for a tridem axle unit. Study 3 recommended limits of 10 tonnes for a single axle and 18.5 tonnes for a tandem axle unit. (A limit of 11 tonnes could be considered for a single air-suspended axle.)

South African Department of Transport Working Group on Dimensions and Loads, February 1992

This Working Group was set up after the conclusion of the previous studies outlined above. Existing mass limits were 8.2 tonnes (single), 16.4 tonnes (tandem), and 21 tonnes (tridem). The summation of axles in a 7-axle vehicle combination resulted in a GCM of: 6.5 + (6 × 8.2) = 55.7 tonnes. The existing bridge formula of 1.8 × L + 16 did not allow a 20 m vehicle combination to realize its full potential. Using the extreme axle spacing of 18.5 m, the bridge formula gave a GCM limit of 1.8 × 18.5 + 16 = 49.3 tonnes. Although there was no upper GCM limit set in the regulations, the bridge formula effectively determined this limit to be 49.3 tonnes.

The Working Group agreed on an interim bridge formula of 2.1 × L + 15 tonnes, which would give 53.9 tonnes for a 20 m vehicle combination, and the Minister endorsed this recommendation. There was to be an immediate overloading monitoring program and a bridge strengthening program. Also, extra budgets were to be made available for road maintenance.

Van Niekerk Kleyn & Edwards, Van Wyk & Louw, The Effect of an Increase in Loads, March 1993

This study showed that the theoretical strengths of bridges were less than the forecast traffic loads that would result from the proposed increase in mass limits. However, field tests showed that the actual stiffness of the bridges exceeded the theoretical stiffness.

Carl Bro International, Axle Mass Study for Southern Africa, May 1993

The objective of this study was to harmonize mass limits in Southern Africa. Dimensions had been previously agreed at 12.5 m for a rigid vehicle, 17 m for an articulated vehicle, and 22 m for a vehicle combination. The HDM-III model was used in the calculations. The study recommended a 63-tonne GCM limit, although consideration had to be given to the strength of bridges and some bridges may have required some restriction.

Developments since 1993 and Comments

Following the 1993 Carl Bro study, various investigations were undertaken by the road transport and freight forwarding industry. One of the submissions found a gain in efficiency for the region by loading 3 × 6 m TEU, or 1 × 6 m TEU and 1 × 12 m ISO container on a vehicle combination. To achieve this gain, the length of the vehicle combination needed to be increased to 22 m.[9] It was found that the GCM over 2 additional meters would cause no more road wear and less stress on bridges.

[9] Generally, this was not seen as presenting a safety problem since the time required to overtake such a vehicle would be increased by less than one second.

Applying the upgraded 2L + 15 bridge formula to a 22 m vehicle combination with an extreme axle spacing of about 19.7 m would give a 54.4-tonne GCM limit. While the 1993 Carl Bro study had recommended a GCM limit of 63 tonnes, this limit was considered too high and therefore SADC recommended a 56-tonne limit (7 axles × 8 tonnes per axle). In South Africa, this recommendation meant that the upgraded bridge formula of 2L + 15, with an extreme axle spacing of 19.7 m, could not achieve the recommended limit.

SADC also agreed with the road transport industry's recommendation of limits of 10 (single), 18 (tandem), and 24 (tridem) tonnes. However, in South Africa the upgraded bridge formula of 2 L + 15 when applied to a tridem axle unit with a 2.72 m extreme axle spacing only gave a 20.4-tonne limit for the tridem, which was well below the 24-tonne limit recommended by SADC.

With the two shortcomings in the 2 L + 15 bridge formula described above, South Africa agreed to revise the formula for a second time, to 2.1 L + 18. This gave a 23.7-tonne limit for a tridem axle unit (considered to be close enough to the agreed 24-tonne limit) and a GCM limit of over 59 tonnes. However, it was agreed that the new formula was not too generous (at 59 tonnes for the extreme axle spacing) because it restricted the limits on the tandem and tridem axle units in a 6-axle articulated vehicle. The extreme axle spacing for the 18-tonne tandem axle unit and the 24-tonne tridem axle unit in the articulated vehicle would have to be at least 11.4 m apart for them to achieve full loading. Since this was in fact not possible, these two axle units have not been able to realize their full potential until recently.

Against this background, all parties in the context of SADC cooperation agreed that the 56-tonne limit was adequate and the new bridge formula gave the tandem and tridem axle units in a 6-axle articulated vehicle combination reasonable mass limits.

Appendix J Examples of Vehicle and Vehicle Combination Drawings to Assist with the Regulations of Member States

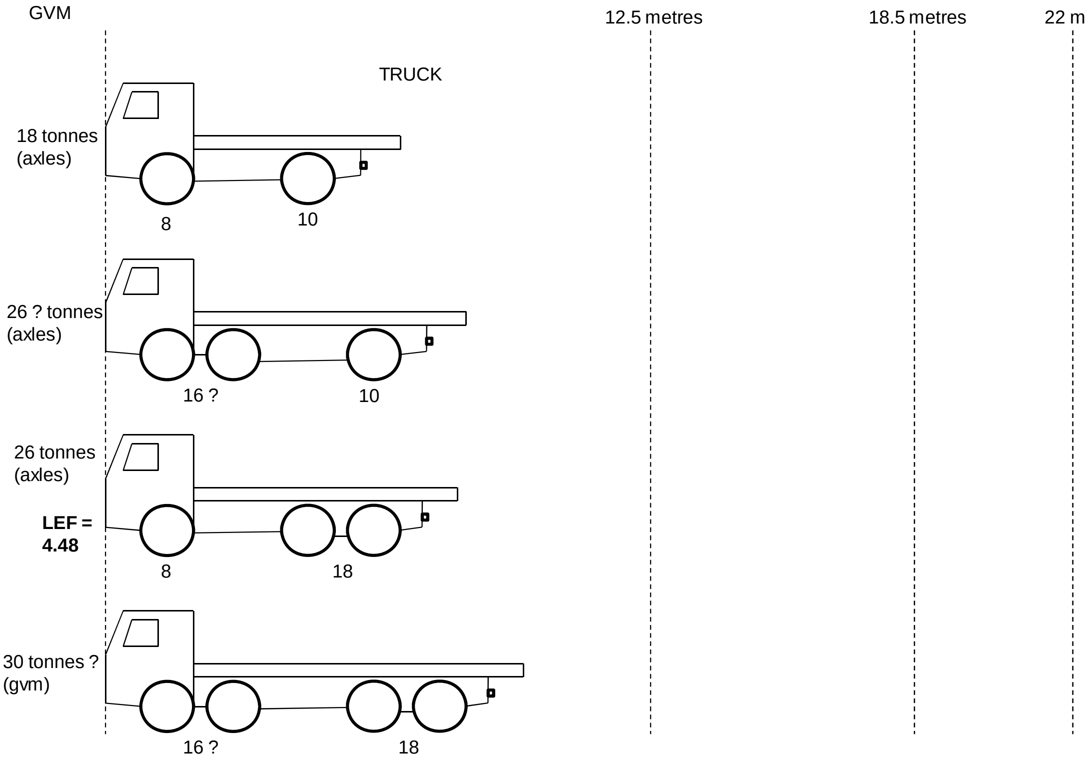
The following drawings of vehicles and vehicle combinations show many of the vehicles and vehicle combinations on the region's roads today. Not every vehicle or vehicle combination is shown. No more than 7 axles per vehicle combination are shown. While 8-axle vehicle combinations will be limited to 56 tonnes and do appear on regional roads, it is not considered desirable to show them since it may encourage overloading.

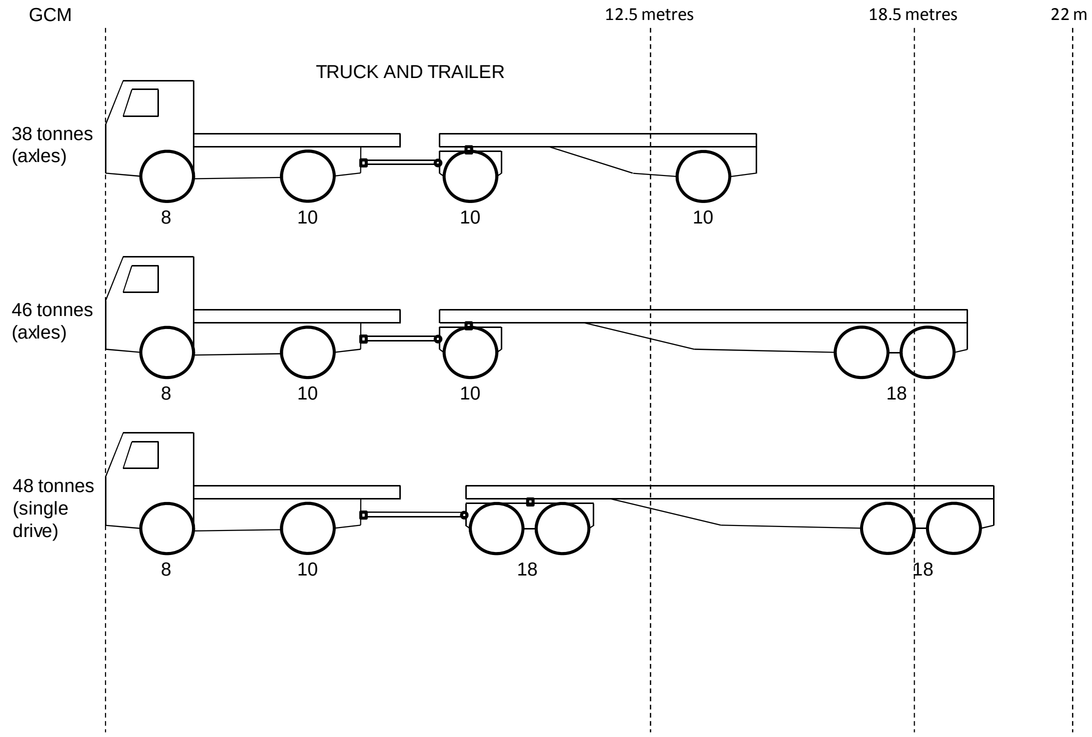
All vehicles and vehicle combinations are covered by the Bridge Formula:
Load (tonnes) = 2.1 × Distance between any two axles (meters) + 18

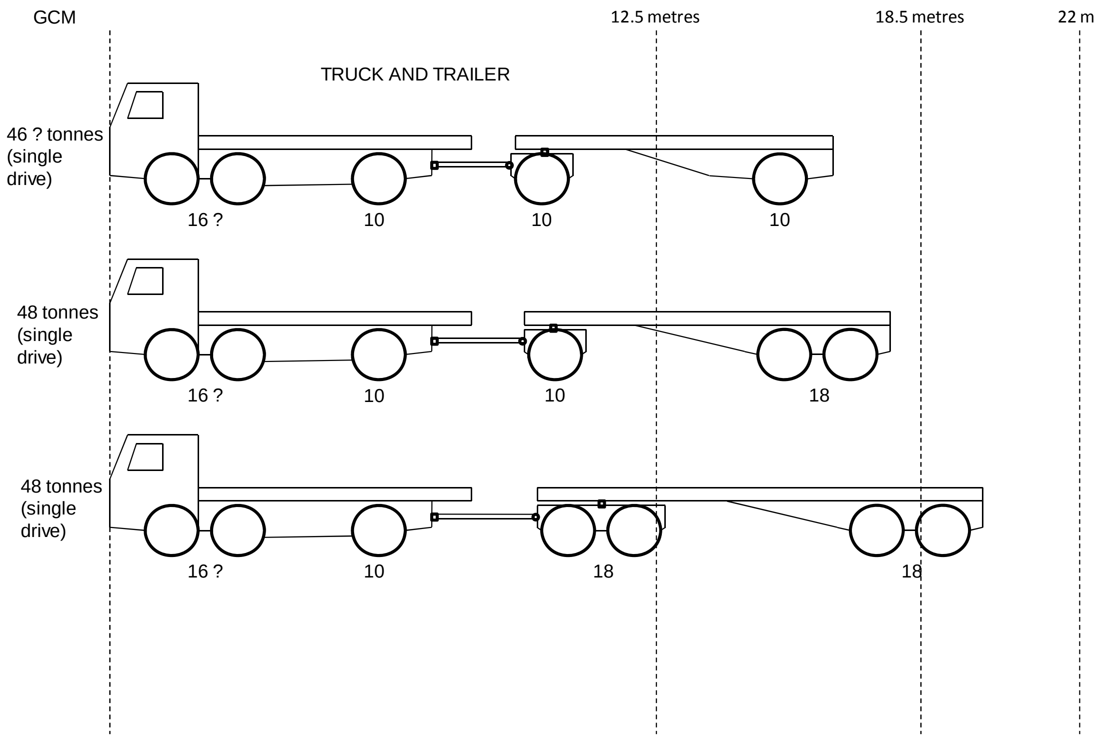
The heavier vehicle combinations comply with the Bridge Formula and are limited to 56 tonnes. For simplicity and apart from the front axle, no axles with single tyres are shown. In most cases, the inclusion of single tyres will reduce the allowable load limits.

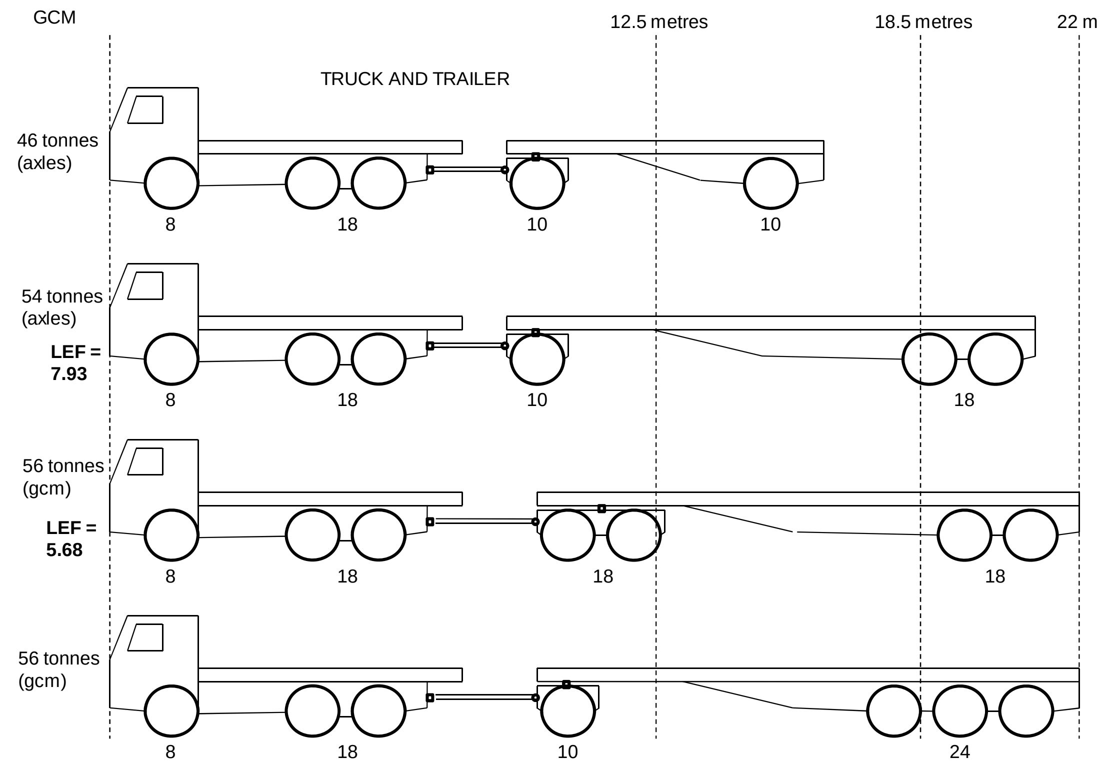
The regional recommendations for single tyre limits in an axle unit still have to be finalized. The load limits shown in the left hand column wee determined by the sum of the axles (axles), or by the single drive axle (single drive), or by the gross combination mass limit (GCM).

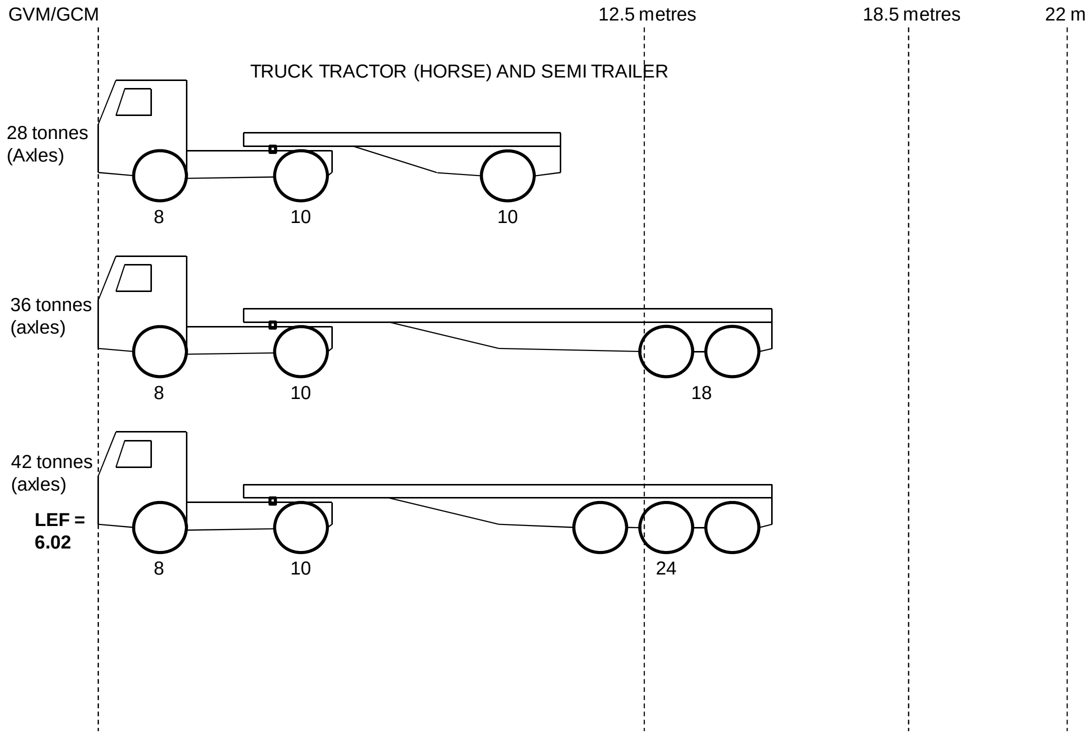
LEF = the Load Equivalency Factor for the seven common vehicle combinations shown, as calculated in the Council of Scientific and Industrial Research (CSIR) study of August 2010.

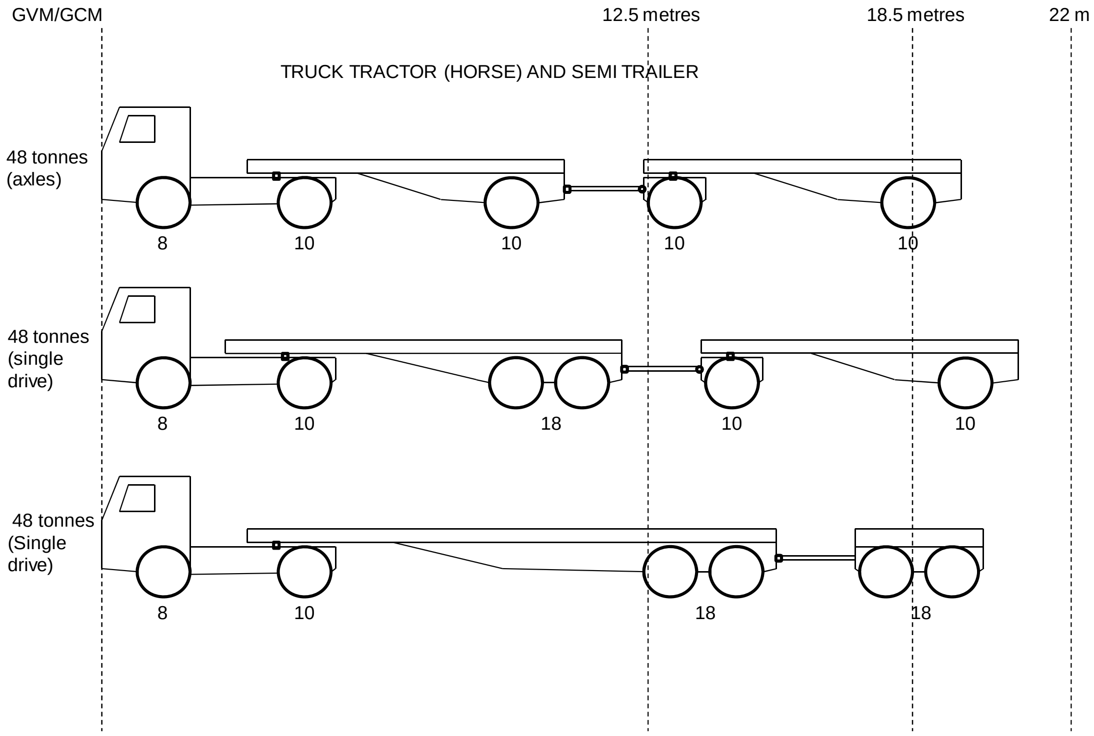

GVM
12.5 metres
18.5 metres
22 m
TRUCK
18 tonnes
(axles)
8
10
26 ? tonnes
(axles)
16 ?
10
26 tonnes
(axles)
LEF =
4.48
8
18
30 tonnes ?
(gvm)
16 ?
18

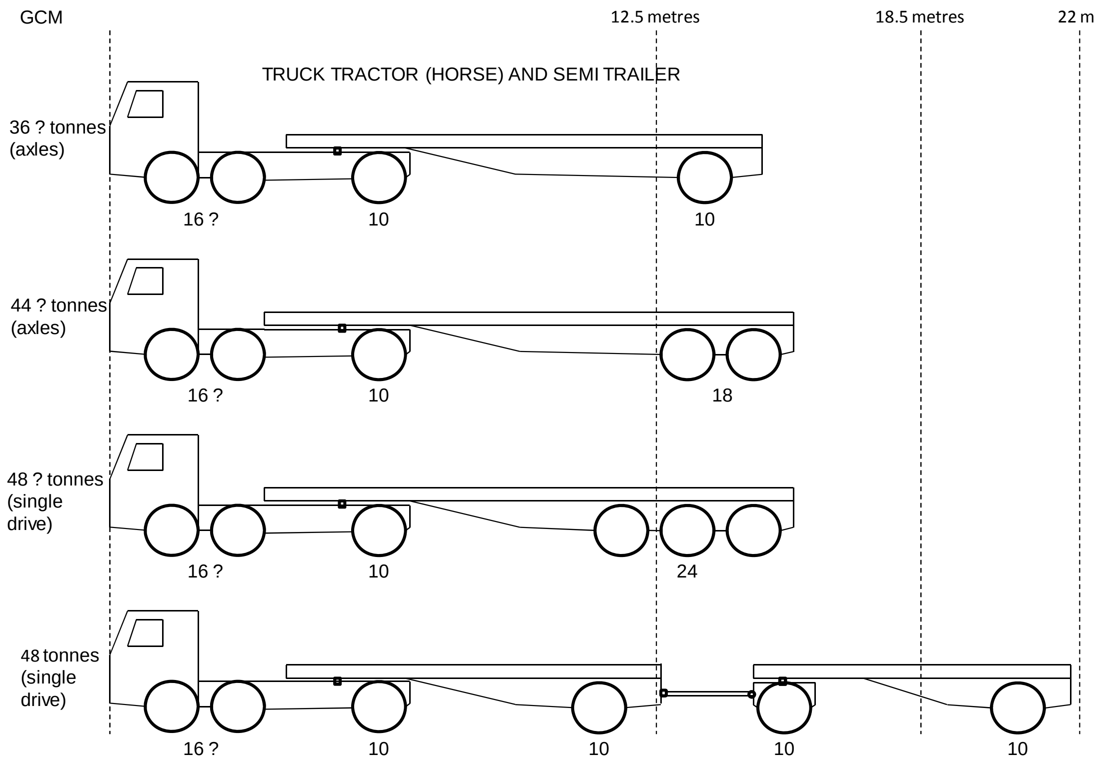

GCM
12.5 metres
18.5 metres
22 m
TRUCK AND TRAILER
38 tonnes
(axles)
8
10
10
10
46 tonnes
(axles)
8
10
10
18
48 tonnes
(single
drive)
8
10
18
18

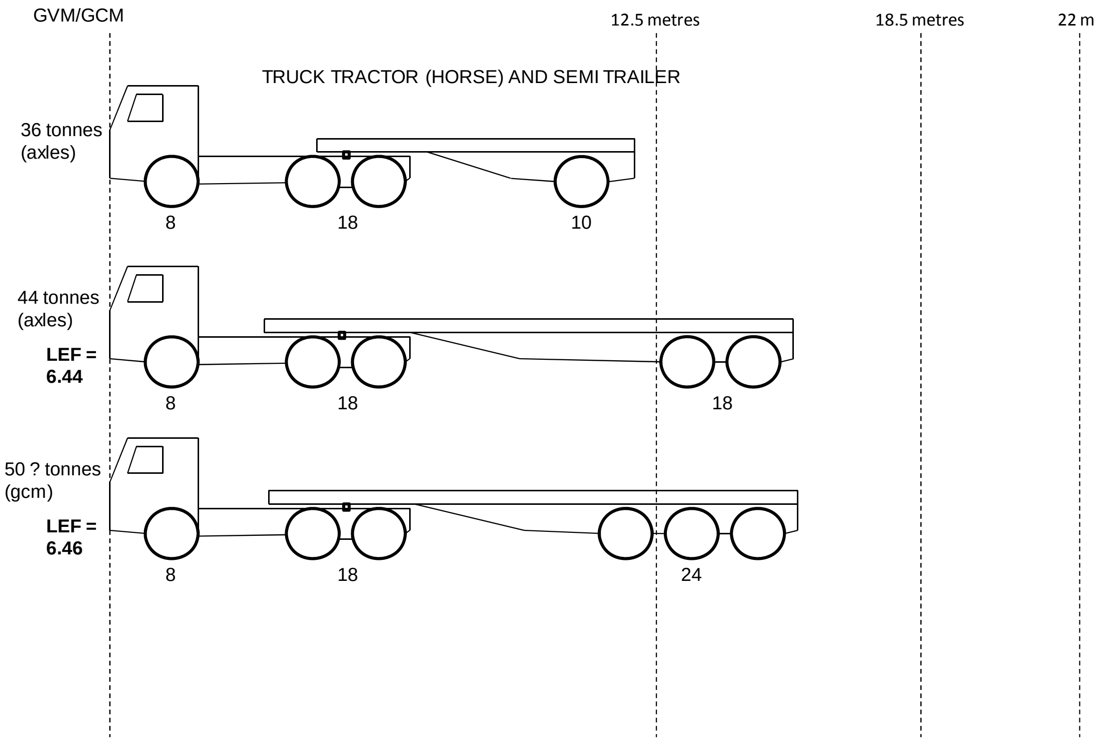

GCM
12.5 metres
18.5 metres
22 m
TRUCK AND TRAILER
46 ? tonnes (single drive)
16 ?
10
10
10
48 tonnes (single drive)
16 ?
10
10
18
48 tonnes (single drive)
16 ?
10
18
18

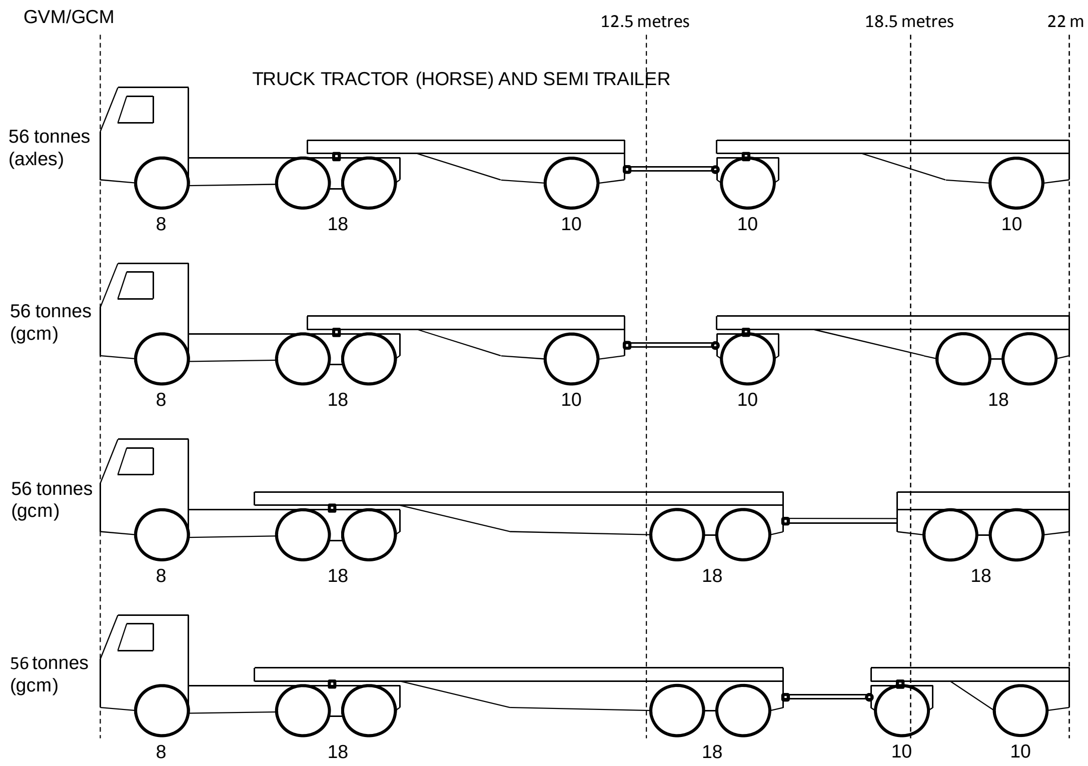

GCM
12.5 metres
18.5 metres
22 m
TRUCK AND TRAILER
46 tonnes (axles)
8
18
10
10
54 tonnes (axles)
LEF = 7.93
8
18
10
18
56 tonnes (gcm)
LEF = 5.68
8
18
18
18
56 tonnes (gcm)
8
18
10
24

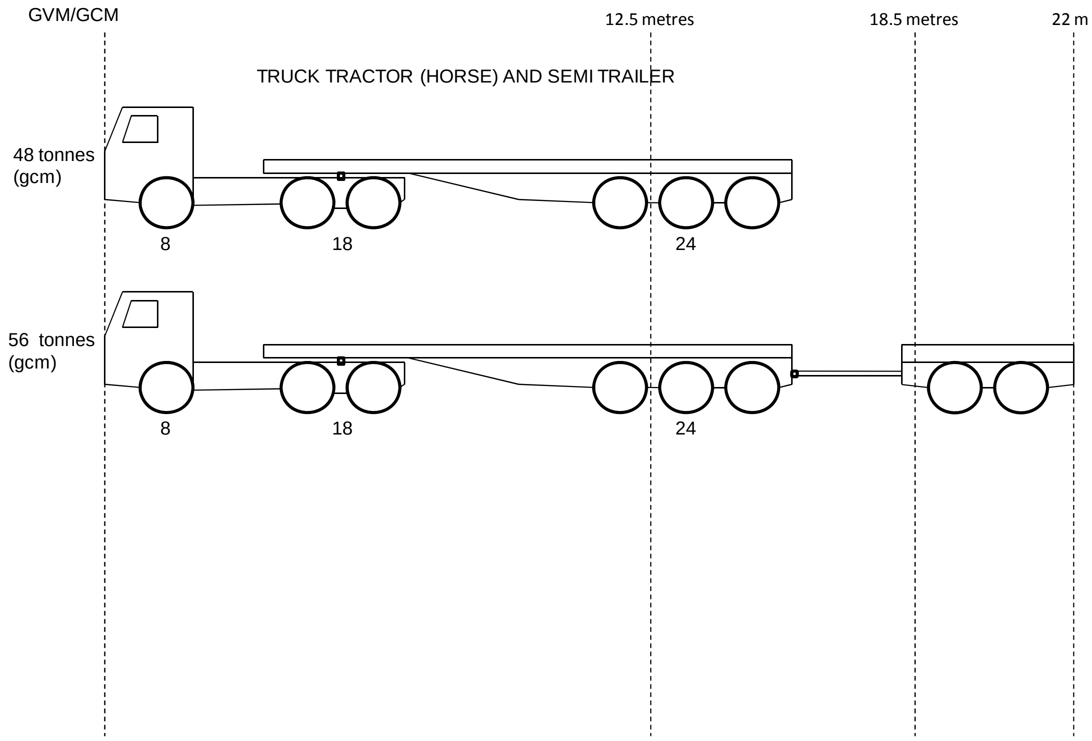

GVM/GCM
12.5 metres
18.5 metres
22 m
TRUCK TRACTOR (HORSE) AND SEMI TRAILER
28 tonnes
(Axles)
8
10
10
36 tonnes
(axles)
8
10
18
42 tonnes
(axles)
LEF =
6.02
8
10
24

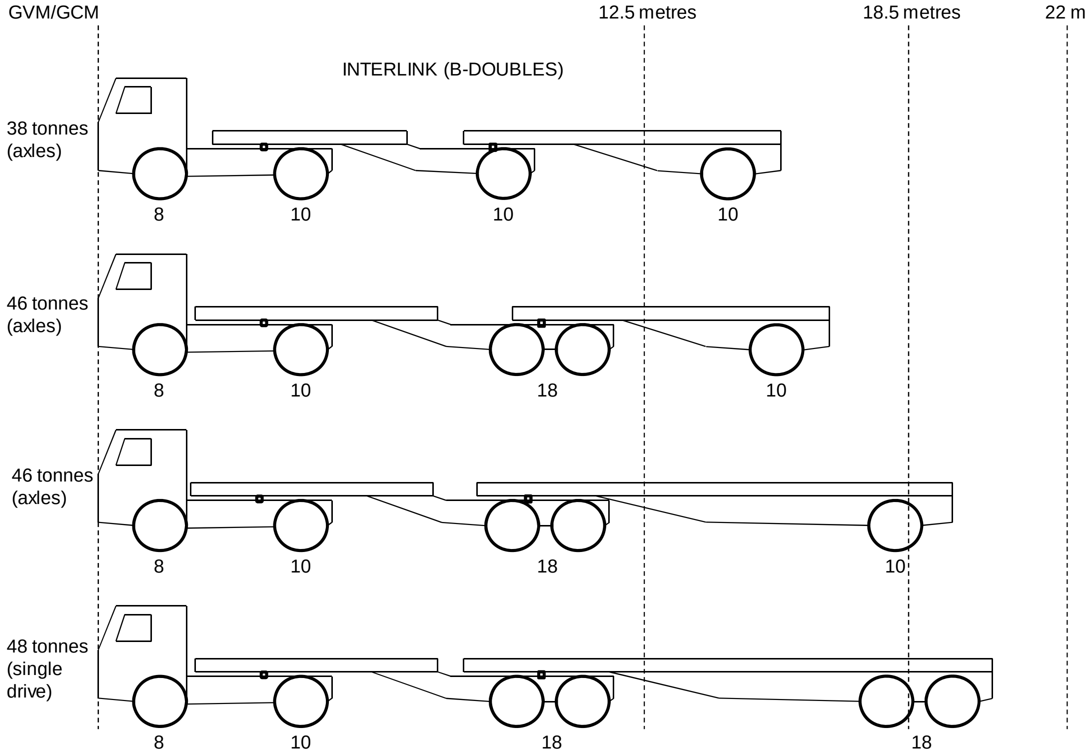

GVM/GCM
12.5 metres
18.5 metres
22 m
TRUCK TRACTOR (HORSE) AND SEMI TRAILER
48 tonnes
(axles)
8
10
10
10
10
48 tonnes
(single
drive)
8
10
18
10
10
48 tonnes
(Single
drive)
8
10
18
18

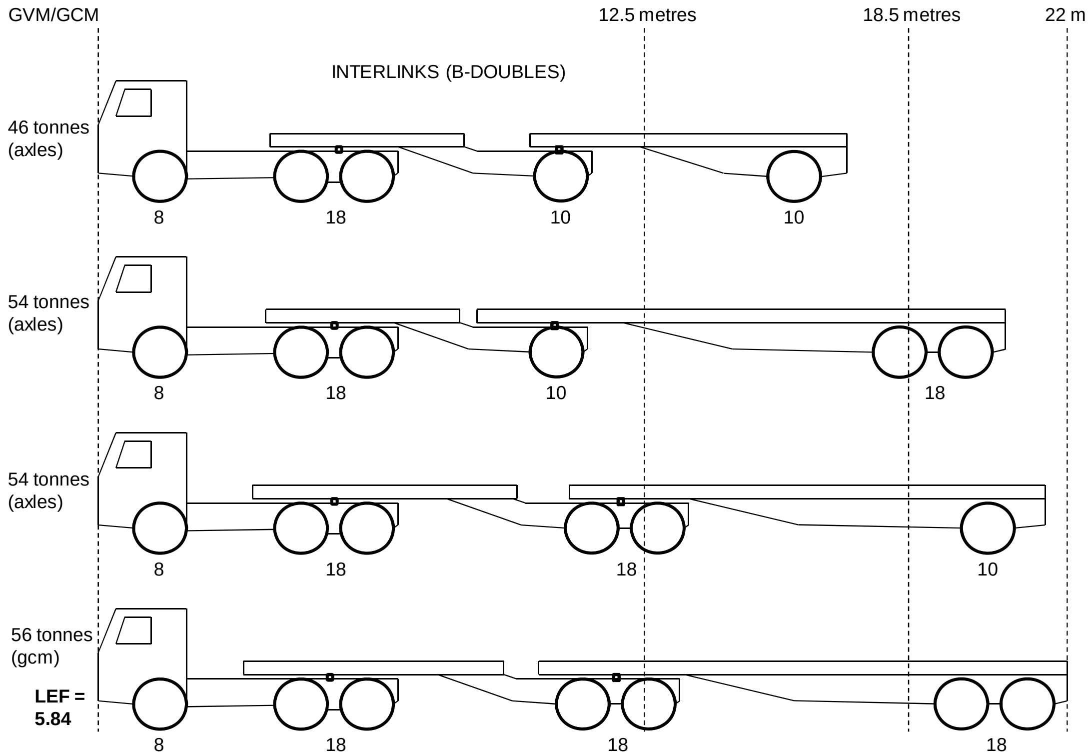

GCM
12.5 metres
18.5 metres
22 m
TRUCK TRACTOR (HORSE) AND SEMI TRAILER
36 ? tonnes (axles)
16 ?
10
10
44 ? tonnes (axles)
16 ?
10
18
48 ? tonnes (single drive)
16 ?
10
24
48 tonnes (single drive)
16 ?
10
10
10
10


GVM/GCM
12.5 metres
18.5 metres
22 m
TRUCK TRACTOR (HORSE) AND SEMI TRAILER
36 tonnes (axles)
8
18
10
44 tonnes (axles)
LEF = 6.44
8
18
18
50 ? tonnes (gcm)
LEF = 6.46
8
18
24


GVM/GCM
12.5 metres
18.5 metres
22 m
TRUCK TRACTOR (HORSE) AND SEMI TRAILER
56 tonnes (axles)
8
18
10
10
10
56 tonnes (gcm)
8
18
10
10
18
56 tonnes (gcm)
8
18
18
18
56 tonnes (gcm)
8
18
18
10
10


GVM/GCM
12.5 metres
18.5 metres
22 m
TRUCK TRACTOR (HORSE) AND SEMI TRAILER
48 tonnes (gcm)
8
18
24
56 tonnes (gcm)
8
18
24


GVM/GCM
12.5 metres
18.5 metres
22 m
INTERLINK (B-DOUBLES)
38 tonnes
(axles)
8
10
10
10
46 tonnes
(axles)
8
10
18
10
46 tonnes
(axles)
8
10
18
10
48 tonnes
(single
drive)
8
10
18
18


GVM/GCM
12.5 metres
18.5 metres
22 m
INTERLINKS (B-DOUBLES)
46 tonnes
(axles)
8
18
10
10
54 tonnes
(axles)
8
18
10
18
54 tonnes
(axles)
8
18
18
10
56 tonnes
(gcm)
LEF =
5.84
8
18
18
18

Appendix K EAC Act or Protocol

K.1 An EAC Act or Protocol?

An EAC Act is preferred to an EAC Protocol because:

- it provides an integrated approach to vehicle overload control with legal effect;
- this approach has been effectively applied before;
- the steps required for adoption of a Protocol are lengthy, making it inappropriate for the required fast tracking of the issue; and
- a Protocol would just provide a general framework and would therefore need to be accompanied by a number of laws and regulations.

K.2 Integrated Approach to Vehicle Overload Control

An EAC Act (pursuant to Article 62 of the EAC Treaty) would provide an integrated approach to vehicle overload control in the EAC with legal effect in the Partner States. It would override contrary national laws and regulations as per subparagraphs (4) and (5) of Article 8 of the EAC Treaty.

Alternatively, if a Protocol is adopted and the Partner States have their own laws/regulations, they will not meet the mandate of Article 90(l) of the EAC Treaty for the Partners States to "adopt common rules and regulations" on "gross weight and load per axle".

K.3 EAC Acts Have Been Effectively Applied Before

EAC Acts have been applied effectively before (e.g., the EAC Customs Management Act, 2004; the EAC Standardisation, Quality Assurance, Metrology and Testing Act, 2006; the EAC One-Stop Border Posts Act, in process).

There are no convincing reasons to abandon this approach.

K.4 The Steps Required for a Protocol are Lengthy

A Protocol would take longer to adopt than an Act, making it inappropriate for the required fast tracking of the issue.

It would require many steps: (i) submission of the draft to the sectoral council and then to workshops in the Partner States, (ii) preparation of a final report with a revised draft Protocol as an official document, (iii) submission of the final report to the Council of Ministers for approval, (iv) article-by-article review by the Attorneys Generals of the Partner States and the Legal Department of the Secretariat, and (v) submission of the resulting draft to the Council of Ministers for signing.

K.5 A Protocol Would Only Provide a General Framework

A Protocol would only provide a general framework and therefore would not meet the mandate of Article 90(l) for "common rules and regulations".

Pursuant to Article 151(l) of the EAC Treaty, a Protocol is an annex of the EAC Treaty to "spell out the objectives and scope of, and institutional mechanisms for co-operation and integration". Therefore, many of the required details could not be specified in a Protocol. It would be unprecedented.

Additional laws and regulations would be required, and if enacted at the Partner State level would result in a fragmented, non-harmonized approach.

Appendix L Dynamic Stability of Interlinks

In response to a request for a comparison of interlinks (B-doubles) and truck-trailers, a brief discussion of existing work is presented. The National Transport Commission (NTC, previously NTRC) of Australia developed performance-based standards (PBS) for heavy vehicles as an alternative means of regulating heavy vehicles. It is the latest edition of these standards that South Africa is using for its PBS initiative. During the process of recommending and reviewing potential performance standards, the NTC conducted an evaluation of the Australian heavy vehicle fleet against these standards.[1] At the time, the range of selected potential standards was as suggested by previous work by the same organization[2] and this list remains essentially unchanged.

In the NTC's evaluation of the Australian vehicle fleet, 139 generic vehicles were chosen to represent the range of typical vehicle combinations including rigid trucks, truck-trailers, truck-semitrailers, and road trains. Numerical computer simulations of these vehicle combinations were conducted (using *Adams* and *AutoSim* multi-body/vehicle dynamics software packages) and the performance statistics of each combination compared against the respective performance standards. The subsequent report from that study is lengthy and detailed and a summary may be downloaded from the NTC's website.[3] A description of the various performance measures may also be obtained from the website.[4]

In support of the safety of interlinks over truck-trailers (more specifically, based on the illustrations provided, *truck and dog trailer*), some overall results of the study are presented in Tables L-1, L-2, and L-3. The tables show the percentage of vehicles simulated in each vehicle group (e.g., B-double, rigid truck) that pass the required performance criteria at the required level. In the right-most column the percentage of vehicles in each group that pass *all* of the standards is given. Hence, a higher quoted percentage of one vehicle group over another gives an indication of the statistically superior performance of that particular vehicle combination over the other in each performance measure. The limiting values for the PBS measures are relaxed for more limited road access – urban road access has the most stringent requirements, major freight routes slightly less stringent and road train routes the least stringent. The tables show the results for each of these access levels respectively.

Arguably, the most safety-critical PBS measures are those pertaining to dynamic characteristics of the vehicle and are: Static Rollover Threshold, Rearward Amplification, High Speed Transient Offtracking, Yaw Damping, and Tracking Ability on a Straight Path. The results show the B-double to be the superior performer in all these standards except rollover threshold and the difference here is not considerable. It can be seen from the performance in low-speed standards that the B-double is not, in general, ideally suited for urban access but performs notably overall. From these results and other research results it may be said that *in general* B-doubles are dynamically safer than truck-dog-trailer equivalents. It should be emphasized however that it is possible to produce an unsafe vehicle in either configuration, even within legal constraints, and as such this deduction is not all-encompassing.

[1] NTRC, *Performance Characteristics of the Australian Heavy Vehicle Fleet*, Melbourne: National Road Transport Commission, 2002.
[2] NTRC, *Definition of Potential Performance Measures and Initial Standards*, Melbourne: National Road Transport Commission, 2001.
[3] http://www.ntc.gov.au/docview.aspx?documentid=255.
[4] http://www.ntc.gov.au/filemedia/Reports/PBSSchemeStandsVehAssRule24Nov08.pdf.

Table L-1: Australian Heavy Vehicle Fleet Performance (Access to Entire Road Network) [1]

#	Vehicle Class	Startability (%)	Gradeability (Max. Grade) (%)	Gradeability (Max. Speed on 1%Grade) (km/h)	Acceleration Capability (s)	Tracking Ability (m)	Low-Speed Offtracking (m)	Frontal Swing (m)	Tail Swing (m)	Steer Tyre Friction Demand (%)	Static Rollover Threshold (g)	Rearward Amplification (-)	High-Speed Transient Offtracking (m)	Yaw Damping Coefficient (-)	Gross Mass per SAR (t/SAR)	Horizontal Tyres Forces (-)	Max. Effect Relative to Ref. Vehicle (%)	**OVERALL (%)**
	Performance Levels	**15**	**25**	**70**	**12**	**3.1**	**7.4**	**1.5**	**0.35**	**80**	**0.35**	**5.7**	**0.80**	**0.15**	**8.4**	**1.8**	**95**	**-**
17	rigid trucks	100	100	100	100	100	100	100	100	100	71	100	100	100	18	29	100	**18**
6	buses/coaches	100	100	100	100	100	100	100	100	100	100	100	100	100	-	83	100	-
43	prime-mover and semi-trailer	100	67	100	98	100	95	100	100	100	79	100	100	100	72	93	100	**47**
23	B-double	100	-	100	35	100	4	100	100	100	78	100	100	100	78	100	100	-
1	B-triple	100	-	100	-	100	-	100	100	100	100	100	100	100	100	100	100	-
9	truck and pig/tag-trailer	100	78	100	100	100	100	100	100	100	56	56	56	100	22	89	100	**22**
14	truck and dog trailer	100	79	100	93	100	100	100	100	100	86	50	71	93	71	79	93	**21**
12	A-double	100	-	100	-	100	8	100	100	100	92	92	83	100	100	100	92	-
12	A-triple road train	-	-	25	-	100	-	100	100	100	75	17	8	83	100	92	100	-
2	AAB-quad road train	-	-	-	-	100	-	100	100	100	100	50	-	100	100	50	-	-
139	**entire fleet**	**90**	**50**	**92**	**68**	**100**	**64**	**100**	**100**	**100**	**79**	**83**	**83**	**98**	**65**	**84**	**97**	**20**

The columns from Startability (%) to OVERALL (%) are grouped under the heading **Performance Measures**.

Notes: *Acceleration Capability* shown in the Table is based on a 25 m cleared-distance intersection clearance time.

Table L-2: Australian Heavy Vehicle Fleet Performance (Access to Major Freight Routes) [1]

#	Vehicle Class	Startability (%)	Gradeability (Max. Grade) (%)	Gradeability (Max. Speed on 1%Grade) (km/h)	Acceleration Capability (s)	Tracking Ability (m)	Low-Speed Offtracking (m)	Frontal Swing (m)	Tail Swing (m)	Steer Tyre Friction Demand (%)	Static Rollover Threshold (g)	Rearward Amplification (-)	High-Speed Transient Offtracking (m)	Yaw Damping Coefficient (-)	Gross Mass per SAR (t/SAR)	Horizontal Tyres Forces (-)	Max. Effect Relative to Ref. Vehicle (%)	**OVERALL (%)**
	Performance Levels	**10**	**20**	**70**	**15**	**3.5**	**10.1**	**1.5**	**0.35**	**80**	**0.35**	**5.7**	**0.80**	**0.15**	**8.4**	**1.8**	**80**	**-**
17	rigid trucks	100	100	100	100	100	100	100	100	100	71	100	100	100	18	29	100	**18**
6	buses/coaches	100	100	100	100	100	100	100	100	100	100	100	100	100	-	83	100	-
43	prime-mover and semi-trailer	100	86	100	100	100	100	100	100	100	79	100	100	100	72	93	100	**53**
23	B-double	100	39	100	100	100	100	100	100	100	78	100	100	100	78	100	100	**30**
1	B-triple	100	-	100	100	100	100	100	100	100	100	100	100	100	100	100	100	-
9	truck and pig/tag-trailer	100	100	100	100	100	100	100	100	100	56	56	56	100	22	89	100	**22**
14	truck and dog trailer	100	93	100	100	100	100	100	100	100	86	50	71	93	71	79	93	**21**
12	A-double	100	-	100	100	100	100	100	100	100	92	92	83	100	100	100	92	-
12	A-triple road train	100	-	25	-	100	8	100	100	100	75	17	8	83	100	92	100	-
2	AAB-quad road train	50	-	-	-	100	-	100	100	100	100	50	-	100	100	50	100	-
139	**entire fleet**	**99**	**65**	**92**	**90**	**100**	**91**	**100**	**100**	**100**	**79**	**83**	**83**	**98**	**65**	**84**	**99**	**27**

The columns from Startability (%) to OVERALL (%) are grouped under the heading **Performance Measures**.

Notes: *Acceleration Capability* shown in the Table is based on a 25 m cleared-distance intersection clearance time.

Table L-3: Australian Heavy Vehicle Fleet Performance (Access to Road Train Routes) [1]

#	Vehicle Class	Startability (%)	Gradeability (Max. Grade) (%)	Gradeability (Max. Speed on 1%Grade) (km/h)	Acceleration Capability (s)	Tracking Ability (m)	Low-Speed Offtracking (m)	Frontal Swing (m)	Tail Swing (m)	Steer Tyre Friction Demand (%)	Static Rollover Threshold (g)	Rearward Amplification (-)	High-Speed Transient Offtracking (m)	Yaw Damping Coefficient (-)	Gross Mass per SAR (t/SAR)	Horizontal Tyres Forces (-)	Max. Effect Relative to Ref. Vehicle (%)	OVERALL (%)
	Performance Levels	**5**	**8**	**60**	**25**	**3.7**	**13.7**	**1.5**	**0.35**	**80**	**0.35**	**5.7**	**0.80**	**0.15**	**8.4**	**1.8**	**75**	**-**
17	rigid trucks	100	100	100	100	100	100	100	100	100	71	100	100	100	18	29	100	**18**
6	buses/coaches	100	100	100	100	100	100	100	100	100	100	100	100	100	-	83	100	-
43	prime-mover and semi-trailer	100	100	100	100	100	100	100	100	100	79	100	100	100	72	93	100	**53**
23	B-double	100	100	100	100	100	100	100	100	100	78	100	100	100	78	100	100	**70**
1	B-triple	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	**100**
9	truck and pig/tag-trailer	100	100	100	100	100	100	100	100	100	56	56	56	100	22	89	100	**22**
14	truck and dog trailer	100	100	100	100	100	100	100	100	100	86	50	71	93	71	79	93	**21**
12	A-double	100	100	100	100	100	100	100	100	100	92	92	83	100	100	100	92	**83**
12	A-triple road train	100	100	100	100	100	100	100	100	100	75	17	8	83	100	92	100	-
2	AAB-quad road train	100	100	100	100	100	100	100	100	100	100	50	-	100	100	50	100	-
139	**entire fleet**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**79**	**83**	**83**	**98**	**65**	**84**	**99**	**<u>42</u>**

Notes: *Acceleration Capability* shown in the Table is based on a 25 m cleared-distance intersection clearance time.

Source of all Tables: NTRC, *Performance Characteristics of the Australian Heavy Vehicle Fleet*, Melbourne: National Road Transport Commission, 2002

Appendix M List of Participants in Task Force Meetings and Stakeholders Workshops

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