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OVERLOAD ROAD DAMAGE MODEL

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DOCUMENT RETRIEVAL PAGE			**Report No:** TR2005/26
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Abstract:

Not only do overloaded vehicles pose an increased safety risk on the road (reduced stability and braking efficiency etc.), but they also accelerate the rate of deterioration of the road network and increase road maintenance costs, which in turn makes many of the roads less safe for travel by other road users (rutting, potholes etc.). Overloading also results in unfair competition between those operators that overload and those that operate within the legal limits. The annual damage to the network of provincial and national roads caused by overloading was estimated in 1995 to be R450 million per annum. At today's prices, this figure would be between R700 and R800 million per annum. However, this figure is now considered to be far too low, as recent studies have shown that the South African heavy vehicle fleet has changed over the past few years and now consists of a higher proportion of high payload vehicles, than in the past. Also, the general condition of our roads has deteriorated to the extent that even slight overloads result in high values of pavement damage.

To combat the overloading problem overload control strategies and programmes are implemented by various state roads and traffic law enforcement departments. This can be quite costly and such strategies and programmes need to be evaluated on a life-cycle cost basis.

One of the benefits of increased overload control is a reduction in damage to the road network infrastructure with a subsequent saving in maintenance costs. A spreadsheet based model was develop to calculate this potential saving in maintenance costs and was then applied to two example, one the N1 Corridor in the Free State and the second the N2 and N3 in KwaZulu-Natal.

In order to illustrate to transport operators the benefit to them of reducing overloading, an analysis was also done of the impact of the deterioration in the condition of the road network on vehicle operating costs.

Keywords: overloading, heavy vehicles, road damage, maintenance costs, life-cycle costing

Proposals for implementation:. To be applied to do life-cycle cost analysis when preparing and evaluating overload control strategies for clients.

Related documents:

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1. INTRODUCTION

Overload control of heavy vehicles has been identified as one of the key areas of focus of the Road to Safety 2001 – 2005 Strategy of the National Department of Transport. Not only do overloaded vehicles pose an increased safety risk on the road (reduced stability and braking efficiency etc.), but they also accelerate the rate of deterioration of the road network and increase road maintenance costs, which in turn makes many of the roads less safe for travel by other road users (rutting, potholes etc.). Overloading also results in unfair competition between those operators that overload and those that operate within the legal limits.

The annual damage to the network of provincial and national roads caused by overloading was estimated in 1995 to be R450 million per annum. At today's prices, this figure would be between R700 and R800 million per annum. However, this figure is now considered to be far too low, as recent studies have shown that the South African heavy vehicle fleet has changed over the past few years and now consists of a higher proportion of high payload vehicles, than in the past. Also, the general condition of our roads has deteriorated to the extent that even slight overloads result in high values of pavement damage.

To further illustrate the cost to the roads authorities of overloading, the South African National Roads Agency Limited has received claims from two toll road concessionaires for road damages amounting to more than R600 million, as a result of overloading not being prevented by the State. Although these claims are currently being evaluated, there can be no doubt as to the severity of the problem.

2. OVERLOAD CONTROL STRATEGIES

In order to address the overload problem as described in the introduction, the national roads department and most provincial roads departments and traffic law enforcement departments have developed or are planning to develop overload control strategies.

These strategies address issues such as corridors for the movement of heavy vehicles, available overload control infrastructure, required overload control infrastructure, manpower requirements, operational planning, screening of alternative routes, calibration and maintenance of equipment and infrastructure, private sector involvement in overload control and cooperation with the Department of Justice.

Implementing these strategies involves a lot of costs, such as the capital costs for the equipment and infrastructure, the operational costs, of which the largest portion is the personnel costs, maintenance costs of the equipment and infrastructure and the costs to calibrate the weighing equipment on a regular basis.

When evaluating overload control strategies it is necessary to evaluate these on a life-cycle cost basis. The benefits of an overload control strategy are the reduction in damage to the road network infrastructure, improvement in road safety and the income from fines for overload offences.

These benefits must be quantified to off-set the costs of an overload control programme. The income from fines can be high in the short-term, but soon reduces once overloading is brought under control. The real long-term benefits lie in the reduction in damage to the road network infrastructure and the improvement in road safety.

The aim of this project was to develop a model that can be used to quantify the benefits of a reduction in the damage to the road network infrastructure.

In order to illustrate to transport operators the benefit to them of reducing overloading, an analysis was also done of the impact of the deterioration in the condition of the road network on vehicle operating costs.

3. TEAM

The project team members are as follow:

- Michael Roux
- Ismail Sallie
- Paul Nordengen
- Henning Ras
- Volanda de Franca

4. OVERLOAD ROAD DAMAGE MODEL

The model is a spreadsheet based model that determines the road damage due to overloaded vehicles in the following manner:

Step 1: Traffic Information.

The available traffic information is analysed to determine the number of heavy vehicles travelling on a road, route or network. This can be very basic, such as heavy vehicles as a percentage of total traffic right through to detail information on the heavy vehicle traffic broken down into various classes of heavy vehicles.

Step 2: Extent of overloading.

The extent of overloading refers to how many vehicles are overloaded, i.e. the percentage of heavy vehicle that are overloaded. If detail information is available, for example from weigh-in-motion surveys, giving the extent of overloading per class of heavy vehicle, this can be used in the model. If such information is not available, input values based on national or regional statistics can be used.

Step 3: Severity of overloading.

Severity of overloading refers to by how much each vehicle is overloaded, i.e. the percentage by which a vehicle is overloaded. If detail information is available, for example from weigh-in-motion surveys, giving the extent of overloading per class of heavy vehicle, this can be used in the model. If such information is not available, input values based on national or regional statistics can be used.

Step 4: Calculate the damage caused by the overloaded vehicles.

The damage caused by overloaded heavy vehicles is calculated as the difference between the E80s of the overloaded vehicle and the E80s of the same vehicle if it was legally loaded. These additional or “overloaded” E80s are then multiplied with the distance that the vehicle would travel and with a road maintenance cost per E80-km to give the monetary value of the road damage.

Step 5: Determine the number of additional legal vehicles to transport the overloaded portion of the load on the overloaded heavy vehicles.

It is taken that the amount of goods that are transported must remain the same. If overloaded vehicles are reduced to zero, the overloaded portion of the loads that was transported on the overloaded vehicles would now have to be transported by legally loaded vehicles. There will therefore be a net increase in the number of heavy vehicles on the road. In this step this number of additional heavy vehicles is calculated.

Step 6: Determine the road damage caused by the additional legal vehicles.

The damage caused by each additional legal heavy vehicle is calculated by multiplying the E80s of the legal vehicle with the distance that the vehicle would travel and with a road maintenance cost per E80-km to give the monetary value of the road damage caused by the legally loaded vehicle.

Step 7: Determine the net saving in road damage.

The net saving in road damage is the difference in the damage caused by the overloaded vehicles and the damage caused by the additional legal vehicles.

5. STANDARDISATION OF THE DATA OUTPUT OF WEIGHING DATA

One of the important input parameters for the overload model is historical weighing data from computerised weighbridges. The two systems that have been developed by Transportek, namely, WinNuwei (vehicle weighing system) and VOMS (vehicle overload management system) were improved to output various weighing data outputs in a standard format. The output of various weighing elements, e.g. axles, power rating, drive axle rating, bridge formula, overall vehicle between the two systems had to be standardised as the systems were designed for different purposes. VOMS used the lowest common format to be compatible with weighing data from other systems that only provided minimal weigh info. WinNuwei stored comprehensive data but the reporting was geared at operational reporting. Due to the nature of the two systems, it was not immediately possible to create a common database structure that could be used by both systems as a key data element in WinNuwei being reweigh records is not used in the VOMS analyses as VOMS uses the initial weigh records. The database structures of both systems were thus modified and improved to allow for additional fields to assist with reporting. By working towards a standard output, the various elements in both systems were improved to allow for data from WinNuwei as well as data from other weighing systems to be used as input for the overload model.

6. APPLICATION OF THE OVERLOAD ROAD DAMAGE MODEL ON THE N1 CORRIDOR IN THE FREE STATE

6.1. Introduction

Axle overloading primarily affects the durability of a road. It reduces pavement life and over stresses bridges and culvert structures. There is an exponential relationship between axle loads and pavement damage (the so-called Fourth Power Law). Overloaded vehicles therefore cause pavement damage well in excess of what legally loaded vehicles cause. By eliminating overloading a significant saving in road infrastructure maintenance can be realised. In this section the savings that are possible on the N1 are calculated but only as far as pavement damage is concerned.

In all calculations the E80s or equivalent standard axle loads (ESALs) are calculated using the following formula:

$$ESALs\,(E80s) = \left(\frac{P}{Ps}\right)^4$$

Where P = axle load

Ps = standard axle, taken as 8 200kg

The calculation of the potential saving in road pavement maintenance costs is done in three steps:

Step 1: Determine the additional E80s due to the overloaded vehicles.

Step2: Determine the E80s of the additional vehicles that will be required to carry the overloaded portion of the loads carried by the overloaded vehicles.

Step 3 Multiply the difference between the two values by the maintenance cost per E80

6.2. Determining the number of additional E80s due to overloading

To determine the number of additional E80s due to overloading, the situation with no overloading control has to be considered. In order to simulate this situation, the data from a SANRAL weigh-in-motion (WIM) site on the N2 between Coega and the Sondags River were analysed (CTO3013). This site was chosen as it has the same split of heavy vehicles between short, medium and long as on the N1 through the Free State. There is also no functional weighbridge in the vicinity of this CTO station. There is currently no WIM site in the Free State. The degree and extent of the overloading calculated for this site was then applied to the traffic information for the three SANRAL CTO stations closest to the proposed three TMCs. These three stations are CTO422-Kroonstad by-pass, CTO418-Bloemfontein by-pass and CTO416-Edenburg South. The degree and extent of the overloading as calculated from data from this station are shown in Table 28.

Table 1 Degree and extent of overloading at CTO 3013

Heavy vehicle Class	Axle group overloads		GVM/GCM overloads	
	Percentage of vehicles overloaded	Average percentage by which vehicles are overloaded	Percentage of vehicles overloaded	Average percentage by which vehicles are overloaded
Short	7.9%	12.6%	2.2%	9.9%
Medium	12.4%	11.6%	2.9%	7.3%
Long	17.4%	9.1%	13.6%	6.9%

Applying these values to the heavy vehicle traffic on the N1 past the three proposed TMCs, the following additional E80s per annum, due to overloaded vehicles (assuming no overload control takes place) were calculated.

Table 2 Additional E80s per annum due to overloaded vehicles on N1

TMC	Additional E80s due to overloaded vehicles			
	Short	Medium	Long	Total
Kroonstad	13 237	33 656	152 162	**199 054**
Bloemfontein	14 772	33 533	189 979	**238 284**
Trompsburg	5 268	18 462	87 054	**110 784**

6.3. Determination of the E80s of the additional legal vehicles required

It is assumed that the total volume of goods transported on the N1 through the Free State will remain constant. The "overloaded portion" of the goods currently carried on overloaded vehicles will therefore have to be carried by legally loaded vehicles. To calculate the E80s of these additional legal vehicles it was assumed that the goods would be transferred to the same type of vehicle. For example the total overloaded portion carried on overloaded two-axle rigid vehicles would now be carried on legally loaded two-axle rigid vehicles, etc. It was also assumed that all additional legally loaded vehicles are loaded to the maximum legal load.

Table 3 E80s of additional legal vehicles

TMC	Vehicle class	Number of additional legal vehicles required	E80/additional legal vehicle	Total E80s for the additional legal vehicles
Kroonstad	Short	954	2.5	2 384
	Medium	1 077	5.9	6 357
	Long	3 778	9.3	35 133
	Total	**5 809**		**43 874**
Bloemfontein	Short	1 064	2.5	2 660
	Medium	1 074	5.9	6 334
	Long	4 717	9.3	43 865
	Total	**6 854**		**55 859**

Trompsburg	Short	379	2.5	949
	Medium	591	5.9	3 487
	Long	2 161	9.3	20 100
	Total	**3 132**		**24 530**

6.4. Determination of the annual potential saving in road pavement maintenance costs

To determine the potential saving in road pavement maintenance costs, a value of R0.20/E80-km is used. This value is based on values that were determined in three other studies. One is the SATCC Axle Load Study for Southern Africa (Final report May 1993) in which a value that converts to R0.12/E80-km was derived. The second is a recent study for the City of Tshwane Metropolitan Municipality by Kwezi V3 Engineers in which a value of R0.25/E80-km was derived. The third study was work done for KwaZulu-Natal by CSIR Transportek in which an upper value of R0.30/E80-km and a lower value of R0.18/E80-km were calculated.

Table 4 Potential annual saving in road pavement maintenance costs on the N1

TMC	Additional E80s due to overloaded vehicles	E80s of the additional legal vehicles	Net additional E80s	Length of N1 per TMC	Cost per E80-km	Total potential saving in maintenance costs
Kroonstad	199 054	43 874	155 180	215	R0.20	R6 672 749
Bloemfontein	238 284	52 859	185 425	175	R0.20	R6 489 874
Trompsburg	110 784	24 536	86 248	123	R0.20	R2 121 700
Total	**548 122**	**121 269**	**426 853**	**513**		**R15 284 323**

6.5. Estimation of annual road maintenance savings on secondary roads due to overload control

The potential saving in road maintenance cost on the secondary roads was calculated on the same basis as that for the N1. The traffic information for the secondary roads are however not as detailed as the information available for the N1. It was therefore necessary to make additional assumptions. In the first place the heavy vehicles on the secondary roads were split into short, medium and long using the average split for the three CTO stations that were used for the N1 calculations. This average split is 23% short, 20% medium and 57% long (in the case of the N6 the available CTO information was used). Secondly, the extent and severity of overloading, as determined from the data for CTO Station 3013, was also applied to the traffic on the secondary roads.

The potential annual savings for national secondary roads are contained in Table 32 and for provincial secondary roads in Table 33. National secondary roads are the R30 from Bloemfontein (N1) to Welkom, the R34 from Welkom to Kroonstad and the N6 from Bloemfontein to Aliwal North.

Table 5 Potential annual saving in road pavement maintenance costs on the national secondary roads

TMC	Additional E80s due to overloaded vehicles	E80s of the additional legal vehicles	Net additional E80s	Length of national secondary roads per TMC	Cost per E80-km	Total potential saving in maintenance costs
Kroonstad	46 479	10 286	36 193	115	R0.20	R832 438
Bloemfontein	44 317	9 807	34 510	137	R0.20	R945 562
Trompsburg	36 991	8 186	28 805	141	R0.20	R812 293
Total	**127 786**	**28 279**	**99 507**	**393**		**R2 590 292**

Table 6 Potential annual saving in road pavement maintenance costs on the provincial secondary roads

TMC	Additional E80s due to overloaded vehicles	E80s of the additional legal vehicles	Net additional E80s	Length of provincial secondary roads per TMC	Cost per E80-km	Total potential saving in maintenance costs
Kroonstad	28 824	6 379	22 445	650	R0.20	R2 917 881
Bloemfontein	12 610	2 791	9 820	174	R0.20	R341 729
Trompsburg	961	213	748	145	R0.20	R21 697
Total	**42 395**	**9 382**	**33 013**	**969**		**R3 281 306**

7. AN ANALYSIS OF THE INCREASE IN VEHICLE OPERATING COSTS AS A RESULT OF A DETERIORATION IN THE CONDITION OF THE ROAD NETWORK

7.1. Introduction

An analysis has been carried out to quantify the increase in the operating costs of heavy vehicles on the national and provincial road network as a result of deterioration in the condition of these networks. The analysis compares the standardised vehicle operating costs (SVOC) for three network condition scenarios. The three scenarios are an ideal network, the network in its current condition and a deteriorated network. The basis against which the comparisons are done is the "perfect network". The perfect network is defined as a network where all the roads are in a very good condition.

7.2. Network Condition Scenarios

Table 7 below gives the percentage of the road network in the various condition categories for the ideal network:

Table 7 Condition of Road Network: Ideal Network

Condition Category	Percentage of Network in the Condition Category
Very Good	30%
Good	30%
Fair	40%
Poor	-
Very Poor	-
Total	**100%**

Table 8 below gives the percentage of the road network in the various condition categories for the two networks in their current condition:

Table 8 Condition of Road Network: Current Status (2004)

Condition Category	Percentage of Network in the Condition Category	
	National	**Provincial**
Very Good	21%	9%
Good	31%	22%
Fair	32%	31%
Poor	12%	29%
Very Poor	4%	9%

Total	100%	100%

Table 9 below gives the percentage of the road network in the various condition categories in a situation of advanced deterioration:

Table 9 Condition of Road Network: Deteriorated Network

Condition Category	Percentage of Network in the Condition Category
Very Good	5%
Good	10%
Fair	20%
Poor	35%
Very Poor	30%
Total	**100%**

7.3. Method to Calculate the Operating Costs of Heavy Vehicles on Road Networks in Different Conditions

To calculate the vehicle operating costs of heavy vehicles on the road networks in different conditions, use was made of three models that give the relationship between the SVOC and the Road Roughness in QI units. The three models that were used are the HDM model, the CB-Road model and the DBSA Guide model.

The assumptions made regarding the range of QI units applicable to the different condition categories are given in Table 10 below.

Table 10 Relationship between Condition Categories and QI units

Condition Category	Road Roughness in QI Units	
	Low Value	High Value
Very Good	0	20
Good	20	40
Fair	40	60
Poor	60	80
Very Poor	80	100

Using these ranges of QI units, low and high values for the SVOC were determined for each condition category with each of the three models. These results appear in Table 11 below.

Table 11 SVOC values per Condition Category

Condition Category	Standardised Vehicle operating Costs (SVOC)					
	HDM Model		CB-Roads		DBSA Guide	
	Low Value	High Value	Low Value	High Value	Low Value	High Value
Very Good	1.00	1.00	1.00	1.00	1.00	1.00
Good	1.00	1.00	1.00	1.00	1.00	1.00
Fair	1.00	1.15	1.00	1.05	1.00	1.10
Poor	1.15	1.30	1.05	1.15	1.10	1.20
Very Poor	1.30	1.45	1.15	1.25	1.20	1.30

Using the values in Table 11 above, a weighted average of the low and high SVOC values were calculated for each of the three models for the three road network condition scenarios. The percentages of the network in the various condition categories were used as the weighting factor.

7.4. Results of the Calculation of the SVOC for the Three Network Condition Scenarios

The results of the calculations as described above appear in Table 12 below.

Table 12 Weighted Average of the SVOC for the Three Network Condition Scenarios

Network	Weighted Average of SVOC								
	HDM Model		CB-Roads		DBSA Guide		Average		
	Low Value	High Value	Low Value	High Value	Low Value	High Value	Low Value	High Value	Average Value
Ideal Network	1.00	1.06	1.00	1.02	1.00	1.04	1.00	1.04	1.02
Current Condition: National	1.03	1.10	1.01	1.04	1.02	1.07	1.02	1.07	1.05
Current Condition: Provincial	1.07	1.17	1.03	1.08	1.05	1.12	1.05	1.12	1.09
Deteriorated Condition	1.14	1.27	1.06	1.14	1.10	1.18	1.10	1.20	1.15

7.5. Discussion of Results

A SVOC of 1 represents the operating costs of heavy vehicles on a road network in a perfect condition, i.e. all the roads in a very good condition.

The average SVOC for heavy vehicles on the ideal network varies from a low value of 1.00 to a high value of 1.04, with an average value of 1.02. This means that the heavy vehicle operating costs on the ideal network is close to that on the perfect network as can be expected. It is on average 2% higher.

The average SVOC for heavy vehicles on the national network in its current condition varies from a low value of 1.02 to a high value of 1.07, with an average value of 1.05. The heavy vehicle operating costs on the national road network in its current condition is therefore on average 5% higher than what it would be on a perfect network and 2.9% higher than what it would be on an ideal network. The current condition of the national road network is close to the ideal network, hence the small increase in vehicle operating costs compared to the ideal network.

The average SVOC for heavy vehicles on the provincial network in its current condition varies from a low value of 1.05 to a high value of 1.12, with an average value of 1.09. The heavy vehicle operating costs on the provincial road network in its current condition is therefore on average 9% higher than what it would be on a perfect network and 6.9% higher than what it would be on an ideal network.

The average SVOC for heavy vehicles on the deteriorated network varies from a low value of 1.10 to a high value of 1.20, with an average value of 1.15. The heavy vehicle operating costs on a road network in a deteriorated condition is therefore on average 15% higher than what it would be on a perfect network and 12.8% higher than what it would be on an ideal network.

The estimated annual operating costs of heavy vehicles on the national and provincial road network is R164 billion. Using a split of 10% national and 90% provincial, the annual operating costs of heavy vehicles on the national road network is R16.4 billion and on the provincial road network R147.6 billion. If it assumed that this represents the situation on the network in the current state, then the heavy vehicle operating cost on the perfect road network would be R15.6 billion for the national road network plus R135.4 billion for the provincial road network, giving a total of R151 billion (these calculations are based on the 5% increase in SVOC for the national road network and the 9% increase in SVOC for the provincial road network when compared to the perfect road network).

The increases in SVOC for the various network condition scenarios in Rand value are summarised in Table 13 below.

Table 13 Estimated increases in heavy vehicle operating costs for the national and provincial road networks in various conditions.

Network Condition Scenario	Percentage increase in SVOC compared to the perfect road network	Estimated increase in annual heavy vehicle operating costs
Ideal	2%	R3 billion
Current:		
National	5%	R0.8 billion
Provincial	9%	R12.2 billion
Total		R13.0 billion
Deteriorated	15%	R22.5 billion

8. ESTIMATING OF ROAD DAMAGE DUE TO OVERLOADED VEHICLES ON THE N3 AND N2 IN KWAZULU-NATAL

8.1. Introduction

In order to determine the damage caused by overloaded vehicles on the N3 and N2 in KwaZulu-Natal, a model was developed based on overload data from weighbridges in KwaZulu-Natal from 1996 to 2003. The model was first used to calculate the value of the road damage per year for each year from 1996 to 2003. The model was then used to calculate the value of the road damage for various degrees and extent of overloading.

The extent of overloading refers to the number of vehicles that are overloaded and is expressed as overloaded vehicles as a percentage of all heavy vehicles on the road. The information from the various weigh-in-motion sites in KwaZulu-Natal was used to determine the extent of overloading.

The degree of overloading refers to the average overload of heavy vehicles and is expressed in E80s. The information of each overloaded vehicle weighed at the various weighbridges in KwaZulu-Natal was used to calculate the degree of overloading. For each vehicle that was overloaded, the overloaded E80s were calculated, i.e. the additional E80s due to the overloaded portion of the total load on the vehicle. A damage coefficient of n=4 was used in the calculations. An average E80 was calculated per vehicle class for each year and these averages were then used to calculate a weighted average per year. The numbers of overloaded vehicles per vehicle class were used as the weighting factors.

8.2. Overview of the data used

The lengths of roads are as follows:

N3:	262km
N2 (south):	240km
N2 (north):	235km
Total:	737km

A rehabilitation cost of R145/m2 for asphalt roads with a design life of 15 years was used. A rehabilitation cost of R250/m2 for concrete roads with a design life of 30 years was used.

The roads were divided into sections with uniform pavement structures and upper and lower values for the design E80s for each uniform section were used in the calculations. The same traffic volumes were used for the calculations for all the years.

8.3. Annual road damage caused by overloaded vehicles

The amount of road damage caused by overloaded vehicles per year, for the period 1996 to 2003 is given in Table 14.

Table 14 Estimated annual road damage caused by overloaded vehicles

Year	Vehicles weighed	Vehicles overloaded	Extent of overloading	Degree of overloading	Annual cost due to overloading R million		
				Ave. O/L E80s/vehicle (n=4)	Low	High	Average
1996	50,595	14,220	16%	1.28	19.7	40.4	30.1
1997	45,657	13,691	15%	1.31	18.8	38.9	28.9
1998	33,235	14,291	15%	1.22	17.6	36.2	26.9
1999	72,546	25,788	15%	1.13	16.3	33.4	24.9
2000	135,152	46,837	12%	0.79	9.2	18.8	14.0
2001	115,193	42,268	12%	0.78	9.1	18.4	13.8
2002	142,295	47,938	14%	0.72	9.6	19.9	14.8
2003	113,377	28,149	15%	0.69	10.0	20.5	15.3

From Table 14 it can be seen that the estimated damage caused by overloaded vehicles reduced from R30.1 million per year in 1996 to R13.8 million per year in 2001. This is mainly due to the increased overload control in KwaZulu-Natal. The big improvement from 1999 to 2000 (from R24.9 million down to R14 million) is as a result of increased overload control on the N3 after the Road Traffic Inspectorate of the KwaZulu-Natal DoT and SANRAL entered into a contract.

The reduction in estimated road damage is primarily due to a reduction in the degree of overloading, rather than in the extent of overloading, which has remained fairly constant. During the period 1996 to 2001 it reduced from 16% to 12%, increasing to 14% in 2002 and 15% in 2003.

The degree of overloading has however decreased significantly. In 1996 the average E80s per overloaded vehicle was 1.28 and this reduced to 0.69 in 2003, representing an improvement of 46%. This is also illustrated by the percentage of vehicles overloaded within and above the 5% tolerance limits as shown in Figure 1. In 1998 97% of all overloaded vehicles weighed were overloaded by more than 5% and only 3% by less than 5%. In 2003 this changed to 26% of vehicles weighed that were overloaded by more than 5% and 74% overloaded by less than 5%.

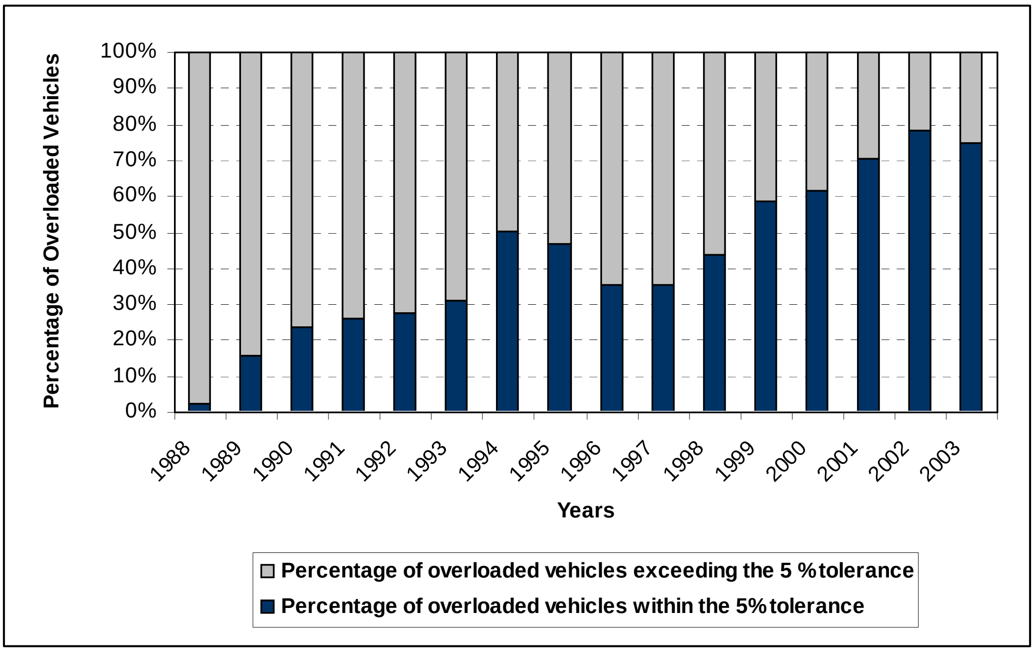

Figure 1. Percentage of vehicles exceeding and within the 5 % tolerance 1988 to 2003

A further illustration of the decrease in the severity of overloading is given in Figure 2, which shows that from 1996 to 2003 there has been a significant trend in terms of the overload distribution. In the 0 to 1 000 kg range there have been significant increases in the percentage of vehicles overloaded, while in the overload categories greater than 2 000 kg, there have been marked decreases in the percentage of overloaded vehicles. The only increases were in the 0 to 500 and 501 to 1 000 kg bands.

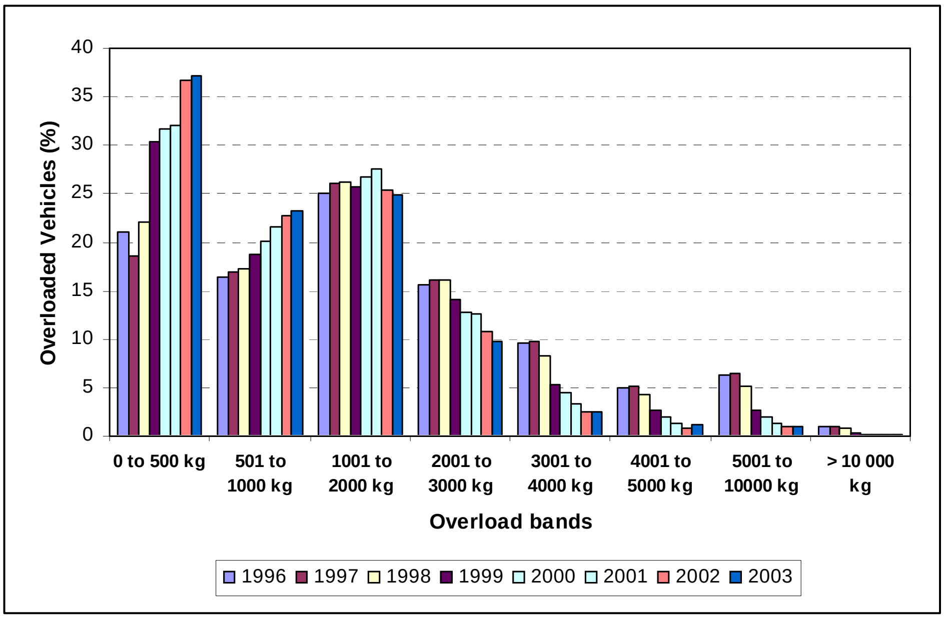

Figure 2. Distribution of vehicle overloads (percentage)

During 2002 and 2003 there was a slight increase in the estimated value of damage caused by overloaded vehicles. This could be as a result of a decrease in overload control caused by implementation difficulties with the Trafman system at all the provincial weighbridges in KwaZulu-Natal in 2002/2003.

The information contained in Table 14 is presented graphically in Figure 3.

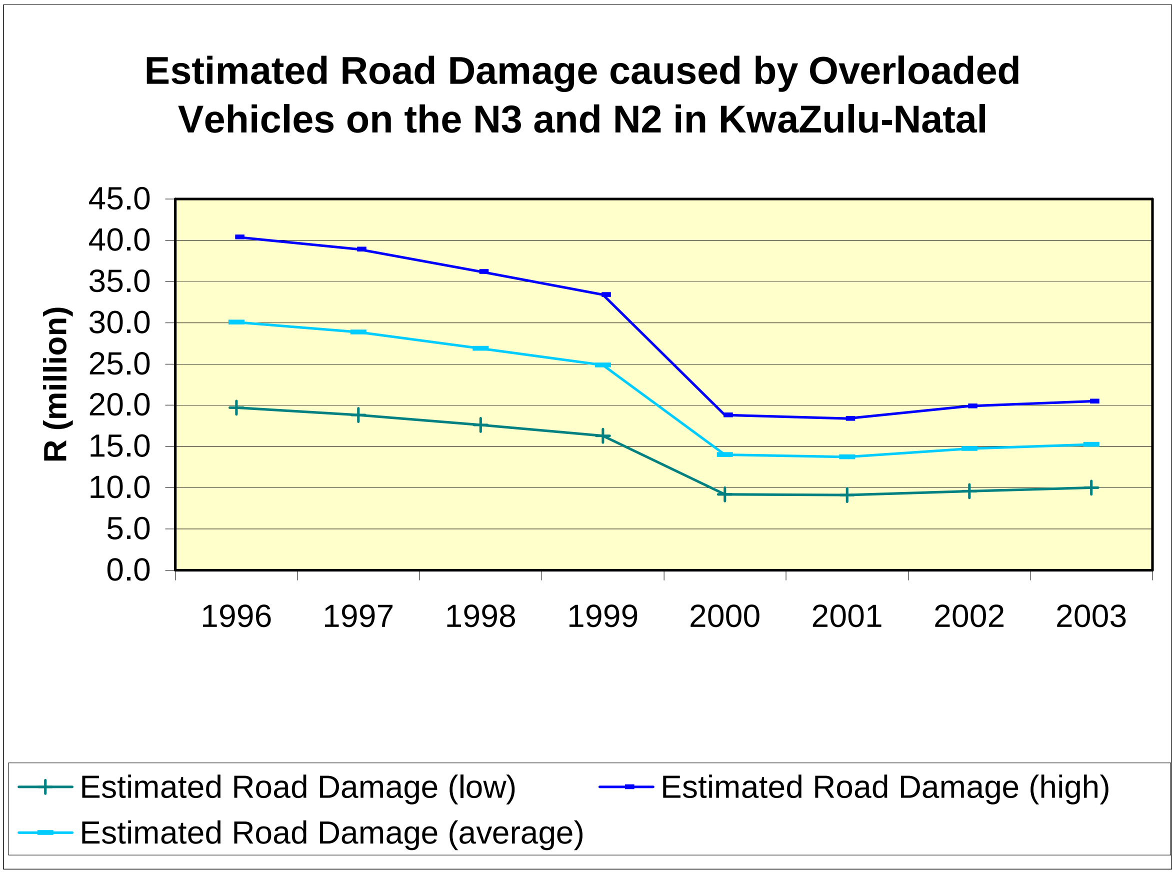

Figure 3. Estimated annual road damage caused by overloaded vehicles

8.4. Prediction of estimated road damage due to overloaded vehicles

Using the model that was developed, the estimated road damage for various degrees and extent of overloading was calculated. These results are shown in Table 15.

Table 15 Estimated Road Damage in R million for Various Degrees and Extent of Overloading

Degree of Overloading: Average overloaded E80/overloaded vehicle	Extent of Overloading: 5%	10%	12%	14%	15%	16%	20%	25%	30%
0.50	3.7	7.3	8.8	10.3	11.0	11.8	14.7	18.4	22.0
0.69	5.1	10.1	12.2	14.2	15.3[8]	16.2	20.3	25.4	30.4
0.72	5.3	10.6	12.7	14.8[7]	15.9	16.9	21.2	26.5	31.7
0.75	5.5	11.0	13.2	15.4	16.5	17.6	22.0	27.6	33.1
0.78	5.7	11.5	13.8[6]	16.1	17.2	18.3	22.9	28.7	34.4
0.79	5.8	11.6	14.0[5]	16.3	17.4	18.6	23.2	29.0	34.8
1.00	7.3	14.7	17.6	20.6	22.0	23.5	29.4	36.7	44.1
1.13	8.3	16.6	19.9	23.3	24.9[4]	26.6	33.2	41.5	49.8
1.22	9.0	17.9	21.5	25.1	26.9[3]	28.7	35.9	44.8	53.8

		1.25	9.2	18.4	22.0	25.7	27.6	29.4	36.7	45.9	55.1
		1.28	9.4	18.8	22.6	26.3	28.2	30.1[1]	37.6	47.0	56.4
		1.31	9.6	19.3	23.1	27.0	28.9[2]	30.8	38.5	48.1	57.8
		1.47	10.8	21.6	25.9	30.2	32.4	34.6	43.2	54.0	64.8
		1.50	11.0	22.0	26.5	30.9	33.1	35.3	44.1	55.1	66.1
		1.54	11.3	22.6	27.2	31.7	34.0	36.2	45.3	56.6	67.9
		1.75	12.9	25.7	30.9	36.0	38.6	41.2	51.4	64.3	77.2
		2.00	14.7	29.4	35.3	41.2	44.1	47.0	58.8	73.5	88.2
		2.50	18.4	36.7	44.1	51.4	55.1	58.8	73.5	91.9	110.2
		3.00	22.0	44.1	52.9	61.7	66.1	70.6	88.2	110.2	132.3

Note: 1 1996
2 1997
3 1998
4 1999
5 2000
6 2001
7 2002
8 2003

The values contained in Table 15 are presented graphically in Figure 4. Each of the lines presents the change in estimated road damage at a different constant extent of overloading and an increasing degree of overloading.

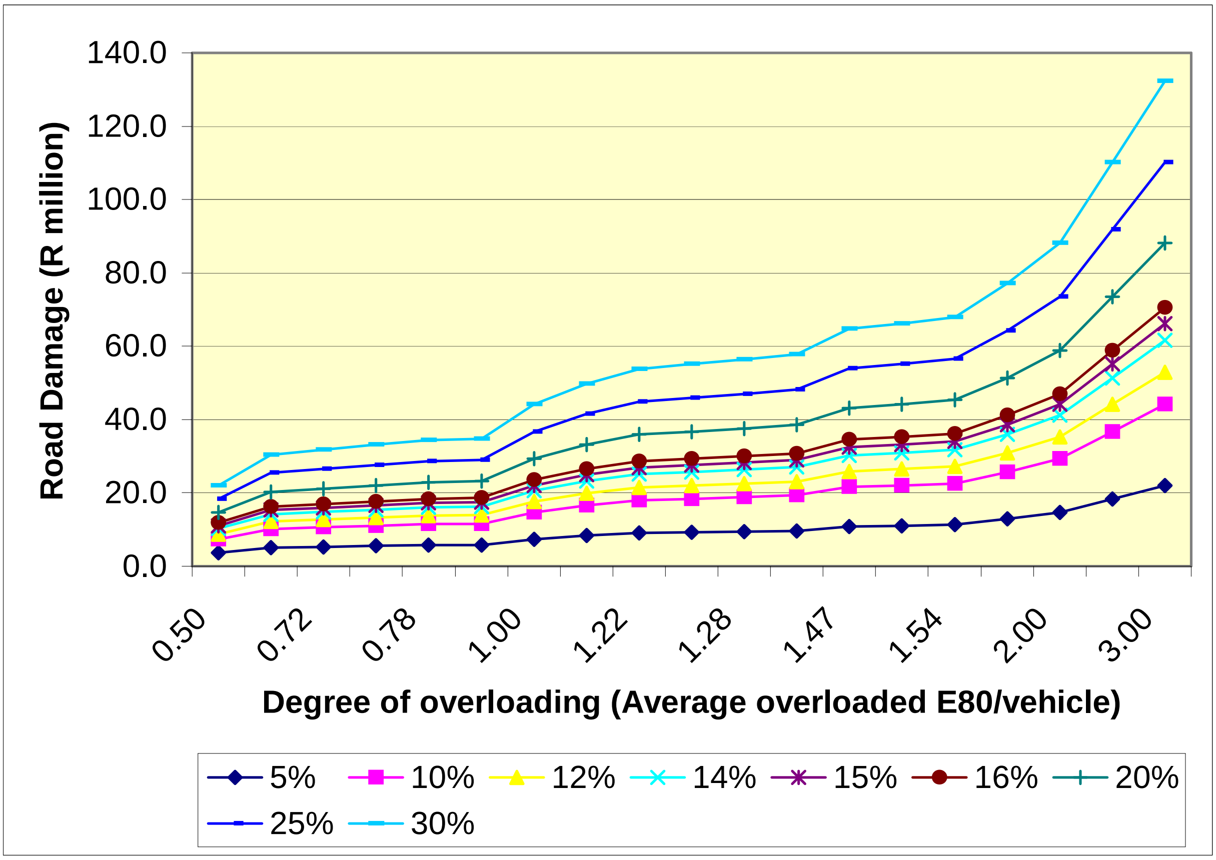

Figure 4. Estimated Road Damage at Constant Extent and Varying Degrees of Overloading