THE DAMAGING EFFECTS OF OVERLOADED HEAVY VEHICLES ON ROADS

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PREFACE

This document is an update of the PAD27 document entitled *Damage to roads by overloaded heavy vehicles* published in 1987 by the CSIR. At the recommendation of the National Overloading Control Technical Committee (NOCTC), which is one of the committees indirectly responsible to the Committee of Land Transport Officials (COLTO) and Mincom, PAD27 was revised as part of an ongoing campaign to make the general public as well as transport operators, law enforcement agencies and representatives of the Department of Justice, aware of the serious nature of heavy vehicle overloading in South Africa in economic terms. It has been estimated that 60% of the damage to the road network in South Africa is caused by illegally overloaded heavy vehicles, costing the taxpayer some R400 million per annum.

Overloading not only causes considerable damage to the South African road network, but also contributes to the serious problem of maintaining road safety on our roads. Furthermore, heavy vehicle operators that do not overload are placed at a disadvantage, as they cannot compete fairly with unscrupulous operators that follow a policy of deliberate overloading.

The Department of Transport views the issue of overloading seriously and intends to prosecute operators who overload continuously to the full extent of the law. Coupled with increased law enforcement, there is also the need to inform operators of the consequences of overloading, both in terms of road and vehicle damage.

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1. INTRODUCTION

Roads and streets are the most important transport communication medium in the country and are used by almost everyone on a daily basis. Besides the fact that roads are provided for the benefit of the road user, they also play a significant role in promoting economic growth and the living standards of the population. By means of roads, people have access to markets, places of work, clinics and hospitals, educational institutions, places for sport and leisure activities and vacations.

In South Africa, the more than half a million kilometres of road have a current replacement value in excess of R165 billion. Approximately R2 155 million per annum is currently spent in South Africa on road construction and maintenance to safeguard this national asset.

Research in the USA and South Africa has shown that damage to the road by axle loads exceeding the legal limit, increases out of all proportion to the loads: for example, an axle carrying double the legal load may cause from 4 to 60 times as much damage as one legal axle load, depending on the condition of the structure and type of road. It is estimated that between 15 and 20% of all heavy vehicles travelling on South African roads are overloaded.

It has been found that legally loaded heavy vehicles cause a relatively small amount of damage to road pavement structures, as opposed to overloaded heavy vehicles which are responsible for approximately 60% of the damage to the road network, representing some 400 million Rands per annum. During 1996, there were 58 904 heavy vehicles weighed at weighbridges in South Africa, 33% of which were overloaded.

The fines currently imposed by the courts on those convicted of heavy vehicle overloading are in most cases negligible in comparison with the damage caused to the roads and are quite clearly ineffective in discouraging overloading. As a consequence, law enforcement of the axle load regulations, which is also adversely effected by logistical problems, is not nearly as vigorously pursued as would seem desirable to control overloading effectively.

Because of the limited funds available for the construction of new roads and also for road maintenance, it is essential that effective enforcement of the axle load regulations be carried out throughout South Africa in order to protect the country's most valuable asset. Moreover, inadequate law enforcement on vehicle overloading allows some transport operators to deliberately grossly overload their heavy vehicles, which not only benefits them in terms of substantially higher profits, but also exposes the law-abiding operators to unfair competition.

Furthermore, overloaded vehicles become a traffic hazard, especially regarding the heavy vehicle's braking system and additional braking distance involved. This situation is aggravated by steep downhill slopes and sharp curves. On steep uphill gradients where no climbing lane is provided, the slow moving heavy vehicle causes traffic disruption.

Traffic accidents caused directly or indirectly by overloaded heavy vehicles are normally not included when the total cost to the country, caused by overloading, is calculated.

For the effective enforcement of the Road Traffic Act and the full implementation of the Road Traffic Quality System (RTQS), it is necessary to support the roadside enforcement programmes by monitoring the technical quality and safety of vehicles, drivers and operators. The new National Traffic Information System (NaTIS) will assist authorities in providing for the continual monitoring of the performance of motor vehicles, drivers and operators through the capturing of enforcement related data and the supplying of current registration information for enquiry purposes. This will facilitate the process to:

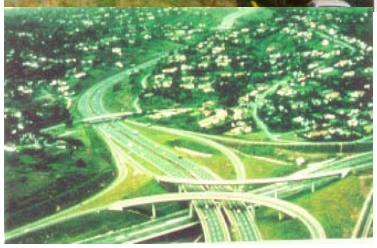
- monitor the non-compliance with the Act of drivers and/or operators of RTQS vehicles by means of a points demerit system, and
- take corrective/punitive action against regular offenders.

There were approximately 1,4 million registered commercial vehicles in 1993. During the same year approximately 400 million tons of goods were transported by road compared to 175 million tons transported by rail.

Since the greater percentage of goods transported by road is increasing, it is expected that heavy vehicles will remain a common sight on our roads in the foreseeable future.
Careful attention should therefore be given to optimising the use of heavy vehicles and to the damage to the road structure caused by them.

2. THE ROAD NETWORK

The South African road network comprises 20 000 kilometres of national roads, 340 000 kilometres of provincial roads as well as 165 000 kilometres of urban roads and streets. This network is estimated to have a replacement value in excess of R165 billion.

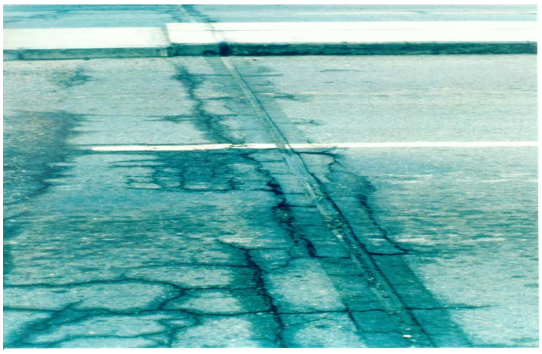


The current expenditure level for maintenance of the rural road networks (national and provincial) is R1,36 billion (less than 1% of the lower estimate of replacement value). To make matters worse, the trend in maintenance expenditure on national roads has been one of steady decline since the late 1980s.
Since then, the number of commercial vehicles on South African roads has increased by between 5 and 10% per annum, while that of other vehicles has grown by between 1 and 7% per annum. In contrast, R0,83 billion per annum is spent on the construction of new roads, thus representing an increase in network size of approximately 0,5% per annum.

In summary, the total road network in South Africa represents a huge investment. This asset is currently facing a crisis in terms of funding for road maintenance and also in terms of the growing vehicle population.

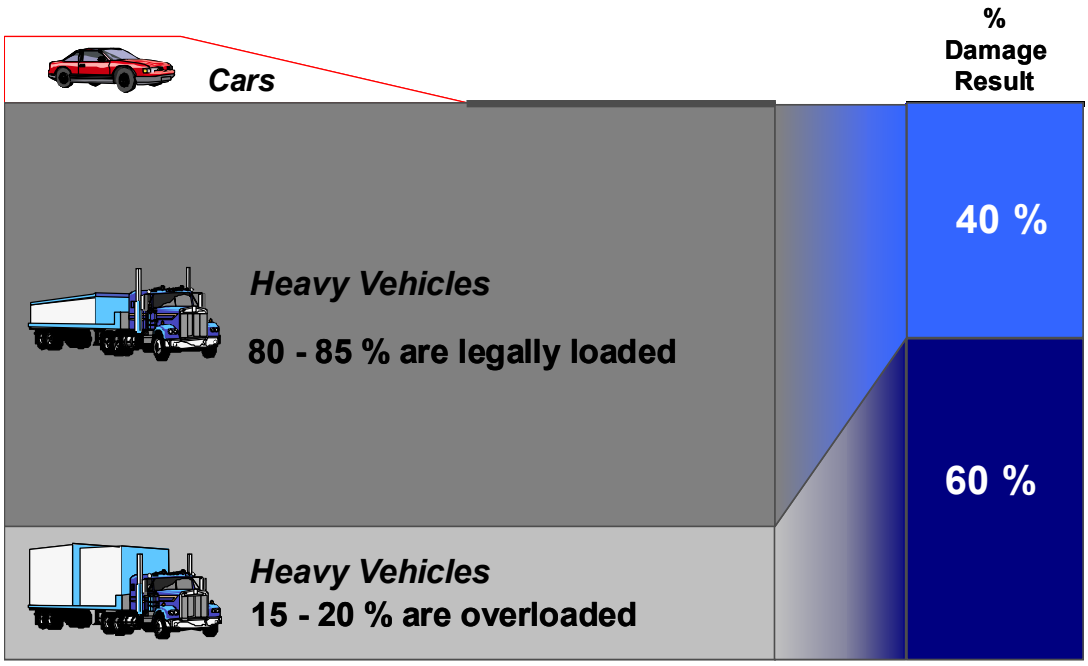
3. ROAD DETERIORATION FACTORS

Paved roads - involving both asphalt and concrete - which carry the bulk of road traffic, deteriorate for a number of reasons and therefore require routine maintenance on a regular basis. For example, sunlight causes a continuous, slow hardening action on bituminous surfaces, while the penetration of water into and from under (poor drainage) road pavement layers can lead to a loss of load-bearing capacity and consequent increased rate of road structure deformation.



However, it is the vehicular traffic on the road which is the major cause of road deterioration, especially on heavily trafficked roads. Every vehicle which passes over a road causes a momentary, very small, but significant deformation of the road pavement structure. The passage of many vehicles has a cumulative effect which gradually leads to permanent deformation and road surface deterioration by cracking.

Research has shown, however, that light vehicles such as cars and light commercial vehicles, make a relatively small contribution to the structural damage of a road pavement compared to that of heavy vehicles. Furthermore, the load carried by each heavy vehicle axle determines its destructive effect.



The damage caused by the passage of any particular heavy vehicle is determined by the magnitude of each of its axle loads, the spacings between the axles, the number of wheels, the contact pressures of the tyres and the travelling speed. In addition, road pavement characterisation has a major influence on pavement deterioration.

4. LIMITING ROAD DETERIORATION

While damage to the road network by heavy vehicles cannot be eliminated, it is clearly in the interest of the travelling public and the road haulier that all reasonable steps be taken to minimise the deterioration of our roads and streets. Cracking and permanent deformation of the road pavement, with a resultant increase in roughness, lead to increased vehicle operating costs, discomfort (decreased riding quality) and reduced safety conditions.

Some thirty years ago, the need was recognised to introduce legislation to limit the maximum load which a heavy vehicle axle could be permitted to carry, in terms of various axle and wheel spacing configurations. Consequently an attempt was made to protect South Africa's national asset and to maintain a reasonable balance between road building as well as road maintenance costs on the one hand, and the economy of the road industry as a whole on the other.

Stronger and therefore more costly road pavements as well as road surface wearing courses are presently being designed for new road construction, taking the phenomenon of overloading of heavy vehicles into consideration. Less money is therefore available for other urgently needed roads and for normal road maintenance.

5. AXLE LOAD REGULATIONS

Heavy vehicles travelling from origin to destination use the public road network, which includes roads as well as bridge structures. If the size and mass of a vehicle are not controlled, heavy loads may cause excessive damage to the road infrastructure. Consequently, legal load limitations have been imposed.

For many years the regulations limiting the maximum permissible axle loads on heavy vehicles in South Africa remained virtually unchanged. Until March 1996, the maximum permissible load on a single axle with four wheels was 8 200 kg, a tandem (double) axle unit was limited to 16 400 kg and a tridem (triple) axle unit was limited to 21 000 kg.

However, as a result of the recommendations contained in an axle load study initiated by the South African Department of Transport and other role players, and the recommendations of an axle load study for southern Africa initiated by the Southern Africa Transport and Communications Commission (SATCC), new regulations governing maximum axle loads on heavy vehicles, as specified in the Consolidated Road Traffic Regulations of the Road Traffic Act of 1989 (Act No. 29 of 1989 as amended), came into effect on 1 March 1996. Besides the load limitations based on the engine power and those specified by the vehicle and tyre manufacturers, two major loading factors that are controlled by the legislation are:

- the damage or wear caused by an axle load to the road, and
- the load *concentration* applied by a group of axles or axle units to bridge structures.

These axle load limitations can be summarised as follows:

• Single wheel load	4 000 kg
• Single axle with two wheels (steering)	7 700 kg
• Single axle with two wheels (non-steering)	8 000 kg
• Single axle with four wheels	9 000 kg
• Tandem axle unit with two wheels per axle	16 000 kg
• Tandem axle unit with four wheels per axle	18 000 kg
• Tridem axle unit	24 000 kg

Regulation 365A, which is also known as the “bridge formula”, limits the concentration of axle loads over any given distance and is defined as follows:

$$P = 2\,100\,L + 18\,000$$

where P is the permissible load in kilograms and
L is the distance in metres between the centres of the extreme axles of any group of axles and/or axle units.

Furthermore, the Gross Combination Mass (GCM) of any combination of heavy vehicles (truck-tractor and trailers) is limited to 56 000 kg.

South Africa's latest axle load regulations compare favourably with those of most other countries. The maximum GCM on the other hand is considerably greater than the corresponding limit in many other countries.

The following table gives an indication of axle, GCM and length limits in other countries:

Axle load and length regulations for various countries

Country	*Single kg*	*Tandem kg*	*Tridem kg*	*Max. GCM kg*	*Max. Length m*
Africa					
South Africa	9 000	18 000	24 000	56 000	22
Lesotho	8 200	16 400	21 000	49 000	20
Botswana	8 200	16 400	24 600	50 200	22
Swaziland	8 200	16 400	21 000	49 000	20
Malawi	9 000	18 000	24 600	55 000	18.3
Zimbabwe	7 700	16 400	24 600	48 700	22
Mocambique	10 000	16 000	22 000	38 000	18
North America					
USA	9 000[1]	18 000[1]	20 000[1]	36 000[1]	25.9[1]
Canada	9 100[1]	17 100[1]	24 000[1]	53 500[1]	25.0[1]
Europe					
Germany	10 000	11 500	21 000	40 000	18
Switzerland	10 000	18 000	-	28 000	18
UK	10 500	20 300	22 500	38 000	18
Australia					
Australia	9 000	16 500	20 000	44 000	17.5

Note: 1. Varies from state to state/province to province

Reference: "Limits of Motor Vehicle sizes and weights" by the International Road Federation, 1989 edition (latest edition)

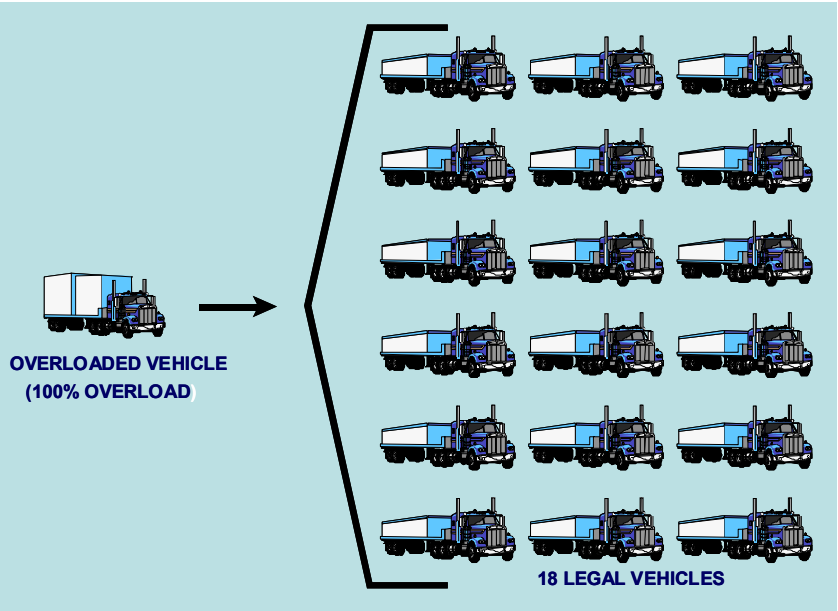
6. THE EFFECTS OF AXLE LOADS

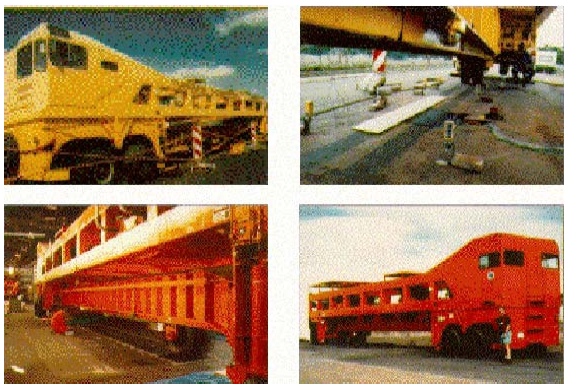
The first systematic attempt to quantify the relationship between the axle load and the damage caused to the road, was made as part of a comprehensive road experiment (known as the AASHO (American Association of State Highway Officials) Road Test) built and then subjected to traffic, in Illinois, USA between 1956 and 1960. The experiment involved allowing vehicles of various axle loads to travel along different sections of road and comparing the number of load repetitions applied to the road before a defined level of distress in the pavement was reached. This work resulted in the following equivalency formula:

$$Equivalancy\ Factor\ F = \left(\frac{Actual\ axle\ load\ (P\ ton)}{Standard\ axle\ load\ (8{,}2\ ton)} \right)^{n}$$

This formula compares the damaging effect on the road structure of any axle load, *P*, with that of a standard single-axle load of 8,2 tons (80 kN). An average value of n = 4,2 was determined in this AASHO Road Test.

The application of the Equivalency Factor, *F*, makes it convenient to convert all axle loads and vehicle configurations into an equivalent number of standard axles. This relationship indicates, for example, that a single four-wheel axle load which is only 25% over the legal load limit of 9 tons, i.e. 11,25 tons, is equivalent to the loads of 3,8 standard axles and has 2,6 times the damaging effect on the road of a 9 ton legal axle. An axle carrying twice the legal load (18 tons) has 18,4 times the damaging effect of a legal axle load. In other words, the passage over the road structure of one such overloaded axle is equivalent to the passage of approximately 18 legally loaded axles.





Extensive research in South Africa, using the Heavy Vehicle Simulator (HVS), revealed that the value of “n” varies significantly according to the type of road under consideration. Roads which are sensitive to overloading, such as those with shallow-structured pavements with thin cemented bases, may have n-values greater than 6, whereas less sensitive deep-structured pavements may have n-values of as low as 2. The HVS applies controlled repetitions of heavy wheel loads and overloads to a small section of existing road at a time. The HVS has made it possible to determine relationships between wheel load, the number of load repetitions and the damage to the road section under test conditions, and also the manner in which these relationships are influenced by local road and climatic conditions.

7. THE EFFECTS OF TYRE PRESSURE ON ROADS

Increased tyre pressures result in increased contact stresses at the tyre/road interface. Recent research done by the CSIR indicates that the measured vertical contact stresses *exceed* the tyre inflation pressures by approximately 30%. On the other hand, *overloaded, under-inflated* tyres may also result in contact stresses *exceeding* the tyre inflation pressures by 2 to 3 times. Generally, this latter condition can be considered the main cause for premature failure of road surfaces and also tyre loss, particularly on rough road surfaces carrying heavy vehicles with sub-standard or worn tyres. The developed stresses, however, are affected, amongst others, by the type and state of the tyre, the load/inflation pressure, the degree of surface roughness of the road and the general operating conditions.

The degree of damage caused to roads by over- or under-inflated tyres can be as much as or even more than the degree of damage caused by overloaded heavy vehicles with correctly inflated tyres. It is thus essential that tyres be inflated according to the manufacturer's specifications for optimum load/inflation pressure, and that the legal axle load limits for roads and bridges, as governed by the axle load regulations, should be complied with.

Generally, this will result in improved longevity of the road infrastructure, tyres and the heavy vehicles that use the road.

8. SOUTH AFRICAN HEAVY VEHICLE OVERLOADING STATISTICS

During 1996, 58 904 vehicles were weighed at weighbridges in South Africa, 33% of which were overloaded. Furthermore, 24% of the heavy vehicles weighed were charged. Until February 1996, the drivers/operators of overloaded vehicles were charged in cases where the loads on non-steering single axles and axle units exceeded the corresponding maximum permissible loads by more than 15% or if the maximum permissible gross combination mass of the vehicle or the permissible mass according to the bridge formula, was exceeded by more than 5%. These tolerances were revised on 1 March 1996 when the increased maximum permissible loads were introduced. A tolerance of 5% is currently applicable to all mass limitations.

9. THE NEED TO INFORM HEAVY-VEHICLE OPERATORS

There remains, however, a degree of misunderstanding in South Africa about the restrictions imposed on axle loading. Transport operators find it difficult to appreciate that one axle, overloaded by a few thousand kilograms, can cause considerably more damage to the road than a legally loaded axle. To the haulier it is financially more beneficial to transport as much as his vehicle can carry in one load. More often than not, however, he is unaware of the added financial burden he is placing on the general taxpayer, who at present provides a relatively large proportion of the funds needed for building new roads and repairing existing roads. At the same time he also harms himself in terms of disproportionately higher vehicle operating costs and the replacement value of his heavy vehicle.

There is therefore an ongoing need in South Africa to inform hauliers - especially new hauliers - of the serious consequences of overloading, and at the same time to give them some guidance, where necessary, on how to load a multiple rear-axle truck in order to make full use of permitted axle loading while still avoiding the illegal overloading of any of the axles involved.

The cooperation of all road users in complying with vehicle axle load limits is vital if the condition of our roads is to be kept consistently good. Only when such cooperation is obtained will road authorities be able to maximise the value of road rands as they go about their task of building new roads and maintaining the existing road network.

Private hauliers compete on a tender or quotation basis. The fellow haulier who limits his loads to the legal maximum finds himself in a greatly disadvantaged situation, compared to the transgressor who overloads. In the end the law-abiding operator is forced to overload for the sake of remaining in business.

The Road Freight Association has been actively campaigning against the practice of heavy vehicle overloading, as indicated in the following extract from a letter addressed to its members:

> *"The Road Freight Association (RFA) earnestly requests all businessmen to assist in the protection of our road infrastructure, the promotion of healthy competition and road safety by ensuring compliance with the law regarding the loading of freight vehicles.*
>
> *The recent accelerated damage to large lengths of our road network by the heavy rains emphasised the impact of the estimated twenty billion Rand backlog of necessary road maintenance. This is exacerbated by the fact that the deterioration of roads is bound to continue due to inevitable under-funding.*
>
> *Overloading of freight and other vehicles must therefore be curtailed to prevent unnecessary further deterioration of the stressed infrastructure. The authorities have thus embarked upon a concerted law enforcement initiative to detect and to prosecute overloading offenders as was illustrated by Gauteng's announcement to blacklist companies that overload. The present maximum fine of R 120 000.00 per offence and the proposed implementation of a forfeiture clause underlines the serious nature of the offence.*

The responsibility to comply with the law rests with all parties involved with the transportation of freight, i.e. the operator, the consignor, consignee, and the driver. These parties may similarly all be blacklisted in due course.

You can do so through managerial systems to facilitate compliance with loading limits, by paying only for legal loads and reporting incidents to the Road Freight Association and the authorities.

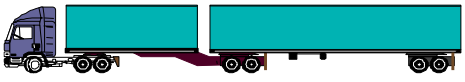
For example, the maximum vehicle combination mass (irrespective of number of axles and excluding abnormal load vehicles) is 56 tons, which will in all cases limit the maximum payload of a vehicle combination to approximately 36 tons."

The National Department of Transport is intent on reducing the damage to our roads caused by overloading, and one of the steps being undertaken is to send letters to companies that continually overload.

An extract from this letter is as follows:

"As the funding for construction and maintenance continues to decline and given the effect of overloading on our road infrastructure, this Department is not prepared to continue to allow overloading. Accordingly, I have directed that in future, the full extent of the Road Transport Quality System is to be applied in respect to the prosecution of the Operators; and where deemed necessary, to be extended to the top management of the company concerned. Discussions have already been held with the Attorneys-General of the various provinces in this regard and they have indicated their full support for such prosecutions."

Certain heavy vehicle configurations are more "road friendly" than other configurations in terms of relative damage per ton of goods being transported. Examples of three common heavy vehicle classes are shown below. The relative damage to the road is expressed as the damage caused by a standard 80 kN axle (E80).

	Tare (tons)	*Payload (tons)*	*Relative damage E80/100t*
	16.5	28.1	18.8
	18.0	32.9	12.9
	20.7	35.3	13.0

10. SUMMARY

- Heavy vehicles play an important role in the economy, and are expected to remain a common sight on our roads in the foreseeable future.

- The relative damage to the road caused by any heavy vehicle axle load can be related to the damage caused by a standard 80 kN axle load. This relation is exponential, in that an axle carrying double the legal load may cause from four to sixty times as much damage as one legal load.

- Road pavement structures are designed to carry a given number of *standard axle load repetitions*. Overloading reduces the design life of these structures.

- Overloaded vehicles are estimated to be responsible for R400 million of unnecessary road damage per annum.

- Transport operators can play an important role in selecting “road structure friendly” vehicles. Improved liaison and communication must be developed between road engineers and transport operations managers.

- The overloaded heavy vehicle is a traffic hazard especially regarding the vehicle’s braking system and the additional braking distance involved. This situation is further aggravated by steep downhill slopes and sharp curves in the road. Traffic accidents caused directly or indirectly by overloaded heavy vehicles are normally not included when the total cost to the country, caused by overloading, is calculated.

- All persons involved in the road transportation of goods, road pavement design and law enforcement should be made aware of the multifaceted impacts of road freight transport and overloading.

- Operators that continually overload their heavy vehicles affect the ability of operators that do not overload to compete on equal terms in the transport market.

Heavy weights !

Tail-End !!!

Kazuyoshi Nomachi

Overloading to the max !

DEPARTMENT OF TRANSPORT

Roads and Transport Technology

CSIR