



CONSULTANCY SERVICES FOR A HEAVY VEHICLE OVERLOADING CONTROL STUDY

FINAL REPORT

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VOLUME 1 OF 2

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EXECUTIVE SUMMARY

The Government of the Republic of Mozambique received a credit from the International Development Association (IDA) for the purposes of improving the transport infrastructure of Mozambique and strengthening the institutional capacity of the road sub-sector and, through the ANE, applied a part of this credit to appoint Africon Limited under the Road and Bridge Maintenance and Management Programme to execute the Heavy Vehicle Overloading Study.

Volume 1 of this report deals with the findings and conclusions of the document reviews and field surveys conducted in the initial stages of the project and includes a chapter reporting on the analysis of some of the review and survey results. Volume 2 of the report outlines the proposed Overload Control Strategy which is explained through final recommendations based on the conclusions contained in Volume 1, the proposed Implementation Programme and proposed Implementation Budget. The Final report will contain work plans to implement these recommendations.

The project scope firstly entailed the review of the legislative environment regulating overload control in Mozambique as well as the status quo of legislation pertaining to the privatising of weighbridge operations and maintenance. An axle load survey was conducted that included traffic surveys and was reported on in the preceding Axle Load Survey Report. This report contains a summary of the findings of this survey. All existing and proposed weighbridges / sites were visited and information regarding layout, equipment and the infrastructure in general was collected and interpreted. Simultaneously the weighbridge personnel were interviewed with the aim of determining the operational procedures, constraints and challenges. The manpower capacity and capability was assessed and the provincial officials were interviewed to assess the state of overload control from a people perspective.

It was found that the Mozambican legislation is outdated and not compatible with its neighbouring countries. Current legislation does not support privatisation of weighbridges or their operation. The results of the axle load studies indicate that the current overload control operations have very little to no effect on overloading in the country. Overloading is therefore rife and the damage to the Mozambican road network is excessive. Traffic levels are reasonably low in the rural areas but increase to capacity near the larger centres. Heavy vehicle traffic is concentrated on a number of freight corridors making effective overload control feasible. The ANE currently has 11 existing weighbridges, of which approximately seven are in use. Two of the above 11 are not functional but are currently being repaired. An additional three new weighbridges are under construction and another five are proposed. These weighbridges are spread over the entire country except for the Niassa province which has no existing or proposed weighbridge. Weighbridges are mostly equipped with outdated mechanical scales but there are a few newly constructed facilities with up to date equipment.

Currently overloading control law enforcement operations are carried out by ANE staff. Staff have a variety of capabilities but somewhat limited and not always the necessary authority enabling them to carry out their tasks. There is a serious lack of proper management, maintenance and supervision. Overload control is ineffective as currently conducted and in serious need of overhaul.

Volume 2 of the report contains the programme, budgets and work plans.

CHAPTER I: INTRODUCTION

1. BACKGROUND TO THE PROJECT

The National Road Administration of Mozambique (ANE) is responsible for the maintenance and rehabilitation of main roads of Mozambique. This responsibility includes the protection of their existing roads and bridges network against the excessive damage caused by overloading of heavy vehicles.

The Government of the Republic of Mozambique received a credit from the International Development Association (IDA) for the purposes of improving the transport infrastructure of Mozambique and strengthening the institutional capacity of the road sub-sector and, through the ANE, applied a part of this credit to appoint Africon Limited under the Road and Bridge Maintenance and Management Programme to execute the Heavy Vehicle Overloading Study.

1.1 PRINCIPLE OBJECTIVE OF THE STUDY

The principal objective of this study is to enable ANE to optimize the life of its road network and to assist the Government of Mozambique through the ANE and INAV to prepare, implement and manage an appropriate Overloading Control Management System on the main road network of Mozambique.

1.2 ESSENTIAL ELEMENTS OF THE STUDY AND COMPOSITION OF THIS REPORT

The study essentially deals with targeted research aimed at reviewing the current overload control environment in Mozambique and defining a comprehensive overload control strategy to the Government of Mozambique that will at the same time be simple and easy to implement, locally applicable, regionally integrated and effective.

Chapter 2 reports on the process and findings of the literature review undertaken during the study. From a **legal and regulations** perspective, a review of the full spectrum of legislation and regulations governing overload control, such as regulations awarding the controlling authority the right to appoint personnel, to monitor and detect overloading, to enforce the law and penalize transgressors of the regulations was conducted. This was also done in a regional context to ensure regional harmonization. Additionally, the potential and possibility of **concessions of the operations and/or maintenance** of weighbridges to private participants were evaluated. The impact of modern heavy vehicles on Mozambican **bridges** designed to older Portuguese design codes, on Bailey Bridges and on the road pavement structure were also evaluated and will be considered in the process of recommending an optimal vehicle load limits regime.

The study addresses basic foundational aspects such as a vehicle classification systems and vehicle loading limits. The review of these aspects included assessing the actual environment through Axle Load Surveys on the major routes of all the provinces. An **Axle Load Survey** Report was submitted in October 2005 and is

reported on in **Chapter 3** of this report. This chapter also reports on the survey conducted to record and assess the current and proposed overload control **infrastructure** with the aim of recommending improvements to the deployment of infrastructure, systems and equipment. From an **operational** point of view, a study of current practise of enforcement and operations at the existing weighbridges as well as the level of staff provision and an assessment of the managerial competence of staff was done.

Axle equivalency factors for Mozambique heavy vehicles were calculated and the **impact of recommendations on pavement and bridge design** codes were analysed and are reported on in **Chapter 4**.

Chapter 5 combines the **conclusions** of the respective studies.

Chapter 6 provides some **comments on the way ahead and preliminary recommendations**. The Final Project Report will recommend improvements to current practises including recommendations for training programmes and a public awareness programme.

1.3 THE IMPORTANCE OF EFFECTIVE OVERLOAD CONTROL

Road transport plays a fundamental role in the social and economic development of many developing countries. In Mozambique as well as in the Southern African region, it provides the dominant mode of freight and passenger movements and carries between eighty and ninety percent of the region's total trade in goods and services. Thus, in order to attain acceptable levels of road transport efficiency, the management and maintenance of road infrastructure and assets form an important part of development programmes.

1.3.1 THE OVERLOADING PROBLEM

In order to fully appreciate the importance of effective overload control, it is necessary to firstly be fully aware of why it is so important to control axle loads and to understand the impact and cost implications of overloading on pavements, bridges and the transport industry.

Road infrastructure represents huge investments for any country. To protect these assets against misuse and damage, countries have promulgated Road Traffic Acts that stipulate permissible axle load, axle group combinations and vehicle dimensions. These limits are meant to ensure that roads last for their full design life with normal maintenance expenditures. In addition, control of axle loads to prescribed limits can be justified for the following reasons:

- ensuring a level playing field between transporters
- limiting the extent of road maintenance required
- improving road safety

Laws and regulations to control overloading have been in existence in Southern African countries for more than 40 years, and have been changed and updated to reflect the

changing circumstances of the road transport industry. During the same period the road transport vehicles have grown in size and road transport has increased with the removal of the protection of railways and the liberalisation of the economies.

A gradual but marked shift from rail to road in the 1980s became more rapid in the nineties. Smaller trucks were substituted with today's interlinks and super-links. Axle load control and enforcement of legal loads have only in very few of the SADC countries kept pace with this development of road transport.

1.3.2 IMPACT OF OVERLOADING

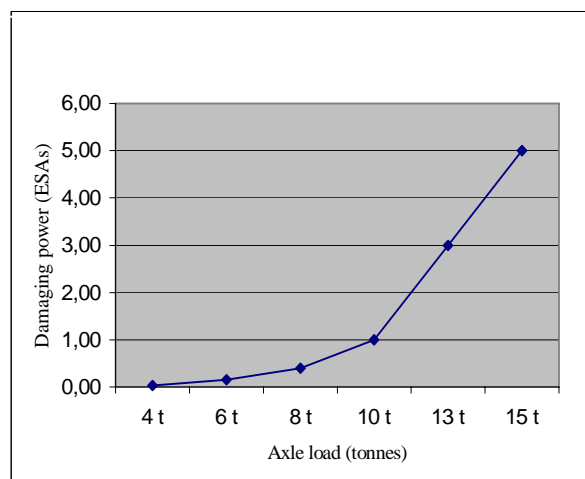
1.3.2.1 PAVEMENTS

Road pavements are designed to carry a range of "standard" (8.2 tonne) axles over a period of time. The number of "Equivalent Standard Axles" (ESAs) are determined with respect to the type of traffic expected to use the road over its design life. The AASHO road tests that were carried out in the USA during the years 1959 – 61 established that the life of a given road is approximately proportional to the fourth power of the axle load for the same number of passes. The test resulted in the following well known formula – the Fourth Power Law - which postulates an exponential relationship between axle loads and damaging power.

$$LEF = (P/W_s)^n$$

Where:

- LEF = load equivalence factor
- P = axle load
- W_s = standard axle (8.2 or 10 tonnes)
- n = power law exponent
(Typically assumed to be 4.2)



Note: Further experimental and research work under-taken since the AASHO road test has indicated that the power law exponent is related to pavement type (granular, cemented, etc.) and mode of distress (rutting, fatigue, sub-grade deformation, etc.) and may vary from less than 1 to over 18!

Figure 1.1: Graph of the exponential relationship between axle loads and road damage

Table 1.1 illustrates the effect of Axle Load on the design life of a pavement that is loaded above a limit of 10 tonnes for varying power exponents.

Table 1.1: Effect of Axle Loads on Pavement Life

Design Axle Load (Tonnes)	Carried Axle Load (Tonnes)	Equivalence Factor			Pavement Life (years) for Varying Power Exponent		
		n = 4.0	n = 4.5	n = 5.0	n = 4.0	n = 4.5	n = 5.0
10.0	10.0	1.0	1.0	1.0	20.0	20.0	20.0
10.0	11.0	1.5	1.5	1.6	13.7	12.9	12.4
10.0	12.0	2.1	2.3	2.5	9.7	8.8	8.0
10.0	13.0	2.9	3.3	3.7	7.0	6.1	5.4
10.0	15.0	5.1	6.2	7.6	3.9	3.2	2.6

The above table indicates, for example, that a single axle that is overloaded by just 20% over a limit of 10 tonnes, i.e. loaded to 12 tonnes, with an assumed power exponent of 4.0, has just over twice the damaging effect (equivalence factor = 2.1) as a legally loaded vehicle. Moreover, if the pavement were to be continually subjected to such overloading, its life would be reduced from 20 years to just less than 10 years! It is noteworthy that the effect of the Fourth Power Law on weak pavements can be catastrophic, whilst the effect does not apply significantly to over designed pavements or gross vehicle mass.

The effect of the exponential relationship is that most road wear is caused by vehicles with more heavily laden axles; (ref. Fig. 1.2) and a disproportionate share of road wear will be caused by overloaded vehicles.

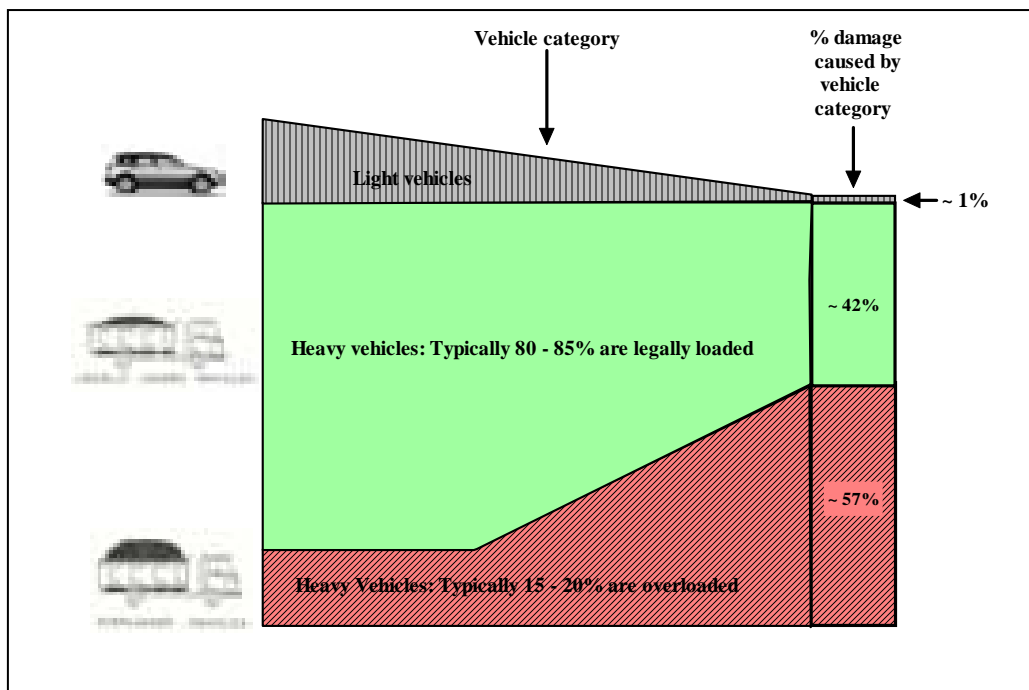


Figure 1.2: Contribution to pavement damage by vehicle category

As the size of a load approaches the design strength of a pavement or bridge, the effects of the load will be more significant. In these cases, a small number of passages of the load can cause significant structural damage. In an extreme case, a single passage of a grossly overloaded vehicle could cause catastrophic failure.

1.3.2.2 BRIDGES

The effects of load on bridges is thought to be more linear than is the case on pavements, with the life of a bridge and the maintenance requirements dependent on the number of passages and the size of the load. While road effects are related to axle mass, bridge effects can be related to either axle mass or gross vehicle mass, depending on the relationship between the axle spacing and the length of the bridge span. Hence, overloaded vehicles are a major contributor to bridge deck deterioration. The extent of deterioration depends on the design loading adopted for the bridge. The impact of overloaded axles on short span bridges (< 20 m) relates primarily to tandem and tridem axles. Vehicles that significantly exceed the legal GVM limit raise the prospect of bridge failures, particularly those with short spans and/or low design standards.

The type of damage which occurs due to overloading is of the following forms:

- Timber decks - local failure of timber deck planks, either longitudinal or transverse and loosening of attachment timber deck planks to supporting members. On timber girder bridges splitting has also been reported as a result of gross overloading.
- Concrete decks - cracking of concrete decks, sometimes leading to extensive crack patterns and the formation of block cracking, which in turn can lead to spalling of concrete from either the deck surface or the underside. Composite action between the concrete deck and its supporting members can also be compromised.

1.3.2.3 ROAD SAFETY

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

- increased severity of accidents when overloaded vehicles are involved
- reduced grade climbing capability and acceleration
- greater loss of lateral stability especially when cornering
- increased braking distance required for overloaded vehicles
- increased vehicle emissions, noise and ground-borne vibrations

1.3.2.4 THE TRANSPORT INDUSTRY

Overloading places transporters who abide by the regulations at a disadvantage as they are not able to compete with those transporters that overload. This has an adverse, knock-on effect on the transport industry as some transporters then resort to overloading in order to be able to compete with those who overload. The net effect is that a transporter's survival in a harshly competitive market is often related to how successful he is at getting away with overloading! Not surprisingly, therefore, overloading has become big business as in most cases the fines imposed by

magistrates in a court of law remain unrealistically low compared with the higher profit made by the transporter in transporting a heavier load.

1.3.3 COST OF OVERLOADING

The marginal cost associated with an overloaded vehicle on a road comprises three main components:

- (i) The increase in transport cost to other vehicles as a consequence of the overloading. This increase in transport cost reflects that the deterioration caused and results in increased costs for operating the vehicle and lower speeds, resulting in higher time costs. This increase is due to higher time cost incurred as a result of lower operating speeds necessitated by deteriorating road.
- (ii) Assuming that routine maintenance actions are condition responsive, overloaded vehicles on a road would lead to earlier and more frequent routine maintenance interventions.
- (iii) Overloading will lead to the road authority remedying the damage by way of periodic maintenance actions or reconstruction at an earlier date than would have been the case without the additional vehicle.

By way of quantifying the costs of overloading, tests undertaken by the South African Council for Scientific and Industrial Research (CSIR) in 2003 indicated that on a typical relatively high standard national road in South Africa, the additional damage over and above the legal payload is of the order of US \$2,500 – \$3,500 per km per annum. On a less substantial provincial road the additional damage would be of the order of US \$10,000 per km per annum and could even extend to over US \$14,000 per km per annum depending on the design of the pavement.

When a conservative average of US \$ 7 500 per km per annum is assumed for Mozambique and costs are extrapolated over the Mozambique primary road network of approximately 5 870 km of surfaced roads, the additional annual cost would be of the order of US \$44 million.

CHAPTER II: LITERATURE STUDIES

2. LEGAL REVIEW: CONTROL OF HEAVY VEHICLE LOADING

2.1 REVIEW METHODOLOGY

This chapter describes the analysis and documentary scan of legislation relating to heavy vehicle loading. In addition to Mozambican law (*Codigo de Estrada*), legislation from the following states¹ was analyzed:

- Botswana
- Malawi
- South Africa
- Swaziland
- Tanzania
- Zambia
- Zimbabwe

Where applicable, the analysis also includes references to the SADC proposals on overloading control.

Our analysis has also taken note that, in practice, Mozambique has adopted an informal set of load limits that differ from the limits specified in the *Codigo de Estrada*. Where applicable, we have referred to both the statutory and the informal limits.

Other than Mozambican law, the analysis focused on the legislation of those states that either border on Mozambique or are the origin or destination of foreign traffic transiting Mozambique. The applicable provisions of the various state laws were summarized in table format Appendix III. This has served to highlight similarities and differences in the legislation and also shows up where gaps occur. It is noteworthy that some states have revised their legislation recently (especially the past 5 years). In Malawi and Tanzania, legal reforms were introduced incorporating elements of the SADC proposals on overloading control, while Zimbabwe had implemented reforms as early as 1993. States which have not recently updated their laws are Botswana, Mozambique, Swaziland and Zambia.

The findings of the legislative analysis have been grouped under the following headings:

- Regulatory approach
- Wheel, axle and vehicle (and combination) mass loads
- Erection and operation of weighbridges
- Statutory powers, duties and liabilities of officers and vehicle operators
- Findings and conclusions

¹The full list of legislation consulted is listed in Annexure A.

2.2 REGULATORY APPROACH

Traditionally, all SADC states have treated heavy vehicle overloading as a criminal offence in their legislation. However, numerous limitations arise from a regulatory approach to overloading control that relies solely on the criminal law. It is a common problem that the serious economic effects of overloading are not fully recognized within the criminal justice system. Most states impose spot fines for overloading or, in more serious cases, prosecute over loaders in the courts. The level of spot fines is determined either in the law or by the judiciary (magistrates). These tend not to reflect the actual economic cost of the damage caused to road pavements by overloading. As laws tend not to be updated regularly, the erosion of monetary value often means that fines lose their deterrent effect. When cases are prosecuted through the courts, there are often long delays before matters are brought to trial. Once a prosecution is initiated, there is no guarantee that an offender may be convicted. If convicted, there is also no guarantee that an effective sentence with real deterrent value will be imposed, because judicial officers enjoy wide latitude in imposing sentences.

A contributing difficulty is that the trucking industry derives significant financial benefits from persistent overloading. Hence, there are strong incentives for corruption. Mostly such corruption occurs when law enforcers are bribed not to enforce load limits. Where weighbridges are located in isolated areas, management and oversight is complicated. This creates an environment where corruption can flourish. The practice of empowering police officers to impose “spot” fines at the roadside can, therefore, be counter-productive. It creates the additional management challenge of countering corruption *in addition* to the administration of actual vehicle weighing and enforcement.

The SADC proposals to introduce administrative controls of overloading aim to overcome the difficulties associated with criminal enforcement. The main feature of the administrative system is the introduction a range of fees aimed at recovering the quantum of the damage caused by overloading. Because overloading is no longer treated as a criminal offence, but an action with certain economic consequences, there is no need for the involvement of the criminal justice system. The focus shifts to mechanism to ensure that the operator of the overloaded vehicle pays compensation for the extent to which overloading has damaged the road pavement. Additional measures to make control more effective include (a) obliging the driver to present a vehicle for weighing at every weighbridge en route and (b) introducing a ban on an overloaded vehicle proceeding with its journey until the load is adjusted to comply with limits². The advantages of the system are that it is simple to administer, significantly reduces the time lag between the overloading action and the imposition of the fees. It also eliminates the uncertainties associated with the criminal law. As overloading fees are high, they are also a more effective deterrent than spot fines or court-imposed fines.

²Most states' legislation currently contains such a ban. In some cases, however, it is not enforced due to logistical reasons such as the shortage of space to detain vehicle at a weighbridge or because the vehicle is carrying perishable or live cargoes.

A further feature of the SADC proposals is that overloading fees are paid to the road authority. Thus the body responsible for maintaining the road is compensated for its higher maintenance costs caused by overloading. The requirement that fees be paid before a vehicle may proceed, means that costs are recovered almost immediately. This contrasts with the criminal approach, especially if overloading is prosecuted in the courts, where several months may lapse before a trial and sentencing.

In view of the difficulties sketched above (and under the impetus of the SADC reform proposals) some states have implemented additional administrative measures to improve the efficiency of their enforcement. The pioneer in this respect was Zimbabwe. In 1993, the Zimbabwean regulations were amended to introduce the principle that the operator of an overloaded vehicle was obliged to pay a fee to compensate for the damage caused to the road. This fee was payable over and above any fine which could be imposed when the over loader was prosecuted and convicted in the courts. More recently, two further states, Malawi and Tanzania, have also introduced administrative controls to strengthen enforcement. The main driving force for their reforms has been the SADC proposals *Enabling Legal Reform: Control of Vehicle Loading, 1999*. Tanzania has followed the Zimbabwean approach of permitting both prosecution and the imposition of overloading fees. Malawi has gone further and decriminalized overloading. Overloading is now only penalized by way of overloading fees that are imposed administratively.

Whether overloading is controlled through the criminal law or by way of administrative measures is not a “either / or” choice. As mentioned, Tanzania and Zimbabwe have opted to retain the option of using the criminal law, while recovering overloading fees. The criminal law continues to have a role to play with regard to other actions associated with an administrative system. For example, if the law imposes a duty on the driver of a vehicle to present a vehicle for weighing, a failure to do so is still treated as a criminal offence.

Setting overloading fees at a level that ensures a real deterrent effect is a key feature of the administrative system. Fees in Zimbabwe, which pioneered this approach, were initially quite high. However, due to the steep devaluation of the local currency, the fees have lost much of their deterrent effect. At present, a flat rate of Zim\$ 500 (US\$ 0.06) is charged for every kilogram overload. Overloading fees in Malawi and Tanzania are as follows:

Table 2.1: Overloading fees in Malawi and Tanzania

	Single Axle (2 wheels)	Multiple axles (4 wheels)	Single axle (4 wheels)	Gross Vehicle Mass
Malawi	\$ 10 / 100 kg to \$ 4785 / 10 000 kg	\$12 / 100 kg to \$3500 / 10 000 kg	\$8 / 100 kg to \$2986 / 10 000 kg	\$4 / 100 kg to \$27264 / 30 000 kg
Tanzania		\$8 / 100 kg to \$ 2986 /10 000 kg		\$ 22 / 500 kg to \$35000 / 31 500 kg

In countries where overloading is still treated solely as a criminal offence, relatively light penalties are imposed (except for South Africa). South Africa prescribes a maximum sentence of 6 years imprisonment, but in most other states prison sentences of between 3 – 6 months (or the equivalent fine) may be imposed. In Tanzania, in addition to the overloading penalty, a fine of \$ 2000 or 6 months imprisonment may also be imposed if the option is exercised to also prosecute an offender criminally. At present, Mozambique imposes a fine of 5,000,000.00 mt (US \$ 206) irrespective of the extent of the overload.

In terms of the draft *Decreto* prepared in 2000, it appears that Mozambique has been considering a revision of penalties for overloading. Art 7 of the *Decreto* stipulates that a fine (“*multa*”) of 500,000.00 mt (\$ 20.60) be imposed for each ton that a vehicle is overloaded. Compared to the overloading fees introduced by Malawi and Tanzania, the proposed fine structure in Mozambique is still fairly low. A 10 ton overload in Mozambique would attract a fine of \$ 206 compared to \$ 2986 in Tanzania (and even more in Malawi – see above).

2.3 WHEEL, AXLE AND VEHICLE MASS LIMITS

Available legislation was analyzed with reference to the following:

- axle mass loads
- axle unit mass loads
- permissible maximum vehicle mass loads
- permissible maximum combination mass loads
- tyre mass loads
- mass load carrying capacity of bridges
- distribution of axle and wheel mass loads

Certain states' laws also contain provisions enabling authorities to vary load limits, to exempt certain vehicles and provide for the special treatment of foreign vehicles.

2.3.1 Axle mass loads

Load limits for single axles are not yet totally harmonized and limits differ between states. The lowest limit applies in Botswana, South Africa and Swaziland (7.7 tonnes), although Mozambique's legal limit (7.5 tonnes) is theoretically the lowest. In practice, Mozambique also applies the 8 tonnes limit which prevails in all other states.

A further difference is that some states (including Mozambique) do not distinguish between steering and non-steering axles for the purposes of specifying load limits.

Current single axle mass limits (in metric tonnes) for all countries are listed below (in the case of Mozambique, both the legal and the informal limits are listed with the latter in brackets):

Table 2.2: Legislated Axle Mass limits for SADC Countries

	<i>Botswana</i>	<i>Malawi</i>	<i>Mozambique</i>	<i>South Africa</i>	<i>Swaziland</i>	<i>Tanzania</i>	<i>Zambia</i>	<i>Zimbabwe</i>
Steering axle	7.7*	8*	7.5 (8)	7.7	7.7*	8*	8	8*
Single axle fitted with 2 to 3 wheels	7.7	8	10 (8)	8	7.7	8		8
Single steering axle with 4 wheels (draw bar controlled)						9+		
Single non-steering axle with 4 wheels	8.2	10	10 (8)	9	8.2	10	10	10

* Legislation does not specify separate limits for steering axles.

+ Only Tanzanian legislation specifies a separate limit for a 4 wheeled steering axle

2.3.2 Axle unit mass loads

Informally, Mozambique also applies the 8 tonne limit to all axles within an axle group. Thus, the overall limit on a tandem axles is 16 tonnes and on a tridem axle 24 tonnes.

Mozambican legislation only specifies mass limits for tandem axles (there are no references to limits for tridem axles). The mass of a tandem axle equipped with pneumatic tyres may not exceed 16 tonnes. Unlike other states, Mozambican legislation also makes no distinction between the numbers of wheels per axle. The overall tandem axle mass limit is qualified by the distance between the two axles. Hence the permissible mass may well be as low as 10 tonnes as illustrated in the following table:

Table 2.3: Relationship between axles and mass limits for Mozambique

<i>Distance between axles</i>	<i>Load limits (tonnes)</i>
Less than 1 m	10
Between 1,01 and 1,10 m	11,5
Between 1,11 and 1,2 m	13
Between 1,21 and 1,3 m	14,5
Above 1,31 m	16

The following table illustrates that Mozambican limits for axle units are generally lower than limits in other states (although the absence of any distinctions based on the number of wheels per axle may well result on higher limits in some cases). Once again, both the legal and the informal limits are listed with the latter indicated in brackets:

Table 2.4: Relationships between axle groups and load limits for SADC countries

	<i>Botswana</i>	<i>Malawi</i>	<i>Mozambique</i>	<i>South Africa</i>	<i>Swaziland</i>	<i>Tanzania</i>	<i>Zambia</i>	<i>Zimbabwe</i>
Tandem axle (2 – 3 wheels / axle)	15.4	16	Between 10 and 16 depending on distance between axles (16)	16 (15.4 in the case of steering unit)	15.4	12 (2 wheels / axle) 15 (3 wheels / axle)		No provisions
Tandem axle (4 wheels / axle)	16.4	18	See above (16)	18	16.4	18	16	18
Tridem axle (2 – 3 wheels / axle)	23.1		No limits specified for tridem axles. Mass load on individual axle unit to be calculated with reference to GVM limits (24)	24	21	21 (on 10 wheeled unit)	12	
Tridem axle (4 wheels / axle)	24.6	24	See above (24)	24	21	24	24	24

2.3.3 Permissible maximum vehicle and combination mass loads

The various states' laws apply different requirements to permissible maximum vehicle mass and combination mass. Most states require that the total vehicle mass may not exceed five times the total axle mass load of the driving axle or axles. This requirement does not apply in Mozambique, Tanzania, Zambia or Zimbabwe. In certain states, the permissible maximum vehicle (or combination) mass is also related to power – mass ratios. In South Africa and Swaziland, the maximum vehicle mass may not exceed the net kilowatt power of the engine multiplied by 240 (South Africa additionally imposes a factor of 400 for drawing vehicles). States whose laws specify a

formula to protect bridges also specify that the mass calculated by applying such formula may not be exceeded (Malawi, South Africa).

Mozambican legislation does not specify any of the above requirements. In stead, gross vehicle and combination mass limits are determined solely on the basis of the number of axles. There are a number of differences between Mozambique's legal limits and those that apply informally. As illustrated in the following table, the legal limits result in gross mass limits between 16 and 38 tonnes depending on the vehicle or vehicle combination. In practice, the informal limits (indicated in brackets) permit gross mass limits of up to 48 tonnes:

Table 2.5: Differences between legal limits and informal application in Mozambique

Axle group	Number of Axles in Group	Formal (informal) limits
Rigid vehicle 2 axles	2 axles	16
	3 axles	22 (24)
Articulated vehicle (truck-tractor & semi-trailer)	3 axles	26 (24)
	4 axles	32 (32)
	5 axles	38 (40)
	6 axles ³	(48)
Vehicle combination	4 axles	32 (40)
	5 axles	38 (40)
	6 axles ⁴	(48)
Trailers	1 axle	10 (8)
	2 axles	16 (16)
	3 or more axles	22 (24)
Trailers for agricultural tractors	1 axle	8
	2 or more axles	12

Tanzania has also adopted the approach of specifying gross vehicle or combination mass purely on the basis of the number of axles⁵. In Botswana, Swaziland and Zimbabwe the permissible maximum vehicle or combination mass is arrived at by calculating the distance between the centre lines of the extreme axles of any group of consecutive axles. Specific maximum limits are also specified. Except for Botswana, Mozambique and Swaziland, current permissible combination mass limits are identical. Current limits are:

³See footnote 4

⁴This configuration is not provided for in the *Codigo de Estrada*.

⁵This varies between 18 tonnes for a 2-axle vehicle and 56 tonnes for a combination with 7 axles.

Table 2.6: Maximum combination mass for SADC countries

	<i>Botswana</i>	<i>Malawi</i>	<i>Mozambique</i>	<i>South Africa</i>	<i>Swaziland</i>	<i>Tanzania</i>	<i>Zambia*</i>	<i>Zimbabwe</i>
Permissible maximum combination mass	50.2	56	16 – 38 (24 – 48) Depending on vehicle type and axle configurations	56	50.2	56	56	56

2.3.4 Tyre mass loads

Provisions governing tyre mass loads are found in the law of only four states (Botswana, Malawi, South African and Swaziland). The provisions are very similar and state that the mass load of a tyre may not exceed the manufacturer's recommendations or 8 kg per 1 millimetre width of the tyre. South African law also incorporates a reference to a tyre standard that may be specified by the Bureau of Standards. South African and Swazi law specifically states that the wheel mass load may not exceed 3.85 tonnes for a steering axle and 4 tonnes for a non-steering axle. No provisions on tyre loads occur in legislation in Botswana, Mozambique, Tanzania, Zambia or Zimbabwe.

2.3.5 Mass load carrying capacity of bridges

Only in Malawi and South Africa does legislation contain specific provisions regulating mass loads in order to protect bridges. The formula applied in both states is identical.

2.3.6 Distribution of axle and wheel mass loads

Except in Mozambique, Tanzania and Zimbabwe, legislation in all states contains provisions regulating the distribution of axle and wheel mass loads. These provisions are largely harmonized. They stipulate that the load on one tyre (or adjacent tyres on a 4 tyre axle) may not exceed the other by more than 10%. There are also provisions governing the minimum mass load on steering axles. The load on a steering axle (or unit) may not be less than 11% of the sum of all the axle mass loads for an articulated vehicle (30% for a rigid vehicle). A different approach is followed in Zambian law, which stipulates that a 2 or 3 axle vehicle may not carry less than 20% of the laden weight on one axle (30% in the case of a 4 axle vehicle).

2.3.7 Varying load limits

Few states have specific provisions in their legislation permitting the variation of load limits. In Tanzania, the Roads Authority may introduce lower limits than those permitted in the regulations. In Zimbabwe, a similar power is vested in the Minister.

2.3.8 Exemptions

In a few states, legislation permits certain vehicles (or vehicles carrying certain classes of goods) to be exempted from limits. These exemptions apply over and above exemption that may be authorised for the carriage of abnormal loads.

In Mozambique, vehicles of the armed forces and military are exempt. South African law specifically lists the types of vehicles that are exempt from load limits. In Swaziland, the authority to exempt a vehicle is vested in the Minister who must give permission in writing. The grounds for exempting a vehicle are not specified. In Tanzania, the Roads Authority may waive a fee or impose a lower fee for vehicles exceeding load limits on three grounds: (a) national security (b) the implementation of bilateral agreements with foreign governments and (c) for vehicles conveying disaster relief or engaged in emergency infrastructure restoration. In Zimbabwe, the Minister enjoys a wide authority to exempt any vehicle or vehicle carrying specific classes of goods, provided a prescribed fee is paid.

2.3.9 Foreign vehicles

Legislation in Malawi contains specific provisions on the treatment of foreign overloaded vehicles wishing to enter Malawi. The driver of such a vehicle may elect to enter Malawi subject to the requirements of the regulations (which imply that the load must be adjusted and the weighbridge processing fee must be paid) or to return. In the latter case, a weighbridge processing fee is still payable. No other states' laws contain any references to the treatment of foreign vehicles that contravene load limits⁶.

2.4 CONSTRUCTION AND OPERATION OF WEIGHBRIDGES

2.4.1 Construction of weighbridges

Few states' laws explicitly provide the authority to erect and operate weighbridges for the purposes of overloading control. In most cases, the authority is implicit in the power given to impose and enforce load limits. This is also the case in Mozambique, where ANE is given the power to perform road traffic control (see discussion in next chapter).

In Tanzania, the Road Authority (TANROADS) is given the express power to "install weighbridges or other devices for detection" and to erect road signs which require any category of motor vehicles to be weighed or tested by such devices. In Malawi, the National Roads Authority has the power to "erect structures" alongside roads, although these are not defined. The legislation does not contain any specific reference to weighbridges.

⁶It is understood from the site surveys at Mozambican weighbridges that the practice is followed to require immediate payment of overloading fines in the case of foreign vehicles. By contrast, Mozambican vehicles are permitted to proceed and the fine is payable within 7 days at any police station. It is not clear that there is any legal basis for this distinction.

2.4.2 Operation of weighbridges

The legislation reviewed differs widely with regard to stipulating procedures for the weighing of vehicles. The following items are commonly addressed:

- Calculation of GVM using single-axle scales
- Tolerance
- Weighing certificates
- Keeping records
- Calculation of fees

2.4.2.1 Calculation of gross vehicle mass using single-axle scales

The issue is only addressed in legislation in Malawi, Tanzania and Zimbabwe. In these cases, legislation permits the mass load of individual axles to be combined in order to calculate overall gross vehicle mass. South African law does not refer expressly to single axle scales, but also permits the mass of individual axle (or groups) to be added to calculate the gross vehicle or combination mass.

2.4.2.2 Tolerance

Legislation in Malawi, Swaziland, Tanzania and Zimbabwe expressly regulates the issue of tolerance. These countries all allow a statutory tolerance of 5% rounded down to the nearest 100kg. In Malawi, there is a further condition that the vehicle may proceed if overloaded within 5% tolerance, but a surcharge is payable equal to 4 times the penalty for the overload. Tanzanian legislation includes a similar provision. This stipulates that the driver may proceed to starting point or destination (whichever is closer) subject to payment of overload fee and surcharge. However, this exception only applies to awkward loads that cannot be removed or adjusted at the weighbridge in order to reduce the vehicle's load to legal limits.

2.4.2.3 Weighing Certificates

Officers operating weighbridges have a duty to issue weighbridge certificates in terms of legislation in force in Malawi, Tanzania, Zambia and Zimbabwe. In Malawi, the driver must co-sign any receipt issued by the authorized officer, while in Tanzania the driver must co-sign the weighing certificate. In Zambia, a certificate must also be issued to a vehicle loaded within legal limits, while in Zimbabwe legislation states that the vehicle is exempt from being reweighed provided it is carrying the same load as when its axle and mass loads were measured.

2.4.2.4 Record keeping

Except in Tanzania, there is no obligation on vehicle owners to keep records of weighbridge certificates. In Tanzania, a copy of the weighbridge report must be kept for at least one year.

2.5 STATUTORY POWERS, DUTIES AND LIABILITIES OF OFFICERS AND VEHICLE OPERATORS

2.5.1 Powers of authorized officers

There is a great deal of similarity in the legislation dealing with the powers of authorized officers to enforce load limits. The most common powers enjoyed by officers are the power to:

- direct a vehicle to stop
- enter a vehicle
- direct a vehicle to a weighbridge
- direct a vehicle to be weighed either in respect of one axle, an axle unit, the entire vehicle or vehicle combination, laden and unladen
- prohibit a vehicle that is overloaded from continuing with its journey, unless the load is readjusted and the vehicle is found to be within limits or the excess load is off-loaded
- require the person in charge of a vehicle to off load excess load or to readjust the load so that axle mass loads are within legal limits
- require the person in charge of the vehicle to furnish his/her name and address and other form of identification
- require the person in charge of a vehicle to produce a document required by law.

Legislation regulating the powers of police officers with regard to overloading enforcement in Mozambique was unavailable for study. This aspect will be canvassed more fully in the draft Final Report.

2.6 STATUTORY LIABILITY AND DUTIES OF VEHICLE OPERATORS

Legislation imposes various statutory duties on vehicle operators. These can be grouped under the following headings:

- Duty to present a vehicle for weighing
- Liability for fines and overload fees / Payment arrangements

2.6.1 Duty to present a vehicle for weighing

As discussed above, all states give law enforcers the power to direct a vehicle to be weighed. The exercise of this power requires physical on-the-road law enforcement and a duty to present a vehicle for weighing only arises if a vehicle is physically stopped and directed to a weighbridge. In contrast with this active form of law enforcement, some states have legislation creating a passive duty to present a vehicle for weighing, even although an officer has not given a direct instruction to this effect.

Zambian legislation creates a standing obligation for a vehicle with a laden weight of 5 tonnes or more to be presented for weighing. In Tanzania, legislation permits the

erection of a road sign obliging all vehicles falling within the category stipulated on the sign to be presented at a weighbridge for weighing. In practice, such a road sign would have a similar effect to the Zambian requirement that a vehicle must be presented for weighing.

Imposing a passive duty on the driver to present a vehicle for weighing, forms part of the SADC proposals. It is unclear why Malawi (which has implemented the SADC proposals in so far as they relate to the imposition of overloading fees) did not also incorporate this feature in its revised legislation.

2.6.2 Liability for fines and overload fees / payment arrangements

Few states specifically identify the party responsible for paying overload fees in their legislation. In Malawi, legislation requires the owner or operator to pay the fees. In Zambia, the owner is held responsible, and in the case of a trailer owned by another party, the owner of the hauling unit is liable.

Legislation in most states is also silent regarding payment arrangements. In Malawi the Director of Road Traffic may designate where an overload fee is to be paid. Tanzanian legislation expressly states that it is payable “on the spot”, while in Zimbabwe fines are payable to the vehicle inspector or any other person designated by the Secretary (of Transport). Only Tanzania has specific provisions governing the eventuality where overloading fees are not paid. The Roads Authority is specifically authorized to sell the vehicle (including the goods being carried) if fees remain unpaid for 90 days.

3. LEGAL REVIEW: CONCESSIONING

This chapter reviews the legal framework in Mozambique and other Southern African states relating to the operation and maintenance of weighbridges by the private sector. It is important to note that private weighbridge operation and maintenance is not addressed specifically in Mozambican law (or in the law of the other states selected for analysis). At most, legislation in some countries (Mozambique, South Africa and Swaziland) can be interpreted to contain implicit references to weighbridge operation. Such references occur mainly in legislation dealing with road concessions (Mozambique) or toll roads (South Africa). Privatization laws adopted in the states concerned all aim to provide a generic framework for private investment and focus mostly on the creation of privatization institutions and laying down procedures for foreign investment. Except in South Africa, such laws are not helpful for present purposes. South Africa has adopted detailed regulations dealing with public – private partnerships (PPPs). These regulations are considered below as they provide a useful framework that could, with adaptation, provide a model to be implemented in Mozambique.

This chapter comprises:

- An overview of public-private partnership (PPP) options in overloading control;

- An analysis of Mozambican legislation relating to concessioning of roads and bridges;
- An analysis of roads and road traffic legislation in South Africa and Swaziland (and applicable PPP legislation in South Africa);
- A summary of findings and conclusions.

3.1 OVERVIEW OF PUBLIC-PRIVATE PARTNERSHIP OPTIONS

A wide range of options exist for public-private partnerships (PPPs) in overloading control. Overloading control is a hybrid function consisting of various activities. Some activities have traditionally been undertaken by the private sector, such as weighbridge construction, scale manufacture and installation, scale maintenance, etc. Others, such as on-the-road enforcement, are policing functions normally undertaken by government. Overlapping these activities are a number of functions that both the private sector and government could undertake, such as infrastructure management and maintenance.

A weighbridge PPP can be designed to combine various functional permutations. The differences between the various options will depend on the answer to the following questions:

- Who owns the weighbridge station and facilities?
- Who conducts weighing operations?
- Who undertakes enforcement?

Depending on the answer in each case, weighbridge PPPs can be categorized as follows:

Table 2.7: Categorization of PPPs

		Ownership		Operations		Enforcement	
		Public	Private	Public	Private	Public	Private
Construction, Supply & Maintenance Contract ⁷		X		X		X	
Outsourcing Contract		X			X	X →	→
Concession	BTO ⁸	X			X	X →	→
	BOOT / BOO ⁹		X		X	X →	→
Divestiture			X		X	X →	→

⁷A contract between government and a private contractor to build and equip a weighing station does not fall within the strict definition of a PPP as it is merely a contract for the provision of supplies and services. It is included in the table for the purposes of comparison.

⁸Build, Transfer, Operate

⁹Build, Own, Operate, Transfer & Build, Own, Operate



The terms of reference require a study of the transfer of the “operation and maintenance of weighbridges” to the private sector. For the purposes of this analysis, this has been interpreted to mean the option of outsourcing or concessioning. Hence, it excludes the typical construction and supply contract (which is current practice in Mozambique and does not require further elaboration). It has also been interpreted to exclude the option of divestiture.

3.1.1 OUTSOURCING

Outsourcing is the most basic method of securing private sector involvement in weighbridge operations. It involves transferring the operational functions at a weighbridge to a private operator. Unlike a concession, the private operator assumes no financial, technical or operational risk, but is paid a fixed fee for his services. The fee may be made up in various ways. It could consist of a guaranteed minimum plus a percentage for each vehicle weighed. Alternatively, the contract could provide simply for the payment of a flat fee.

Under an outsourcing contract, the private operator would provide staff to man the weighbridge and to conduct weighing operations. The infrastructure and facilities remain the property of the state. Traffic inspectors are still required to assist with enforcement, i.e. to stop vehicles, direct them to the weighbridge, direct them to remove overloads, etc. However, provided it is permitted in the law, a contract to outsource weighing operations could provide for the private contractor to assume the functions of traffic control (stopping vehicles, directing vehicles to a weighing station, etc). A potential stumbling block exists as long as overloading is classified as a criminal offence, which usually requires the police. The contract may provide for the operator to assume responsibility for periodic maintenance of the weighbridge. The option also exists to require the operator to conduct training of government officers in weighing procedures so that the state can assume the function more effectively once the contract expires.

Generally, a outsourcing contract would be concluded for a shorter period of time than a concession (see below). The main reason is that the private operator makes no initial investment and does not need a specific period of time to recover expenditure. At the same time, a shorter period allows government to review the effectiveness of the arrangement and if necessary, to recruit another operator or to move to a full-scale concession.

3.1.2 CONCESSION

The main features of a concession agreement are:

3.1.2.1 Ownership.

Under a BTO concession, the state would retain ownership of the land on which the weighing station is situated. However, the use of the land could be leased to a private operator to (a) construct (b) operate a weighbridge. In terms of general legal principles, the state would also own the weighbridge as it is located on state land and can be regarded as a permanent fixture. However, the concession would normally provide for a guarantee that the state will give the weighbridge operator undisturbed

possession of the land for the purposes of operating the weighbridge. If a BOOT or BOO concession is granted, ownership of the land and permanent fixtures would pass to the concessionaire. Under a BOOT arrangement, provision would be made for the ownership to be transferred back to the state at the end of the concession period.

3.1.2.2 Finance.

The construction of the weighing station, the installation of scales and equipment would be financed either through a combination of public and private funds or purely through private funds. In order to obtain project finance, it will be necessary for the state to provide the private operator with some revenue guarantee. To give effect to the guarantee, the state may need to pass legislation whereby all heavy vehicles are obliged to report to the weighbridge for weighing (to ensure a steady revenue stream for the operator from weighing fees). Legislation would also need to authorize the private operator to collect a weighing fee which would normally be calculated on a cost recovery basis plus profit.

3.1.2.3 Operation and maintenance.

The concessionaire constructs the weighing station and installs the weighbridge and other equipment (if a weighing station already exists, the concession could allow for the operator to rehabilitate it and renew or upgrade the equipment). The private operator would operate the weighbridge and be responsible for maintenance. Provision could be made for periodic inspections by the responsible state body, e.g. the Bureau of Weights and Measures. Staff employed by the private operator would also be responsible for weighing vehicles and issuing certificates. They could also take responsibility for collecting fees (see below).

3.1.2.4 Duration.

The concession will be granted for a specific time period, e.g. 15 years. At the end of the concession, the operator would hand over the facility to the state. An option to negotiate an extension of the concession term would normally be allowed.

3.1.2.5 Risk.

The concessionaire must assume some commercial risk. This is one of the main features distinguishing a concession from outsourcing. By its nature, a weighbridge concession is unlikely to generate significant direct returns for the state (as a well-functioning concession should result in reduced rates of overloading and hence reduced revenue from overloading fees). Government's indirect returns would, however, increase significantly as its road maintenance bill would be reduced as overloading declines. There may be limited investor interest in these concessions, as investors have little control over factors which affect their revenues (mainly traffic volumes). Traffic volumes can be negatively affected by factors such as reduced economic activity, fuel prices, road user charges, port congestion, etc. All these factors can have a very detrimental impact on the concessionaire's ability to generate revenue and significantly reduce the attractiveness of a concession. For this reason, government may need to provide some incentives in the form of sharing revenue risk, such as providing revenue guarantees should traffic volumes fall below an predetermined level.

3.1.2.6 Law enforcement.

Under a concession on-the-road law enforcement could remain a function of the state. However, certain functions could also be transferred to the concessionaire. Traffic inspectors would co-operate with staff of the weighbridge operator in conducting weighing operations. Traffic inspectors would be required to stop vehicles, instruct a driver to proceed to a weighbridge and to issue a summons or fine or impose overloading fees (if the law provides for administrative penalties). If overloading fees can be imposed, the weighbridge operator could be made responsible for levying and collecting the fee. The option exists to involve the private sector in on-the-road enforcement of load limits, as set out in the SADC proposals. This option is also possible under the legislation of at least one state (Swaziland – see below). Private sector involvement in enforcement is enabled by extending the powers given to traffic inspectors to designated staff of the weighbridge operator. If the decision is taken to decriminalize overloading and to impose overloading fees (as has been done in Malawi), it becomes possible to eliminate the role of traffic inspectors completely.

3.2 OVERVIEW OF CURRENT LEGISLATION

3.2.1 MOZAMBIQUE

There is authority in Mozambican law to outsource the operation and management of weighbridges to the private sector. However, the legislation that applies to concessioned roads is vague and it is not clear that it would be legal to conclude a concession contract for private weighbridge operation and management that incorporates all the traditional features of a PPP.

3.2.1.1 Outsourcing

The authority for the outsourcing of functions is found in Decree 23/2003 which contains the Statute of the National Roads Administration (ANE). Art 4 gives the ANE the authority to perform the functions of road traffic control. This authority is reinforced by Art 5(3) of ANE's Statute¹⁰ which gives the ANE powers to “police and protect roads and bridges”¹¹. It is implied that this includes powers to construct and operate weighbridges and enforce load limits. The ANE is also authorised to appoint firms to provide services, supply goods and execute works (Art 4 (a)(iii)). These provisions are adequate authority for ANE to:

- contract for the building of weighing stations and the supply of weighbridges and equipment;
- contract for the provision of weighing services (i.e. the conduct of operations); or
- contract for the maintenance of weighbridges and equipment.

There are no provisions in the Decree allowing ANE to delegate its policing and control powers to any other party.

¹⁰Estatuto Orgânico da Administração Nacional de Estradas, Decreto No 23/2003 de 20 de Maio.

¹¹“Poderes Para Policiar A Protecção Das Estradas E Pontes”

3.2.1.2 Concessioneering

A separate regime applicable to concessioned roads and bridges has been established by Decree 31/96. The Decree stipulates that the principal function of the concessionaire is to construct, maintain and manage the road which is subject to the concession (Art 13(1)). To this end, a concessionaire has the power to erect toll gates and to collect tolls using its own staff. The concessionaire is also given powers to erect service areas for the supply of fuel, repair services and catering facilities.

The concessionaire is further entitled to undertake “ancillary and complementary activities”¹², as long as these are duly authorized (Art 13(2)). “Ancillary and complementary activities” are not defined in the Decree. The question arises whether the control of vehicle loading can be regarded as an “ancillary and complementary activity”.

It is logical to conclude that the preservation of the road subject to a concession is an adjunct of the concessionaire's primary task to manage and operate a road. Hence, Decree 31/96 could be interpreted to permit a concessionaire to construct and operate weighbridges, subject to authorisation by ANE. There is no wording in the Decree suggesting an intent that a concessionaire would be able to collect weighbridge fees. The Decree contains an express authority permitting the concessionaire to collect tolls. If it had been the intention that a concessionaire could collect weighbridge fees, it is probable that the Decree would expressly make provision for such a power.

There is also no authority for the concessionaire to undertake policing functions. Thus, a concessionaire undertaking overloading control would have relied on the co-operation of the ANE and the police to do so effectively.

3.2.2 SOUTH AFRICA

The inclusion of PPPs in the roads sector is governed by the South African National Roads Agency and National Roads Act, 1998 and by general PPP legislation made under the Public Finance Management Act, 1999.

3.2.2.1 Outsourcing

Roads legislation provides a wide authority to the Roads Agency (SANRA) to involve private expertise. SANRA may appoint any private person, institution or body to perform any work on behalf of the Agency with regard to the planning or design of a national road or proposed national road or the construction, operation, management, control, maintenance or rehabilitation of a national road (Sec 26(c)). With regard to a toll road, it may appoint any person finance, plan, design, construct, operate, manage, control and maintain such toll road (Sec 28(1)).

These provisions permit the outsourcing of weighbridge management and operation. It enables SANRA to contract with a private party to:

- construct a weighbridge;
- install scales and equipment;

¹²“Actividades Conexas Ou Complementares”

- maintain infrastructure and equipment;
- manage a weighing station and undertake operations.

As such, the provisions do not permit the private party to undertake policing functions related to overload control.

3.2.2.2 Concessions

Under the Public Finance Management Act, 1999, the South African Treasury has issued extensive instructions to government departments (and agencies such as SANRA) regarding the public – private partnerships (Treasury Regulation 16).

Under Treasury Regulation 16, a “public – private partnership” is defined as a commercial transaction between a government institution and a private party in terms of which the private party performs an institutional function on behalf of that institution. A PPP may also consist of a private party acquiring the use of state property for its own commercial purposes. In terms of Treasury Regulation 16, a private party may only perform an institutional function if this is authorised in another applicable law. As discussed above, there is authority in the roads legislation permitting a private party to conduct weighbridge operations and maintenance.

A further requirement is that the private party must assume substantial financial, technical and operational risks in performing the institutional function and/or using state property. In turn, the private party is compensated for its performance either by being paid directly by government and/or by being allowed to collect fees from users or customers. The question arises as to the nature of the risk that a private party must assume. Within this context, financial risk would consist primarily of revenue risk. If government were to compensate the private weighbridge operator for its services to the extent that it covers the costs of investment plus profit, this would not qualify as a PPP as the operator would not be assuming any revenue risk. Such a scenario would amount to mere outsourcing. To distinguish a concession from outsourcing, the weighbridge operator would have to either:

- assume a “volume” risk, i.e. be compensated by government on the basis of the number of vehicles processed (which implies a heavy reliance on the efficiency of traffic officers whose co-operation will be essential to direct vehicles to a weighbridge); or
- derive some revenue from user fees, such as a weighbridge processing fee (at present, this would require an amendment of law as there is no authority in current law to charge and collect such fees).

As in Mozambique, policing functions performed by traffic officers such as stopping a vehicle, directing it to a weighbridge and ascertaining its mass are “reserved” functions that only government can perform. At present it is not possible to set up a PPP which permits the private party to undertake the policing functions. A legislative amendment permitting the appointment of employees of the private party as traffic officers for the purposes of overloading control, would, therefore, be required.

To sum up, a weighbridge concession is possible under South Africa law, but its scope would be limited by the inability of the operator to charge and collect for its services or

to undertake policing functions. The risks associated with the reliance on traffic officers to direct vehicles to weighbridges may render such a concession unattractive. These shortcomings could, however, be overcome by legislative amendments that permit a concessionaire to:

- undertake policing functions for the purposes of overloading control (enabling the concessionaire to better manage its risks); and
- collect weighbridge processing fees (to provide the concessionaire with a constant revenue stream).

The provisions could be further strengthened by the introduction of a statutory duty on all vehicles over 3500 kg to report to a weighbridge for weighing.

3.2.3 SWAZILAND

Sec 124 of the Road Traffic Act, 2004 permits the Minister of Transport to enter into an agreement with “any person or local authority” to perform a function assigned to the Minister by the Act.

These provisions provide authority for the Minister to appoint a private person to all functions vested in the Minister related to overloading control. It is a requirement that the Minister delegate the function to be performed by the private person or entity in writing. The Minister must also give notice in the *Gazette* within ninety days that such an agreement has been concluded.

4. REGIONAL CONTEXT

4.1 MOZAMBIQUE AND SADC

As a member state of the Southern Africa Development Community (SADC) and a signatory to the Protocol on Transport, Communications and Meteorology¹, Mozambique has undertaken to implement the Protocol in accordance with the principles of the organization. In so doing, the Government has undertaken to promote convergence and compatibility with regional trends by adopting a unified approach to issues of common interest in the transport sector, such as overload control.

In light of the above, this chapter places the issue of overload control in a regional context in terms of developments that have taken place since the preparation of the SADC Model Legislative Provisions (MLP) entitled *“Enabling Legal Reform: Control of Vehicle Overloading”*. The MLP may be viewed as a point of departure for developing a strategy for Mozambique on overload control.

4.2 BACKGROUND TO OVERLOAD CONTROL INITIATIVES IN THE REGION

The challenge of control of overloading is one of the most important roads sector issues in the Southern African region today. The issue of vehicle overloading and the urgent need for its effective control have been under consideration by SADC for more than two decades. Overloading not only significantly accelerates the rate of deterioration of road pavements but, when coupled with inadequate funding for road maintenance it contributes significantly to poor road conditions and high transport costs, which are typically four to five times those prevailing in developed countries.

The high magnitude of what essentially are avoidable costs due to overloading underscores the importance of dealing with this problem effectively. Failure to address it is detrimental to the infrastructure of the region and the competitiveness of its products in the world markets. There is an urgent need to take corrective action to avoid a situation in which poor roads and related high transport costs become an obstacle to economic growth and development in the SADC region. On this, there is unanimity among key policy bodies as reflected in the high prioritisation of the problem in SADC as well as in regional organisations such as the Association of Southern African National Roads Agencies (ASANRA) and the Federation of East and Southern African Road Transport Associations (FESARTA).

Against the above background, the following key issues arise:

- What are the shortcomings of traditional approaches to overload control?
- How can traditional approaches be reformed to provide a more effective means of overload control?
- To what extent are the agreed, new, approaches to overload control being implemented?
- These issues are discussed briefly below.

4.3 TRADITIONAL APPROACHES IN THE REGION

Based on consultations with officials involved in overload control in the SADC region, the most significant features of the traditional approaches that have been adopted may be summarized as follows:

Traditional approaches provide a criminal response to incidences of overloading which results in very low conviction rates due largely to legal technicalities and the inability of the courts to effectively cope with what is considered “non-serious” cases compared to more serious crime cases. As a result, there are few incentives to restrict overloading.

In-house operation of weighbridges involving relatively low paid staff has been conducive to bribery and corruption with the result that unscrupulous operators readily engage in such malpractice.

The criminal response does not provide any institutional controls or financial links between road authorities and actual road damage.

There is no “price” for overloading and offenders pay little, if any, money to road authorities to compensate for their increased burden of maintenance costs. What they do pay to Government is very low in relation to the cost of the damage done and is not really a deterrent to overloading. Indeed, it pays operators to deliberately overload and pay relatively low fines on “*admission of guilt*” for so doing.

Among transport authorities, only the traffic police (and sometimes transport inspectors) have a direct responsibility to control overloading practices. However, their efforts have little deterrent value due to the constraints of the criminal justice system.

Road authorities, who have a primary responsibility for preserving the road infrastructure, have a limited role in regulating vehicle loading.

The current systems fail to achieve the primary goal of preserving the road infrastructure. Instead, they are characterized by inefficiency and inequities.

4.4 NEW APPROACHES / THE MODEL LEGISLATIVE PROVISIONS (MLP)

Based on extensive consultations with a cross-section of both public and private sector stakeholders in the SADC region, SADC prepared Model Legislative Provisions (MLP) entitled: *Enabling Legal Reform: Control of Vehicle Loading*². The MLP comprises the following two legal instruments:

- *Memorandum of Understanding on Vehicle Loading*; and
- *Model Legislative Provisions on Management of Vehicle Loading*.

In addition, a *Model Agency Contract in respect of Facilitation and Operation of Weighing Stations*³ has also been prepared.

The above documents constitute important reforms in overload control which respond to the most glaring shortcomings of traditional approaches. They incorporate the relevant legal reform recommendations contained in the SATCC 5 Country Special

Working Group on Overload Control⁴. In so doing, they respond to the following shortcomings of traditional approaches to overload control:

- a high degree of lawlessness in respect of vehicle overloading;
- ineffectiveness of the criminal justice system in effectively regulating overloading;
- Institutional fragmentation, i.e. the lack of real institutional controls and financial links between road authorities and road damage;
- recognition of the need to move to a “decriminalized” regulatory approach.

4.4.1 MAIN ELEMENTS OF THE MLP

The main elements of what may be termed an Overload Control Management Initiative (OCMI), similar in concept to the well known *Road management Initiative (RMI)*, may be summarized as follows:

Introduction of a Regional Vehicle Overloading Control Association (REVOCA) comprising public and private sector representatives to oversee implementation of the OCMI as well as a national Vehicle Loading Advisory Committee (VLAC) comprising public/private sector stakeholders to advise the responsible Minister on overloading fees

- Introduction of a regional strategy on overload control which focuses on controlling heavy vehicles moving on regional corridors in order to ensure a co-ordinated approach within SADC countries.
- Operation of a self-regulatory system which places the onus for overload control on transport operators and freight forwarders.
- Application of administrative disincentives to combat overloading practices.
- Decriminalisation of offences for overloading by handling them administratively and imposing a requirement on the overloader to pay an overloading fee.
- Linking the level of imposed fees for overloading with the actual cost of road damage, i.e. imposing economic fees.
- Outsourcing weighbridge operations to the private sector on a concession basis, i.e. embarking on a commercialised public/private sector approach to overload control.

4.4.2 IMPLEMENTATION OF THE MLP

It is now six years since the MLP was produced with an exhortation by SADC that they should be implemented as a matter of policy. Based on a survey of current practice undertaken by a member of the Consultant’s team, the extent to which such implementation has taken place may be summarised as follows:

4.4.2.1 Legal and regulatory

During the past two decades there has been a clear trend towards an **increase in legal axle load limits** in many countries in the SADC region. For example, single axle limits have increased from 8.0/8.2 to 10 tonnes, tandem axle limits from 16.0 to 18.0 tonnes and tridem limits from 21.0 to 24.0 tonnes. There has also been an increase in GCM limits to 56 tonnes, one of the highest in the world and significantly higher than

that prevailing in other Regional Economic Communities in Africa, such as ECOWAS (50 tonnes) and COMESA (53 tonnes).

There is still **lack of harmonisation** of many aspects of vehicle weights and dimensions limits in SADC. For example, single axle load limits of 8.2, 9.0 and 10.0 tonnes still prevail in the SADC region. Such differences also occur with tandem, tridem and GVM limits as well and do not appear to be justified. These disparities contribute to the incidence of overloading and are very disruptive to the efficient circulation of commercial vehicles within and between SADC countries. There is much less difference in vehicle dimension limits amongst SADC countries which tend to be more uniform as regards, for example, vehicle combination length (20–22 m), vehicle width (2.5–2.65 m) and vehicle height (4.0–4.6 m).

The **legislation** pertaining to overload control is **outdated** in many countries and is deficient in many respects, such as dealing with hazardous substances and offering protection to bridges through the application of an appropriate Bridge Formula. However, all responding countries report that they are in the process of updating their legislation which, in the case of SADC countries, is in line with their Model Legislative Provisions (MLP) on Management of Vehicle Loading. These provisions consolidate vehicle overloading reform efforts carried out in recent years and advocate such trend-setting measures as decriminalisation of offences, operation of a self-regulatory system, imposition of an “economic” progressive fee structure for overloading and outsourcing and eventual privatisation of overload control operations.

Penalties and sanctions applied in most countries are **inadequate** to effectively deter overloading or to recover the additional damage to pavements caused by overloaded vehicles. Moreover, some offenders deliberately overload and are prepared to pay a relatively low “admission of guilt” fine for doing so, i.e. they view overloading as rational and cost-effective business behaviour. In addition, existing control measures involving specific sanctions and penalties are so varied that they render a regional approach impractical in the absence of a more rationalised system.

In most countries overloading is typically of the order of 25 – 40 per cent with a number of countries reporting figures in excess of 50 per cent whilst some do not know the extent of overloading. Such overloading appears to depend on the effectiveness of the legal sanction against offending operators which is closely related to the **quality of the enforcement** process and enforcement officials.

The reasons typically cited for the overloading problem include:

- a criminal prosecution procedure that hinders enforcement;
- lack of coordinated efforts at national and regional level;
- ignorance and lack of appreciation in Ministries of Finance;
- the level of fines imposed that are not a deterrent to overloading;
- controlling overloading is not a government priority;
- delays in implementation of harmonised axle load limits; and
- lack of effective reporting systems.

4.4.2.2 Institutional and Organisational

Weighbridge operations are carried out in most countries by a Government body, typically a weighbridge unit, involving relatively low-paid staff lacking incentives to control overloading effectively and susceptible to bribery and corruption. However, there is an increasing trend in a few countries towards outsourcing some aspects of the weighbridge operations to the private sector. The use of police for enforcement purposes is prevalent in most countries although in a few countries it is carried out by a traffic inspectorate. Increasingly, the fees collected for overloading are deposited into a Road Fund, although in a number of countries, especially where there is no autonomous/semi-autonomous roads agency, it still reverts to Government.

4.4.2.3 Overload Control Infrastructure

The number of weighbridges available for overload control varies widely from country to country. In general, there are an insufficient number of units to adequately cover all strategic border crossings and internal routes adequately in most countries. Moreover, there is concern over the adequacy of many of the existing weighbridges in terms of the type, reliability and proper assizing of the equipment. Substantial investments will be needed to put in place an adequate network of weighbridges in the SADC region.

There is recognition in many countries that weighbridge operations and standards should be harmonised and coordinated in the region. Moreover, any investment in weighbridges should be analysed carefully in terms of type, costs, location, installation, management, etc., in order to arrive at an optimal regional strategy.

4.4.2.4 Operations and Manpower

The type and standard of training varies significantly within and between regions and is generally inadequate to provide a cadre of trained officials able to effectively manage, operate and maintain weighbridges. As a result, the quality and competence of weighbridge staff and the efficiency of weighing operations vary considerably and are adversely affected by lack of both weighbridge operations manuals and refresher training courses.

In some countries, the weighbridge stations are not open at night and, not surprisingly, many vehicles simply do not bother to stop. Worse, at borders, they are generally not required to produce a weighbridge clearance certificate for customs clearance purposes and generally proceed to the host country overloaded.

4.4.2.5 Database on Overload Control

An increasing number of countries, including a majority in the SADC region, collect, analyse and report on the vehicle weighing data captured. However, this information is generally not shared at regional level which reduces the chances of identifying habitual offenders. In those countries where data is not collected there is little awareness of the extent of the overloading problem.

4.4.2.6 Assessment of Current Practice

For a variety of reasons - political, legal, institutional, technical, financial, etc. - control of vehicle overloading in the majority of countries in all RECs is far from satisfactory.

Almost all responding countries assessed their performance on overload control as being either *fair* or *poor* with the incidence of overloading typically being in the range 25 – 40% with a few in excess of 50%.

There is lack of harmonisation in most aspects of overload control amongst SADC member states as discussed above. This has caused local and regional inefficiencies and has contributed to the relatively high incidence of overloading in many countries.

There is now wide-spread recognition amongst most countries that traditional approaches to overload control have generally not worked and that there is need for a fundamental shift in approach. To this end, most SADC countries view the SADC MLP on vehicle loading as offering trend-setting reforms which respond to the most glaring shortcomings of traditional approaches. However, they concede that for a variety of reasons, the pace of implementation of these reforms has been slow and that SADC member states should play a stronger coordination and monitoring role in ensuring that the agreed strategies are implemented according to a realistic timetable.

4.4.3 PERCEIVED OPPORTUNITIES AND OBSTACLES TO IMPLEMENTING THE MLP

4.4.3.1 Legal and Regulatory

Most countries are in agreement, in principle, with the concept of decriminalisation of offences by treating them administratively and outside of the traditional but inefficient prosecution procedures.

Most countries are sceptical of the efficacy of a self-regulatory system that places the onus for controlling overloading on transport operators and freight forwarders. However, some countries believe that such a system could work where certain industries (e.g. quarrying, timber, fertiliser, etc.) are identified as “mass controlled” and can be required to provide their own weighbridges at points of loading or delivery.

Most countries are in favour of imposing an “economic” progressive fee structure for overloading which recovers the total cost of overloading including that due to the extra damage to road pavements. However, many countries cite lack of the necessary regulations as a constraint to this development.

4.4.3.2 Institutional and Organisational

Most countries are in favour of outsourcing overload control operations to the private sector on a commercialised basis. However, a minority of countries feel that there was no need to change the status quo as the state-controlled system could be made to work and changing from that system could cause administrative and legal problems.

4.5 REVIEW OF AXLE LOAD, GCM AND VEHICLE DIMENSION LIMITS IN THE REGION

4.5.1 SADC RECOMMENDED LIMITS

The recommended axle load and gross combination mass limits for the SADC Regional Trunk Road Network (RTRN) are based on a study for Southern Africa which was carried out in 1993 to determine the optimum axle load limits⁵, i.e. such axle loads and weights that will minimize the total transport cost on a regional basis in the SADC region. This concept is illustrated in Figure 4.1 which shows the various inter-acting elements in relation to the derivation of the optimum axle load limits.

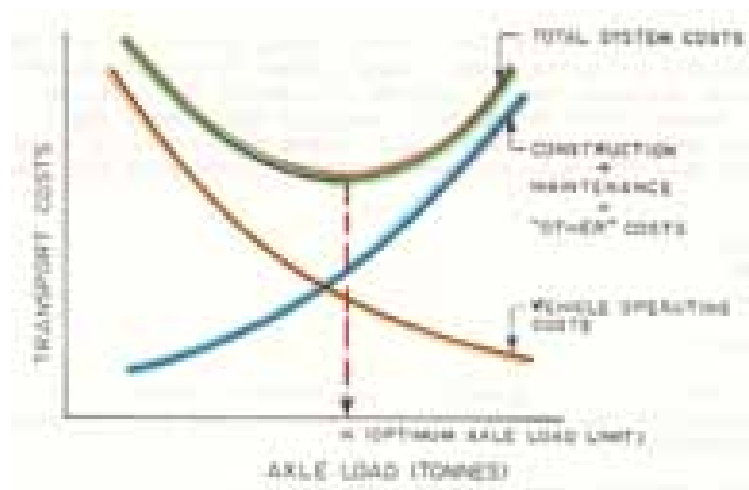


Figure 4.1: The concept of the Economic Axle Load Limit

The important assumption used in the SADC study is that axle load regulations should be based on a trade-off between road haulage cost and costs related to road and bridge wear. Simply stated, this means that axle loads and gross vehicle weights should be increased to the point where the savings to the hauls affected from a further increase is less than the increase in costs due to the additional wear on roads and bridges. The analysis was undertaken using the World Bank's Highway Design and Maintenance Standards Model (HDM-III).

Based on the outcome of the HDM-III analyses, the regional optimum single axle load limit was determined as 13.0 tonnes. However, based on consideration of the axle load Economic Efficiency Frontier, in terms of the benefits versus costs of increasing from the prevailing limits to the optimum limit (ref. Figure 4.1 and Table 4.1), the harmonized limits recommended for the region were less than the optimum limits, as shown in Table 4.2.

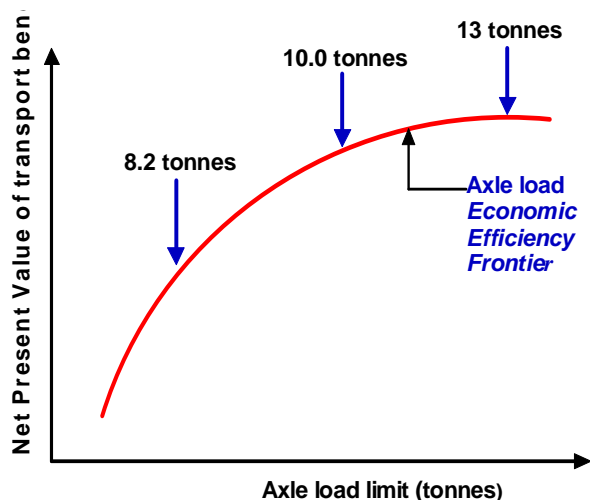


Table 4.1: NPV of transport costs in relation to increase in axle load

Increase in axle load limit		Benefit/cost ratio
From	To	
8.2	10.0	10.1
10.0	12.0	3.6
12.0	13.0	1.7

Figure 4.2: Axle load Economic Efficiency Frontier

In addition to axle load economic efficiency considerations, there were a number of other reasons for recommending limits which were less than the optimum limits. These included the large proportion of sub-standard pavements, a significant amount of backlog maintenance and concern over the adequacy of future maintenance funding. In the event, the recommended regional axle load and gross combination mass limits for the SADC region are as follows:

Table 4.2: SADC recommended harmonized axle load limits

Maximum Axle Load Limits (Tonnes)				Gross Combination Mass (GCM) (Tonnes)
Single		Tandem	Tridem	
Steering	Drive			
7.7	10	18	24	56

4.5.2 REGIONAL AXLE LOAD LIMITS

In practice, there is still lack of harmonisation of axle load limits amongst SADC countries. For example, as shown in Table 4.3, single axle load limits of 8.0, 8.2, 9.0 and 10.00 tonnes still prevail and such variation also occurs with tandem, tridem and GVM limits.

Table 4.3: Existing axle load limits in the SADC region

Country	Steering Axle Two Tyres	Single Axle Dual Tyres	Tandem Axle Dual Tyres	Tridem Axle Dual Tyres	GCM (Tonnes)	Weighing Tolerance
Angola	6	10	16	24	38	
Botswana	7.7	8.2	16.4	24.6	50.2	5%
Lesotho	7.7	8.2	16.4	21	49	
Malawi	8	10	18	24	56	
Mozambique	7.5	10(8)	16	24	38*	Nil
Namibia	7.7	9	18	24	56	5%
South Africa	7.7	9	18	24	56	5%
Swaziland	7.7	8.2	16.4	21	50.2	
Tanzania	7	10	18	24	56	Nil
Zambia	8	10	16	24	56	10%
Zimbabwe	8	10	18	24	56	5%
SADC	7.7	10	18	24	56	

* Except for the N4 corridor which is 56 tonnes.

4.5.3 SADC RECOMMENDED VEHICLE DIMENSION LIMITS

Based on previous consultations amongst the countries of the region, the recommended SADC vehicle dimension limits are as follows:

Table 4.4: Recommended SADC harmonized vehicle dimension limits

Vehicle Combination Length (m)	Articulated Vehicle Length (m)	Width (m)	Height (m)	Rigid Vehicle Length (m)	Trailer Length (m)	Semi-Trailer Length (m)
22	18.5	2.6	4.6	12.5	12.5	N/A

4.5.4 EXISTING VEHICLE DIMENSION LIMITS IN THE SADC REGION

As shown in Table 4.5, there is much less difference in vehicle dimension limits within the SADC region which tend to be more uniform as regards, for example, vehicle combination length (20 - 22 m), vehicle width (2.5 - 2.65 m) and vehicle height (4.0 - 4.6 m). In any event, there is a Working Group on Vehicle Dimensions and Combinations which has made proposals on obtaining even greater harmonisation in this area.

Table 4.5: Existing vehicle dimension limits

Country	Vehicle Combination Length (m)	Articulated Vehicle Length (m)	Width (m)	Height (m)	Rigid Vehicle Length (m)	Trailer Length (m)	Semi-Trailer Length (m)
Angola	20	18	2.5	4	15	15	15
Botswana	22	17	2.5	4.1	12.5	12.5	12.5
Lesotho	22	17	2.6	4.1	12.5	12.5	12.5
Malawi	22	17	2.5	4.6	12.5	12.5	12.5
Mozambique	18/22 *	15	2.5	4	12	12	12
Namibia	22	18.5	2.6	4.3	12.5	12.5	N/A
South Africa	22	18.5	2.6	4.3	12.5	12.5	N/A
Swaziland	20	17	2.5	4.1	12.5	12.5	12.5
Tanzania	22	17	2.6	4.4	12.5	12.5	12.5
Zambia	22	17	2.65	4.6	12.5	12.5	12.5
Zimbabwe	22	17	2.65	4.6	12.5	12.5	N/A
SADC	22	18.5	2.6	4.6	12.5	12.5	N/A

5. BRIDGE LOADING STUDY

The aim of the bridge loading study was to make a general determination of the design load capacities of existing bridges in Mozambique. The results of the study are taken into account during the process to make recommendations subsequent to the finalization of the Heavy Vehicle Overloading Study. Recommendations are also made to avoid the overloading of specific bridges.

5.1 DATA COLLECTION

The bridge loading study commenced with the collection of relevant information and data. The bulk of the information was sourced from the Bridge Design Office of the client in Maputo. The following information was obtained:

- A basic inventory of existing bridges on main routes, including location, overall length and the type of crossing
- Identification of important freight routes
- Different versions of the Portuguese Codes of Practice
- The SATCC Code of Practice for the Design of Highway Bridges and Culverts

Information that would have assisted in the study, but could not be obtained included:

- Type of bridge, i.e. concrete, steel, timber, etc
- Superstructure configuration e.g. number of spans, individual span lengths and deck widths
- Condition reports on existing bridges

The following technical literature was also collected:

- "A model for evaluating the effect of vehicle overloading on bridge deterioration", Division of Roads and Transport Technology, Research Report DPVT 164, Pretoria, CSIR, March 1991
- Analytical and Experimental evaluation of an aluminium deck panel: Part I: Service Load Performance", Virginia Transportation Research Council
- "Looking to Load and Resistance Factor Rating", B Jaramilla and S Huo, US Department of Transportation, Federal Highway Administration

5.2 REVIEW OF COLLECTED DATA

5.2.1 BRIDGE INVENTORY

The **inventory table included in Annexure II** is based on information received from the ANE Bridge Office:

5.2.2 IDENTIFICATION OF IMPORTANT FREIGHT ROUTES

Bridges on the following important freight routes were identified by the ANE Bridge Engineer for having strategic significance:

- Maputo to Komatipoort
- Beira to Mutare
- Tete to Malawi
- Tete to Zambia
- Tete to Zimbabwe

5.2.3 LITERATURE REVIEW

The following information, applicable to this project, was extracted from the literature:

"Analytical and Experimental evaluation of an aluminium deck panel: Part I": Service Load Performance", Virginia Transportation Research Council

Deck deterioration is responsible for the majority of deficient bridge ratings in the United States. Subject to dynamic loading, cyclic loading and occasional overloading, bridge decks are also the most severely stressed elements in bridge structures.

"Looking to Load and Resistance Factor Rating", B Jaramilla and S Huo, US Department of Transportation, Federal Highway Administration

In the AASHTO Standard Specifications for Highway Bridges, the live load impact factor, accounting for speed, vibration and momentum of vehicular traffic, is defined as follows:

$$I = \frac{50}{L+125} \leq 0,3$$

This formula implies that for deck spans up to 41,6m long, the design impact load factor is 1,3. For span lengths in excess of this length, the impact factor reduces progressively.

"A model for evaluating the effect of vehicle overloading on bridge deterioration", Division of Roads and Transport Technology, Research Report DPVT 164, Pretoria, CSIR, March 1991

This paper describes the development of a model to assess the long-term damage of heavy vehicles on bridges. The influence of other effects such as corrosion, temperature and quality control during construction, interacting with the effects of overloading were also considered.

Field observations and tests in the United States have shown that bridge damage under loading normally starts as deck cracking, which subsequently progresses to other parts of the structure. Although transverse cracking occurs first, longitudinal cracking may also occur due to differential deflection of beams and insufficient transverse reinforcement. Other cracking mechanisms include cracks in the deck slab or at beam-slab interfaces. The progress of overload damage from the deck to the abutments , piers and foundations is very uncertain and difficult to quantify.

Tests conducted in Japan indicate that the load carrying capacity of concrete decks is more than three times the design load. However, field observations on damaged deck slabs indicate that the effects of the rolling overloaded wheel loads on fatigue are highly significant. Increased deterioration results from water that infiltrates the cracks and washes out the fine powder of the crushed concrete.

In order to assess the effects of heavy vehicles on bridge deterioration in South Africa, a total of 178 bridges were inspected for signs of traffic-related damage. Of the 178 bridges visually inspected 27 or 15%, exhibited signs of distress under the heavy vehicle lane. Most of the damaged bridges were simply supported solid slab or voided slab decks with a span ranging from 6m to 13m.

A model was developed for the deteriorating of bridges subjected to overloading, based on the established laws of concrete fatigue. Based on this theory, the fatigue strength of concrete reduces to approximately 40% of the static strength at 10^6 cycles. Concrete fatigue strength is very sensitive to the range of cyclical stress, i.e. the difference between the highest and lowest stresses. Consequently, the maximum stress that can be sustained for a given fatigue life increases as the stress range decreases, as indicated in the endurance curve below:

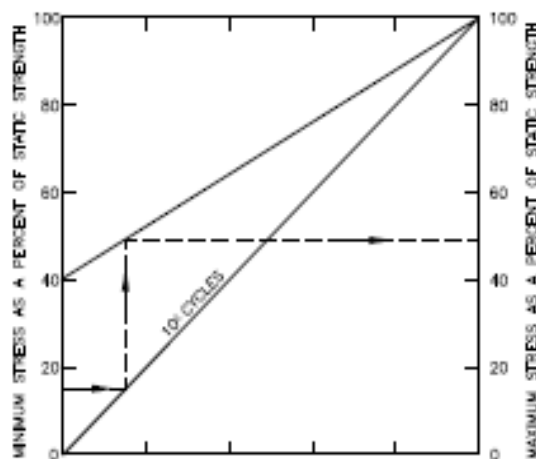


Figure 5.1: Endurance Curve of Galloway and Rathby

In the development of the model, simulated heavy vehicles with three, five, six and seven axles, as well as a single axle, a tandem and a tridem were used to generate bending moment on five selected bridge decks. The results are summarized in the table overleaf. Only the oldest bridge in the group, constructed in 1942, showed potential fatigue failure after 10^6 cycles of 12 tonne axle overloading. This bridge has a span length of 9,6m.

Table 5.1: Results of critical Bridges analysed for fatigue

Bridge Number	Maximum load per axle (tonne)	Applied maximum load ratio	Allowable maximum load ratio at 10 ⁶ cycles
B156	8,2	0,47	0,53
	10,0	0,52	
	12,0	0,58	
	14,0	0,64	
B28	8,2	0,45	0,57
	10,0	0,48	
	12,0	0,52	
	14,0	0,56	
B75	8,2	0,25	0,50
	10,0	0,26	
	12,0	0,28	
	14,0	0,30	
B5520	8,2	0,32	0,53
	10,0	0,34	
	12,0	0,36	
	14,0	0,38	
B5665	8,2	0,41	0,59
	10,0	0,42	
	12,0	0,44	
	14,0	0,45	

In conclusion, it was found that overloaded single axles have a negligible effect on the long-term damage of bridge decks. Overloaded tandem and tridem axle groups, on the other hand, can contribute significantly to bridge deterioration. The study focused on relatively short-span bridges and the scope of future research will need to be extended to include a longer range of span lengths.

5.3 DESIGN CODE LOADING DESCRIPTION

The following Codes of Procedures have been used for the design of bridge structures in Mozambique:

Prior to 1985: Regulations for the Design of Reinforced Concrete Bridges (Old Portuguese Code) latest revision 1967

Between 1985 and 1998: Regulations for the Design of Reinforced Concrete Bridges (New Portuguese Code) latest revision 1985

Subsequent to 1998: SATCC Code of Practice for the Design of Highway Bridges and Culverts in Southern Africa

5.3.1 OLD PORTUGUESE CODE

Two separate load conditions are described in the Code. The least favourable load for any specific condition is used for design purposes.

a) Single vehicle load

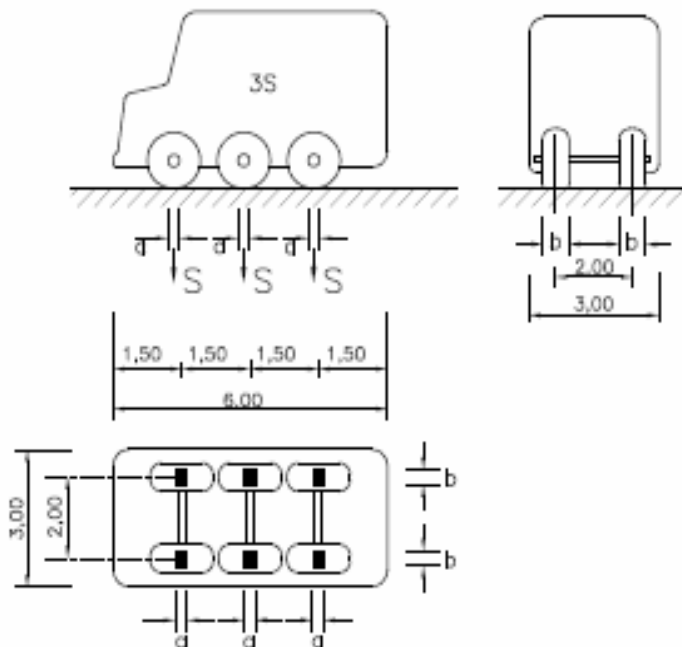


Figure 5.2: Single Vehicle loading (Old Portuguese Code)

Class A Road: $S = 20$ tonne

Class B Road: $S = 15$ tonne

Class C Road: $S = 10$ tonne

A dynamic factor of 1,2 are applicable to all axle loads. It is unknown for which road class the bridges of the various routes were designed for.

b) Uniformly distributed load and axle load, as follows:

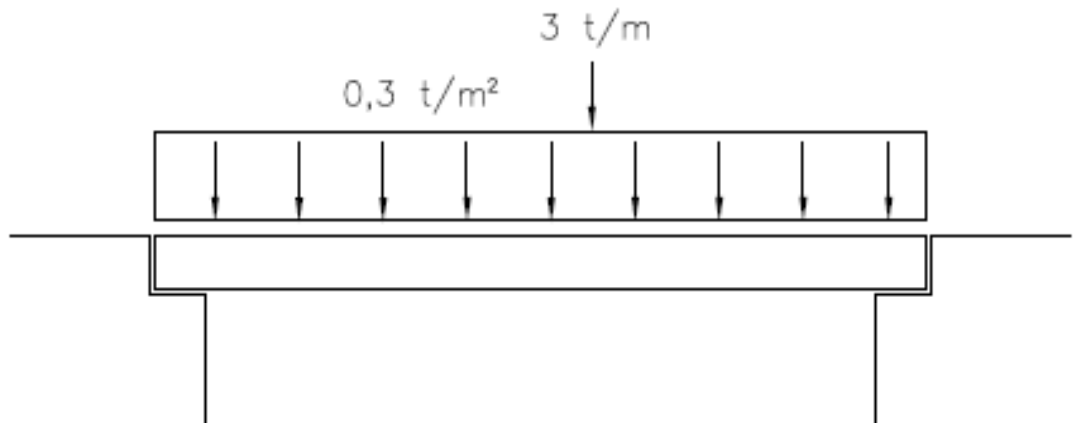


Figure 5.3: Uniform distributed load and axle loading (Old Portuguese Code)

This loading is not subjected to dynamic factors.

5.3.2 NEW PORTUGUESE CODE

Two separate load conditions are described in the Code. The least favourable load for any specific condition is used for design purposes.

a) Single vehicle load

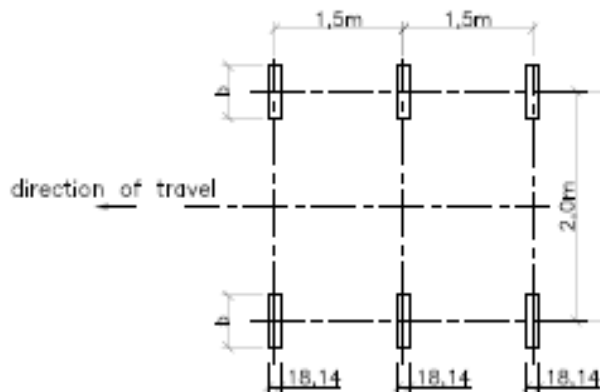


Figure 5.4: Single vehicle load (New Portuguese Code)

Class I Road: Axle load $Q = 20$ tonne

Class II Road: Axle load $Q = 10$ tonne

A dynamic factor of 1,2 is applicable to all axle loads

b) Uniformly distributed load and axle load

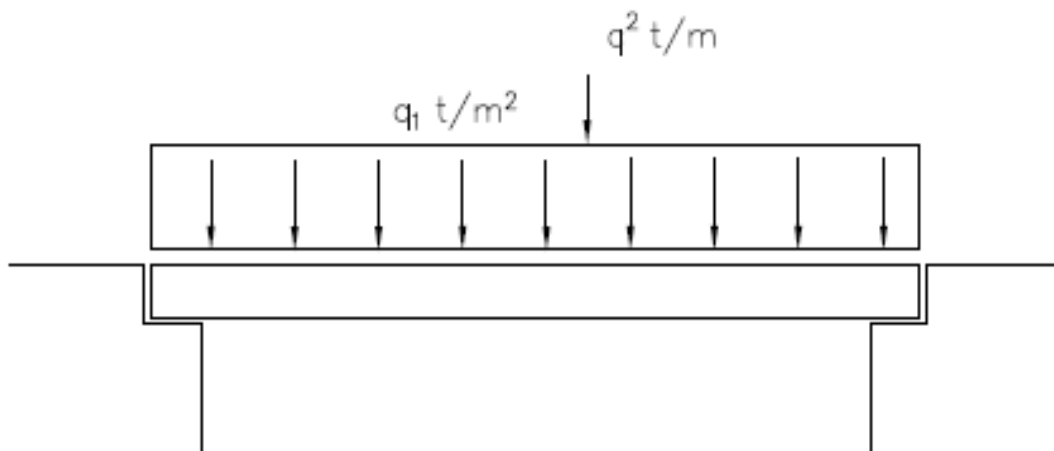


Figure 5.5: Uniform distributed load and axle loading (New Portuguese Code)

Class I Road: $q_1 = 0,4 \text{ tonne/m}^2$

Class II Road: $q_2 = 0,3 \text{ tonne/m}^2$

No dynamic factor is applied for this loading.

5.3.3 SATCC CODE OF PRACTICE FOR THE DESIGN OF HIGHWAY BRIDGES AND CULVERTS IN SOUTHERN AFRICA

The design live loads for primary roads are NA-loading, NB-loading and NC loading. For the purposes of this comparison exercise only NA and NB24 loading will be considered. A nominal deck width of 7m was assumed for comparative purposes (narrowest possible two-lane deck width).

a) NA loading as follows:

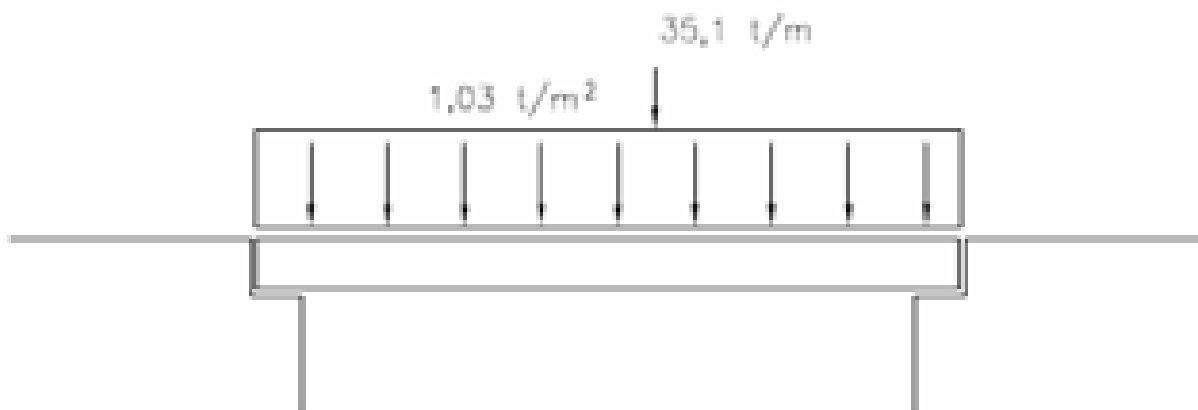


Figure 5.6: Uniform distributed load and axle loading (SATCC Code)

The intensity of the uniformly distributed load above is based on span lengths up to 12m. The load intensity reduces for longer span lengths.

b) NB loading

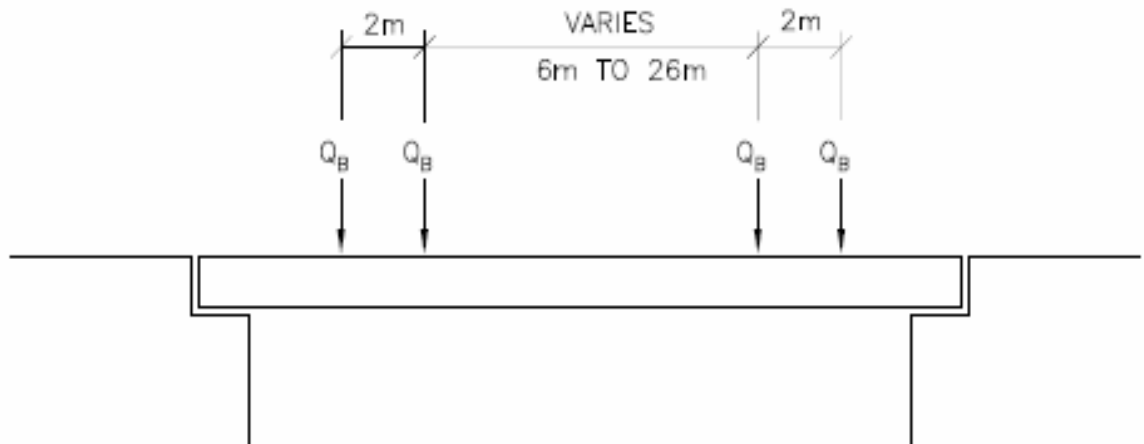


Figure 5.7: NB24 loading (SATCC Code)

$Q_b = 24$ ton per axle for NB 24 loading

5.4 DESIGN CODE COMPARISON

During a comparison of the design loadings of the three different Codes of Practice, it was easy to conclude by simple inspection that the old 1967 Portuguese Code specified the lightest design loadings. Since the majority of bridges on the Mozambique national road network were designed with the use of this particular Code of Practice, the two other design codes will be ignored during all subsequent analyses and comparisons with the effects of actual or future live load applications.

5.5 ANALYSIS OF ALLOWABLE AXLE LOADS

The design axle load for single vehicles on Class C roads in the old Portuguese Code is 10 tonnes, with a dynamic impact factor of 1,2.

In accordance with the findings obtained during the literature survey (“Looking to Load and Resistance Factor Rating”, B Jaramilla and S Huo, US Department of Transportation, Federal Highway Administration), the impact factor for short-span bridges is 1,3. Considering the 10 tonne working load specification in the old Portuguese Code, combined with a design impact load factor of 1,2, the safe axle load is therefore as follows:

$$A_L = 10\text{tonne} \times \frac{1,2}{1,3}$$

$$= 9,23\text{tonne}$$

From the above it can be concluded that the existing bridges in Mozambique have the theoretical capacity to accommodate individual 9 tonne axles, irrespective of deck width and length.

5.6 ANALYSIS OF ALLOWABLE GROSS VEHICLE MASS

Consideration is given to increase the allowable gross vehicle mass in Mozambique from 36 tonnes to 56 tonnes. In order to assess the maximum allowable gross vehicle mass (GVM) on bridges of various span lengths, the following design vehicle have been assumed. (GVM = 56 tonnes):

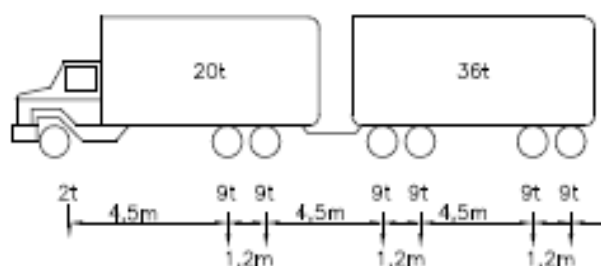


Figure 5.8: Design Heavy Vehicle

Referring to the failure mode types described in the literature, only bending moment failure was investigated and not shear failure or other secondary failure modes. The design bending moments were calculated by superimposing the above heavy vehicle on different span lengths and factoring all loads with a dynamic factor of 1,3.

Bending moment resistances have been calculated by assuming all bridges has been designed to sustain the loads as specified in the old Portuguese Code for Class C roads. The results are displayed in the table below:

Table 5.2: Comparison of applied bending moments by a design vehicle with a GVM of 56 tonnes and the resistance of existing bridges for 7m wide bridge deck

Deck span length	Applied Bending moment	Bending moment resistance	Safety margin
7m	334	486	45,6%
10m	509	763	52,5%
12,5m	791	1060	34,0%
15m	1225	1378	24,8%
17,5m	1604	1708	6,5%
20m	2053	2093	1,9%
22,5m	2608	2510	-3,8%
25m	2775	2934	5,7%

The negative value in bold font indicates a theoretical overstress percentage. For span lengths longer than 25m, no overstress was found.

The 7m deck formation assumed in the analysis is relatively narrow. The narrower the deck, the more will be the percentage overstress on the deck as applied by the vehicle. The table below illustrates the overstress on a 3,5m wide single-lane bridge deck.

Table 5.3 : Comparison of applied bending moments by a design vehicle with a GVM of 56 tonnes and the resistance of existing bridges for 3,5m wide single-lane bridge deck

Deck span length	Applied Bending moment	Bending moment resistance	Safety margin
7m	334	441	32,0%
10m	509	711	39,7%
12,5m	791	940	18,8%
15m	1225	1169	-4,5%
17,5m	1604	1386	-13,6%
20m	2053	1615	-21,3%
22,5m	2608	1845	-29,3%
25m	2775	2061	-25,7%

5.7 FATIGUE ANALYSIS

5.7.1 MEDIUM SPAN BRIDGES

Neglecting narrow-width single-lane bridges (not expected on important freight routes and other national routes), overstress was only encountered at bridge span lengths in the order of 22,5m during the previous static analysis. A fatigue analysis is performed for this span length to investigate the effect of increasing the allowable gross vehicle mass on bridges.

A typical deck cross-section for a 22,5m simply supported bridge deck is shown below. The span over depth ratio is 16.

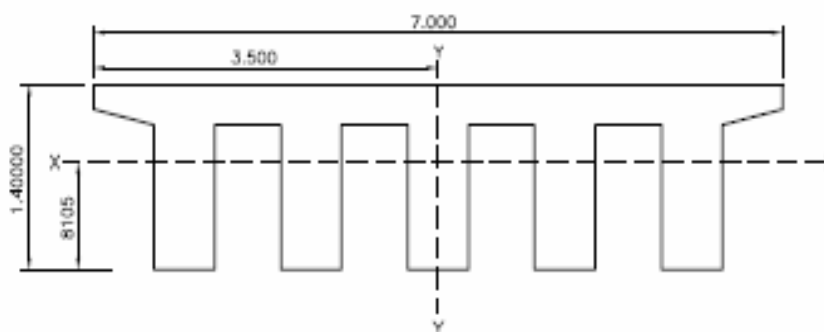


Figure 5.9: Typical deck cross section

From the reference "A model for evaluating the effect of vehicle overloading on bridge deterioration", the following equation is extracted:

$$\sigma_2 = 60\sigma_1 + 40$$

where σ_1 = minimum stress as a percentage of static strength

σ_2 = maximum allowable stress as a percentage of static strength at 10^6 cycles

The minimum stress refers to the stress associated with static self weight and imposed dead load. A simple frame analysis of the deck configuration shown above indicates a self weight and imposed dead load bending moment of 8 227 kN.m. This corresponds to a maximum bending moment fibre stress of 7,4 MPa.

Using classical elastic theory and assuming an average concrete compressive strength of 30 MPa, the bending moment stress capacity is 11 MPa (30 MPa / 2,73).

$$\begin{aligned}\sigma_2 \text{ allowable} &= 60 \frac{7,4 \text{ MPa}}{11,0 \text{ MPa}} + 40 \\ &= 80\% \text{ of static strength}\end{aligned}$$

Using the same frame analysis, the calculated bending moment due to a vehicle with a 36 tonne GVM is 1 739 kN.m (including impact), resulting in a total bending moment of 10 434 kN.m. The corresponding bending moment stress is 8,7 MPa which is **79% of static strength** and less than the calculated 80% of static strength calculated above. Therefore the hypothetical bridge deck considered in this example will theoretically attain 10^6 cycles of maximum allowable GVM loading of 36 tonnes.

Moving to a vehicle with a GVM of 56 tonnes, calculated live load bending moment is 2 608 kN.m, resulting in a total bending moment of 11 303 kN.m. The corresponding bending moment stress is 9,6 MPa which is **87% of static strength**. This is in excess of the calculated 80% of static strength calculated above, and therefore the hypothetical bridge deck considered in this example will **not attain** 10^6 cycles of maximum allowable GVM loading of 56 tonnes.

In theory, a bridge with a span length of 22,5m will experience a 10,1% reduction in fatigue service life if the legal GVM is increased from 36 tonnes to 56 tonnes.

5.7.2 SHORT-SPAN BRIDGES

Short-span bridges are more susceptible to fatigue failure, given the higher live load over total load ratio, compared to medium and long span bridges.

Below is a typical cross-section for a 7m-long simply supported deck span:

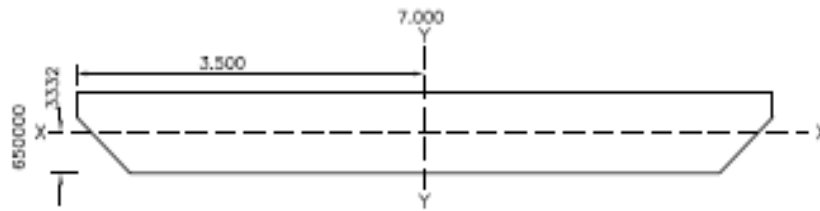


Figure 5.10: Typical deck cross section for 7m span

Dead load bending moment = 665 kN.m

Maximum associated fibre stress = 1,5 MPa

$$\begin{aligned}\sigma_2 \text{ allowable} &= 60 \frac{1,5 \text{ MPa}}{11,0 \text{ MPa}} + 40 \\ &= 48,2\% \text{ of static strength}\end{aligned}$$

The calculated bending moment due to a vehicle with a 56 tonne GVM is 334 kN.m (including impact), resulting in a total bending moment of 999 kN.m. The corresponding bending moment stress is 2,2 MPa which is **20% of static strength** and significantly less than the calculated allowable 48% of static strength calculated above.

It is clear that the increased susceptibility of short-span bridges to fatigue failure is comfortably offset by the fact that these bridge decks have large static factors of safety.

CHAPTER III: FIELD SURVEYS

The Terms of Reference (TOR)⁽¹⁾ for the Heavy Vehicle Overloading Control Study (HVOCS) required the Consultant to perform field surveys to gather data and information regarding:

- Heavy Vehicle Traffic
- Axle Loading
- Weighbridge Infrastructure
- Weighbridge Operations and Manpower

The traffic and axle loading surveys were required at two sites in each of the ten Mozambican provinces while the latter two surveys concentrated on the existing weighbridge sites as well as at a number of potential weighbridge sites indicated by the ANE representative accompanying the survey teams.

The traffic and axle loading surveys were carried out separately from the Weighbridge teams due to different schedule requirements. However the traffic and axle loading survey sites coincided with weighbridge locations as far as possible. This enables the traffic and axle loading information to be used to as input to the infrastructure strategic plans.

6. AXLE LOAD SURVEY

6.1 INTRODUCTION

The Axle Load Surveys were mainly required to assess the status quo of traffic loading in Mozambique. The main feature of the surveys was 12-hour weigh-in-motion (WIM) axle-load measurements in each direction of travel at each survey location. Apart from these, 7-day classified electronic traffic counts were also performed at all sites. A South African contractor, Traffic Engineering Services (TES), who specializes in electronic traffic monitoring, carried out all the surveys.

6.1.1 INFORMATION REQUIREMENTS

The information obtained from the Axle-Load Survey needs to provide a platform for competent decision-making and the design of the Overloading Control Strategy.

It was anticipated that pavement issues would play a crucial role in the decision process. This accentuated the need for the information on the ESAL (Equivalent Standard Axle Load) per heavy vehicle. Combined with the magnitude of heavy vehicle traffic this information could be expanded to cover the annual ESAL-loading of the roads, its impact on the pavement and its costs, and thus facilitate economic comparisons between blends of various strategy elements such as pavement and bridge reinforcement, changes in permissible load limits, and intensification of law enforcement.

Attention was also given to the possible re-use of the gathered information.

Without increasing its cost, the survey was designed not only to achieve the above but also to produce additional information such as:

- Detailed classification of all vehicles on the road during daylight hours.
- The percentage of interstate travel (to gauge the merits of various existing and new border-post weighbridges).
- Typical tyre pressures (to refine the pavement calculations using mechanistic methods such as Elsym5).
- Dual wheel distances.
- Axle spacing.
- The position of kingpin(s) to estimate the impact of changed payload on axle-loading.
- Other relevant data.

This additional information was then used to enhance the traffic-loading picture, check the obtained data, resolve data conflicts and eliminate errors, and create a reserve of information that might be drawn upon later in the study.

6.1.2 SURVEY OBJECTIVES

The objectives of the surveys were formulated in accordance with the information requirements. The surveys were aimed at obtaining adequate data on the following:

1. Magnitude and composition of traffic.
2. Traffic flows and peaks.
3. Day/night time split.
4. Percentage of interstate trips.
5. Distribution of axle loads.
6. Extent and severity of overloading.
7. Traffic loading of pavement in terms of equivalent standard axle loads (ESAL).
8. Types and categories of heavy vehicles.

The 7-day continuous traffic counts were used to estimate items 1, 2 and 3, whereas the 12-hour truck-weighing exercises were used to estimate items 4 to 8.

6.1.3 LOCATION OF SITES

Prior to the survey, twenty survey locations (two per province) were selected on busy primary roads, in the proximity of existing weighbridges, where possible.

For practical reasons two additional sites were added during the survey: one on the EN6 west of Inchope in the Manica Province and the other on the N304 north of the EN7 junction in the Tete Province (ANE requested the coverage of this site after the survey had started).

The axle-load surveys were conducted at all 22 sites. However, the 7-day electronic counts were carried out on 19 sites only. The three missing ones are sites G.1 and G.2 in the Niassa Province (where there was no black-top surface required for the

placement of inductive loops), and site J.2 in the Cabo Delgado Province (where the TEL 2CM equipment miss-performed and, due to logistical constraints, the electronic count could not be repeated).

The positions of the sites, their abbreviated designations and the type of survey conducted are shown in Table 6-1.

Table 6.1: Survey Locations

Province	Description	Axle-Load Surveys	Electronic Counts
A: Maputo	A.1) on EN4 east of Moamba Tollgate	Yes	Yes
	A.2) on EN2 east of Boane Weighbridge	Yes	Yes
B: Gaza	B.1) on EN1 east of Macia	Yes	Yes
	B.2) on EN1 west of Macia	Yes	Yes
C: Inhambane	C.1) on EN5 south of Inhambane	Yes	Yes
	C.2) on EN1 north of Maxixe	Yes	Yes
D: Sofala	D.1) on EN6 west of Dondo	Yes	Yes
	D.2) on EN1 north of Inchope	Yes	Yes
E: Manica	E.1) on EN6 east of Machipanda	Yes	Yes
	E.2) on EN7 south of Vanduzi	Yes	Yes
	E.3) on EN6 west of Inchope	Yes	Yes
F: Tete	F.1) on EN8 west of Luenha	Yes	Yes
	F.2) on EN9 north of Tete	Yes	Yes
	F.3) on N304 north of EN7 junction	Yes	Yes
G: Niassa	G.1) on EN13 north of Mandimba	Yes	No
	G.2) on EN13 east of Mandimba	Yes	No
H: Zambezia	H.1) on EN10 south of Nicoadala	Yes	Yes
	H.2) on EN1 south of Macuba	Yes	Yes
I: Nampula	I.1) on EN1 east of Nampula	Yes	Yes
	I.2) on EN12 north of Monapo	Yes	Yes
J: Cabo Delgado	J.1) on EN1 south of Pemba	Yes	Yes
	J.2) on EN1 south of Metoro	Yes	No

The positions of the survey locations are shown on the Map of Mozambique attached in **Appendix 1**.

6.1.4 AXLE-WEIGHING

Axle-weighing was planned at each site for a period of 12 daylight-hours during hours, from 06:00 to 18:00. All weighing was done on normal week days.

Weigh-In-Motion scales - Vehicle Load Monitors (VLM) - were used for the axle load survey. The scales used are manufactured by the South African company, Irengo, and are approved by the South African Bureau of Standards.

Six VLM scales were used for the execution of the axle-load surveys. The sensors were checked and calibrated prior to the onset of the surveys to ensure the quality of weighing. After the survey has been completed all scales were returned to the manufacturer for inspection, to verify that they were still in good working condition. It was found that one of the scales suffered damage during the surveys and was therefore replaced. Six VLM scales, with the certification by the manufacturer that they

are in good order and properly calibrated, will therefore be supplied to ANE in accordance with the Terms of Reference.

6.1.5 CLASSIFICATION OF HEAVY VEHICLES

The detailed classification of weighed vehicles was necessary to provide loading statistics per various vehicle classes.

The approach to grouping was motivated by possible re-use of the ESAL/Heavy Vehicle indicators established in this study in combination with future or different heavy vehicle counts. The grouping – heavy-vehicle classification – was then determined by the format in which heavy-vehicle counts may be available.

All vehicles weighed during the axle-load surveys were classified according to the descriptive heavy-vehicle classification scheme fully described in the Axle Load Survey Report. The database containing the descriptive classification has been compiled, and is available for future use.

6.1.6 ELECTRONIC COUNTS

The 7-day electronic counts were done using electromagnetic inductive loops with the TEL 2CM machines manufactured by Mikros Systems in Pretoria, South Africa. The TEL 2CM machines are standard equipment used routinely on numerous Comprehensive Traffic Observation (CTO) stations all over South Africa. The inductive loops were of the stick-on type. These were affixed onto the road black-top using bitumen tape, and are commonly used for temporary electronic counting stations. The electronic counts could not be done on site G.1 and G.2 in the Niassa Province, because the road was not surfaced.

6.1.7 SURVEY SCHEDULE

All surveys were carried out in the period from 22 July 2005 to 28 August 2005.

6.2 SURVEY RESULTS

6.2.1 EXTENT OF TRAFFIC

The electronic counts provided a full 7-day record of traffic flows that are assumed to be representative of annual traffic characteristics. The extent of traffic at each of the survey locations is summarized below:

Table 6.2: Overview of 7-day Electronic Count Results (from Axle Load Report)

Province	Site	Road	File	TES No	Located Near	ADT	%HV	% Big HV	% HV night	HV Speed (km/h)
Maputo	A.1	EN4	MAe	880	Moamba	1854	16%	51%	25%	76
	A.2	EN2	MAw	881	Boane	6156	18%	13%	19%	46
Gaza	B.1	EN1	GAe	883	Macia East	1736	25%	39%	24%	81
	B.2	EN1	GAw	882	Macia West	1997	29%	38%	31%	75
Inhambane	C.1	EN5	INe	884	Inhambane	423	24%	11%	18%	65
	C.2	EN1	INw	885	Maxixe	665	24%	49%	29%	50
Sofala	D.1	EN6	SOe	886	Dondo	1495	34%	60%	30%	73
	D.2	EN1	SOw	879	Inchope North	268	32%	45%	45%	72
Manica	E.1	EN6	MNw	888	Machipanda	627	15%	49%	21%	68
	E.2	EN7	MNe	889	Vanduzi	555	35%	73%	32%	72
	E.3	EN6	MNthird	887	Inchope West	892	38%	70%	39%	69
Tete	F.1	EN8	TEw	890	Luenha	195	49%	81%	24%	71
	F.2	EN9	TEe	891	Tete	224	16%	30%	29%	53
	F.3	N304	TEthird	878	EN7 junction	286	32%	39%	32%	62
Niassa	G.1*	EN13	NIw	893	Mandimba North	138	44%			
	G.2*	EN13	NIe	892	Mandimba East	92	23%			
Zambezia	H.1	EN10	ZAw	894	Nicoadala	835	26%	13%	26%	65
	H.2	EN12	ZAe	895	Macuba	313	32%	33%	21%	58
Nampula	I.1	EN1	NAw	896	Nampula	692	23%	34%	31%	74
	I.2	EN12	NAe	897	Monapo	615	26%	36%	31%	75
Cabo Delgado	J.1	EN1	CDe	899	Pemba	1271	31%	14%	22%	65
	J.2*	EN1	CDw	898	Metoro	216	47%			
All **	-	-	-	-	-	1110	25%	36%	26%	66

From the above it is concluded that:

- Even on the major road network, traffic flows in Mozambique are generally low with ADTs below 1 000 veh/day.
- The average percentage of heavy vehicles is about 25 %.
- Approximately 36 % of heavy vehicles may be classified as big heavy vehicles with a total length greater than 12 m.
- Approximately 74 % of traffic occurs between 06:00 and 18:00, i.e. during daytime.

The distributions of light and heavy vehicle traffic flows by day of week and by the hour of the day are given in the Axle Load Survey Report.

6.2.2 EXTENT OF LOADING

The extent of loading at each survey site was evaluated as follows:

- The percentages of interstate travelers, overloaded heavy vehicles (without and with grace), overloading excess above legal limit, overall ESAL/HV and ESAL/day.
- The ESAL/HV in different heavy vehicle classes.
- The load distribution of all weighed axles.

The general overview of the axle-load survey results, for all heavy vehicles at each survey location, is given in Table 6-2. From the results it was concluded that:

- The occurrence of overloading in Mozambique is high – approximately 35 % of all heavy vehicles on major roads are overloaded, and 30 % are overloaded above grace.
- The extent of overloading is severe – vehicles that are overloaded above grace, i.e. those that should be prosecuted, are typically overloaded by 34 %.
- Axle loads of 10 t were observed frequently and axles over 15 t sporadically, in spite of the legal limit being 8 t (or 9 t on EN4).
- The level of law enforcement is poor – the percentage heavy vehicles overloaded above grace is almost as high as for all overloaded heavy vehicles (i.e. without grace), which implies that law enforcement is not considered when trucks are loaded.
- The current extent of heavy vehicle loading poses a major threat to the Mozambican road network, and urgent intervention is necessary to maintain the road infrastructure in a serviceable condition.

As mentioned in earlier sections, loading information is required for different classes of vehicles in order to estimate the total loading on similar road sections but with a different distribution of heavy vehicle classes. The loading information gathered during the surveys was thus presented for the following heavy vehicle categories:

- All heavy vehicles combined.
- Short, medium and long heavy vehicles, as from electronic loop counts.
- Total axles per heavy vehicle, from 2 axles to 7 axles.
- Toll classes 2, 3 and 4, as used by TRAC on EN4.
- Descriptive classification (most frequent vehicles only).

The ESAL/HV for different heavy vehicle classes is summarized in Table 4-3 of the Axle-load survey report.

The axle load distributions for all survey locations are shown in Appendix H of the Axle-load survey report.

The tyre pressures and wheel widths were recorded as extra information during the axle-load survey, since this information is valuable to pavement engineers. The tyre pressures of the steering axles were measured when possible. The tyre pressures of

other wheels could not be measured due to the positioning of valves. The results are summarized as follows:

- The average front axle tyre pressure was 698 kPa, with a standard deviation of 190 kPa.
- The average single wheel width was 232 mm (standard deviation 48 mm).
- The average dual wheel width (i.e. including both tyres and the space in between) was 537 mm, with a standard deviation of 87 mm.

7. WEIGHBRIDGE INFRASTRUCTURE AND OPERATIONS SURVEY

7.1 INTRODUCTION

7.1.1 Background

The National Road Administration of Mozambique (ANE) is responsible for the maintenance and rehabilitation of main roads of Mozambique. This responsibility includes the protection of their existing roads and bridges network against the excessive damage caused by overloading of heavy vehicles.

The ANE currently has 11 existing weighbridges, of which approximately seven are in use. Two of the above 11 are not functional but are currently being repaired. An additional three new weighbridges are under construction and another five are proposed. These weighbridges are spread over the entire country except for the Niassa province which has no existing or proposed weighbridge.

Currently overloading control law enforcement operations are carried out by ANE staff. Staff have a variety of capabilities but somewhat limited and not always the necessary authority enabling them to carry out their tasks.

7.1.2 Survey Objectives

The principal objective of this study is to enable ANE to optimize the life of its road network and to assist the Government of Mozambique through the ANE and INAV to prepare, implement and manage an appropriate Overloading Control Management System on the main road network of Mozambique.

The study requires the consultant to survey, record and assess the current and proposed overload control infrastructure with the aim of recommending improvements to the deployment of infrastructure, systems and equipment. The main objective of the Infrastructure Survey was therefore to gather as much information as possible from visiting and inspecting the various existing weighbridge sites around the country. Sites visited included potential future sites indicated to the team by the ANE representative accompanying the survey team.

From an operational point of view, the project requires a study of current practise of enforcement and operations at the existing weighbridges as well as the level of staff provision and also assesses the managerial, legal and maintenance competence of staff. The main objective of the Operations Survey was therefore to gather as much information as possible from observing overload control operations on site and through interviews with the respective weighbridge officers and provincial officials.

7.2 SURVEY LOGISTICS AND SCHEDULE

7.2.1 Schedule

The survey was carried out during a three week period between 19 July and 8 August 2005. Three survey teams were deployed, each consisting of:

- ANE Delegate
- Infrastructure Specialist (Team Leader)
- Operations and Training Specialist
- Driver / Interpreter

The survey was divided into three regions namely Southern, Central and Northern and approximately 6000km was covered by road covering most of the main routes and ten of the country's 11 provinces as shown in Figure 7.1

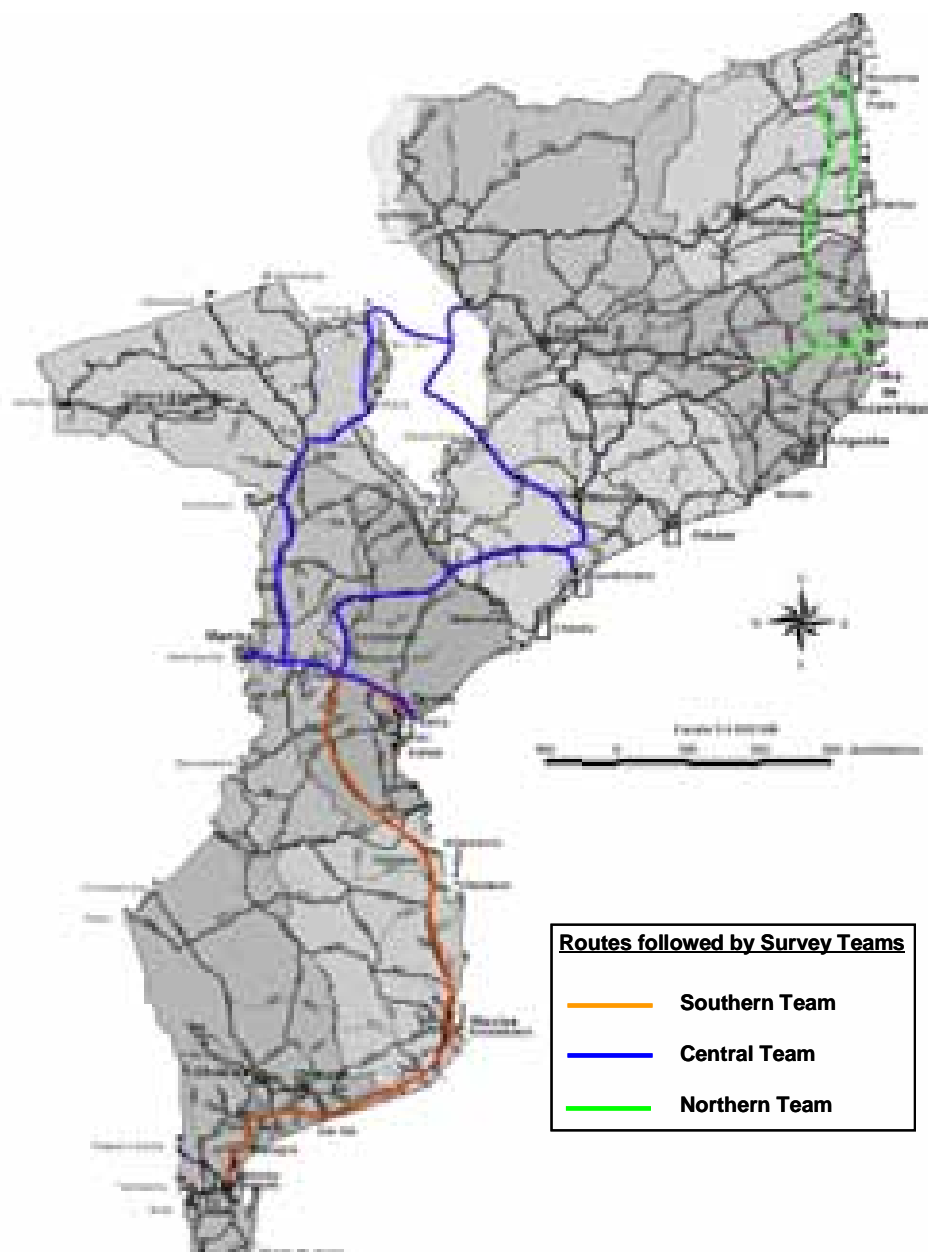


Figure 7.1: Map of Mozambique showing the routes followed by survey teams

7.2.2 Survey Procedure

The survey procedures entailed a pre arranged visit to an existing or proposed weighbridge site including interviews with the officials running the weighbridge facility or the persons responsible for traffic law enforcement in the area of a proposed site. This was usually followed by a meeting with the provincial officials who were located in the main provincial centres.

All information gathered whether through interviews or via observation and inspection was recorded on interview sheets and in the form of digital photographs. A GPS co-ordinate of each site was also taken to allow future plotting of the sites on a GIS Map.

Refer to Annexure IV for an example of the typical questionnaire used to record data.

Interpreters and the ANE representative who accompanied the teams were invaluable for effective communication with locals.

Routes and alternative routes were inspected *en-route* and potential weighbridge sites were discussed with the ANE official on site.

7.2.3 Information Requirements

These surveys deal with a wide variety of elements all related to overload control and weighbridges in particular. All available information regarding the existing and planned (proposed) weighbridges was collected. The following information was gathered from the respective sites and routes travelled:

- Alternative routes,
- Road conditions, such as geometry and pavement composition and strengths (visual impressions only),
- Major river crossings and bridge loading restrictions on the route
- Major river crossings and bridge loading restrictions on the route
- Existing weighbridges infrastructure,
- Proposed weighbridges sites,
- Overload control equipment in use and being proposed,
- Other services such as electricity, potable water, housing,
- Inventory and condition of equipment,
- Impressions of maintainability of equipment,
- Availability of spare parts,
- Overload control operational aspects in use at the weighbridges, which included:
 - Personnel numbers and designations,
 - Personnel presentation in terms of uniforms,
 - Traffic regulation procedures and equipment,
 - Load monitoring procedures,
 - Procedures for detainment, off-loading and storage of overloads,
 - The weighing and/or handling procedures of dangerous goods, livestock, liquids and passengers,
 - Record keeping procedures,
 - Data analysis and reporting formats,

- WIM load monitoring and data collection procedures.

Information was also requested from officials such as:

- General traffic information regarding the route
- Traffic numbers using feasible alternative routes to escape detection
- Heavy vehicle traffic numbers and daily and seasonal patterns
- Actual engineering information regarding road conditions, geometry and pavement composition and strengths
- Technical details of overload control equipment in use,
- Communication channels and equipment being used
- Costs and reliability of other services such as electricity and potable water
- Availability of dedicated housing
- Technical evidence of the condition of equipment
- Maintenance records such as record of assizing of scales
- Availability of spare parts
- Maintenance cost
- Operational cost
- Qualifications and training records of the personnel

It must be noted that although the information requirements listed above is comprehensive, the actual information received through interviews was very limited and of limited use. On the contrary, the site inspections and visual inspections provided the team with sufficient information to define the current state of overload control infrastructure, operations and maintenance.

7.3 SURVEY RESULTS

Due to space constraints it is not practical to include the Infrastructure and Operations & Manpower survey results in the body of this report. The results are therefore included as Appendixes V and VI. Below follows a concise summary of the findings.

7.3.1 GENERAL LOCATION, CONDITION AND STATUS

There are 13 existing weighbridges in the 10 provinces, five of which are merely weighbridge sites with no equipment or broken equipment. Eight more weighbridge sites were identified and evaluated. Only eight weighbridges are equipped and could be operated although to different levels of efficiency.

7.3.1.1 Site Location:

Existing weighbridges:

Most of the existing weighbridges are located at average to good locations. Especially weighbridges such as **Tete** and **Save**, which are located at the river crossings preventing heavy vehicle operators to bypass the facilities using alternative routes. Some other facilities such as the **Inharrime** weighbridge currently under construction are also located at a critical river crossing.

The **Dondo** and **Macia** sites as well as some other sites in the Northern Provinces have potential escape routes but alternative routes are mostly very poor to non-existent especially in the wet season.

The **Boane** and **Matolo** sites are at good locations considering the abundance of roads in the areas.

The two **Pemba** sites are on the same road a few hundred metres apart. The older site, equipped with an old mechanical scale is evidently not in use anymore.

Proposed weighbridges:

The proposed sites inspected were varying in quality.

- The **Caia south** site is excellent due to the topography being acceptable and the site being at the critical Zambezi river crossing.
- The **Caia north** on the other hand is considered not feasible due to difficult topography.
- The **Michafutene** site is acceptable but not ideal due to the high level of traffic and commercial activity in the area.
- The **Lindela** site was rejected and replaced by the Inharrime site currently under construction.
- At Rio **Save** a proposed site **north** of the river was abandoned as it was considered not to be justifiable with the current Save site at the southern side of the bridge being functional.
- The Rio **Buzi** site was selected just north of the Buzi river and promises to be excellent from a strategic point of view. The site is in the town of Buzi just after the bridge and due to a lack of alternative river crossings for a long distance up- or downstream from this site, it would be difficult to avoid.
- The proposed **Machipanda** weighbridge at the Border post is located at the Mozambique / Zimbabwe border and is considered essential as the N6 corridor (Beira Corridor) is one of the busiest and fastest growing of the routes in the country. Many vehicles using the N6 travel between Zimbabwe and the Beira port.
- The **Changara** site is located north of the N7 / N8 junction on the road to Tete. It is considered to be excellent as it is on the route between Tete and Beira as well as on the route between Zimbabwe and Malawi through Tete. Some local and international traffic will be intercepted at this site. The site already has a surfaced entrance but no further facilities.
- The **Namialo** site is located at a strategic junction between the two prominent routes in the area namely the N1 and N12. The site is also between Nacala and Nampula and is bound to intercept important freight traffic. The site is however in the centre of the little village which would make security and traffic control difficult.
- The site at Mocimboa da Praia is also located at a junction between the two most prominent routes in the area. There is no significant town in the area and the site is more than 40km from Mocimboa da Praia. It would thus be logistically difficult to operate and maintain this facility.

Table 7.1: Existing and Proposed Weighbridges per Province

Province	Weighbridge	Route	Type / condition
Maputo	Boane	N8	New / reasonable condition
	Matola	N4	New / good condition
	Michafutene	N1	Demolished / new to be built
Gaza	Macia	N1	Existing / poor condition
Inhambane	Inharrime	N1	New under construction
	Lindela	N1	Proposed / replaced by Inharrime
	Save (South)	N1	Existing / poor site reasonable equipment
Sofala	Rio Buzi	N1	Proposed / good site
	Dondo	N6	Existing / reasonable old type
	Inchope	N1	Existing / new in good condition
	Caia (South)	N1	Proposed / good site
Manica	Vanduzi	N7	Existing / reasonable
	Machipanda	N6	Proposed at Border Post
Tete	Changara	N7	Proposed / good site location
	Tete	N7	Existing / poor condition
Zambezia	Caia (North)	N1	Proposed / poor site - to be rejected
	Nicoadala	N1	Existing / poor
Nampula	Nacala	N8	Existing / not functional
	Namialo	N1/N12	Proposed / strategically good, built-up area
	Nampula	N1	Existing / not functional
Cabo Delgado	Pemba (New)	N1	Existing / reasonable
	Pemba (Old)	N1	Existing / poor – replaced by Pemba new
	Metoro	N1	Existing / to be upgraded
	Mocimboa-da Praia	N380 / R698	Proposed / good strategic site

The shaded rows indicate proposed weighbridge sites inspected during the survey. There are no existing or proposed weighbridge facilities in Niassa Province.

From the study a number of other proposed weighbridge sites were identified, namely:

- On the N101 north of Macia on the way to Massingir due to the large amount of industrial freight traffic being generated in this corridor;
- On the N304 / N7 junction in Tete province, due to the recent upgrading of the N304 and the large amount of agricultural traffic using this route;
- At the Milange border post between Mozambique and Malawi, to be constructed when the N11 between Namacurra and Milange is upgraded;
- At the junction of the N1 and N103 (to Gurue) north of Mocuba in Zambezia province, to be constructed when the N1 between Namacurra and Nampula is upgraded;
- East of Nampula at the junction between the N1 and N13, to be constructed when the N13 to Cuamba is constructed; and
- Two weighbridges between Lichinga and Montopuez when the N14 is upgraded, the weighbridges to be close to Lichinga and close to Montopuez respectively.

- At the Cassacatiza border post between Mozambique and Zambia in Tete province.
- At the Colomue border post between Mozambique and Malawi in tete province
-

The general condition of most weighbridges can be described as reasonable to poor. For detailed information on the weighbridges refer to Appendix VI.

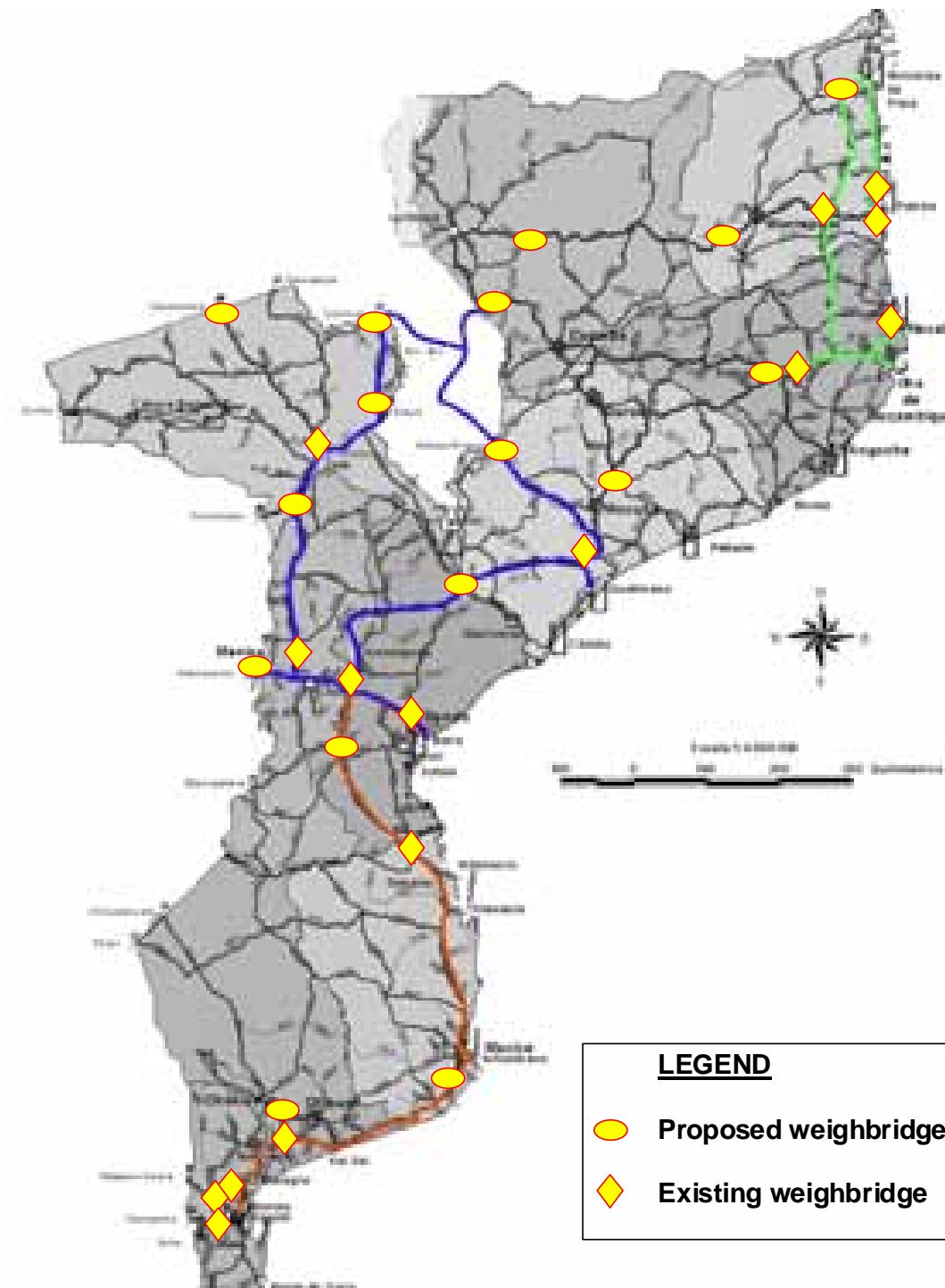


Figure 7.2: Map of Mozambique showing positions of existing and proposed weighbridge sites

7.3.1.2 General layout

Most of the older existing weighbridges were constructed to a similar design in terms of layout and buildings as indicated in Figure 7.3.

These weighbridges are typically combined with a traffic police checkpoint which has its own building. Such weighbridges are equipped with old type single deck mechanical scales, with 40 tonne capacity. No dedicated parking facilities are allowed to detain overloaded vehicles. Vehicles approach these single deck scales from both directions.

The approaches to these scales are mostly in a poor state of repair with potholes and ruts evident. This results in inaccurate weighing due to the fact that scales are in the order of 10m long and partial weighing is practised. Due to the scale deck configuration, the weighing of axle groups is difficult and would be inaccurate due to the unevenness of the scale approaches. In some instances such as Rio Save, the approach to the scale is not level making accurate weighing of an axle group impossible. At the busier weighbridges such as at Tete, a single deck scale is inadequate as the throughput capacity of such a scale too low for the demand. Queues of trucks wait to be weighed daily resulting in bribery of officials to avoid being weighed and thus held up.

The newer weighbridges, namely the Matolo, Boane, Inchope, Pemba and Metoro weighbridges have different layouts designed to suit the particular conditions of the traffic and the site. At the Matolo and Inchope weighbridges parking facilities are provided but unfortunately not used as intended.

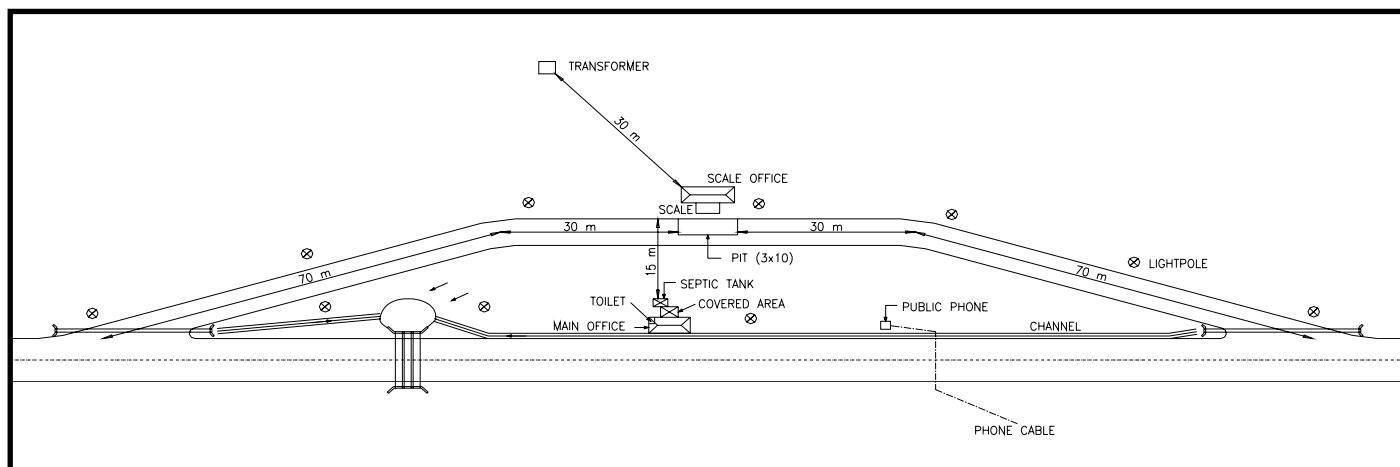


Figure 7.3: Typical Layout of “old type” existing weighbridges

7.3.1.3 Services

Except for the new facilities, most weighbridges have marginal and inadequate services such as electricity or potable water supply and sewer systems. Some of the old facilities had been provided with electrical power and water but due to lack of maintenance and vandalism, almost nothing is left of the services. See pictures in Appendix VI.

The buildings of these old facilities therefore have very little to no lighting. Scale rooms mostly have no electric lighting and some have such poor natural lighting that the scale readings are difficult to see in broad daylight.

The Save weighbridge has no scale building. The scale equipment is protected by a metal enclosure.

Weighbridge officers have no dedicated housing and some have to travel some distance to the weighbridge.

Almost all weighbridges have no communications equipment; however, the traffic officials manning the traffic control point sometimes have radio or telephone equipment. This is however very rare and were only evident nearer the main centres.

Appendix VI contains the tabulated results of the general assessment of each weighbridge site together with some selected photographs of each site.

7.3.2 EQUIPMENT

Appendix VI contains the tabulated results of the equipment assessment. Equipment assessment focussed mainly on the weighbridges, area lighting, electricity supply to the site and building electricity supply and reticulation.

There are no mobile screening scales or traffic monitoring equipment in use at any of the weighbridges. Two sets of VLMs (mobile axle load scales) are provided under the contract and are discussed in the Axle Load Report.

Scales:

- Pemba and Metoro have new electronic scales but are not being used due to a lack of buildings (as reported by the local officers)
- Inchope has a new electronic / mechanical scale that has not been used due to lack of electrical supply – this has since been provided
- Boane and Matola have new electronic scales and are being used effectively
- All other scales are similar mechanical scales of 40ton capacity

Lighting:

Due to the fact that electricity supply is a general problem especially in the Northern provinces and further away from the main centres, there is no proper area lighting provided. Some facilities have minimal street lighting on the approaches to the scale. Lighting is however not suitable to night time operations and it is considered a security risk.

Electricity Supply:

Electricity supply is mostly from local towns with some of the towns reliant on generators to generate the power. Power cuts occur frequently. The electrical reticulation and fittings in buildings are poorly maintained and dangerous. Light fittings and sockets have mostly been removed. Generally the building electricity reticulation should be redone entirely.

7.3.3 OPERATIONS

According to the observations made by the survey team approximately 20% of existing facilities are operating reasonably well. This does not mean that the facilities are being operated to their potential or capacity. On the contrary, most if not all observations observed appear to be very basic and without clear procedures. To explain this statement the following explanation is offered:

Weighbridge operation at the average weighbridge is conducted by one or maybe more than one individual (weighbridge operator) employed by ANE. This weighbridge officer largely if not entirely relies on the traffic police at the adjacent traffic control point to stop heavy vehicles and to direct them to the scale. Selection of heavy vehicles is therefore completely arbitrary and manual, which inevitably leads to biased selection and potential targeting of certain truck operators. It was mentioned to the survey team that foreign truck drivers had to pay a fine before proceeding on their journey, while local truck drivers had seven days to pay the fine at any magistrate's office. These spot fines paid on the spot is collected by either the traffic police or the weighbridge operator. Very limited information of the offence is recorded and evidence of such records could only be found at the Save weighbridge. If a truck is selected to be weighed, the truck parks partially on the scale (because the scale is too small to carry the whole truck at once) and the weight measurement is approximately taken visually. No paper record of any sort is produced. The truck is then moved to weigh the remainder of the axles, again only approximate measurements are taken and no record is kept. The driver is then verbally informed that his vehicle is overloaded and that a 5 million MZM fine is payable. No official notice or summons is issued to the driver and if particulars of the vehicle are recorded (as mentioned such records were found at only one place) the records will only include the registration number and the approximate gross vehicle mass recorded and the fine paid against the date of the offence. No particulars of the driver, drivers licence, vehicle license, capacity of the vehicle or trailer, vehicle configuration, axle or axle group mass, allowable masses etc is recorded. No paper evidence could be found what happened to the fines collected on site. At Beira some records were viewed at the provincial headquarters of traffic and weighbridge operations. Records were very basic and information full of gaps and therefore of limited to no use at all.

The following summary view is given of operations in general:

- Maintenance is questionable if judged by the appearance of the equipment and the facilities.
- The records that could be found indicate that most scales had been assized so long ago to reasonably doubt the accuracy of scales ;
- There is a general lack of manpower, it was observed that some weighbridges only operated a few hours per day and other that operated on 24hr shifts, had only two weighbridge operator each working a 24 hour shift. The weighbridge operators rarely stopped any heavy vehicle at night and slept at the facility. Should one of the officers fall ill or go on leave operations is suspended for the particular person's shift. In other words there is a lack of depth in available manpower.
- Weighbridge operators and mostly also the traffic police did not have their own transport and had to make use of public transport to get to work.

- The capacity and ability of weighbridge operators is doubtful and it was observed that some officials could not add or subtracts accurately to determine a vehicles total weight. According to officials at the provincial headquarters the only training weighbridge officers receive is how to operate the scale. Apparently no or very little is known of the legislation and its application.
- Weighbridge operators are also tasked to maintain their equipment but do not have the necessary technical skills to effectively do this. They are however supported by a Maputo based company that can do limited repairs to the scales. The day to day maintenance such as cleanliness of the scale pit and deck as well as prevention against rust is not done at all.
- In general it could thus be conclude that there is a lack of or total absence of operational and managerial training.
- There is a lack of consistent measurable operational procedures (operational system)
- It appears that there is a lack of management / supervision (capacity and motivation)
- There is a lack of accountability (no formal traceable management) and a lack of reporting evidenced by no paper trails;
- A flat fee of MMC 5 million is levied for any overloading, which implies that no distinction is made in the fine structure between the severity of the overloading offence. (no sliding scale for lesser or worse offences)
- No consistently used dedicated destination for fine income – some information indicate that the fines go to the local police station or magistrates office while other information state that it is sent to the provincial headquarters
- There is a split responsibility between authorities on site namely the ANE and the Traffic Police;
- There is no road signage compelling heavy vehicle to proceed to weighbridge – in other words if a heavy vehicle is not manually called into the weighbridge by a traffic officer it would just carry on past the facility.
- As indicated above there is evidence of discrimination against foreign vehicles;
- A very serious shortcoming of the operational procedure is the fact that no detaining of overloaded vehicles to rectify loads is enforced. This results in damage to the road pavement not being prevented by the overload control operations at all.
- Bribery and corruption reportedly rife, mostly due to the disparity between the salary of the weighbridge officer and the fine structure and coupled to this a total lack of control and auditable systems. There is for example no independent system that can give an indication of the number of heavy vehicles travelling past a weighbridge and even less so any indication what percentage of these vehicles would be overloaded and how many was weighed and fined.

The operations at the Matola and Boane facilities have not yet been assessed and are expected to be better especially as the N4 concessionaire; TRAC is involved with these operations.

The above paints a very negative picture but in defence of our conclusions the actual axle load measurements recorded during the Axle Load Survey corroborate these observations and confirm that the overload control operations have little to no effect on overloading at all.

CHAPTER IV ANALYSIS

8. ANALYSIS OF TRAFFIC LOADING AND ITS INFLUENCE ON PAVEMENTS

8.1 INTRODUCTION

As part of the objectives of the Heavy Vehicle Overloading Control Study this section focus on the characterization of heavy vehicle loading in Mozambique and the influence that it would have on countries road pavement infrastructure.

The data obtained from a series of traffic counts and axle load surveys (the Axle-Load Survey) are discussed and then analysed in terms of its effects on pavement life and road deterioration. The influence of a change in the legal load limit as well as the implementation of an overloading control system is discussed in terms of its effects on the local pavement infrastructure.

8.2 TRAFFIC AND AXLE LOAD SURVEYS

During the months of August and September 2005 an axle load survey was executed in various regions of Mozambique and included two survey sites in each of the ten provinces. At each site a 7-day classified electronic traffic count was performed followed by a 12-hour weigh-in-motion (WIM) axle-load measurement. The location of the sites covers all the main hauling routes traversing the country. These include:

- The EN4 corridor between South Africa and Mozambique,
- The EN2 corridor between Swaziland and Mozambique,
- The EN1 connecting the North and the South of the Country,
- The EN6 Beira corridor linking Zimbabwe with the port of Beira,
- The EN7 link between Beira and Malawi including the EN9 link to Zambia,
- The EN13 and EN14 links that covers the interior of the Northern part of Mozambique and connects the harbour of Pemba and Nacala to Malawi.

8.3 AXLE LOAD MEASUREMENTS

Table 8.1 summarizes the traffic volumes and weighing statistics for all the sites surveyed. The traffic flows measured are generally low with Average Daily Traffic (ADT) below 1000 vehicles per day for most of the sites. The average percentage of heavy vehicles is about 25%. Most of the traffic flows during daytime hours with 74% of ADT's being measured between 06:00 and 18:00. Roughly a third (36%) of the heavy vehicles is big trucks with a length in excess of 12m.

Table 8.1: Summarized Traffic and Weighing Statistics

Province	Site	7 day count data		WIM data			
		ADT	%HV	HV weighed	% Overloaded	Tons/HV	E80/HV
Maputo	Moamba	1854	16	113	33	29.7	3.5
	Boane	6156	18	140	29	17.1	2.0
Gaza	Macia East	1736	25	146	45	21.9	3.6
	Macia West	1997	29	155	47	21.8	5.6
Inhambane	Inhambane	423	24	14	0	6.4	0.2
	Maxixe	665	24	49	43	27.2	5.2
Sofala	Dondo	1495	34	98	55	31.0	6.5
	Inchope North	268	32	31	45	26.1	6.1
Manica	Machipanda	627	15	24	38	24.3	3.4
	Vanduzi	555	35	91	52	33.7	5.7
	Inchope West	892	38	69	49	29.2	4.9
Tete	Luenha	195	49	82	62	39.8	5.9
	Tete	224	16	30	17	14.2	1.5
	EN7 Junction	286	32	30	57	35.9	3.7
Niassa	Mandimba North	138	44	41	22	14.5	2.1
	Mandimba East	92	23	17	6	4.2	0.5
Zambezia	Nicoadala	835	26	53	25	14.7	2.3
	Macuba	313	32	28	21	14.0	2.4
Nampula	Nampula	692	23	80	36	18.8	3.5
	Monapo	615	26	61	51	22.7	6.1
Cabo Delgado	Pemba	1271	31	57	14	10.8	0.9
	Metoro	216	47	6	33	14.2	2.1

Notes: ADT = Average Daily Traffic; HV = Heavy Vehicle; E80 = Equivalent 80kN axle load

The cumulative distribution of axle loads for different sites surveyed during the Axle Load Survey is summarized in Figure 8.1.

The large percentage of axles weighing over the 8 ton limit signifies the current lack of overloading control. The 35% of trucks that are overloaded are on average loaded 30% over the overloading grace limit (10% grace). On average the tonnage of those overloaded over the grace limit exceeded the permitted maximum load by 34%.

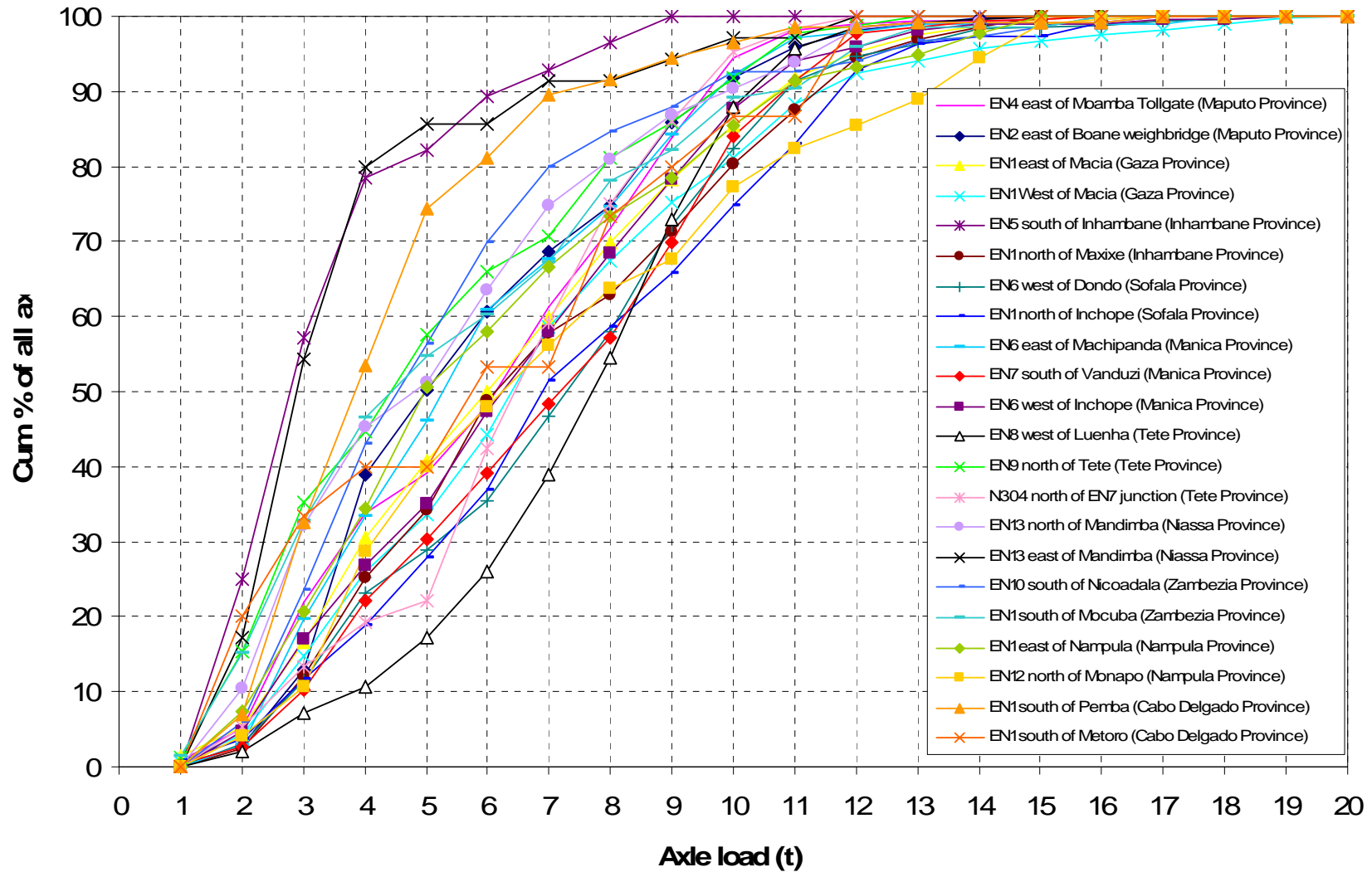


Figure 8.1: Cumulative distribution of axle loads for different sites surveyed during the Axle Load Survey

Figure 8.2 shows the distribution of heavy vehicles by axle class and indicates that the larger trucks are usually overloaded.

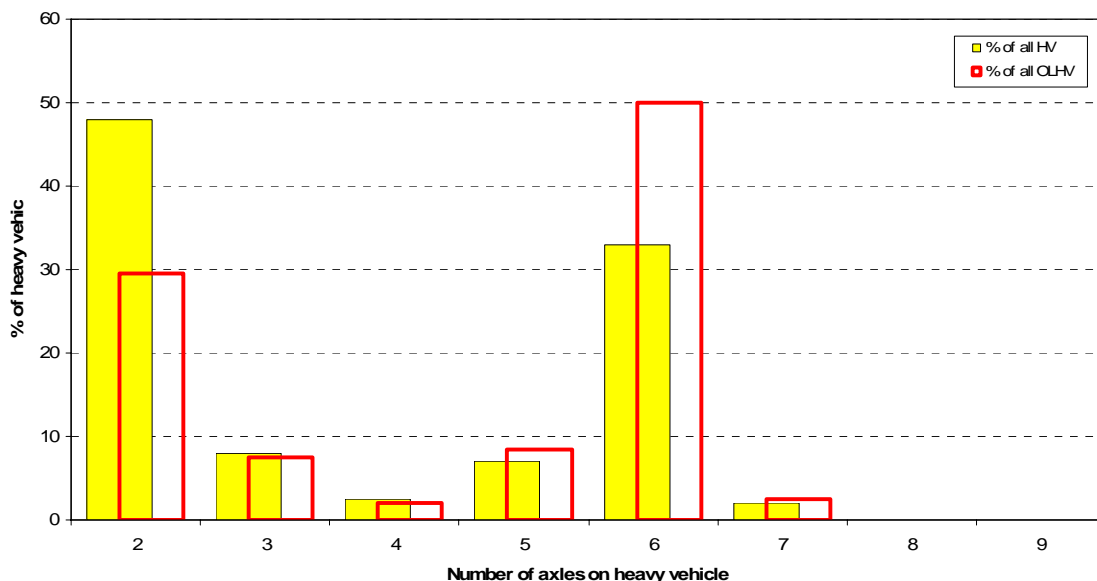


Figure 8.2: Distribution of heavy vehicles (22 sites; 1415 vehicles)

8.4 DETERMINATION OF LOAD EQUIVALENCY FACTORS

A pavement is designed to carry a certain number of axles, expressed as equivalent 80 kN axle loads (E80's) over its structural design life. The number of E80's is a function of the number and mass of the axle loads. The E80 is an indication of the structural damage caused by any axle load in relation to that of an 80 kN axle and is determined by (TRH 16, 1991):

$$DF = E80 = \left(\frac{P}{80}\right)^n \tag{1}$$

where: DF = damage factor
 P = axle load in kN
 N = damage coefficient ranging mainly from 2 to 6 (although higher and lower values have been reported).

The value of the damage coefficient is normally taken as 4.2, but is actually dependent on:

- the pavement composition, condition (state), temperature
- the definition of failure
- the axle load, configuration, suspension
- vehicle speed
- tyre pressure (Hutchinson, 1990; Marshek et al, 1982; Terrel and Runsrington, 1976)



All these factors should ideally be considered in the determination of pavement damage due to increases in axle loads. In the procedure that is discussed below, most of these factors were either directly or indirectly taken into account in the evaluation of pavement damage under existing and likely future loading patterns

A series of eight different pavement structures were selected that represents the typical designs currently in use in Mozambique. Although the eight pavement structures, shown in Figure 8.3, were linked to specific regions, their occurrence is not necessarily restricted to these regions.

For each of these pavements a load equivalency factor was determined for different wheel configurations using the following procedure:

Select a series of axle loads typical of vehicle loading conditions:

- Using the South African Mechanistic Design Method (Theyse et al, 1996), typical material properties (i.e. stiffness, Poisson ratio, failure modes, etc.) was assigned to each pavement structure.
- For each load and wheel configuration the expected number of loadings to pavement failure was calculated using trafPADS (CSIR, 2004) software.
- Using the predicted pavement life and Equation (1) the load equivalency factor (n) for each pavement structure was determined through regression analysis.

Values of the load equivalency factor for different axles configurations and pavement types are summarized in Table 8.2. The load factors generally vary between 1.6 and 5.6.

The Southern part of the country that generally carries the higher traffic volumes with stronger pavement structures, has lower LEF's and accordingly is less sensitive to overloading. Also, as expected, the steering axle is generally the most sensitive to overloading. Without assigning weights to specific pavement structures, the average load factor is 2.9 while the 90th percentile value is in the order of 4.0.

Table 8.2: Load equivalency factors for different pavement types and axle configurations

Pavement structure	Load equivalency factor			
	Steering	Single	Tandem	Tridem
N1	5.6	3.2	3.1	3.1
N2	4.1	3.4	3.2	3.2
N3	4.8	2.5	2.5	2.4
C1	3.1	3.2	2.7	2.7
C2	3.9	3.8	3.7	3.7
S1	2.1	2.1	1.6	1.6
S2	1.9	2.1	2.0	2.0
S3	2.7	2.1	2.0	2.0

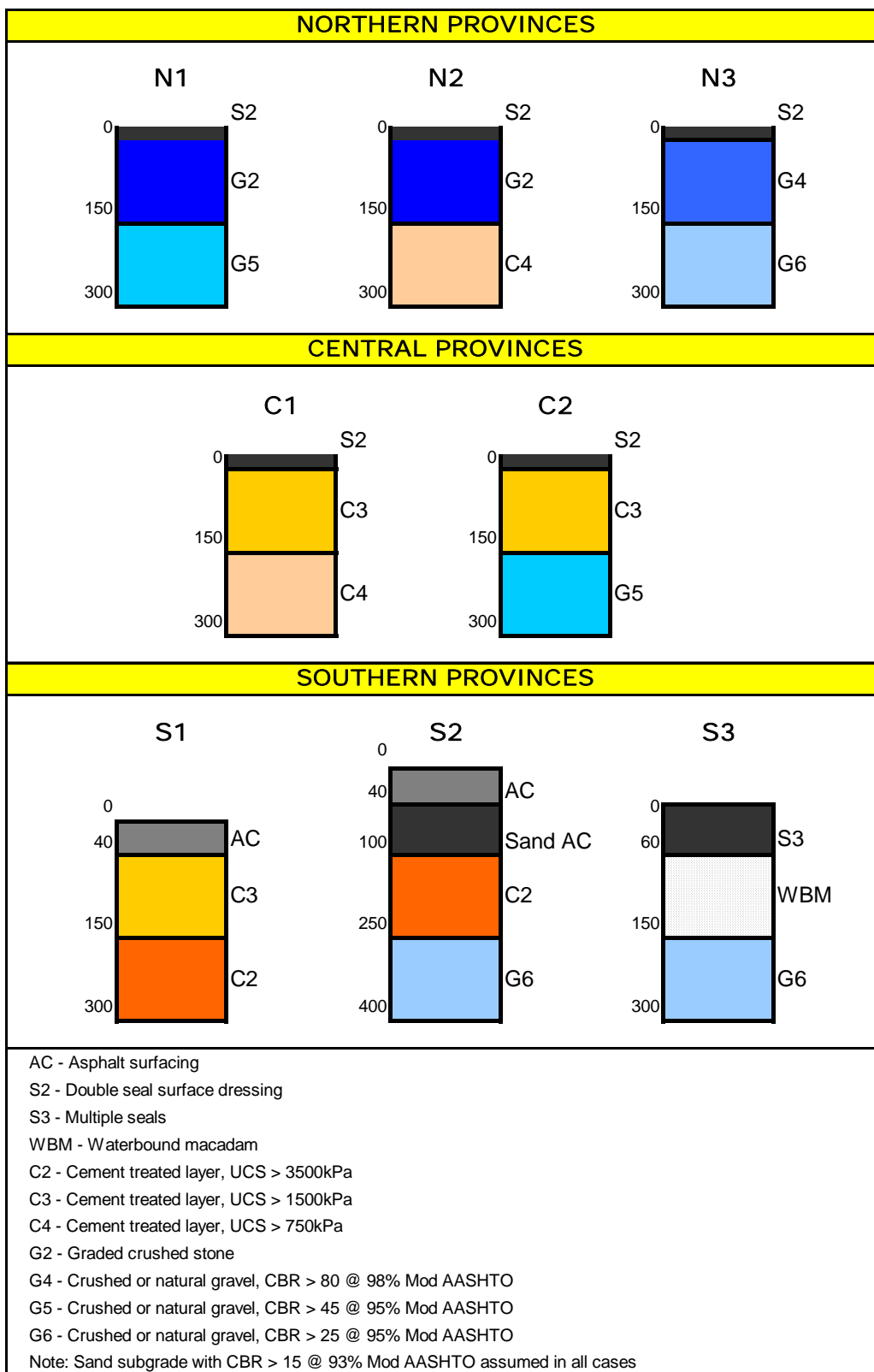


Figure 8.3: Typical pavement structures used in analysis

8.5 INFLUENCE OF DIFFERENT LEVELS OF ENFORCEMENT ON VEHICLE LOADING

The level of overloading control and enforcement has a significant impact on the axle loading distributions of heavy vehicles. Figure 8.4 shows actual measured data at weighing stations where different levels of overloading control is enforced for a 9t axle load limit:

- High = Heidelberg Overloading Control Facility N3 South Africa,
- Medium = Harrismith N3 South Africa,
- Low = Polokwane N1 South Africa,
- None = N4 Mozambique.

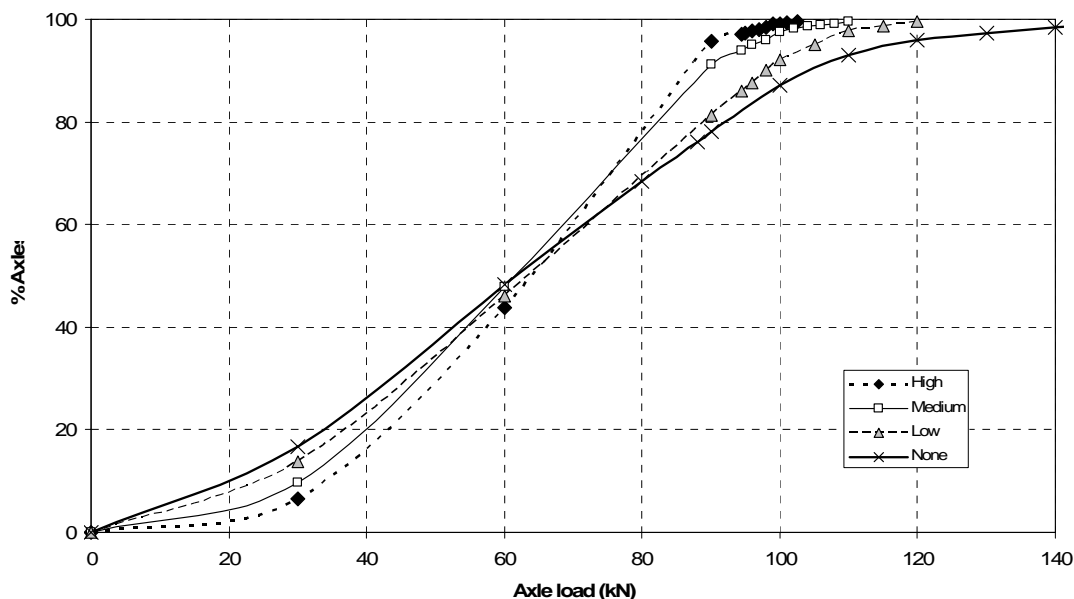


Figure 8.4: Axle load distribution for different levels of enforcement

Typically less than 5% of vehicle weighed will be overloaded when proper enforcement is maintained with most of the overloaded vehicles falling within the grace limit. With no enforcement more vehicles are overloaded and typically significantly higher than the limit.

A different way of expressing the distribution of loads and its impact on the pavement is by calculating the number of E80's per axle. A constant damage coefficient (4.0 in this case) was assumed and the impact of each axle range was cumulatively added and expressed per axle. Table 8.3 summarize the E80's/axle for the different survey sites. Also listed in the table are E80/axle values where different levels of enforcement were assumed. It is shown that for a high level of enforcement (5% exceeding limit) the axle load limit can be increased to 10t without increasing the current pavement loading significantly.

Table 8.3: Damage per axle for different levels of enforcement

Province	Site	E80's per axle									
		Existing	8t limit			9t limit			10t limit		
			20% exceed limit	10% exceed limit	5% exceed limit	20% exceed limit	10% exceed limit	5% exceed limit	20% exceed limit	10% exceed limit	5% exceed limit
Maputo	Moamba	0.98	0.79	0.55	0.44	1.08	0.79	0.65	1.63	1.18	0.95
	Boane	0.92	0.78	0.51	0.37	1.13	0.77	0.59	1.45	1.00	0.77
Gaza	Macia East	1.37	1.01	0.66	0.48	1.30	0.87	0.66	1.65	1.13	0.87
	Macia West	2.16	1.45	0.89	0.62	1.83	1.15	0.81	2.25	1.43	1.02
Inhambane	Inhambane	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
	Maxixe	1.64	1.01	0.64	0.46	1.28	0.86	0.65	1.66	1.16	0.91
Sofala	Dondo	1.86	1.08	0.73	0.55	1.51	1.06	0.84	2.00	1.42	1.13
	Inchope North	2.14	1.21	0.78	0.57	1.45	0.97	0.73	1.85	1.28	1.00
Manica	Machipanda	1.08	0.90	0.58	0.41	1.26	0.84	0.62	1.85	1.22	0.90
	Vanduzi	1.55	0.90	0.62	0.48	1.22	0.89	0.73	1.72	1.30	1.09
	Inchope West	1.41	1.01	0.67	0.50	1.33	0.91	0.70	1.85	1.28	0.99
Tete	Luenha	1.49	0.94	0.72	0.61	1.31	1.04	0.91	1.77	1.41	1.24
	Tete	0.76	0.79	0.51	0.37	0.95	0.63	0.47	1.21	0.83	0.64
	EN7 Junction	0.93	0.83	0.63	0.54	1.07	0.83	0.71	1.44	1.11	0.94
Niassa	Mandimba North	0.95	0.99	0.61	0.42	1.29	0.81	0.57	1.55	0.98	0.69
	Mandimba East	0.33	0.67	0.37	0.22	0.85	0.48	0.30	1.16	0.67	0.43
Zambezia	Nicoadala	1.05	1.30	0.76	0.49	1.56	0.92	0.59	2.20	1.29	0.84
	Macuba	1.16	1.08	0.66	0.46	1.27	0.79	0.55	1.73	1.10	0.79
Nampula	Nampula	1.40	1.11	0.68	0.46	1.32	0.83	0.58	1.74	1.12	0.81
	Monapo	2.33	1.41	0.84	0.56	1.58	0.97	0.66	2.12	1.37	0.99
Cabo Delgado	Pemba	0.50	0.99	0.57	0.36	1.29	0.74	0.47	1.72	0.98	0.61
	Metoro	1.19	0.98	0.66	0.50	1.19	0.82	0.63	1.49	1.05	0.82
	Highlighted cells indicate increased damage compared to existing loading										

8.6 IMPACT OF INCREASED AXLE LOAD LIMITS ON PAVEMENT LIFE

The impact of increased axle load limits on pavement life was investigated by calculating the effective pavement lives for the different representative pavement structures under expected loading conditions with enforcement for an 8, 9 and 10t limit using the typical distributions as indicated in Figure 8.4. The calculated pavement life was then compared to pavement life under the current loading conditions as indicated in Figure 8.5. Table 8.4 summarize the relative pavement life under existing loading conditions relative to conditions of strict overloading control and higher loading limits. The calculations indicate that the current lack of overloading control has a more severe effect on the deterioration of the pavements than an increase in the axle load limit under conditions of strict overloading control.

Table 8.4: Pavement life under existing loading conditions relative to conditions of strict overloading control and higher loading limits

Pavement structure	Location	Relative pavement life			
		Existing	8t	9t	10t
N1	EN10 south of Nicoadala (Zambezia Province)	1.0	1.6	1.2	1.0
N2	EN1 south of Metro (Cabo Delgado Province)	1.0	1.7	1.4	1.2
N3	EN1 south of Mocuba (Zambezia Province)	1.0	1.5	1.2	1.0
C1	EN1 north of Inchope (Sofala Province)	1.0	2.3	2.1	1.9
C2	EN8 west of Luenha (Tete Province)	1.0	2.3	1.9	1.7
S1	EN1 north of Maxixe (Inhambane Province)	1.0	1.6	1.5	1.4
S2	EN1 east of Macia (Gaza Province)	1.0	1.3	1.2	1.1
S3	EN1 west of Macia (Gaza Province)	1.0	1.4	1.3	1.3

8.7 EFFECT OF TYRE PRESSURE AND SUSPENSION SYSTEMS

Axle configurations, suspensions and tyre types also influence the damage to the pavement and should ideally also be incorporated in the regulation of heavy vehicles (Markov et al, 1987). Increase in tyre pressures from 620 kPa to 835 kPa can result in a 38% decrease in pavement life according to Hudson and Seeds (1988). TRB (1990) reported a decrease of 15% in pavement life for an increase in tyre pressure from 520 kPa to 590 kPa.

The influence of increased tyre pressures on the life of the different typical pavements, as identified in Figure 8.3, was assessed. Again using the South African Mechanistic Design Method (Theyse et al, 1996) and mePADS (CSIR, 2001) software, the life of the different pavement layers under a 20kN duel wheel load with different inflation pressures was calculated. Figure 8.5 summarize the calculations and shows that particularly the granular base pavements are very sensitive for high tyre pressures.

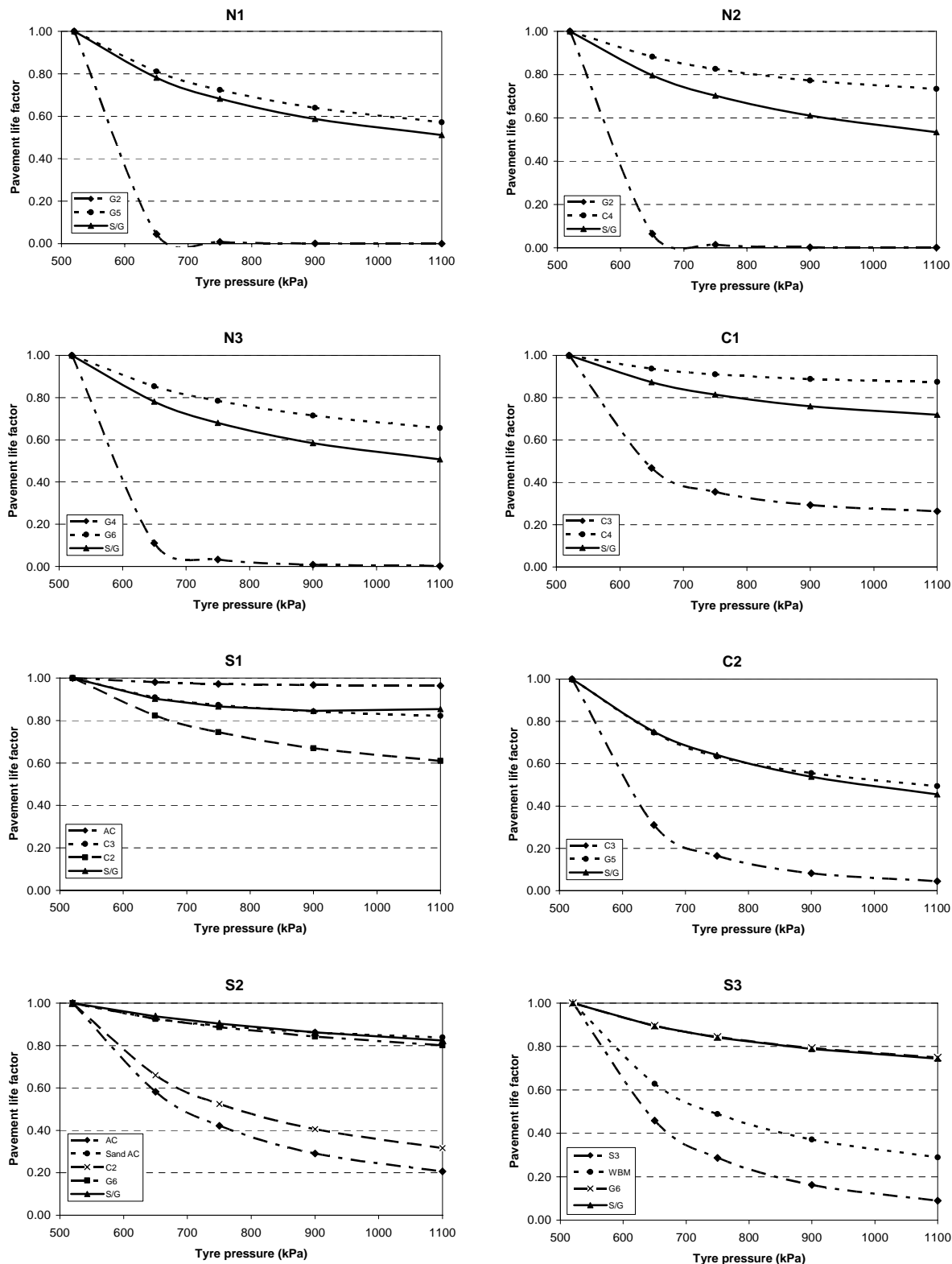


Figure 8.5: Influence of tyre pressure on pavement life for different pavement structures Regional Integration Findings
 (Pavement life factor = [Life @ tyre pressure > 520kPa] / Life @ 520kPa)

The calculations also confirm that the influence of tyre pressure is mainly in the upper pavement layers.

Vehicle suspension systems also impacts on the interaction between the loaded wheel and the pavement and accordingly the pavement life. Defective suspensions have been reported (Hutchinson, 1990) to do up to 200% more damage than axles with proper suspensions. Some countries (Belgium and West Germany) therefore allow higher loads on some types of suspensions.

CHAPTER V: CONCLUSIONS

9. CONCLUSIONS: LEGAL REVIEW AND CONCESSIONING

9.1 LEGAL ASPECTS OF OVERLOADING CONTROL: CONCLUSIONS

9.1.1 Regulatory Approach

National states can be grouped into two categories with regard to their regulatory approach to overloading control. One group comprises those states that have opted to expand their enforcement options to include various administrative measures (such as the imposition of overloading fees). This group includes Malawi, Tanzania and Zimbabwe. All other states rely solely on criminal enforcement.

As our analysis has been confined to a desk top scan, it is not possible to present any findings that compare the effectiveness of the two approaches. To this end, we propose to undertake interviews with various role players to verify the operational results of reforms in Malawi, Tanzania and Zimbabwe. The following role players were identified:

- Tanzanian Roads Authority (TANROADS)
- Tanzanian Transport Operators Association (TATOA)
- National Roads Authority of Malawi
- Road Transport Operators Association (Malawi)
- Ministry of Transport and Energy (Zimbabwe)
- Association representing Zimbabwean road transporters
- FESARTA

Views will also be gathered from ASANRA and the SADC secretariat. The views gathered will be synthesized for the purposes of developing recommendations on a proposed regulatory approach in Mozambique.

9.1.2 Legislative Approach to Load Limits

At a technical level, states have partially harmonized legislation governing load limits. In the case of Mozambique, the lack of harmonization is most significant in respect of single axles and gross vehicle and combination mass, although the lack of legal harmonization is partially neutralized by the informal limits that are applied in practice. The following are most significant exceptions to regional harmony:

The 7.5 tonnes limit specified in the *Codigo de Estrada* for single front axles in Mozambique is the lowest in the region (although the maximum permissible mass of 10 tonnes on other single axles is higher than the limit permitted in any other state in the case of an axle fitted with only 2 wheels). As mentioned the absence of legal

harmonization is overcome in practice by the fact that Mozambique allows 8 tonnes on any single axle irrespective of the number of tyres.

Lower limits for steering axles in Botswana, South Africa and Swaziland (7.7 tonnes vs. 8 tonnes elsewhere). Lower limits for single axles in South Africa (9 tonnes (8.2 tonnes in Botswana and Swaziland) vs. 10 tonnes elsewhere) are also exceptions, although it is understood that Botswana intends reviewing its legislation.

Maximum vehicle or combination mass of 38 tonnes (48 tonnes in practice) in Mozambique compared to 50.2 tonnes in Botswana and Swaziland and 56 tonnes in all other states.

Limits for tandem and tridem axles are closer to uniformity, although the absence of any prescribed limits for tridem axles in Mozambique renders comparison difficult. Botswana and Swaziland are also once again not in uniformity with other states. A noteworthy exception is Tanzania's limit of 12 tonnes on a tandem axle with 2 wheels per axle, while most other states prescribe 15.4 or 16 tonnes. Another noteworthy exception is Zambia which prescribes 12 tonnes for a tridem axle with 2 wheels per axle, as opposed to 21 tonnes or even 24 tonnes in other states, e.g. South Africa.

Lastly, it should be noted that most states (including Mozambique) do not prescribe power to mass ratios in order to limit gross vehicle or combination mass. Similarly, only two states (Malawi and South Africa) incorporate bridge formulas in their laws.

9.1.3 Weighbridge Operations Regulation

Provisions on the operation of weighbridges tends to be sparse or non-existent in the legislation of most states. A noteworthy difference occurs between states that have legislated a 5% tolerance as opposed to states which have not included a tolerance in their legislation (such as Mozambique). In effect this implies that limits are 5% higher in those states that have a statutory tolerance. The effect of this may, however, be neutralized by states, e.g. South Africa, which implement a 5% tolerance under a guidelines issued to prosecutors. It is understood that Mozambique, in practice, applies no tolerance.

There is a significant degree of harmonization in the powers, functions and duties that states' laws vest in officers to enforce load limits (although, as mentioned above, the position in Mozambique could not be verified). It is noteworthy that few states impose an obligation on vehicle operators to present a vehicle for weighing. This is surprising considering that this measure could facilitate enforcement. Only Zambia has such a provision in its law, while Tanzanian legislation has the option that road authorities may erect a road sign obliging vehicles to report to a weighbridge. Few states' laws identify the party liable to pay a fine or fee for overloading. This is an omission which has created enforcement difficulties in some states, as vehicle operators or drivers plead ignorance about the mass of consignment to escape liability.

A noteworthy omission in the legislation of all states relates to provisions to enable private participation in weighbridge management and operation. This issue is discussed further in the following chapter.

9.2 CONCLUSIONS: CONCESSIONING

In principle, there are various options for public – private partnerships in weighbridge operation and management. For the purpose of this assignment, the analysis focussed on *outsourcing* and *concessioning*.

9.2.1 Outsourcing

Private sector involvement in the operation and maintenance of weighbridges is **not expressly dealt with** in the legislation of any of the states. Legislation in Mozambique and South Africa is adequate to permit *outsourcing*. This entails contracting a private operator (against payment of an agreed fee) to operate and maintain a weighbridge. The operator assumes no technical or financial risks, while ownership of the weighbridge and its facilities remain in public hands. Policing functions are also still performed by traffic officers.

9.2.2 Concessioning

Existing legislation provides **no guidance** with regard to the introduction of a weighbridge *concession*. This option would entail the concessionaire assuming technical and financial risk, especially revenue risk. However, current legislation in Mozambique and elsewhere makes it difficult to structure a concession in a manner which makes it possible to transfer risk to the concessionaire. There is no authority in current law for a concessionaire to charge and collect weighbridge fees. Nor is there authority in the law (except in Swaziland) permitting a concessionaire to take responsibility for policing functions such as stopping a vehicle, directing a vehicle to a weighbridge, etc. Hence, under existing law a concessionaire would still have to rely on co-operation from the police or traffic authorities both to undertake policing and to ensure a flow of vehicles through the weighbridge to secure a revenue stream. Due to these limitations, a weighbridge concession is unlikely to be an attractive investment option under existing law.

10. CONCLUSIONS: BRIDGE LOADING STUDY

10.1 SUMMARIZED ASSESSMENT

A review of Design Codes of Practice being employed to the design of bridges in Mozambique during the recent past decades revealed that the 1967 Portuguese Code was the most widely used. In addition the design loads specified in this code is the lightest and therefore the code is the critical code used for the evaluation of existing bridges in Mozambique.

Isolated axle loads are not a problem for existing bridges in Mozambique. However, total vehicle mass needs some serious consideration.

A static analysis was performed on hypothetical bridge decks of different span lengths, using a vehicle with a GVM of 56 tonnes. Narrow-width single-lane bridges designed in accordance with the 1967 Portuguese Code indicate significant overstress in the case of medium span bridges (in excess of 15m long).

With the exception of a simply supported span length of 22,5m (3,8% overstress), two-lane existing bridges in Mozambique will be able to accommodate a vehicle with a GVM of 56 tonnes. This includes an impact factor of 1,3.

Fatigue service life is more critical than static load carrying capacity. It was demonstrated that the fatigue life of a bridge deck with a 22,5m will theoretically be reduced by 10,1% if the legal GVM is increased from the current 36 tonnes to 56 tonnes. However, not a lot of research has to date been devoted to fatigue deterioration and failure of concrete bridges. During the principal condition inspection of bridges for nine authorities in Southern Africa, including bridges up to 100 years old, no signs have been encountered of any deterioration associated with fatigue.

In the 22,5m example above, the maximum live load associated with a GVM of 56 tonnes only contributes 23% to the total applied bending moment. Fatigue problems are more pronounced at shorter span bridges, but the static safety margin on these bridges, designed in accordance with the 1967 Portuguese Code, are sufficient to offset any potential fatigue deterioration.

10.2 CONCLUSION

It appears that there may be occasional overstress at specific bridge deck spans if the GVM in Mozambique is increased to 56 tonnes. These problems may be so isolated that it is probably not economically warranted to use this as a reason not to increase the GVM. Borderline bridges may rather be surveyed and assessed individually and strengthened where required.

Single-lane bridges, including temporary steel Bailey-type bridges on important freight routes and other national routes should be replaced, in case the existing legal GVM is increased by the lowest of margins.

It is recommended to perform the following bridge inspection survey per route, prior to the increase of the GVM to 56 tonnes

- Inventory survey to obtain the number of single-lane bridges
- Inventory survey to obtain the number of steel Bailey-type bridges
- Condition inspection of existing single-lane bridges, Bailey bridges and simply supported bridges deck spans between 20m and 25m long

Should the legally allowed GVM be increased, it is recommended to implement a programme of annual routine inspections to monitor the condition of all deck spans between 20m and 25m long, unless the load carrying capacities of these deck spans are individually assessed and strengthened where required.

11. CONCLUSIONS: AXLE LOAD STUDY AND ANALYSIS

11.1 CONCLUSIONS

During the months of August and September 2005 an axle load survey was executed throughout Mozambique and included two survey sites in each of the ten provinces. Measurements indicated that 35% of trucks are overloaded and of these overloaded trucks 30% on average are loaded over the overloading grace limit (10% grace). On average the tonnage of those overloaded over the grace limit exceeded the permitted maximum load by 34%. This large percentage signifies the current lack of overloading control.

Calculations on a series of eight different pavement structures, representing the typical designs currently in use in Mozambique, indicate that axle load factors vary between 1.6 and 5.6. The Southern part of the Country that generally carries the higher traffic volumes with stronger pavement structures, has lower LEF's and accordingly is less sensitive to overloading.

For a high level of enforcement (5% exceeding the legal limit) the axle load limit can be increased to 10t without increasing the current pavement loading significantly. The calculations indicate that the current lack of overloading control has a more severe effect on the deterioration of the pavements than an increase in the axle load limit under conditions of strict overloading control.

Vehicle suspension systems, axle configurations, tyre types and pressures also impacts on the interaction between the loaded wheel and the pavement and accordingly the pavement life. Calculations show that particularly the granular base pavements are very sensitive to high tyre pressures. Overloading control systems should therefore also focus on controlling these parameters.

12. CONCLUSIONS: WEIGHBRIDGE INFRASTRUCTURE AND O&M STUDY

12.1 INFRASTRUCTURE AND EQUIPMENT STUDY

In summary the conclusions of the infrastructure and equipment survey indicated that:

- ANE were operating in nine provinces on 13 existing weighbridges sites and that eight more weighbridges are proposed or planned. Eight weighbridges are poorly to reasonably equipped and operational while five weighbridges are not functional (broken or nonexistent scale).
- Most weighing equipment is outdated, inaccurate and not maintained.
- There is a general lack of utility services such as electricity, water and telecommunications equipment.
- Buildings unequipped or non functional and in some cases they have been vandalized.
- No screening equipment (Weigh-in-Motion) was in use anywhere.

- There is a lack of mobile screening equipment, however three sets are being provided under this contract.
- At the mechanical scales there is no electronic production of weigh-slips
- The evidence indicates that there is questionable routine maintenance and day-to-day maintenance
- It was learned that there is a lack of regular assizing of scales
- There is no electronic data collection system (operations not auditable) and no electronic production of fine or recording of issued fines.

12.2 OPERATIONS AND MAINTENANCE

From the operational and manpower survey one can conclude that:

- Approximately 20% of existing facilities are operating reasonably well
- Maintenance is questionable (accuracy of scales questionable)
- General lack of manpower (numbers and capacity) / 24hr shifts

There is a:

- Lack of or total absence of operational and managerial training
- Lack of consistent measurable operational procedures (operational system)
- Lack of management / supervision (capacity and motivation)
- Lack of accountability (no formal traceable management)
- Lack of reporting / paper trail

The fine system consists of:

- A flat fee of MMC 5 million (no sliding scale for lesser or worse offences)
- No consistently used dedicated destination for fine income

Regarding responsibilities on site, there is a:

- Split responsibility between authorities (ANE / Traffic Police)

The system for selecting vehicles to weigh is questionable as there is:

- No signage compelling heavy vehicle to proceed to weighbridge
- Weighing is not compulsory – ad hoc selection
- Discrimination against foreign vehicles observed
- No detaining of overloaded vehicles to rectify loads
- Bribery and corruption is reportedly rife

Evidently overload control operations is ineffective as proved by the high level of overloading prevailing on the country's roads recorded during the Axle Load Survey.

13. FINAL COMMENTS AND THE WAY FORWARD

The Overload Control Strategy aims to give ANE guidance to focus its efforts with regard to overload control to achieve its objectives of:

- extending pavement life and reduce maintenance costs of the road network
- Reduce road user costs through improved road conditions
- Improve safety

The Strategy takes cognisance of the need to integrate Mozambique's overload control operations with that of its neighbours and a new and progressive approach based on current international best practise ensures that mistakes of the past manifested as current inefficiencies are not repeated, is envisaged.

Volume 2 of the report continues with the Strategy, Recommendations, Implementation Programme and Budgets. The report is concluded with work plans for all major tasks aimed to simplify implementation of the Strategy.

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