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Analysis of the extent of heavy vehicle overloading on Namibian trunk roads and evaluation of the effectiveness of existing mitigation measures

G Agoro, P Johannes, R Ambunda

GODFREY AGORO is a professional civil engineer with a diverse work background spanning Kenya, Namibia and Djibouti. Having recently served as an international consultant with the World Food Programme in Djibouti, he brings a wealth of experience to the table. Holding an MSc degree in Civil Engineering from the University of Namibia, his 15-year career encompasses extensive consulting roles in both the private and public sectors, focusing primarily on transportation infrastructure such as roads, bridges and railway construction. Currently he dedicates his time to consultancy work, contributing valuable insight and expertise to the civil engineering industry.

Contact details:
PO Box 14242-00100
Nairobi
Kenya
E: godfreyagoro@gmail.com

Affiliation:
Department of Civil and Mining Engineering
University of Namibia
PO Box 3624
Ongwediva
Namibia

DR PETRINA T JOHANNES is a civil engineer with over 15 years of industry and research experience. She has authored more than 30 publications on performance evaluation of pavement materials, material specifications, product standardisation, and transport-related water resource management. She currently works as a Senior Lecturer at the University of Namibia and also serves on various technical committees and related bodies, including the Engineering Council of Namibia. She holds a BSc degree in Civil Engineering from the University of Cape Town, as well as an MSc and PhD in Civil Engineering from the University of Wisconsin Madison, USA.

Contact details:
Department of Civil and Mining Engineering
University of Namibia
PO Box 3624
Ongwediva
Namibia
E: pjohannes@unam.na

DR ROBERT AMBUNDA is a transportation lecturer, consultant and the lead researcher in the Mobility Lab at the School of Engineering and the Built Environment (SEBE), University of Namibia. His research interests include areas around transport policy and regulation, resilient and equitable urban and rural transport systems, transport modelling, climate change and adaptation, and road safety. In his current post, he is responsible for teaching (undergraduate and postgraduate), and leading and coordinating research and commercial projects in transportation. He holds MSc and PhD degrees in Transportation Engineering.

Contact details:
Department of Civil and Mining Engineering
University of Namibia
PO Box 3624
Ongwediva
Namibia
E: rambunda@unam.na

Overloading of heavy vehicles reduces pavement life and increases pavement life cycle costs. As part of Namibia's strategy to control heavy vehicle overloading on the road network, weighbridge facilities have been constructed at strategic locations on primary routes (trunk roads). The study analysed the extent of heavy vehicle overloading on Namibian trunk roads, as well as the effectiveness of existing overloading mitigation measures. The dataset comprised heavy vehicle loading information from the year 2015 to 2019, from ten static weighbridge facilities. The parameters investigated include overloading magnitude, the effect of overloading on road pavement life, and the effectiveness of current overload mitigation measures. The results showed that 13.3% of the vehicles weighed were overloaded, with a compounded decrease in overloading of approximately 0.5% per annum. Despite the overloading decrease, the study found that the estimated road service life was reduced by as much as nine years over the study period. High levels of weighbridge avoidance and poor stakeholder coordination in mitigating overloading were identified. The study recommends deploying high-speed weigh-in-motion systems, an increase in fines charged for overloading offenses, and developing a demerit point-based system for habitual offenders to strengthen mitigation measures.

Keywords: overloading, heavy vehicles, vehicle classification, axle loads, weighbridges

INTRODUCTION

Overloading has been recognised as both a safety concern and a cost concern. Overloading occurs when a vehicle is loaded beyond its maximum legal weight (Yassenn *et al* 2015). Damage to roads as a result of overloading leads to higher maintenance and repair costs, and shortens the life of a road (Hornych 2015; Shahul & Prathap 2018). Consequently, these costs are carried by the road user if overloading is not controlled. Previous studies have shown that this condition escalates when the control of traffic is poor (Rys *et al* 2016). It has been found that legally loaded heavy vehicles cause a relatively small amount of damage to road pavement structures, as opposed to overloaded heavy vehicles which are responsible for approximately 60% of the damage to roads in South Africa (CSIR 1997). Roads are designed based on an assumed projected traffic load and volume. In the pavement design process, overloading is usually not taken into account and thus any heavy vehicle overloading damages the structural design period (SDP) of a pavement (CSRA 1996). The SDP for roads in Namibia ranges from 7 to 30 years depending on the road categories. The SDP for the various road categories are as follows:

- Class A roads (SDP between 15 and 30 years)
- Class B roads (SDP between 15 and 25 years)
- Class C roads (SDP between 10 and 20 years)
- Class D roads (SDP between 7 and 15 years) (CSRA 1996; RA 2014).

The Namibian road network consists of 8 250 kilometres of paved roads out of a total of 48 900 kilometres of road

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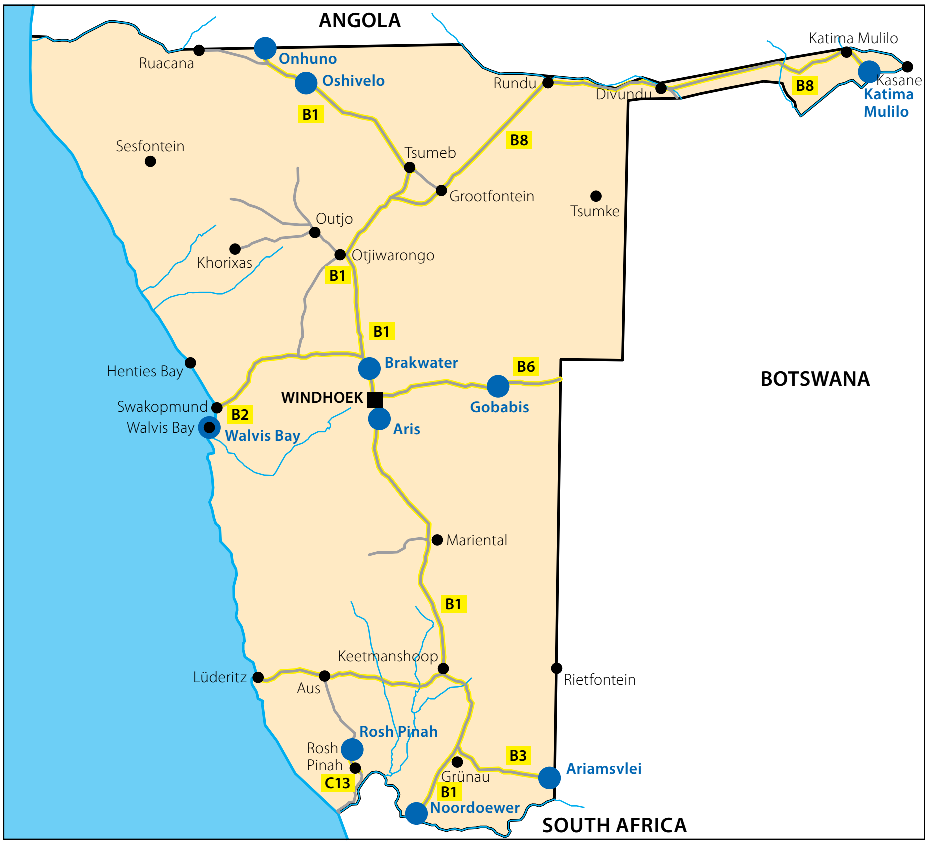

Figure 1 Weighbridge locations and road classification (NSA 2017)

(RA 2022). The biggest threat to the paved road network is the prevalence of heavy vehicle overloading across the road network (Kiggundu & Lutombi 2004). Previous studies by Kiggundu and Lutombi (2004) and Pinard (2010) reported an average overloading rate between 20% and 29% on Namibian trunk roads between the years 2000 and 2010. Recognising the need for an effective overload strategy for Namibia, the Roads Authority of Namibia (RA) built ten static weighbridge stations on the trunk road network – Class B and Class C roads (Kemp *et al* 2018). Despite the overloading mitigation strategy, there has been added pressure on the entire road network due to an increase in weighbridge route avoidance (poor compliance) by heavy vehicle operators, and an observed increase in overloading (RA 2020).

Although Namibia has introduced heavy vehicle overloading detection measures, a knowledge gap exists regarding the extent and impact of overloading on Namibian roads and the effectiveness of the current alleviation measures. To this end, the goal of this study was to quantify the level of overloading on Namibian roads from 2015 to 2019. Furthermore, the study assessed the changes in heavy vehicle characteristics, and evaluated the effectiveness of both existing overloading detection and mitigation measures. Thus, the study employed both qualitative and quantitative approaches. The heavy vehicle axle loading data and overloading volume were collected from the weighbridge records and systems of the RA. Information, such as fines imposed due to overloading, was collected from survey questionnaires and from desktop literature reviews.

DATA

Heavy vehicle (HV) traffic and loading data

Heavy vehicle (HV) overloading data for the period 2015 to 2019 was obtained for all the weighbridge stations (see Figure 1) for the different HV classes (see Table 1). HVs were classified according to Bosman's classification system. This system classifies HVs based on the traffic loading characteristics of South African HVs (Bosman 2004), with seven main classes shown in Table 1. Bosman's classification system was applied in the study as it adequately captured the different HV axle load configurations recorded by Namibian weighbridges.

The names of the weighbridges that were studied, the route names on which the weighbridges are located (see Figure 1) and their strategic importance in serving traffic (commercial or otherwise) from neighbouring countries are indicated in Table 2 (on page 14). The study obtained the HV overloading data from the TRAFMAN vehicle system (vehicle reports) at the Roads Authority of Namibia (RA) for the period from 2015 to 2019.

The data collected from the TRAFMAN vehicle system included overloaded heavy vehicles (HV) volumes, HV axle configurations, HV axle loads, and the punitive measures and amounts of traffic fines issued for overloading.

Table 1 Heavy vehicle (HV) axle classification (Bosman 2004)

Vehicle class	Axle load configuration
Class 2 (2 axles)	1-1
Class 3 (3 axles)	1-1-1
	1-2
Class 4 (4 axles)	1-1-1-1
	1-1-2
	1-2-1
	1-3
Class 5 (5 axles)	1-1-2-1
	1-2-1-1
	1-2-2
	1-1-3
Class 6 (6 axles)	1-1-2-1-1
	1-1-2-2
	1-2-1-2
	1-2-2-1
	1-2-3
Class 7 (7 axles)	1-2-2-1-1
	1-2-2-2
	1-2-4
Class 8 (8 axles)	1-2-2-3
	1-2-3-2
	1-3-2-2

Effectiveness of the overloading mitigation measures

The study conducted questionnaire interviews at all ten weighbridge stations operated by the Roads Authority of Namibia (RA). The questionnaire served as a tool to evaluate the effectiveness of the existing mitigation measures and strategies for curbing heavy vehicle (HV) overloading on the selected road classes. The questionnaires were developed to investigate the following:

- The frequency of weighbridge avoidance
- The impact of existing strategy in discouraging non-compliance with HV axle loading regulation

Table 2 Route names and information on weighbridge stations on the Namibian road network

Weighbridge station name	Route name	Route number	Strategic importance
Grootfontein	Grootfontein – Otavi	B8	Connects Namibia to Zambia, Botswana and Zimbabwe
Katima Mulilo	Kongola – Katima Mulilo	B8	Connects Namibia to Zambia and Botswana
Brakwater	Windhoek – Okahandja	B1	Connects Namibia to South Africa, Zambia, Botswana and Zimbabwe
Oshivelo	Oshivelo – Omuthiya	B1	Connects Namibia to DRC and Angola
Oshikango	Oshikango – Ondangwa	B1	Connects Namibia to DRC and Angola
Rosh Pinah	Noordoewer – Rosh Pinah	C13	Connects Namibia to South Africa
Noordoewer	Keetmanshoop – Noordoewer	B1	Connects Namibia to South Africa
Ariamsvlei	Ariamsvlei – Karasburg	B3	Connects Namibia to South Africa
Walvis Bay	Walvis Bay – Swakopmund	B2	Connects Namibia to Zambia, Botswana and Zimbabwe
Gobabis	Buitepost – Gobabis	B6	Connects Namibia to Botswana and Zimbabwe

- The adequacy and impact of HV overloading fines on curbing non-compliance.

METHOD

Coefficient of determination for traffic growth analysis (overloading trend)

The study applied summary statistics and simple linear regression coefficient of determination (R^2), as a goodness-of-fit measure, to assess the degree of HV overloading between 2015 and 2019, at a 95% confidence interval. The coefficient of determination was determined using Equation 1 (Dufour 2011).

$$R^2 = 1 - \frac{SSR}{SST} \quad (1)$$

Where:
SSR = sum squared regression
SST = total sum of squares.

The probability value (p-value) test was also done to determine the level of statistical significance of the HV overloading trend. A p-value less than 0.05 (≤ 0.05) indicates that the trend is statistically significant.

Calculation of E80s / heavy vehicle (HV) axle

The study quantified the road damage on the selected road classes caused by the various wheel loads by converting mixed traffic axle loads to an equivalent number of "standard" loads – equivalent standard axle loads 80 kN (E80s). The conversion was done using the Fourth Power-Law represented by Equation 2 (CSRA 1996).

$$F = \left(\frac{P}{80}\right)^n \quad (2)$$

Where:
n = relative damage exponent
F = load equivalency factor (LEF)
P = axle load in kN.

The average E80s / HV were computed for each class of HVs with two to eight axles (see Table 1) using Equation 3.

$$\frac{E80}{HV} = \sum\frac{F}{n} \quad (3)$$

Where:
F = load equivalency factor (LEF) from Equation 2
n = total number of heavy vehicles.

Estimation of road service life due to HV overloading

Heavy vehicle overloading accelerates the decline of the road's design life (Mulyono *et al* 2010). The impact of HV overloading on the service life of the road was determined by calculating the decline rate in the road service life cycle using Equation 4 (CSRA 1996). The equivalent standard axle loads (ESALs) for normal and overloaded axles were determined using Equation 2.

$$SL = \left[\frac{ESAL_{NORMAL}}{ESAL_{OVERLOAD}}\right]DL \quad (4)$$

Where:
SL is the actual service lifetime (years)
DL is the design lifetime (years)
$ESAL_{NORMAL}$ is the equivalent number of normal loaded HV traffic
$ESAL_{OVERLOAD}$ is the equivalent number of overloaded HV traffic.

Effectiveness of the existing overloading mitigation measures

The study developed a questionnaire to assess the effectiveness of existing overloading detection and mitigation measures in the regulation and at the weighbridge stations. The questionnaires focused on the following aspects:

- Weighbridge compliance (use and axle load compliance by HV operators)
- Weighbridge operations
- Relationship between stakeholders in curbing HV overloading practices.

RESULTS AND DISCUSSIONS

Heavy vehicles (HVs) overloading magnitude and trend in Namibia

The study found that a total of 218 546 heavy vehicles (HVs) out of a total of 1 642 254 HVs weighed between 2015 and 2019 were found to be overloaded. This represented an average degree of overloading of approximately 13%. The detailed results for the ten weighbridges are given in Figure 2.

The Walvis Bay weighbridge station was observed to have the highest percentage of HV overloading, with 25% of all HVs recorded identified as overloaded over the study period. The Oshivelo, Katima Mulilo, Ariamsvlei, Brakwater, Gobabis, Rosh Pinah and Onhuno weighbridge stations recorded overloading magnitudes between 21% and 6%. The lowest percentage of overloaded HVs was observed at the Noordoewer weighbridge station, accounting for 6% of the total vehicles weighed over the study period.

The aggregate overloading trend for all ten weighbridges was calculated from 2015 to 2019 (see Figure 3). The study applied a simple linear regression analysis to the data. The coefficient of determination (R^2) was used to define the best fit linear regression trend line for HV overloading between 2015 and 2019. The coefficient of determination indicates that the HV traffic

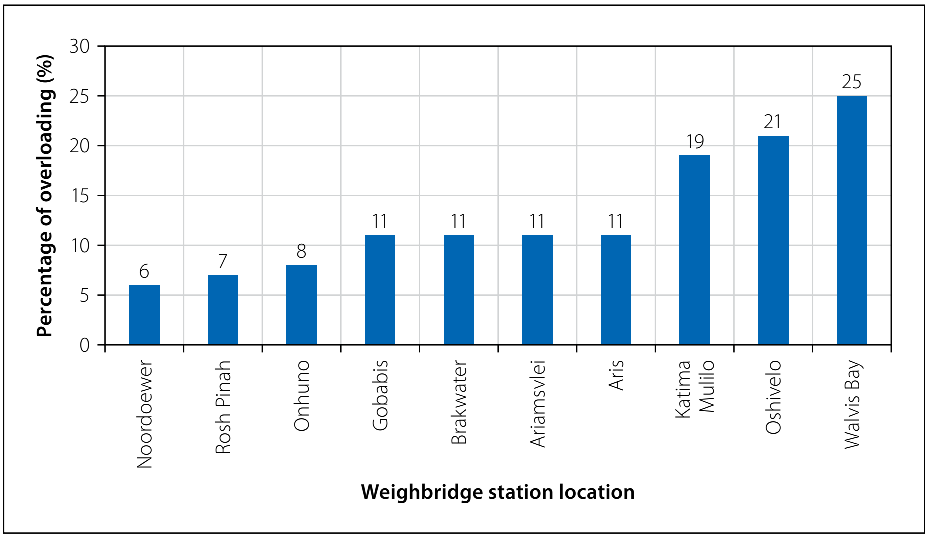

Figure 2 Overloading magnitude per weighbridge station

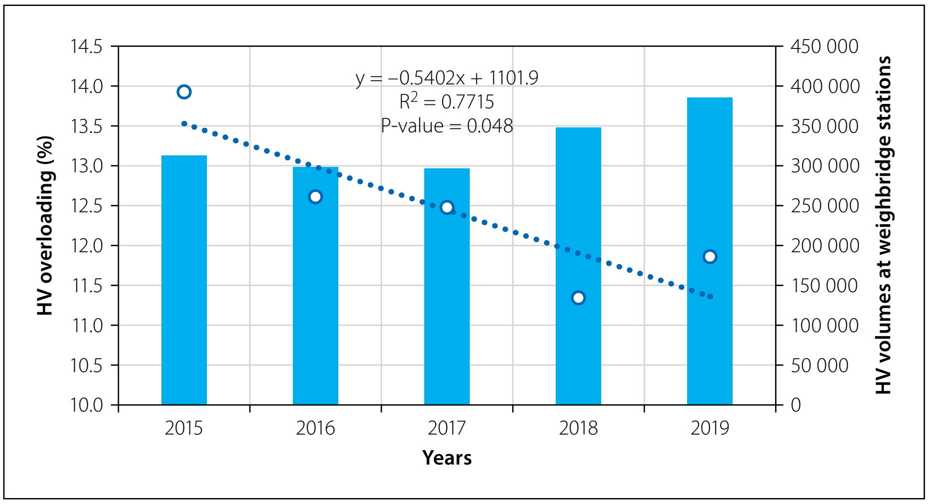

Figure 3 Overview of the heavy vehicle overloading trend in Namibia 2015 – 2019

growth regression model represents 77% of the variance in the HV overloading trend at a 95% confidence interval. In all, the study observed a statistically significant ($p < 0.0048 \leq 0.05$) cumulative reduction of 0.5% per year in HV overloading normalised against HV volumes over the study period.

Analysis of the HV traffic characteristics

The study interrogated the vehicle characteristics (HV volumes) trend over the study period (2015 to 2019), considering the decreasing overloading trend over the same period (see Figure 3). It was observed that, while overloading slightly reduced over the study period, the overall volume of HV vehicles recorded at the weighbridge stations increased over the same period (see Figure 4).

The combined growth of HV traffic volumes was observed to have slightly decreased from 280 318 HVs in 2015 to 270 129 HVs in 2017, representing an approximately 4% decrease in HV volumes at the weighbridge stations. The HV volumes then steadily increased from 2017 to 2019 (385 664 HVs). This represented a 30% increase over the two years (2017 to 2019). Over the study period (2015 to 2019) the weighbridge stations experienced a 26% compounded increase in HV volumes. The compounded increase in HV volumes over

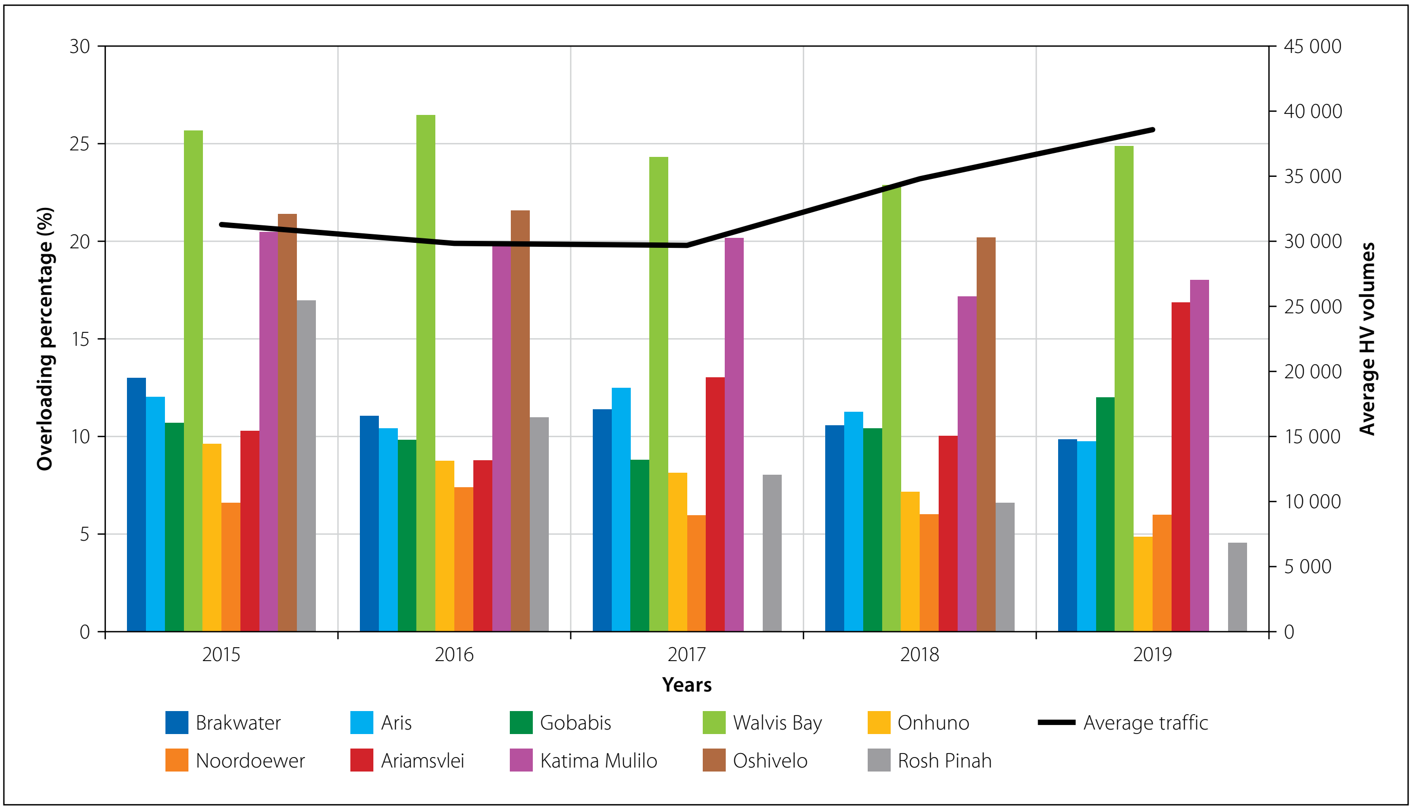

Figure 4 Overloading frequency per weighbridge 2015 – 2019

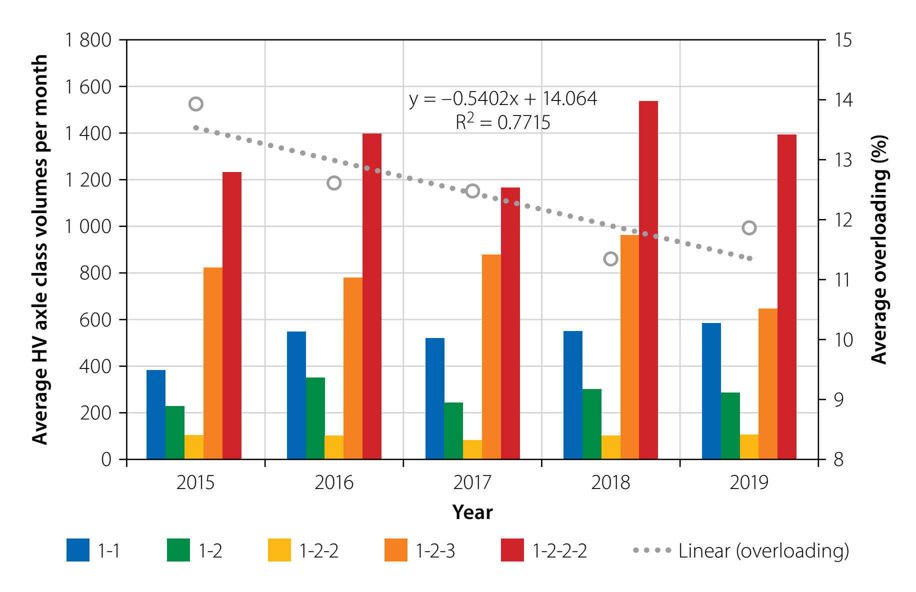

Figure 5 Vehicle classification and overloading trend 2015 – 2019

the study period could be a possible reason why a decreasing overloading trend (HV overloading normalised against HV volumes) was observed over the study period (see Figure 3 on page 15).

Analysis of the HV axle classification and overloading trend

The study identified various HV axle configurations on Namibian trunk roads, which include 1-1 (2-axle HVs), 1-2 (3-axle HVs), 1-1-1 (3-axle HVs), 1-1-2 (4-axle HVs), 1-1-3 (5-axle HVs), 1-2-2 (5-axle HVs), 1-2-3 (6-axle HVs), 1-2-2-1 (6-axle HVs), 1-2-2-2 (7-axle HVs) and 1-2-2-3 (8-axle HVs). The five most frequent HV axle configurations (axle configuration provided in Table 1) on Namibian roads between 2015 and 2019 were observed to be the 1-1, 1-2, 1-2-2, 1-2-3 and 1-2-2-2 axle configurations. Notably, it was observed that, while the average HV overloading trend slightly reduced from 2015 to 2019, the volumes of the 1-2-2-2 HV configurations (7-axle HVs) recorded an overall 25% increase over the study period, with 7-axle HV volumes ranging between 1 200 and 1 500 HVs per month over the study years. Several studies have found an increase in road damage due to an increase in overloaded higher axle configuration HVs over an extended period (Pinard 2010; Kandeke 2018). See Figure 5.

Calculation of E80/heavy vehicle (HV)

Given the overloading magnitude observed, the study calculated E80/HV for different vehicles to establish whether they were within the recommended values (see Table 3) of the TRH 16 (*Technical Recommendations for Highways*) on traffic loading for pavement and rehabilitation design (CSRA 1991). The study found that the average E80/HV values for Namibia are lower than the recommended average TRH 16 values. The differences between the Namibian E80/HV values and the TRH 16 ranged from as high as 34% (Class 2) to as low as 10% (Class 7/Class 8) (see Table 3). In the context of road pavement design, this implies that roads in Namibia may be over/under-designed according to the TRH 16, which may considerably impact the service life of the road pavements.

Impacts of overloading on structural design life (SDL) – road service life

The study analysed the impact of heavy vehicle (HV) overloading on the service life (structural design life) of pavements using Equation 3, and the results are given in Figure 5. The study observed a varying degree of road service life for the roads serving the weighbridges due to HV axle overloading (see Figure 6), with the assumption that all trunk roads have a uniform design life of 25 years for Class B and Class C roads (CSRA 1996). The road serving the Walvis Bay weighbridge was estimated to have the highest reduced service life, i.e. from 25 years to 16 years. The roads serving the Katima Mulilo, Noordoewer, Aris, Rosh Pinah and Ariamsvlei weighbridges were also expected to exhibit declines of varying magnitudes in the service lives. The trunk routes using the Gobabis and Onhuno weighbridges were expected to have a service life above the assumed 25 years. Brakwater and Oshivelo were excluded from the analysis due to insufficient structural design values. A study by Kiggundu and Lutombi (2004) noted that the average age of the Namibian bitumen road network, based on the date of the first upgrade, was 25.8 years. In comparison, the study observed an expected average road service life of 23.3 years with the HV overloading magnitude recorded and HV traffic volumes. The average expected road service life is below the design life (25 years) and the average age of the bitumen road network (25.8 years), as recorded in 2004.

The effectiveness of existing overloading mitigations and enforcement measures

One of the main reasons for premature failures and unsatisfactory performance of roads in Namibia is the overloading of heavy vehicles (HVs) (Kandeke 2018). Road authorities need to protect roads from unnecessary damage and premature wear. Enforcement can help to eliminate overloaded HVs on the roads and can act as a deterrent by declaring that those travelling in disregard of laws and regulations would be apprehended or face effective punishment (Bagui *et al* 2013).

The effectiveness of existing overload mitigation measures was evaluated by analysing the extent of HV overloading

Table 3 Comparison of average TRH 16 (CSRA 1991) and calculated E80/HV values for HV configurations from 2015 to 2019

HV class	TRH 16 (CSRA 1991) E80/HV			Average E80/HV for Namibia			Difference (%)
	Min	Max	Ave	Min	Max	Ave	
Class 2 (2 axles)	0.30	1.10	0.70	0.35	0.57	0.46	34
Class 3 (3 axles)	0.80	2.60	1.70	0.37	2.12	1.24	27
Class 4 (4 axles)	0.80	3.00	1.80	0.84	1.91	1.37	24
Class 5 (5 axles)	1.00	3.00	2.20	0.81	2.19	1.50	32
Class 6 (6 axles)	1.60	5.20	3.50	0.81	2.19	2.84	19
Class 7/Class 8 (=> 7 axles)	3.80	5.00	4.40	2.21	3.46	3.97	10

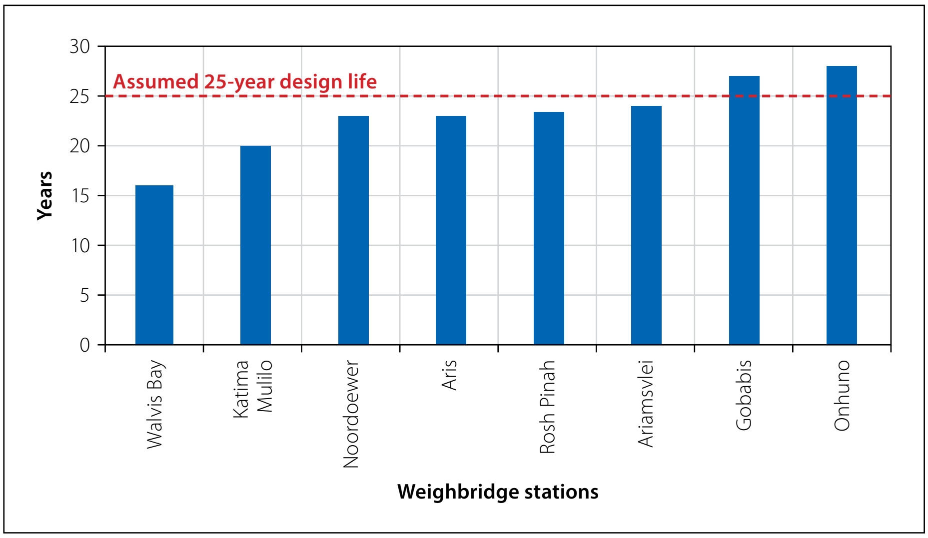

Figure 6 Expected road service life (years) due to overloading

offences at the ten weighbridge stations over the study period (2015 to 2019). The study found that warnings for HV loading non-compliance were issued to 88.3% of offenders. The high number of warnings can be attributed to the 5% HV overloading tolerance provided for in the existing Road Traffic and Transport Act of 1999 (RTTA) (LAC 1999). It was also observed that 11.6% of offenders were either fined or prosecuted. This normally happens when overloading exceeds the 5% tolerance stated in the RTTA. Table 4 refers.

The RA 2015/2016 annual report worryingly notes that 93% of overloaded HVs were not fined for overloading (RA 2016). The study observed a gradual increase in the percentage of admission-of-guilt fines paid to the Namibian government (through lower courts and police stations) between 2015/2016 (31%) and 2019/2020 (61%) (see Table 5). The remaining fines have been converted to arrest warrants due to the failure/refusal of offenders to pay the fines (RA 2020). Some operators were reported to deliberately overload HVs due to the relatively low fines imposed on admission of guilt for loading non-compliance (Pinard 2010). In instances where the HV is overloaded to an extent where an admission of guilt cannot be imposed (HV overloading over 2 000 kg per axle), the operator is arrested and the vehicle is seized (Pinard 2010). Based on the above, Namibia needs to find innovative solutions to improve the effectiveness of the current mitigation measures to avoid HV operators taking advantage of the laws and regulations.

A study by Taylor *et al* (2000) found a general functional relationship between enforcement capability and overloading violation rates. This was based on several studies performed by seven state enforcement agencies in the United States. The findings observed a low overloading rate where there were high levels of overloading enforcement, resulting in an improvement in the service life of road infrastructure.

Table 4 Heavy vehicle overloading distribution on trunk roads in Namibia

Weighbridge stations	Number of weighed vehicles	Total overloaded vehicles	Percentage of vehicles receiving warnings	Percentage of fined vehicles	Percentage of total overloaded vehicles
Brakwater	447 877	49 039	10.2	0.8	10.9
Aris	321 075	35 864	10.3	0.9	11.2
Gobabis	284 850	30 105	10.2	0.4	10.6
Walvis Bay	202 523	51 184	24	1.3	25.3
Onhuno	86 633	6 757	6.7	1.1	7.8
Noordoewer	38 957	2 516	6.1	6.3	6.5
Ariamsvlei	61 317	6 976	10.3	1.1	11.4
Katima Mulilo	103 932	19 560	17.3	1.5	18.8
Oshivelo	68 324	14 590	19.8	1.6	21.4
Rosh Pinah	26 766	1 973	6.4	1	7.4
Average			**12.13**	**1.6**	**13.73**
Overloading (%)			**88.3**	**11.6**	**100**

Table 5 Heavy vehicle overloading violations – fines issued and paid from 2015 to 2020

Year	Total fines issued (N$)	Total fines paid (N$)	Percentage of fines paid
2015/2016	6 965 315.00	2 191 875.00	31
2016/2017	7 934 028.00	2 575 022.00	32
2017/2018	4 584 195.00	1 883 525.00	41
2019/2020	8 717 629.00	5 314 675.00	61

Heavy vehicle (HV) overload control shortcomings identified

The study carried out interview questionnaires with weighbridge operators and users to investigate the effectiveness of HV overloading measures, and to identify shortcomings in existing strategies for curbing non-compliance. The results of the questionnaires are discussed below.

Weighbridge avoidance

The study found that weighbridge avoidance offences are a daily occurrence at most of the weighbridges in Namibia. Worryingly, the study found that 25% of the weighbridge stations experience weighbridge avoidance offences every hour. Respondents also mentioned that, due to the regular breakdown of the weighbridges, the drivers in some instances altogether avoid making the effort to go through the weighbridges for axle load measurements.

A study by Bagui *et al* (2013) noted that fixed overloading inspection stations restrict the flexibility of catching overloaded HVs. Thus, a combination of fixed and portable weighing systems (weigh-in-motion (WIM) systems) is necessary for more effective monitoring of weighbridge routes (Odula 2016; Bagui *et al* 2013). WIM systems are reported to greatly contribute to transparency at weighbridge stations and reductions in HV overloading transgressions (Odula 2016; Jacob & Cottineau 2016).

Overloading mitigation coordination with various stakeholders

Interview questionnaires were sent to the managers (ten managers) of the ten weighbridge stations operated by the Roads Authority of Namibia. The study observed that 50% of respondents indicated poor coordination between operating and axle load enforcement stakeholders at multiple weighbridges. These three stakeholders are the Roads Authority of Namibia (vehicle load management), the Road Fund Administration (funding agency that collects road user charges) and the Namibian Police (enforcement). The respondents mentioned a lack of 24-hour operational police patrol vehicles that should be used to spot weighbridge-avoiding offences. This shortcoming hinders overload control enforcement. Several studies have recommended enhanced stakeholder participation and coordination to deter loading non-compliance and create more awareness of the dangers of overloading (Taylor *et al* 2000; Pinard 2010; Odula 2016).

Enhanced stakeholder participation can be achieved through involving the private sector to foster a multifaceted approach to mitigate overloading. This includes necessary collaborations between government agencies and the freight industry to educate and train truck drivers and operators on the consequences of overloading, and to promote compliance with loading weight limits. It is also vital for the government to work closely with the freight industry in implementing and strengthening weight monitoring and load management practices. These include regular maintenance of vehicle scales. Additionally, the Roads Authority of Namibia could consider partnering with companies that offer advanced weighing technologies, such as onboard scales and weigh-in-motion systems, to help monitor and prevent overloading in real time. Government agencies can also partner with research institutions and academia to conduct studies on the effects of heavy vehicle overloading and to identify innovative solutions and best practices.

CONCLUSIONS AND RECOMMENDATIONS

This paper presented a study investigating the magnitude of heavy vehicle (HV) overloading on selected Namibian trunk road classes (Class B and Class C roads), and an analysis of the effectiveness of existing strategies and measures in curbing non-compliance to axle loading. The findings of this study indicated that an average of 13% of the total HV traffic volumes on the selected road classes in Namibia were overloaded over the study period of 2015 to 2019.

Despite this, the study revealed a cumulative reduction of 2% in HV overloading from the year 2015 to 2019 (0.5% per year). The decrease is possibly attributed to the compounded increase in HV volumes rather than effective mitigation measures, which were found to be deficient. In comparison, previous studies by Pinard (2010), and Kiggundu and Lutombi (2004), had found an average rate of overloading between 20% and 29% respectively, between the years 2000 and 2010. Despite the cumulative reduction in the magnitude of overloaded HV traffic over the study period, the study revealed a reduced expected road service life. The reduction in the expected road service life can possibly be attributed to the observed overall increase in overloaded higher-axle configuration HVs (7-axle HVs) between 2015 and 2019. The average expected road service life over the study period was found to be 23.3 years, which is a reduction from the road service life of 25.8 years observed by Kiggundu and Lutombi (2004) in 2004.

The study also found that Namibia experiences lower E80 values compared to the values recommended by the TRH 16 on traffic loading for pavement and rehabilitation design (CSRA 1991). This finding is indicative of the differing traffic loading properties experienced in Namibia and South Africa. It is recommended that a study should be undertaken to aid with the investigation and adoption of a more localised pavement design approach for Namibian roads. This could help address the possible over- and under-design of pavements using equivalent single axle load (ESAL) recommendations that may not reflect the actual axle loading on the roads.

An evaluation of the HV overloading punitive measures that are in place found that between 31% and 61% of fines issued over the study period were paid directly to the Namibian government through local courts and police stations. The rest of the fines were converted to arrest warrants due to non-payment. The right to enforce these warrants/payments does not fall under the Roads Authority (RA) of Namibia nor the Road Fund Administration (RFA) of Namibia despite being the custodian of roadway infrastructure. This provides a challenge in that these institutions are unable to ringfence the funds collected from HV overloading offences to maintain weighbridge infrastructure, improve mitigation measures, and address road pavement damage resulting from overloading. This structural challenge also explains the lack of coordination between stakeholders, as observed by the questionnaire respondents, which has led to weighbridge equipment breakdowns and consequently a high rate of weighbridge avoidance offences by HV operators.

The study recommends the installation of high-speed weigh-in-motion (HSWIM) scales and cameras on roads leading to all existing weighbridges and other alternative routes to address the issue of high weighbridge avoidance by HV operators. The HSWIM system is useful in accurately detecting patterns of weighbridge avoidance and identifying non-compliant HV operators (Odula 2016). With the easy identification of non-compliant HV operators provided by the HSWIM system, the study then recommends the development of a driver demerit point-based system to discourage habitual offenders. This point-based system is envisaged to function by allocating points to each vehicle and driver within a period of time. Each traffic and overloading transgression will reduce the points until the points are exhausted. In South Africa, the Administrative Adjudication of Road Traffic Offences (AARTO) Act of 1998 came into full effect in June 2020. The AARTO Act has a streamlined traffic fine and demerit points system which provides for the suspension and cancellation of driving licences or permits of repeat offenders (Du Plessis *et al* 2020)

The study recommends an increase in the HV overloading fines to fully recover the road pavement damage costs associated with axle loading non-compliance. For more effective use of HV overloading fines collected, the study recommends that fines be paid directly to the RA or RFA by incorporating them into the vehicle licensing and the Namibian Traffic Information System (eNaTIS).

The recommended revisions to the Namibian HV overload strategy (operational and punitive measures) aim to address operational issues relating to overload control facilities, reduce non-compliance to axle loading regulations and reduce the deterioration of road pavements on the Namibian trunk road network.

DECLARATION OF INTEREST

None.

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