A SOUTH AFRICAN ROAD NETWORK CLASSIFICATION BASED ON TRAFFIC LOADING

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ABSTRACT

As South Africa's road system comprises a total road network of rural and urban roads of approximately 534 000 kilometres, it is of utmost importance to have an effective road network level management system in place, which utilises reliable traffic loading data for long-term planning. Road authorities are therefore largely dependent on the availability and accuracy of traffic loading information to achieve the above and to assist them with their long-term strategic planning.

In addressing these needs, this paper has three objectives. Firstly to evaluate the feasibility of the road network classification as presented by Bosman in 1988 after changes to the legal axle loads, which occurred in 1996. Secondly to revise the route classification system based on the actual traffic loading for the South African road network, if appropriate and finally to present a traffic loading reference guide for design, rehabilitation and maintenance purposes. Based on a literature review covering the South African and international vehicle and route classification systems, traffic loading data for South African road traffic routes are analysed. This comprises the analysis of traffic loading data collected at 301 Comprehensive Traffic Observation (CTO) stations along 40 different traffic routes. Utilising the South African National Roads Agency Limited's (SANRAL) vehicle classification system, selected road traffic routes were divided in three classification categories, namely short (S-roads), medium (M-roads) and long (L-roads). Each of the three road classification categories represents a unique set of heavy vehicle characteristics, which are highlighted in this paper. Finally the South African rural road network is classified accordingly.

INTRODUCTION

Background

South Africa's total road network consists of approximately 534 000 kilometres of road and is being used on a daily basis by various types of road users (DOT, 2002). The total road network comprises of a rural road network component of 364 000 kilometres of road and an urban road network component of 170 000 kilometres of road. Of the rural road network component, 63 000 kilometres of road are surfaced with the balance, 301 000 kilometres, being gravel roads. Road authorities in South Africa are therefore largely dependent on the availability of accurate traffic loading data for effective road network level management and long-term transportation strategic planning. It is therefore important to have a proper road network classification based on the actual traffic loading which will assist in the design of new roads, rehabilitation of existing roads and the overall network level management throughout South Africa.

Problem definition

Due to a growth in the road freight industry in South Africa, a demand has developed for the design and construction of new roads, the effective maintenance of the existing road infrastructure and the overall road network management in South Africa. To achieve these goals, a need has developed to investigate the existing road network classification based on the actual traffic loading for the major traffic routes throughout South Africa.

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Objectives

This paper has the following objectives:

- To evaluate the feasibility of the road network classification as presented by Bosman (1988) after changes to the legal axle loads (DOT, 1996).
- To revise the route classification system based on the latest available traffic loading data for the South African road network, if appropriate. National routes (N-routes), rural routes (R-routes), interurban routes (M-routes) and other road traffic routes will be assessed.
- To present a traffic loading reference guide for design, rehabilitation and maintenance purposes.

Scope of the paper

This paper will in the first place present the vehicle classification system presently being used in South Africa. Secondly, together with the previous information available and the road classification information provided by Bosman (1988), the traffic loading composition on selected traffic routes will be evaluated. Finally a route classification system based on these findings are proposed here for the South African road network.

LITERATURE REVIEW

South African vehicle classification system

The most simple vehicle classification used is a system that distinguishes between light and heavy vehicles, i.e. the number of heavy vehicles is expressed as a percentage of the total number of vehicles (Bosman, 1988). This system was used for many years but due to the large diversity in the characteristics of different heavy vehicles, a need for a more sophisticated classification system has developed.

Slavik (1985) presented a system that takes into consideration the difference in characteristics between heavy vehicles. According to this system heavy vehicles are classified into short heavy vehicles (rigid-chassis two or three-axle heavy vehicles), medium heavy vehicles (horse-plus-semi-trailer combination) and long heavy vehicles (horse-plus-semi-trailer combination with a full trailer). This classification system furthermore assumed that short heavy vehicles had an overall length of not more than 11 meters, medium heavy vehicles with an overall length between 11 meters and 18 meters and long heavy vehicles with an overall length of more than 18 meters.

Table 1. Comparison of the electronic vehicle classification schemes (Mikros, 1998).

SINGLE LOOP	DUAL LOOP	CODE	DUAL LOOP WITH AXLE SENSOR (RSA full)	DUAL LOOP WITH AXLE SENSOR (Toll)
None	***None***	1	Motorcycle *	Toll Class 1
Light	***Light***	2	Light Motor Vehicle	
		3	Light Motor Vehicle + Trailer	
Heavy	***Short Truck***	4	Two Axle Bus	Toll Class 2
		5	Two Axle Single Unit	
		6	Three Axle Bus + Trailer	Toll Class 3
		7	Two Axle Unit + Trailer (Max 4 Axles)	
		8	Three Axle Single Unit Incl Single axle Light Trailer	
	Medium Truck	9	Four or Less Axle Single Trailer	
		10	Buses with 5 or more Axles	Toll Class 4
		11	Three Axle Single Unit and Light Trailer (More than 4 Axles)	
		12	Five Axle Single Trailer	
		13	Six Axle Single Trailer	
	Long Truck	14	Five or Less Axle Multi-trailer	
		15	Six Axle Multi-trailer	
		16	Seven Axle Multi-trailer	
		17	Eight or more Axle Multi-trailer	

* Weigh in motion using capacitive sensors are not sensitive enough axle detection devices to be activated by motorcycles or very light trailers

Bosman (1988) proposed a route classification system based on the number of axles per heavy vehicle. Heavy vehicles in this method were defined as any rigid vehicle or vehicle combination with a gross vehicle mass (GVM) of more than 5 500 kg (TRH 16, 1991). This vehicle classification system consists of eight main categories, and is sub-divided into twenty-two sub-categories. The number of axles per heavy vehicle could therefore be derived from the class category.

The South African National Roads Agency Limited (SANRAL) presently uses an electronic vehicle classification system, which consists of five main vehicle categories and seventeen different vehicle codes as indicated in Table 1. For tolling purposes at the 28 toll plazas across South Africa, SANRAL has divided vehicles into four main classes, namely Toll Class 1 (all light vehicles), Toll Class 2 (two axle heavy vehicles), Toll Class 3 (three and four axle heavy vehicles) and Toll Class 4 (five and more axle heavy vehicles) (SANRAL, 2001).

International vehicle classification system approach

Heavy vehicle classification systems vary extensively from country to country. The type of vehicle in a specific country or region is a function of the legislation stipulating the permissible vehicle lengths and axle loads, the available vehicles on the local markets and the commodity that is being transported. Most of the different heavy vehicle classification systems provide heavy vehicle combinations commonly known.

Currer and Thompson (1972) have indicated a vehicle classification, which is mainly used for pavement design. The Transport and Road Research Laboratory's (TRRL, 1979) has a vehicle classification system which is used in England and other European Economic Community (EEC) countries. The emphases of these classification systems are on the type of heavy vehicle, i.e. rigid-chassis, linked-chassis or a combination. Thirteen vehicle classes (Scheme F classification codes) has been presented by the Federal Highway Administration (FHWA), USA (TRB, 2001). This vehicle classification system is based on the number of axles per vehicle and is exclusively used for collecting the traffic data needed for mechanistic-empirical pavement design by State Highway Agencies (SHAs) throughout the USA. Class 9, which are typically five axle single trailer type vehicles, are responsible for 80 to 90 percent of traffic loading on the interstate system.

South African route classification systems

The type of route classification used depends on the purpose of the classification, which can include those for transportation planning purposes, those for traffic count requirements, those for traffic composition purposes (Bosman, 1988) and those for structural design of pavements (TRH 4, 1996). The TRH 4 document divides road traffic routes into four different road categories, namely Category A (major interurban freeways and major rural roads), Category B (interurban collectors and rural roads), Category C (lightly trafficked rural roads, strategic roads) and Category D (rural access roads), based on the importance and design reliability.

The pavement design catalogue of the previous Transvaal Provincial Administration's Roads Branch (TPA, 1994), now Gautrans, divides road traffic routes into seven different classes, namely Class I (rural roads), Class II (rural access roads), Class III (rural major access roads), Class IV (rural major access roads), Class V (freeways and major access roads), Class VI (freeways and important major access roads) and Class VII (freeways) for pavement design purposes, based on cumulative equivalent 80 kN axle loads (E80s).

The different levels of roads are defined within the South African context as follows (DOT, 1991), i.e. primary roads, secondary roads and tertiary roads. These three levels of roads can be compared with the American Association of State Highway and Transportation Official's (AASHTO, 1990) classification system, namely rural principal and minor arterial system, rural collector system and rural local road system respectively.

This paper will analyze the route classification system presented by Bosman (TRH 16, 1991) which divides the road network into two main classes, namely L-roads and S-roads as indicated below. Selected routes, including those investigated by Bosman (1988), will be analyzed to determine if Bosman's route classification system based on the actual traffic loading is still applicable. In this regard, the E80–values used by Bosman would also be compared with the latest findings.

- L1: Two axle HV > 70 % of total HV's
- L2: 55 % < Two axle HV ≤ 70 % of total HV's
- S1: 35 % < Two axle HV ≤ 55 % of total HV's
- S2: Two axle HV ≤ 35 % of total HV's

The Class 20 (typical two axle vehicles) vehicles have been used as the categorizing criteria as its percentage shows the biggest variance in comparison to the other vehicle classes. The majority of the South African routes can be classified as L2 and S1-roads.

International route classification system

Route classification systems differ from country to country with many countries having their own distinctive route classification system. AASHTO (1990) divide roads into three main systems, namely the rural arterial system, the rural collector system and the rural local road system. Each of these systems is divided into subsystems again.

Conclusion

The literature review indicates that a difference in heavy vehicle characteristics, regulations as a result of legislation and changes in technology can all impact on vehicle classification systems. Based on the purpose of a road classification system, such a system could differ substantially from country to country. No drastic changes have taken place regarding the South African vehicle classification systems. Bosman's (1988) vehicle classification system has been replaced by SANRAL's (Mikros, 1998) electronic vehicle classification system, which is still in use to date. Bosman's (1988) road classification system is presently still in use as part of the TRH 16 document (1991). Based on the previous findings it was decided that SANRAL's vehicle classification system and the corresponding heavy vehicle traffic information collected by Mikros Traffic Monitoring on behalf of SANRAL would be used as a basis for this paper.

TRAFFIC LOADING DATA

Comprehensive traffic observations

In 1985 the Department of Transport (DOT) embarked on a program of comprehensive traffic observations (called the CTO program). Since then the counting network has been expanded to 110 permanent and 312 secondary stations, although the analysis in this paper only used 301 stations. Traffic information used in this paper, are those as condensed in the 1997, 1998 and 1999 CTO Yearbooks.

The average daily E80 on the road is calculated from the table of short, medium and long trucks observed during the period of monitoring and is based on the following assumptions:

- Axles / Truck : Short = 2, Medium = 5 and Long = 7
- Mass / Truck (ton) : Short = 10.9, Medium = 31.5 and Long = 42.8
- E80's / Truck : Short = 0.6, Medium = 2.5 and Long = 4.1

It has to be noted that the mass/truck and E80/truck-values for the long vehicles have been adjusted from 39.8 t to 42.8 t and 2.1 to 4.1 respectively (CTO, 1990).

Processing and interpretation of traffic loading data

The traffic loading data for four main traffic routes that involve 40 individual road traffic routes throughout South Africa were assessed (Smith, 2001). This traffic data were collected at 301 different CTO stations, which include 242 stations along N–routes (national routes), 57 stations along R-routes (rural routes), one station along a M-route (interurban route) and one station along a minor route.

To be able to process the traffic loading data, the actual data collected over the three-year period at the different CTO stations has been combined and the averages for the different traffic loading characteristics calculated. This has been done for all the different traffic routes and their respective CTO stations. Once the data had been processed, a route classification system representative of the data had to be chosen. For the sake of simplicity it was decided to restrict the road classification to three major road categories. To be able to relate to the electronic vehicle classification scheme used by SANRAL (Mikros, 1998), it was decided to refer to three road classification categories only, namely Short roads (S-roads), Medium roads (M-roads) and

Long roads (L-roads) (Smith, 2001). The S-class (typical short trucks) vehicle results show the largest variation of the three different vehicle class categories and were therefore taken as the standard of comparison. This was done similar to Bosman's (1988) approach to use the two axle heavy vehicle as the standard of comparison. The N3 and N4–national road traffic routes were initially used as experimental sections to determine what the proposed cut off values for the three different road classification categories should be. In line with the aforementioned and to assure that each road classification category has it own distinct characteristics, the following cut off values were selected, which differed from that proposed by Bosman (1988) in the range limits:

- S-road category : S-class vehicles > 65 % of total heavy vehicles
- M-road category : 35 % < S-class vehicles ≤ 65 % of total heavy vehicles
- L-road category : S-class vehicles ≤ 35 % of total heavy vehicles

Once the road classification system criteria have been applied, each CTO station was sorted to its applicable road classification system, i.e. S-road, M-road or L-road. In addition to this, the M-class/S-class vehicle ratio, L-class/S-class vehicle ratio and the L-class/M-class vehicle ratio for each of the CTO stations were calculated to provide additional information on each distinctive road category.

Following this process, average values for each of the estimated heavy vehicle characteristics were calculated for the three different road classification categories. Finally average values for each of the heavy vehicle characteristics along the specific road traffic routes, within the three different road classification categories, were also calculated. These results are summarized in Table 2, and are discussed in section 4.

A further observation is that the majority of the N–national road traffic routes CTO readings fall within the L-road category. Out of a total of 242 CTO stations analyzed, 91 percent fall within the L and M-road category CTO readings and the remaining 9 percent is made up of S-road category CTO readings. This is as a result of the longer multi-axle heavy vehicles been used to transport road freight over long distances and inter provincial national routes (N-routes).

In contrast with the latter, R-rural road traffic routes consist largely out of a combination of S and M-road category CTO stations. This is evident from the 57 CTO readings of which 93 percent consist of S and M-road category stations and 7 percent of L-road category stations. This is due to the fact that shorter heavy vehicles with fewer axles are used to transport road freight over the shorter distances which is the road network consisting mainly of the R-routes.

The M-interurban and other road traffic routes consist largely out of M-road category CTO stations and no L-road category CTO stations.

EVALUATION OF THE PROCESSED DATA

Bosman's traffic loading data

Bosman (1988) divided traffic routes into L-routes and S-routes. The L-routes consist mainly of the light heavy vehicles, i.e. Class 20 and Class 30–vehicles. The S–routes consist of the larger heavy vehicles, i.e. Class 40, Class 50, Class 60, Class 70 and Class 80–vehicles. The L–routes are divided into L1 and L2–routes and S–routes into S1 and S2–routes. Bosman's heavy vehicle classification is based on surveys done from 1979 to 1988 at 116 different locations along provincial and national routes throughout South Africa.

Comparison between the latest and Bosman's traffic loading data of 1988

To be able to compare the latest traffic loading data with Bosman's traffic loading data, it was decided to in the first instance compare Bosman's heavy vehicle classification system (Bosman, 1988) with the classification system used by the SANRAL (Mikros, 1998). Although it is not possible to compare Bosman's vehicle classification precisely with that of SANRAL, a certain resemblance can be observed.

Secondly it was decided to compare Bosman's road classification system with the proposed road classification system. Ideally, one would have liked to compare the traffic loading data collected at 116 different locations with the latest traffic loading, but because no precise descriptions of where these 116 locations are situated could be traced, it was decided only to compare the final average values presented by

Bosman (1988) with the latest findings. In Table 2 Bosman's and the proposed road classification findings are presented.

Table 2. Comparison between Bosman's (1988) and the proposed road classification system.

BOSMAN'S ROAD CLASSIFICATION SYSTEM									PROPOSED ROAD CLASSIFICATION SYSTEM				
	HEAVY VEHICLE CLASSES									HEAVY VEHICLE CLASSES			
	20	***30***	***40***	***50***	***60***	***70***	***80***			***S-class***	***M-class***	***L-class***	
	AVERAGE E80 – VALUE PER HEAVY VEHICLE CLASS									AVERAGE E80– VALUE PER HEAVY VEHICLE CLASS			
	1.17	1.97	2.70	3.05	3.92	3.12	3.12			0.60	2.50	4.10	
ROAD CATEGORY	**HEAVY VEHICLE COMPOSITION (%)**							**AV. E80-VALUE**	**ROAD CATEGORY**	**HEAVY VEHICLE COMPOSITION (%)**			**AV. E80-VALUE**
L1–ROAD	77	9	5	6	1	1.5	0.5	1.5	**S–ROAD**	71	19	10	1.3
L2–ROAD	61	12	8	14	2.5	2	0.5	1.8	**M–ROAD**	49	26	25	2.0
S1–ROAD	46	12	10	21	6	5	-	2.1	**L-ROAD**	26	26	48	2.8
S2–ROAD	26	11	9	30	12	12	-	2.5					

Utilizing the average E80–value indicated for each road category as the comparative criteria, it could be seen that Bosman's L1-road compares well with the proposed S-road category. Similarly Bosman's L2-road category and the proposed M-road category can be compared. Finally Bosman's S1 and S2-road categories appear to be equivalent to the proposed L-road category.

A South African route classification system based on the latest traffic loading data

Based on the findings summarized in Section 3 of this paper, a South African route classification system was compiled. This system is based on the traffic loading data that was analyzed for the 301 CTO stations along the 40 various routes across South Africa.

The latest route classification system indicates that along the N-routes more than one road classification category can be applicable. This is mainly due to the fact that the N-routes have much longer overall lengths compared to the R or M-routes which lend itself to a larger variation in the nature of the heavy vehicle traffic composition.

Comparing Bosman's route classification system with that of the proposed route classification system, with specific reference to certain N-road traffic routes, the following is observed:

- N1-route: The road classification category (L-road) is similar to that described by Bosman (S1-road).
- N2-route: For the majority of this route, the M-road classification corresponds with Bosman's L2-road classification. However, there are sections where the road classification has changed from a M-road (L2-road) category to a L-road category (S1 or S2-road). This can be observed near Heidelberg and Humansdorp in the Eastern Cape. Near Port Elizabeth the road classification changed from a M-road (L2-road) category to a S-road (L1-road) category.
- N3-route: The road classification for this route (L-road) is similar to that indicated by Bosman. Near Durban the road category has changed from a S-road (L1-road) category to a M-road category.
- N4-route: The road category (M and L-roads) corresponds well with that previously indicated by Bosman. Near Middelburg, east of Pretoria, certain sections appear to be of the S–road category.
- N14-route: This road traffic route has changed from a L-road (S1-road) category to a M-road category.
- Another interesting phenomenon can be observed along the road traffic routes surrounding Johannesburg. The N1-route north of Johannesburg mainly falls under the M-road category whereas the traffic routes (N12-route) south of Johannesburg carries S-road category traffic.
- L-road category roads appear to be applicable to the longer N-road traffic routes, whereas M and S-road categories are mostly confined to the major cities and their immediate surrounding areas.

Table 3 summarizes the heavy vehicle characteristics unique to the three road categories based on the data found from the CTO Data Bank of 1997, 1998 and 1999 (this study).

Table 3. Summary of the Heavy Vehicle Characteristics for the three Road Categories.

AV. TRUCK SPLIT (%)			AV. NUMBER OF AXLES PER TRUCK	AV. TRUCK MASS (Ton/truck)	AV. E80/TRUCK	AV. DAILY E80 ON THE ROAD	AV. M/S-RATIO	AV. L/S-RATIO	AV. L/M-RATIO
S	M	L							
S-ROADS									
71	19	10	3.1	18.0	1.3	1 757	0.3	0.1	0.6
M-ROAD									
49	26	25	4.1	24.2	2.0	2 350	0.6	0.6	1.1
L-ROAD									
26	26	48	5.2	31.2	2.8	2 576	1.0	2.2	2.3

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This paper had the following three objectives in mind, namely:

- To evaluate the feasibility of the road network classification as presented by Bosman (1988) after changes to the legal axle loads (DOT, 1996).
- To revise the route classification system based on the latest available traffic loading data for the South African road network, if appropriate. N-routes, R-routes, M-routes and other road traffic routes were assessed.
- To present a traffic loading reference guide for design, rehabilitation and maintenance purposes.

With the aforementioned objectives in mind, traffic-loading data obtained from the CTO Data Bank were analyzed. A three-category road classification system, namely S-road, M-road and L-road categories, has been implemented (Smith, 2001). The applicable cut off values, which differs from that proposed by Bosman (1988) in the range limits, are the following:

- S-road category : S-class vehicles > 65 % of Total heavy vehicles
- M-road category : 35 % < S-class vehicles ≤ 65 % of Total heavy vehicles
- L-road category : S-class vehicles ≤ 35 % of Total heavy vehicles

Further findings include the following:

- For the N-road traffic routes, 91 percent of the CTO readings fall under the L and M-road classification categories. For the R-road traffic routes it is observed that 93 percent of the CTO readings fall under the S and M-road classification categories. Traffic loading data for M and other road traffic routes consist out of M-road classification CTO readings and no L-road classification CTO readings.
- Under the S-road category CTO stations, the N-routes have the higher average number of axles per truck, average truck mass and E80/truck–values compared to those average values of the combined N, R, M and other road traffic routes. For the M-road category CTO stations the pattern is similar to that for the S-road category CTO stations. For the L-road category CTO stations, the average number of axles per truck, average truck mass and estimated E80/truck–values of the N-road traffic routes are higher than those of the average values for the combined N, R, M and other road traffic routes.
- The proposed South African road classification system compares well with the classification system proposed by Bosman. A change in the applicable road category along certain road traffic routes is observed.

Recommendations

Based on the findings and conclusions made in this paper, the following recommendations can be made:

- A three-category road classification system consisting of the S-road, M-road and L-road categories with their respective heavy vehicle characteristics should be used to classify road traffic routes across South Africa.
- The proposed national road classification system, based on the aforementioned road classification categories, should be used as a traffic loading reference guide for design, rehabilitation and maintenance purposes.
- Follow up research on outstanding road traffic routes, based on the latest road traffic classification system proposed in this paper, should be encouraged to enable an even fuller picture of the South African road traffic network traffic loading characteristics.
- In addition to the aforementioned research, certain road traffic routes with available high speed weigh in motion (HSWIM) devices, should be selected to verify the recorded heavy vehicle loading characteristics, as proposed by SANRAL and Mikros Traffic Monitoring, applicable to these selected road traffic routes.

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