OVERLOAD IMPACTS ON PAVEMENT DESIGN AND PERFORMANCE – BRAZILIAN TRAFFIC LOAD LAW CHANGE AND IT'S CONSEQUENSES

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ABSTRACT

Pavement are designed to withstand the action of a given traffic over a pre-established period, considering that the volume of commercial traffic transports total loads. Traffic is composed by diverse types of vehicle with different axles configurations and tires types. The impact of these axles on pavement is responsible for pavement fatigue and permanent deformation – progressive damage caused from many load applications. A variation of load profile may adversely affect the accuracy of pavement investment plan and lead to poorer asphalt performance. Studies indicate that excess loads in Brazilian highways are recurrent and are increasing due to a higher axle load tolerance. It is known that small increases in load results in an exponential impact on pavement damage. At this point, it should be noted that the increase in the tolerance of axle loads occurred in 2014 in Brazil, resulting on the increase of the cargo transported, incorporating the so-called "load tolerance" in the transported load may decrease the pavement performance. Thus, this paper investigates the impact of overloaded vehicles on road pavements by studying the impact of the new Brazilian law to traffic load control on pavement design and performance.

Keywords: Overload. Traffic load control. Pavement performance. Pavement maintenance.

1. INTRODUCTION

Pavement are designed to withstand the action of a given traffic over a pre-established period. By knowing the traffic profile of a given highway and assuming compliance with the law it is possible to design a pavement structure and estimate maintenance works. While on the one hand the excess of loads per axle increases the productivity and profits of the transport industry, on the other hand, it produces an undesirable effect on the pavements structures [1]. Higher loads imply a more accelerated damage to the pavement that can be verified by the widely used concept of equivalent axle loads. Variations of the load profile may have a significant impact on pavement maintenance plan.

In 2014 an important change has occurred in Brazilian vehicle load rules when it was published in June a new resolution allowing an extra 2,5% tolerance on vehicle axles loads. This has become a national law one year later.

This paper presents results of this new resolution / law on the traffic load profile of an important São Paulo state road, and consequently estimates this impact in terms of equivalent axels factor, used in pavement design and maintenance plans.

1.1 Background

The equivalent curves of tonne per axle associated to pavement damage are exponentially accentuated, which means that adopting a higher limit of load per axel results in a significant impact on the number of equivalent standard axes [2]. Several studies have already analyzed the overweight effects on the pavement and/or the associated costs [1, 2, 3, 4]. This makes even more evident the importance of studding the overload effects on pavement performance.

According to the National Department of Terrestrial Infrastructure (DNIT) traffic study manual [5] overweight vehicles can cause serious disorders to the safety, comfort and traffic flow, as well as road structures. Weight control is, therefore, a procedure of the highest relevance.

Although historically acknowledged the relevance of the axle loads damages on the pavement, in Brazil little attention is given to the activities of load control. In practice there is an inefficient control system, due to the poor location, distance between the weighing stations and the need for a prosecutor with police power to fine an irregular truck. As result, there is an abuse of overweight traffic on the highways, which is not discouraged by an efficient system of sanctioning and supervision. According to Brazilian transport planning company (GEIPOT) and DNIT it is estimated that Brazilian highways trucks travel with overloads of 10 to 30% [1].

In 2014 significant changes have been made in the maximum legal truck load control legislation. Among the main changes trucks were allowed to travel with larger axles loads and, consequently, a higher load profile was established on the highways. In the last changes that occurred allowed a higher tolerance in the maximum load over the maximum limit stablish in Brazilian law. Impacts has been noticed on pavements performance, that are supporting a new traffic load profile not originally predicted.

1.2 Summary of Maximum Legal Load Brazilian Legislation

On November 25, 1985, law Nº 7,408, Article 1 [6], allowed a 5% tolerance over the total gross weight limit and gross weight limit transmitted by axle to the surface of public roads. Only in 1994 the tolerance reason was clarified, by the Nation Transit Council (CONTRAN) 6º decision [7], claiming that the margin is intended to equalize possible weighing gauging discrepancies.

On August 31, 1999, CONTRAN Resolution Nº 102, Article 1 [8], allowed a maximum tolerance of 7.5% of the limits of gross weight transmitted per axle was allowed. Shortly after, on December 21, 1999, CONTRAN Resolution No. 104, Article 6 [9], stated that when the measured weight is above the total gross weight limit established for the vehicle, added the 5% tolerance, the corresponding fine should not consider the excess weight relative to the tolerance portion. This article created an opening to transporters for incorporating the tolerance to the total gross weight. Peterlini (2006) [10] verified this outcome analyzing weighing data of the State of Paraná before and after the tolerance change from 5% to 7.5% by determining the vehicle factors behaviors.

On November 30, 2007, CONTRAN Resolution No. 258 [11], revoked the No. 102/99 [8], No. 104/99 [9] and No. 114/00 [12] resolutions and established a maximum tolerance of 5% over the limits of regulatory weights due to the measurement uncertainty of the equipment. However, at its 17º article the 7.5% tolerance of the limits of gross weight transmitted per axle was allowed until December 31, 2008. At this point, the 7,5% tolerance period, that was supposed to end at December 31, 2008, was continuously renewed by several resolutions, presented at Table 1.

TABLE 1 Resolutions updating the 7.5% tolerance validity period

Description	Date	Extension Period
Resolution Nº 301 [13]	12/18/08	06/30/09
Resolution Nº 328 [14]	08/14/09	12/31/09
Resolution Nº 337 [15]	12/17/09	06/30/10
Resolution Nº 353 [16]	12/31/10	12/31/10
Resolution Nº 365 [17]	11/24/10	12/31/11
Deliberation Nº 117 [18]	12/19/11	05/31/12
Resolution Nº 403 [19]	04/16/12	01/31/13
Resolution Nº 430 [20]	01/23/13	12/31/13
Resolution Nº 467 [21]	12/11/13	06/30/14

The June 05, 2014, Resolution No. 489 [22], ended the updating cycle and increased the gross weight transmitted per axle tolerance from 7.5% to 10% for those vehicles that do not exceed the maximum legal load limits plus the tolerance of 5.0% in the combined total gross weight. The same resolution establishes that if the excesses measured on each axle or set of axles are both less than 12.5%, regardless the nature of the load, the vehicle may proceed without re-routing or transhipment. This article creates an opening for vehicles with overloads up to 12.5% per axle, even though fined, to travel on the roads.

Lastly, on March 2, 2015, law No. 13,103, Article 16 [23] revoked the law 7,408, Article 1 [7], and allowed a maximum tolerance of 10% on the gross vehicle weight limits transmitted by vehicle axle to the surface of public roads, regardless the combined total gross weight limit.

2. DATA AND METHODOLOGY

The aim of the present study is to clearly verify the impact of the last legislations changes on vehicle load traffic control on the fleet load profile of a selected highway based on actual weighing data. The objective is to prove that the legislation latest changes had a significant impact on the fatigue consumption rate and accelerated the damage cause by commercial vehicles transporting higher weights since June 2014.

2.1 Data

There are several possible weighing control procedures, such as permanent balances, portable balances, weigh in motion systems, among others. The data analyzed in this study was selected from a permanent weighing station on a main highway in the state of São Paulo. Care has been taken to select a station that had been running for a minimum period to evaluate the two latest legislation changes (June/2014 [22] and March/2015 [23]) based on a consistent historical database.

There are two weighing steps on the considered station: selective weighing and punitive weighing. At first, the vehicles are evaluated in the selective weighing and, those with suspected overload, are sent to the punitive weighing (with a higher accuracy). To determine the actual highway load profile, the selective weighing data was chosen to be analyzed, since the punitive weighing has the tendency to present higher load profile because it just weighs overload suspected vehicles.

From each vehicle analyzed were collected a list of relevant data to the study: date and time of the weighing, number of axles, DNIT classification, combined total gross weight and individual weight transmitted by the vehicles axles. It was selected data from four months to fully characterize the gross weight transmitted per axle tolerance from 7.5% to 10%: May/2013, May/2014, Aug/2014 and May/2016. Notice that two months were selected in 2014, one before the legislation change and one after, to clearly demonstrate the legislation impact.

In addition, records of the punitive balance were collected to analyze the relative behavior of the number of infractions over the total inspected. To verify if it is occurring changes in overload vehicles it was stablish the percentage of vehicle overload as a relation of total fined vehicle (after punitive weighing analyze) and the total inspected (considered from the selective weighing).

2.2 Methodology

All the collected data were tabulated, classified and organized to standardize all the weighing records and allow a fair comparison between the months data. Once it was collected the station raw data, it was necessary to purge some records that can be considered as possible errors. The records that fitted within the following criteria were purged from the sample:

- Vehicles with identification inconsistency (different sets of axles from the expected to vehicle classification);
- Vehicles with load on some axle above 10% of the maximum legal load;
- Vehicles with load on some axle higher than 100% of the maximum legal load.

The convert the vehicle fleet into an equivalent traffic it is applied on a so-called load equivalence factors. These factors allow converting an application of a selected axis by a given load into a determined number of applications of a standard axis that should produce an equivalent effect.

The monthly equivalence factors to the standard single load of 8.2 tf considering the DNIT Traffic Study Manual [5] equations of the U.S. Army Corps of Engineers (USACE) methodology, reproduced on Table 2.

TABLE 2 Load equivalent factors USACE equations

Axis Type	Load Range (t)	Equations (P [t])
Single Front /	< 8	$FC = 2.0782x10^{-4} \times P^{4.0175}$
Single Back	> 8	$FC = 1.8320x10^{-6} \times P^{6.2542}$
Double Tandem	< 11	$FC = 1.592x10^{-4} \times P^{3.472}$
	> 11	$FC = 1.528x10^{-6} \times P^{5.484}$
Triple Tandem	< 18	$FC = 8.0359x10^{-5} \times P^{3.3549}$
	> 18	$FC = 1.3229x10^{-7} \times P^{5.5789}$

Source: DNIT Traffic Study Manual [5]

The equivalent load factor was calculated considering several conditions: real load profile and limited legal load profile. The real load profile was determined considering the real data of the weighing and the limited legal load profiles were determined limiting the axles loads in the legal load plus the legal tolerances (0%, 7.5%, 10% and 12.5%). The loads beyond the legal limit plus the tolerance were accumulated and later converted into additional vehicles in the fleet.

In the other hand it was determinate the percentage of fined trucks related to the total the total inspected considered to verify if it is occurring or not more overload vehicles in the fleet.

3. LEGISLATION CHANGES IMPACTS IN THE OPERATIONAL TRAFFIC LOAD PROFILE

Once calculated the load equivalence factor, the individual vehicle factors for each analyzed vehicle were determined, and, subsequently, the month mean. The fleet representative vehicle factor is presented in Figure 1 for each month and tolerance scenarios considered.

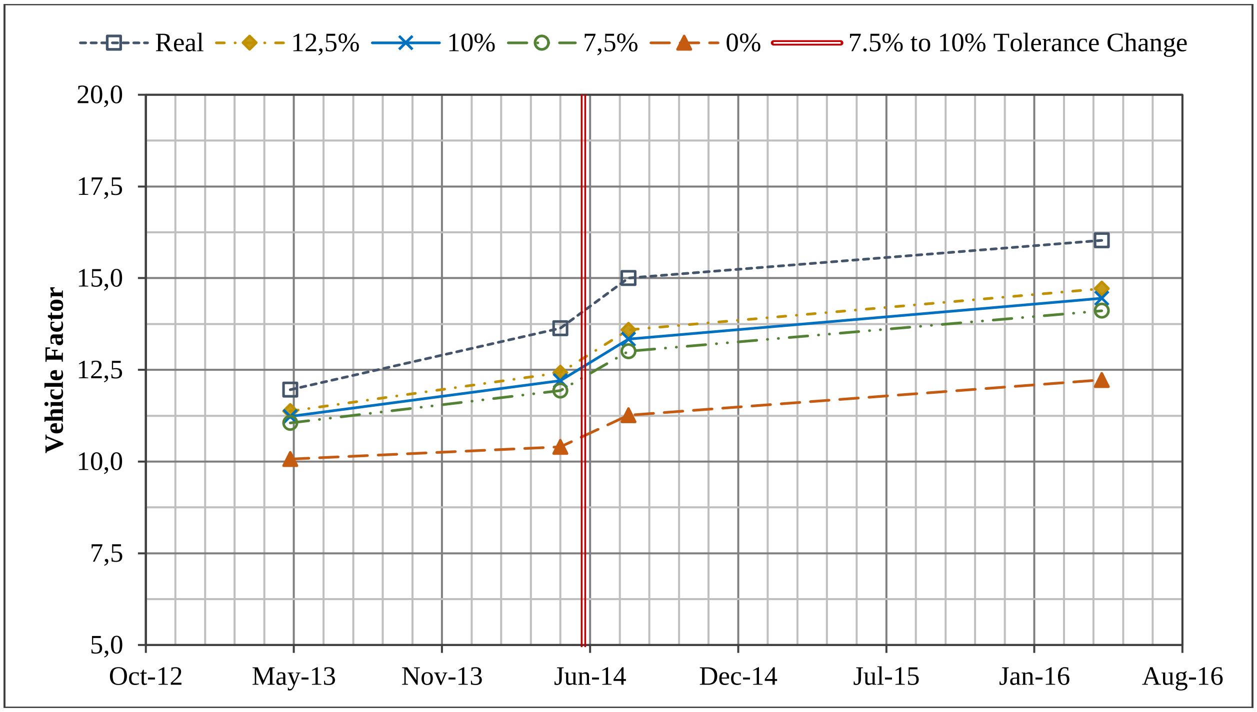

FIGURE 1 Fleet representative vehicle factors over years considering data from punitive weighing

The increase in the legal load limited vehicle factor also demonstrates the incorporation of the tolerance on the total gross weight. Once the tolerance was incorporated on the gross weight, more vehicles travel closer to the legal limit (without any tolerance) and the load profile increased. It is possible to visualize, in Figure 1, that load profile increased over the years, mainly in the year of 2014, before and after the legislation change. All the vehicles factors in Aug/14 were roughly 10% higher than the calculated in May/14. This gap represents the effect of the tolerance legislation change on the load profile. Trucks travel with more cargo, due to the higher tolerance, and, consequently, the fleet vehicle factor increases.

Also, Figure 1 explicitly shows the increase in the load profile when several tolerances are considered. The vehicle factors real, limited at 12.5%, 10%, 7,5% and 5% tolerances are roughly 30%, 20%, 18% and 15%, higher than the limited without any tolerance, respectively. This analysis shows the effects of changing the tolerance from 7.5% to 10% and allowing vehicles with overloads up to 12.5% per axle, even though fined, to travel on the roads, resulting in accelerated damages caused by commercial vehicles, reducing on expected pavement live and resulting on increases on pavement maintenance costs.

It is worth noticing that the vehicle factor was even higher in May/2016, what can reflect either that more vehicles are transporting a higher cargo throw a change in vehicles types that composes the fleet. Figure 2 shows that the percentage of fined vehicles are round 1,8% ± 1%, and that results previously presented are not affected by increases on overload vehicles. This value was 1,7% in May/13 and 1,5% in May/16. In Aug/14 the records were 0,2% above May/14 values.

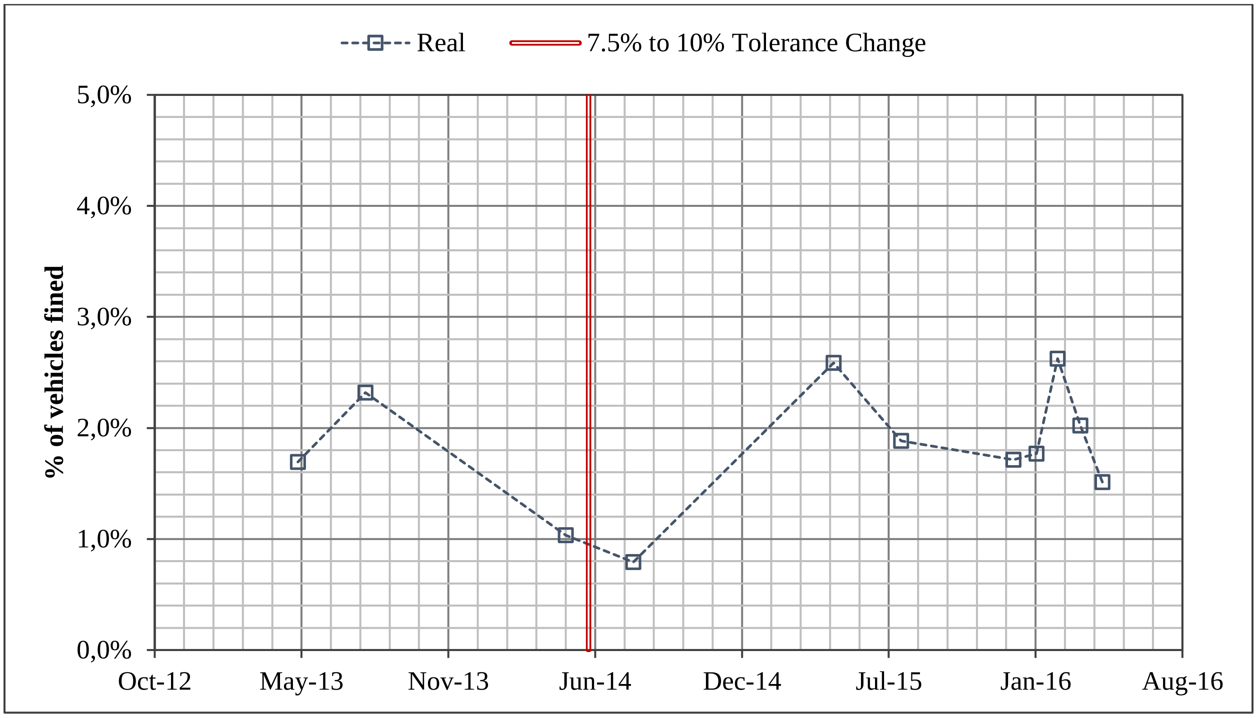

FIGURE 2 Percentage of vehicles fined because of load excess (over the allowed tolerance)

4. CONCLUSIONS

The impact of the last legislations changes on vehicle load traffic control on the fleet load profile of a selected highway based on actual weighing data was demonstrated. These recent changes on Brazilian traffic load control are resulting in more cargo per vehicle, impact on the fatigue consumption rate and accelerated the damage cause by commercial vehicles transporting higher weights since June 2014.

Assuming tolerances of 5%, 7,5%, 10% and 12,5% over the maximum legal load per axel results in an equivalent traffic 15% to 30% higher than the obtained without any tolerance, reducing on expected pavement live and resulting on increases on pavement maintenance costs. This study demonstrates the importance of establishing an analysis methodology and determining the overloads impacts on the highways and its consequences on investments plans. It must be noted that lack of a continuous enforcement results is another factor that was not considered on these results.

5. ACKNOWLEDGMENT

The authors would like to thank Ecorodovias Concessões e Serviços and to RoadRunner Engenharia by the support offered in the development of the present study.

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