Impact of Heavy Vehicle Axle Overload and Axle Configuration on Road Damage in Afghanistan

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Abstract

Aim: This study aimed to determine the percentage of heavy vehicles, overloaded vehicles, and heaviest vehicle that leads to deterioration of asphalt roads. Furthermore, the study aimed to assess the impact of ESALs and axle configuration on asphalt thickness and subgrade.

Methods: This research used quantitative truck traffic data collected for three months in the Laghman WIM (Weigh in Motion) station located on the Kabul Torkham National Highway. Observed axle loads and GVW (Gross Vehicle Weight) data collected from April/ 10/2022, up to June/7/2022 average daily truck traffic of 73895 was estimated axle loads converted to the standard axle ESALs (Equivalent Single Axle Loads).

Results: The percentage of heavy overweight vehicles is 13% while the heaviest vehicle is T2-Bedford truck vehicles at 20.17%. The T2 Bedford truck percentage was 42.17% in overall volume; this truck was overloaded 20.17%, compared to the general trend of Ministry of Public Works (MoPW), the T3 Hino truck contribution was 1.24% in total volume and 18.64% was overloaded, the ST112 semi-trailer contributed 3.02% in total volume, and 8.52% were overloaded. The ST113 5-axle and TT123 6-axle trailers percentile in entire volume was 9.6 % and 40.85% whereas, the overloading degree for these heavy vehicles was 2.29% and 6.72% respectively.

Conclusion: Overloading percentage is 13% while, T2 Truck is the heaviest vehicle The variation of ESALs and axle configuration on asphalt thickness and subgrade modulus illustrates the higher thickness of asphalt decreases the damage to asphalt roads.

Recommendations: Afghanistan Weigh-in-Motion stations need professional employees, internet facilities, electricity, and proper databases to record the data. By applying tight legislation and fines overloading will be minimized. Researchers may also research heavy vehicle tires' impact on road damage. Furthermore, it needs to determine the level of fatigue cracking and rutting failures by overloading.

Keywords: _ESALs, heavy vehicles, axle configuration, road damage_

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INTRODUCTION

The transport network is an essential contributor to a country's socioeconomic well-being. The characteristics of materials and layer thickness of pavement, heavy vehicle traffic, and environmental effects or climate conditions play an important role in the premature deterioration of a road structure. Heavyweight traffic has a significant role in the failure of asphalt roads. The constant movement of loaded trucks or semi-trailers on the road surface causes fatigue, which reduces a road's design year, and rutting, which reduces the serviceability of the bounded surface. Fatigue cracking is caused by excessive horizontal tensile strain, and vertical compressive stresses cause permanent deformation rutting. Heavy traffic axle loads deteriorate roads and raise the cost of pavement maintenance after construction (Zaghloul & White, 1994).

It is determined that compressive and tensile strength on road pavement is the result of loaded tractor-trailer force applied on a road surface(Officials, 1993). Truck traffic is the primary cause of roadway destruction, reducing the design life of a road. Heavy vehicle overloading is a huge concern in Afghanistan, with trucks carrying more weight than the allowable Loads of MoPW (Ministry of Public Works). Maximum load creates fatigue distress on road surface, the weight of 10000 LB on an axle with a single tire is more devastating than 20000lb weight on single axle dual tires (Gillespie, 1993). Results from the field and laboratory experiments showed that overloaded axles induce asphalt pavement to rut and develop fatigue cracks(Chatti et al., 2004).

A conventional five-axle tractor-semitrailer operating at 80,000 pounds gross vehicle weight (GVW) is equivalent to 2.4 ESALs. If GVW increases to 90,000 pounds (a 12.5 percent increase), its ESAL value goes up to 4.1 (a 70.8 percent increase). A six-axle tractor-semitrailer at 90,000 pounds has an ESAL value of only 2.0 because the distribution of loads was on six axles instead of five, and pavement damage increases at a geometric rate with weight increases(Hong & Prozzi, 2005). To calculate the TEF (Truck Equivalency Factor) for pavement design in Columbia, data from 38 WIM stations were obtained. C3-class single-unit trucks with three axles, one single axle, and one tandem axle, as well as C3-S3-6 class vehicles with a single and tandem tractor and tridem in the trailer, were massively overloaded (Fuentes et al., 2012). In Pakistan heavy vehicle overloading percentage is calculated for 101,585 heavy vehicles which collected from the WIM station on the N-5 national highway axle loads were converted to standard axle of 80 KN truck factor, resulting in more than 50% of heavy vehicle traffic being overloaded.

The percentage of overloading in a B2 Bedford truck with single steering and a rear axle was 34.45%. The S113 five-axle semi-trailer that has a single steering axle, the tractor axle, and rear tridem axles were 1.84% lower than the permissible GVW across all types. Overloading in the B2 class was the highest in all classes(Raheel et al., 2018). The Truck factor determined from WIM data, axle loads converted to the standard axle of 80KN. For the impact of ESALs, five different types of asphalt thickness (10, 15, 20, 25, and 30 cm) and sub-grade modulus (40, 60, 80, and 120 MPA) were considered. The results demonstrated that the effect of overloading vehicles was reduced by increasing the thickness of the asphalt layer, and the impact of overloading damage on the subgrade was reduced. The percentage of overloaded vehicles ranged between 40% and 60%. On the other hand, overloaded vehicles increase costs by more than 100% when compared to the same vehicles with legal loads (Pais et al., 2013).

Problem Statement

In Afghanistan, heavy vehicle body makers make the body larger to accommodate excessive weight and this action promotes damage the road network. WIM heavy vehicle overloading weak control system in Afghanistan. Local fabricators' modification of trucks to maximize freight volume has resulted in unmanaged axle load, which may damage the transportation system. The dynamic characteristics of the vehicle caused by tire-road interaction contribute to the axle load effect, which might hasten damage if/when it occurs. Ministry of Public Work reported in 2015 that 54 percent of roads need maintenance and repair also said, that 20 percent of roads are destroyed and 80 percent continue to deteriorate. USAID declared 150$ million dollars for Afghanistan road maintenance, in 2015 If roads are not properly maintained then it would cost $8.3 billion to replace Afghanistan's road infrastructure.

Objectives

This research's purpose was to determine:

1. Percentage of heavy vehicles, and overloaded vehicles.

2. The heaviest vehicle load that can deteriorate and cause major failure to the pavement.

3. Examining the general trend of heavy vehicle overloading in Afghanistan by comparing various GVW loads to the (MoPWs) permitted axle loads.

4. Impact of ESALs on asphalt thickness and subgrade modulus.

LITERATURE REVIEW

The structural number (SN) is the strength of the pavement that concludes layers thicknesses, indicating the total number of ESALs that a specific road surface can support a standard axle load of 80 KN or 18 Kips (Kilo pounds)(Schnoor & Horak, 2012). In Egypt, it was determined by BIASR software that the effects of axle overload on pavement performance and the tensile strain at the base of the asphalt layer and the top of the subgrade layer, axle overload increases compressive and tensile strain, causing fatigue damage raising axle load significantly reduces the relationship between the decline of asphalt modulus fatigue and rutting (Behiry, 2012). (Lakušić, 2016)studied the effect of different axle combinations of single axle single wheel, single axle with dual wheels, and dual and triple tandem axles with dual wheels; overweight was 120%, 135%, 150%, and 170% of the allowable axle weights in Brazil. It was explained that axle overload reduces pavement life by causing fatigue in road infrastructure.

Hadiwardoyo et al (2012) observed that truck traffic in Indonesia places a load on the road's surface depending on the type and number of axles, with two-axle trucks being more harmful to the road's pavement than vehicles with 3, 4, 5, and 6 axles. It is advised that a correction factor for ESAL take into account the additional impact caused by overweight axles, which will lengthen the life of the pavement and prevent early damage to the pavement. In Poland overloading of heavy vehicles is 5%; overweight is heavily regulated by enforcement, but with insufficient regulation, it rises to 23%, and the majority of truck traffic exceeds the maximum axle permissible weight limit. It shows that freight weight within trucks is frequently not distributed properly, which may be the result of drivers' recklessness or transport companies' ignorance (Rys & Jaskula, 2018).

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METHODOLOGY

Traffic Data Collection

Since overloading is a significant problem in Afghanistan the percentage of all trucks and overweight trucks of each class as well as the observation of maximum and average weights computed and compared to MoPW permitted loads. From April 10, 2022, and June 7, 2022, an average daily truck traffic of 73895 was estimated. The data was collected from Laghman WIM stations installed along the (Kabul-Torkham) national route. During the weighing of heavy traffic axle numbers (single, tandem, tridm), axle loads (steering and non-traction axles, tandem axle distance, and tridm axle outer distance), gross vehicle weight, and loaded traffic type were determined. This road is important for connecting Pakistan's Torkham border with Afghanistan's capital, as well as Tajikistan, Uzbekistan, and Iran with Afghanistan and Pakistan.
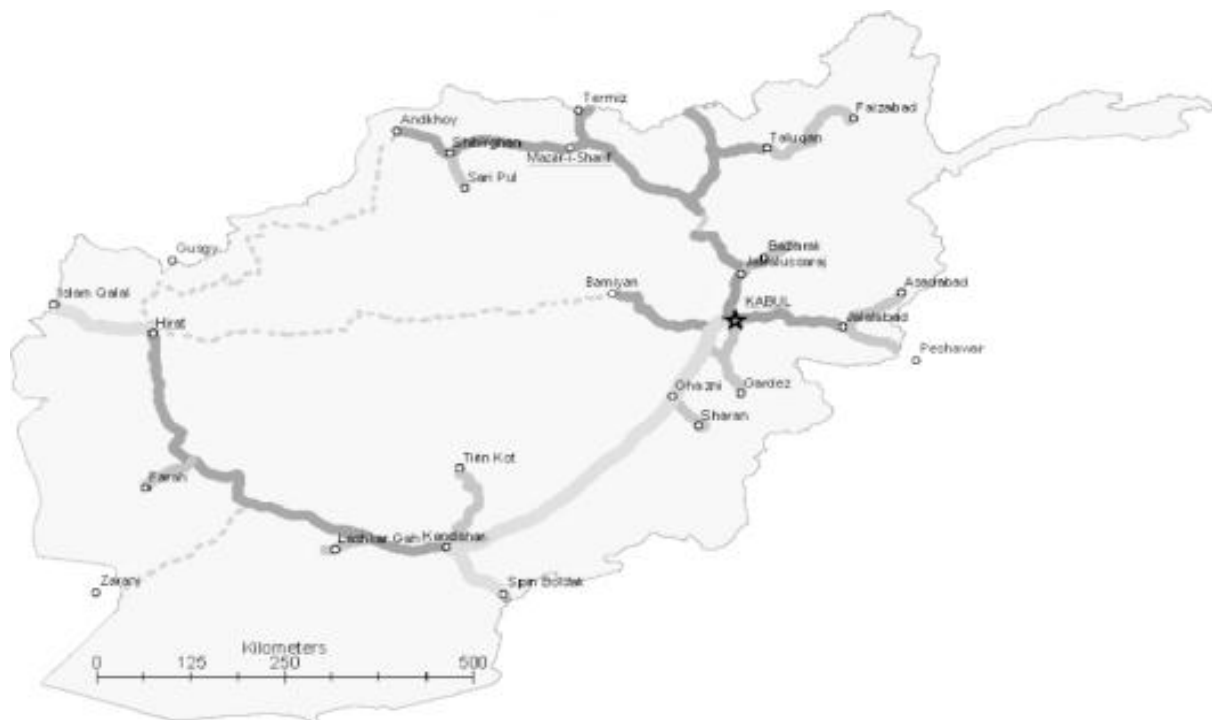

Figure 1: Kabul Jalalabad Highway and Afghanistan major ring road

Source: USAID

Ministry of Public Works classified truck traffic into two-axle, three-axle, four-axle, five-axle, and six-axle categories. The WIM (Weigh In Motion) station provided truck traffic data that included axle numbers, loads, and the total number of heavy vehicles. In addition, WIM explains the GVW (Gross Vehicle Weight). The data contrasted permissible axle weight, average, and maximum. Axle load converted to AASHTO1993 standard axle load of 80 KN; LEF (Load Equivalency Factor) and ESALs computed to demonstrate the impact of ESALs on road pavements. Table 1 shows the permitted axle loads for various types of heavy vehicles.

Table 1: Permissible axle loads of MoPW

Permissible Maximum Load Per Axle KN							
Vehicle Class	Vehicle Figures	First Axle	Second Axle	Third Axle	Fourth Axle	Fifth Axle	Sixth Axle
T2		53.94	117.68				
ST3		53.9	107.78	107.78			
ST112		53.9	117.68	107.78	107.78		
ST113		53.9	117.68	101.33	101.33	101.33	
TT123		53.9	107.78	107.78	101.33	101.33	101.33

Source: MoPW ("Afghanistan–Pakistan Transit Trade Agreement," 2022)

Figure 2: 2-axle truck
Source: filed visit

Figure 3: 3-axle truck
Source: filed visit

Figure 4: 4-axle truck
Source: filed visit

Figure 5: 5-axle truck
Source: filed visit

Figure 6: 6-axle truck
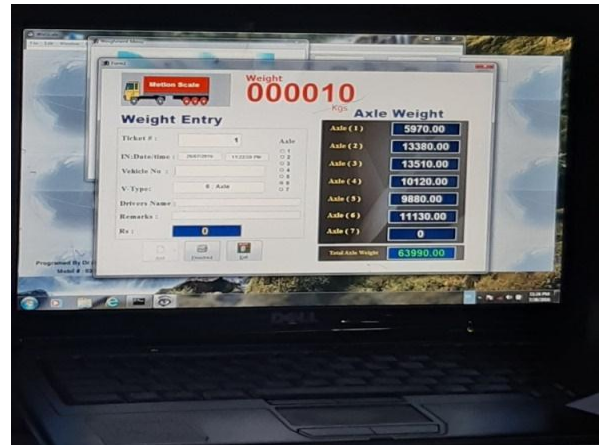*Source: filed visit*

Figure 7: Weighing in Motion
Source: filed visit

FINDINGS

Figure1. Illustrate the observation of truck traffic on Kabul-Torkham national highway 2-axle Bedford trucks and 6-axle trailers make up a significant portion of the truck traffic on the Kabul-Jalalabad national highway, which accounts for 42.7% of the T2 2-axle class and 4.8% of the ST3 single-unit tractor. The ST112 percentage is 3.02%, 9.6% of the ST113 semi-trailers, and 40.85% of the TT123 trailers.
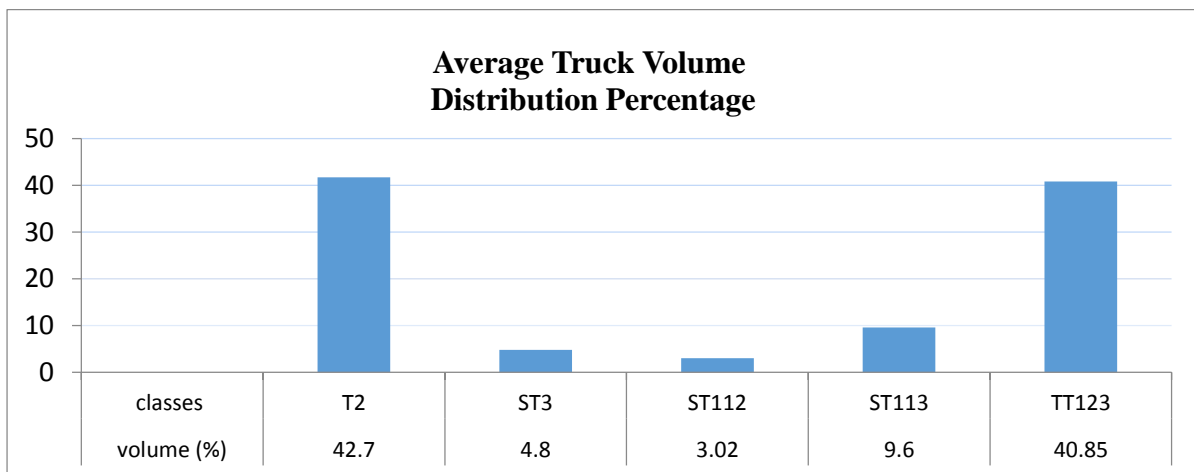

Average Truck Volume Distribution Percentage

classes	T2	ST3	ST112	ST113	TT123
volume (%)	42.7	4.8	3.02	9.6	40.85

Figure 8: Heavy vehicle volume percentage

Table 3 shows minimum, maximum, and average axle loads, T2 Bedford truck 2-axle single describes a high level of overloading (170.7 %), a maximum load of 292.72 KN, and an average load of 206.3 KN. The percentage of maximum overloading for ST3 Hino truck 3-Axle Tandems is 161.51%, however a maximum load of 435.45 KN and an average weight of 319.95 KN were recorded. The peak load for such a 4-axle Single Tandem ST112 semi-trailer was 532.26 KN, with a degree of overloading of 137.41%, and the ST113 semi-trailer truck's 5 Axle Single Tridem overloading percentage was 145.07%, and its measured weight was 690 KN. The TT1123 semi-trailer, which has six tandem axles, was found to be overloaded by 121.77%, with a maximum load of 698.56 KN and an average weight of 612.23 KN.

DISSCUSION

Figure 8 shows the average percentage of overloaded trucks in Afghanistan. The average load on a 2-axle truck is 206.23 KN, which is 20.17% more than the MoPW's permissible weights. The proportion of 3-axle Hino trucks in total truck traffic is 4.8%, and their average weight is 319.95 KN, which is 18.64% more than the MoPW's allowable weights. The proportion of 6-axle semi-trailers in the entire volume is 40.85%, and the overloading percentage is 6.72% with a weight of 612.63KN. Figure 12, illustrates the remaining categories of heavy trucks are listed.
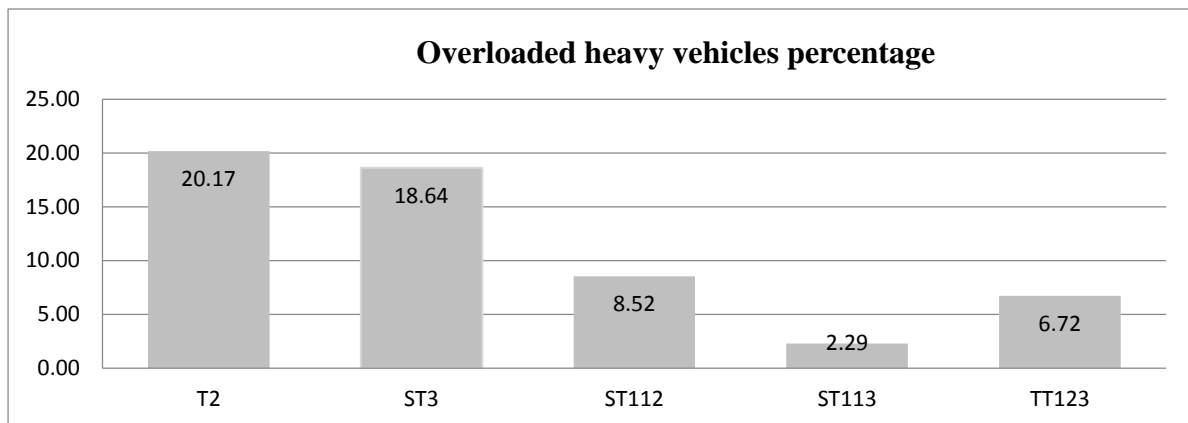

Figure 9: overloaded heavy vehicles

In comparison of GVW (Gross Vehicle Weight), three types of loads are compared. Legal load, WIM maximum Load, and WIM average load Figure 10 clearly shows the difference Max weight is on the top, while average weight is higher than permissible load.
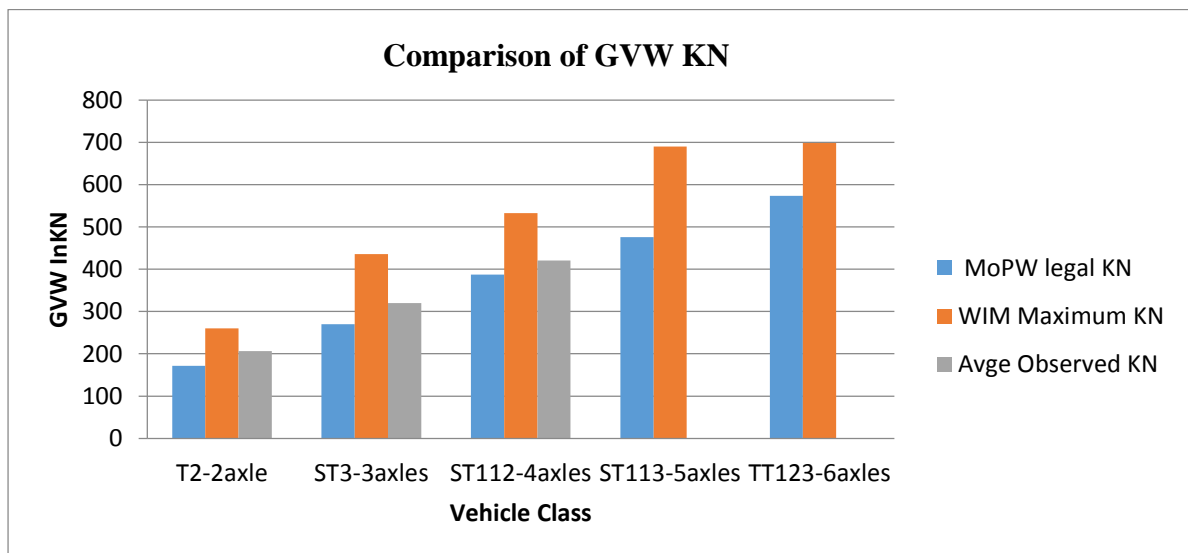

Figure 10: GVW Comparison

Figure 11 is the obtained WIM axle's field data compared with axle's weight which has been declared by MoPWs. Observed WIM data has compared for average axle loads and maximum axle loads with permissible loads and displayed the difference and overloading degrees of each axle in graphs. The data illustrates that rear axles are more overloaded than steering axles and the damage of single axles is higher than tandem and tridem axles.
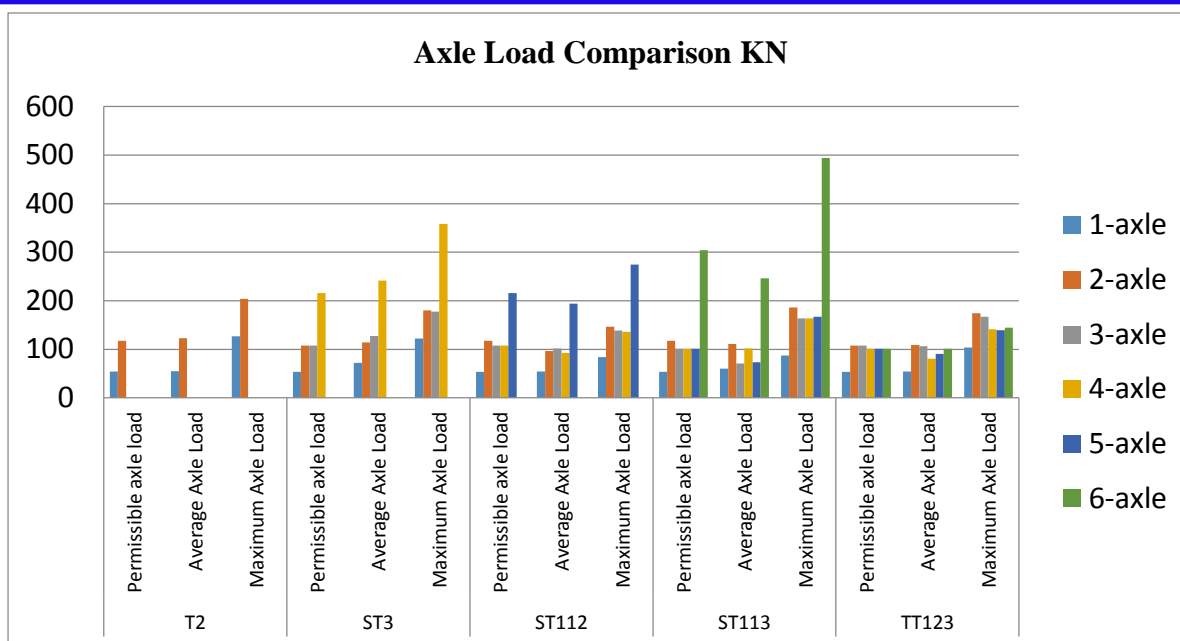
Figure 11: Permissible, average/max axle load percentage

CONCLUSION

Heavy vehicle overloading is 13% and the heaviest vehicle is T2-Bedford 2-axle truck furthermore, the T2-Truck is on top in overall volume. Since the freight traffic stream is the sum of distinct types of vehicles needed to convert the data to standard axle and ESALs, this relation is based on observed axle and standard axle of 80 KN this equation is presented by (De La Roche et al., 1994).

$$\text{ESAL}= K\left(\frac{Px}{P80}\right)^{\alpha} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(1)$$

Px= actual axle load (KN)

P80= standard axle 80 KN

K= coefficient that defines axle type (single, tandem, tridm)

α= coefficient that represents the distress of (Fatigue, Rutting)

French pavement design manual has determined the K value however it specifically incorporates the effect of axle configuration, furthermore (Pais et al., 2013)promoted an equation for K that contains asphalt layer thickness, subgrade modulus, and axle configuration in addition to axle load as given in equation 2, this equation represent the benefit of evaluation of truck factor while incorporating the configuration of axles as well.

K=254.03 * (Esub) 0.033393 * (h)-1.0416*(e)-1.2928*AP…………………………………(2)

Where

Esub= Modulus of subgrade (MPa)

H= Asphalt layer thickness (cm)

AP= Axle parameter defined in table

Equation 2 uses asphalt pavement that has a subgrade modulus of 500MPa and a granular layer of 20cm however, the indices of Esub, e, and h were calculated based on these values (Amorim et al., 2015a). The stiffness of the minimum asphalt layer and granular layer thickness is 10 cm and the modulus of 2500 MPa while the other layer thickness and subgrade modulus are introduced by (Amorim et al., 2015b). A value of 4 for α is representative of pavement failure mode, i.e. Fatigue (Pais et al., 2013). An α value obtained of 3.89 for tandem axles and rutting (Archilla & Madanat, 2000). Using a recursive nonlinear model, obtained a value of 4.2, which is near to 4, as considered in this study. Since the pavements in the study region suffer from fatigue failure, therefore, the value of α taken is 4(Prozzi & Madanat, 2003).

Table 2: Axle type and parameter value

Axle type	Axle parameter value
Single axle single wheel	1
Single axle double wheel	2
Tandem axle single wheel	3
Tandem axle dual wheel	4
Tridem axle single wheel	4.5
Tridem axle dual wheel	5.5

Figure 12 for average axle loads with α= 4 illustrates that the increase in subgrade stiffness has a minimal impact on the ESALs. Figure 14 depicts the impact of the coefficient, which is heavily influenced by the kind of pavement breakdown. As both rutting and fatigue mode of failure occur in Afghanistan, a value of 3.89 for the coefficient for rutting mode of failure and a value of 4.2 for the coefficient for fatigue mode of failure are employed, along with a value of 4 for the coefficient, throughout the research investigation.
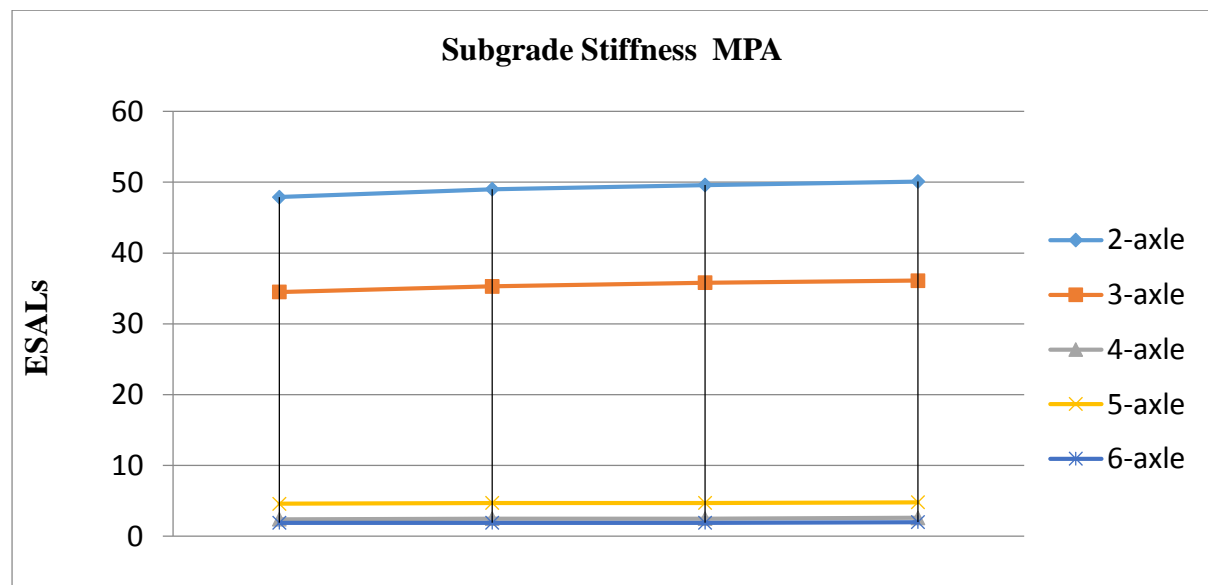

Figure 12: Effect of subgrade modulus on ESALs

Fig. 13 depicts the thickness of the asphalt layer with different ESALs; as the thickness of the asphalt layer increases, the truck factor decreases appropriately for all vehicle classes. By

raising the asphalt layer thickness for all vehicle classes from 10 cm to 20 cm, ESALs were lowered by roughly 45–47%. For classes T2, ST112, and ST113, the ESAL reduction followed a nearly identical reduction trend. This is justified by the vehicle's two single axles, which have an impact on ESALs' value (in terms of AP value in the equation).
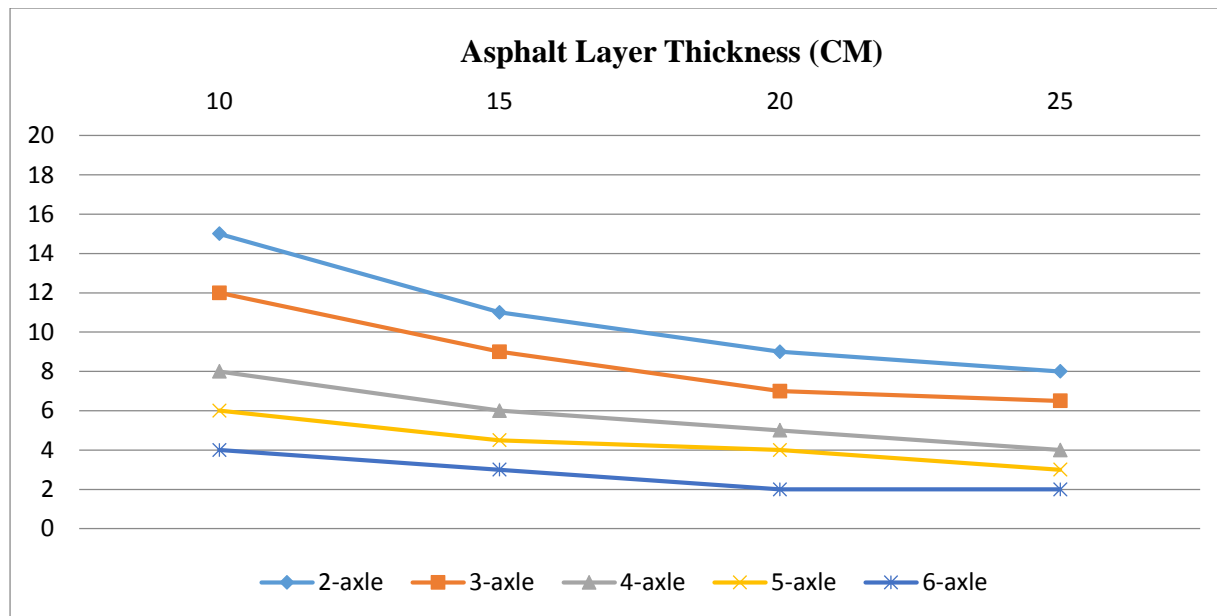

Figure 13: Four types of asphalt layer thickness and the effect of ESALs

RECOMMENDATIONS

To prevent early pavement breakdown in Afghanistan, truck weights and volumes should be taken into consideration when designing the pavement. For 2-axles, 3-axle, and 6-axle trucks, overloading should be avoided through tight legislation and campaigns to raise awareness such as the installation of allowable loads billboards in weigh-in-motion stations, distribution of MoPW anti-overloading acts to goods transportation companies, traders, and heavy traffic drivers furthermore, the government should hire professional employees in the maintenance and rehabilitation department of the road network.

Afghanistan heavy vehicles Weigh-in- Motion stations need professional employees, internet facilities, electricity, and proper databases to record overloading and all truck traffic with small vehicles daily. Overloading of the vehicles cannot be stopped solely by the severity of the load enforcement and the amount of punishment. Therefore, while taking into account additional policies, fines should be linked to increased enforcement. Early on, enforcement is more effective. However, as the level of enforcement gradually rises, efficacy falls quickly. Therefore, it is important to balance the effectiveness of enforcement with the intensity of enforcement.

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