Effects of Variation in Truck Factor on Pavement Performance in Pakistan

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ABSTRACT

Seasonal variation coupled with heavy axle loading is the key factor in rapid road deterioration in Pakistan. The serviceability loss is further accelerated by the fact that truck drivers and owners consider overloading as a profitable practice unaware of the adverse effects of this practice. Weigh-in-motion data from two stations located between two major cities of Pakistan (Peshawar and Rawalpindi) on Grand Trunk Road (N-5) were collected and analyzed. Analysis of variance and comparison of actual and designed truck factor were performed to identify the most damaging axle truck type. It was found that axle truck type 3 (single/tandem axle) is most damaging among all truck types. The actual truck factor for axle truck type 3 is 6.4 times greater than design truck factor. Regression expressions of different forms were also investigated to determine the relationship between truck factor and gross vehicular weight for the specified truck types. An optimum generalization strategy was used to prevent over-generalization and ensure accuracy. For data analysis, 75% of data was used to develop regression models and remaining 25% was to validate those models. The results show that the polynomial expressions performed best and provide a robust relationship that can be employed by the highway authorities to estimate truck factor from gross vehicular weight with a high degree of confidence. It was also observed that damaging effect of various types of trucks was very severe and quite high.

Key Words: **Truck Factor, Weigh-in-Motion, Overloading, Gross Vehicular Weight.**

1. INTRODUCTION

The sustainable socio-economic development of Pakistan significantly depends upon its communication facilities i.e. road, rail, air, and coastal infrastructure. The process of economic growth cannot be continued without related efforts not only to spread out the current facilities but also to renovate them to keep up with the rising requirements of the economy [1]. Like many developing countries of the world, in Pakistan also, the road transportation is the preferred mode of communication for both passenger and freight traffic. The roads share of freight transport is estimated at 90% while that of railways and air is 8 and 2% respectively [2].

Increase in vehicle overloading and the shift from rail to road has led to a rapid and premature deterioration of the road network in Pakistan. During the design life of a pavement, it undergoes traffic loads of various axle

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configurations. Accordingly, the damage effects of different axle configurations on the pavement structure also vary during life cycle of pavement [3]. Therefore, each pavement structure is designed to withstand a certain number of standard axle loads (8.165 tons). In order to ascertain the standard axle load for a truck traffic mix incorporating multifarious axle configurations, the factors effecting include total vehicle load, axle and tire configuration, repetition of loads, distribution of traffic across the road, vehicular speed, material and environmental /climatic impact etc [4]. Damaging effect of each axle configuration on the pavement structure will be different from others. Variations in EALF (Equivalent Axle Load Factor), ratio of damaging effect of non-standard axle load to standard axle load, strongly influence the road user cost and economy of country [5]. Similarly, the number of vehicle trips for transportation of goods is also based on axle-load, which also influences the road user costs [6].

The NAH (National Highway Authority) under the Federal Ministry of Communications is responsible for the 7000 kms long National Highway Network and Motorway systems, which carries 75-80% of the total commercial traffic. NHA's main artery is the 1760 km long N-5 highway, which carries over 55% of the country's Inter-City traffic [2]. In view of the increasing magnitude of road transport in Pakistan and the lack of adequate maintenance, rehabilitation, and renovation, the road system often faces a premature collapse.

The objective of this paper is to evaluate the actual truck/damage factor and designed truck load factors. This paper also incorporates the effects of variation of truck factors on road performance of the 174 km long section between two major cities of Pakistan (Peshawar and Rawalpindi) on Grand Trunk Road (N-5). Truck factor are ascertain in accordance with the current road condition, truck loads and overloading with economical and financial justification, by working out a relationship of EALF with GVW (Gross Vehicular Weight).

2. MOTIVATION FOR STUDY

Pakistan like most other developing countries is facing with the problem of vehicle overloading. The vehicle loads plying on the roads are much heavier than the strength of road infrastructure of the country [7]. Most of the existing roads were built 40-50 years ago, when there was no forecast of the heavier loads of today as the economic activity was low and transportation by trucks was smaller as compared to railways. But today, the situation has entirely changed and goods transportation by railways has mostly shifted to road, resulting in rail - road modal split for freight traffic to 5:95 [2].

With the growth in truck traffic, highways will be overburdened. Increased traffic will increase traffic congestion, highway maintenance costs, frequency of roadway replacement, air pollution, fuel consumption, and travel times for road users [8]. The over loading has two implications, on one hand it gives economic benefits by reducing the haulage cost, on the other hand it causes premature failure of roads and results in poor performance, thereby, causing loss of billions of rupees every year. The question is how to balance these opposing trends. In most of the developed countries, the problem of overloading is dealt by imposition of axle load limits and enforcing it after thorough economic analyses.

In Pakistan axle-load limits have been introduced in the year 2000 based on the results of axle load survey [9]. However, its physical implementation is yet not fully ensured, due to lack of enforcement/of leave. Furthermore, is the reluctance of truck owners to observe the laid down limits.

3. BACKGROUND

Performance of pavements and its interaction with truck traffic and loading is a foremost research topic in the field of transportation engineering. Pont, et. al. [10] investigated the New Zealand highway network consists of thin surface unbound pavements, which are different from the pavements used in the AASHO road test where the fourth power law originated. The study compared the pavement deterioration generated by a 10 ton axle load with that of a standard 8.2 ton axle and estimated the cost implications of a change in the legal axle load limit in New Zealand.

Tjan and Fung [11] developed EALF of ten axles 80 tires trailer on flexible pavement structures, which is used to transport segmented concrete girder from fabricator site to project site. It was concluded that thicker pavement structure will have lower EALF when its failure is based on fatigue cracking, otherwise, its EALF will be higher. Chen, et. al. [6] studied the effects of increased wheel loads on the performance of thin surfaced pavements. Twelve instrumented full-scale test pavements were built inside a temperature-moisture controlled environment, and subjected to accelerated traffic by means of a HVS (Heavy Vehicle Simulator). It was observed that with 10% overloading the 4th Power Rule underestimate the damage of light pavements by approximately 68% as compared to damage from 8th Power Rule. Based on the results, it is concluded that the impact of overload on rutting for low SN pavements are more significant than the 4th Power Law predicts for the pavement conditions investigated. Load damaging effect (EALF) increases with increasing moisture contents.

Haider, et. al. [12] evaluated that cracking, surface rutting, and ride quality are related to the fourth root of the fourth moment of axle load distributions. It was concluded rutting in the hot-mix asphalt layer is strongly associated with the overall mean, but in base and subbase layers it is related to the 95th percentile load of axle load spectra.

Fernandes, et. al. [13] investigated the effects of traffic loading on the performance of Portuguese and Brazilian pavements, aiming to contribute to a better technical regulation of heavy vehicles and cost allocation related to the pavement deterioration. The empirical-mechanistic EALF developed in this study, is useful to determine the relative effects of traffic loading factors. Hong, et. al. [14] used the two most common failure criteria of flexible pavements; surface rutting and fatigue cracking. It was found that ESALs to failure determined by the fourth power law (empirical ESALs) generally agree with pavement damage caused by a similar number of 18 kips single axles (mechanistic ESALs) when fatigue cracking is considered.

Kawa, et. al. [5] used the concept of AASHTO 18 Kips equivalency concept to find out that an increase in axle weight generally causes a more than proportional increase in pavement damage. The relationship appears to approximate an exponential function. It was concluded that the pavement damage from vehicle traffic depends mainly on the number of axle passes over the pavement and axle weights.

National Transport Commission of Australia [15] review the heavy vehicle load data and developed the regression expressions using GV as the independent variable and summed ESALS values as the independent variable for a number of common heavy vehicle types. They also investigated the distribution and extent of overloaded axle groups among vehicles that are not exceeding GVW limits for a number of common heavy vehicle types. They found that cubic polynomial equations were the best ESALS predictor for nine heavy vehicle types.

The research presented in this paper is in line with the work done by National Transport Commission of Australia [15]. The work in this paper aims at developing models to estimate ESALS or Truck Factor and identifying the most influential truck type for pavement deterioration in Pakistan.

4. STUDY AREA

The referencing system for the National Highways of Pakistan has been based on the North-South orientation of the country. The main north-south corridor has been designated as N-5 where "N" stands for national highway. The section chosen for the research in this paper is part of N-5, Karachi-Torkham highway. The study section is 174 km long southbound Peshawar-Rawalpindi section of N-5. Main problem on this section is very high volume of overloaded freight traffic as well as passenger traffic, which results in poor performance of road in terms of ride quality and comfort. It also effects adversely on the financial and economic cost of the section due to premature deterioration before reaching its design life.

5. DATA COLLECTION

Data was collected from two weighing stations located at Sanghjani and Mullah Mansoor. Three month data from October to December 2006 was collected at Sanghjani weighing station and Six month data from October 2006 to March 2007 was collected at Mullah Mansoor. The data consist of various details as time, date, gross vehicular weight, loaded/overloaded, per axle loads, percentage overweight, etc. Data reliability was also calculated. A sample of raw data sheet is shown in Table 1.

TABLE 1. SAMPLE OF TRUCK LOAD RAW DATA AXLE WISE FROM MULLAH MANSOOR WEIGHING STATION

<table>
<tr><th>Location</th><th>Carriageway</th><th>Date</th><th>Overweight</th><th>Abs (GVW)</th><th>Gross</th><th>Axle1</th><th>Axle2</th><th>Axle3</th><th>Axle4</th></tr>
<tr><td rowspan="17">Mullah Mansoor</td><td rowspan="17">South</td><td rowspan="17">1st December, 2006</td><td>-10.36*</td><td>37.86</td><td>-37.86</td><td>-8.86</td><td>-14.54</td><td>-14.46</td><td rowspan="5">-17.03</td></tr>
<tr><td>-18.8</td><td>58.3</td><td>-58.3</td><td>-6.11</td><td>-21.13</td><td>-14.03</td></tr>
<tr><td>-3.19</td><td>30.69</td><td>-30.69</td><td>-7.21</td><td>-12.87</td><td>10.61</td></tr>
<tr><td>-16.44</td><td>43.94</td><td>-43.94</td><td>-8.68</td><td>-19.67</td><td>-15.59</td></tr>
<tr><td>-28.55</td><td>56.05</td><td>-56.05</td><td>-10.71</td><td>-25.57</td><td>-19.77</td></tr>
<tr><td>6.2</td><td>42.3</td><td>-42.3</td><td>5.4</td><td>9.98</td><td>6.24</td><td rowspan="2">10.54</td></tr>
<tr><td>-26.38</td><td>53.88</td><td>-53.88</td><td>-11.32</td><td>-19.68</td><td>-22.88</td></tr>
<tr><td>2.66</td><td>36.84</td><td>36.84</td><td>4.46</td><td>-12.93</td><td>10.21</td><td rowspan="5">9.24</td></tr>
<tr><td>-14.38</td><td>41.88</td><td>-41.88</td><td>-9.13</td><td>-16.66</td><td>-16.09</td></tr>
<tr><td>-9.11</td><td>26.61</td><td>-26.61</td><td>-6.41</td><td>-20.2</td><td>-</td></tr>
<tr><td>-1.86</td><td>19.36</td><td>-19.36</td><td>-5.59</td><td>-13.77</td><td>-</td></tr>
<tr><td>0.83</td><td>16.67</td><td>16.67</td><td>5.31</td><td>11.36</td><td>-</td></tr>
<tr><td>1.46</td><td>38.04</td><td>38.04</td><td>4.76</td><td>-12.6</td><td>9.6</td><td>-11.08</td></tr>
<tr><td>-0.52</td><td>40.02</td><td>-40.02</td><td>4.27</td><td>-14.53</td><td>10.5</td><td rowspan="2">10.72</td></tr>
<tr><td>-25.26</td><td>52.76</td><td>-52.76</td><td>-10.69</td><td>-20.79</td><td>-21.28</td></tr>
<tr><td>4.78</td><td>34.72</td><td>34.72</td><td>4.63</td><td>10.15</td><td>10.15</td><td rowspan="2">9.79</td></tr>
<tr><td>-21.43</td><td>38.93</td><td>-38.93</td><td>-7.4</td><td>-31.53</td><td></td></tr>
<tr><td colspan="10">* (-ve) sign indicates over loaded truck's</td></tr>
</table>

The distribution of load over front and rear axles for various axles' configurations was already determined in past studies [9] and is also widely used by highway agencies all over the country. The distribution of load over front and rear truck axles is tabulated in Table 2. Fig. 1 shows the NHA of Pakistan allowable load limits and configuration of different axle types.

7. DATA DESCRIPTION

Figs. 2-3 show the summary of total truck traffic at Sanghjani and Mullah Mansoor, respectively. 62% of trucks on Sanghjani weighing station and 76% at Mullah Mansoor weighing station were loaded. Out of total truck traffic about 33% were overload at Sanghjani weighing station where as at Mullah Mansoor weighing station 48% were overload.

Figs. 4-5 graphically represent number of loaded trucks with respect to number of overloaded trucks at both weighing stations. It was clearly observed that number of truck traffic at Sanghjani weighing Station is lesser than Mullah Mansoor weighing Station the reason behind this difference is that there are number of links/alternative routes (e.g. N-35: Hassanabdal-Thakot-Khunjrab) before Sanghjani weighing station.

7.1 Data Reduction and Processing

Following steps were taken for omitting outliers and data processing:

- Damaging effect of empty trucks was negligible therefore empty trucks were omitted from data base.
- Trucks having extreme EALF values or data values making no practical sense had been omitted to avoid 'outliers'.
- Data was randomly shuffled using random numbers in excel sheet.
- To ensure compatibility, available data was divided into two subsets for each axle type. The first subset (75%) was used to develop the model. The second subset (25%) of the data) was used for validation. The data points used in the various stages of the model development is shown in Table 3.
- For statistically analysis the data, only Mullah Mansoor Weighing Station axle load data had been used because average EALF values were

TABLE 2. DISTRIBUTION OF LOAD OVER FRONT AND REAR AXLES [9]

Truck Type	Axle Location					
	Front(%)	Rear 1(%)	Rear 2(%)	Rear 3(%)	Rear 4(%)	Rear 5(%)
2-Axle Single	31	69	-	-	-	-
3-Axle Single	21	40	39	-	-	-
3-Axle Tandem	21	39	40	-	-	-
4-Axle Single	14	30	28	28	-	-
4-Axle Tandem	14	30	28	28	-	-
5-Axle Tandem	12	20	20	24	24	-
6-Axle Tandem Tridem	10	18	18	18	18	18

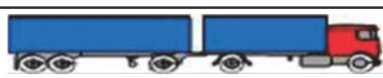
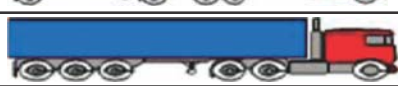
high in available 6 months data which means overloading on this side was high.

8. DESIGN TRUCK FACTOR VERSUS ACTUAL TRUCK FACTOR

For each heavy vehicle type, the EALF value for each axle group was computed using Fourth Power Law [4] as given in Equation (1). The axle group EALF values were summed to produce a total vehicle EALF for each observation individually.

$$EALF = \left(\frac{\text{Axle/Group Load}}{\text{Reference Load}}\right)^4 \quad (1)$$

Where EALF is Equivalent Single Axle Load Factor (Truck Factor).

TRUCK TYPE		Permissible Gross Vehicles Weight (in Tons)
	2 AX SINGLE (Bedford)	17.5
	2 AX SINGLE (Hino/Nissan)	17.5
	3 AX TENDEM	27.5
	3 AX SINGLE	29.5
	4 AX SIGNLE-TENDEM	39.5
	4 AX TENDEM-SINGLE	39.5
	4 AX SINGLE	41.5
	5 AX SINGLE-TRIDEM	48.5
	5 AX TENDEM-TENDEM	49.5
	5 AX SINGLE-SINGLE-TENDEM	51.5
	5 AX TENDEM-SINGLE-SINGLE	51.5
	6 AX TENDEM-TRRIDEM	58.5
	6 AX TENDEM-SINGLE-TENBDEM	61.5

Axle Load Limits					
Single Axle	=	12 Tons	Tridem Axle	=	31 Tons
Tandem Axle	=	22 Tons	Front Axle	=	5.5 Tons

Tire Pressure		
Rear Axle	=	120 psi
Front Axle	=	100 psi

FIG. 1. ALLOWABLE LOAD LIMITS AND TRUCK CONFIGURATION IN PAKISTAN

Fig. 6 shows the comparison of average truck factor and design truck factor for each type of axle. Average truck factor for each axle type of truck was higher than the design truck factor used for flexible pavement. It is also clear from the Fig. 6 that average truck factor for each month is very high with respect to the design truck factor. For example design truck factor for 3 axle type trucks is 8.18 where as it was observed that the average truck factor ranges from of 25-45. Overloading is the major factor for these high values of average truck factor. It was also observed that 3, 5 and 6 axle type of trucks had highest values of truck factors and were most damaging trucks with respect to other truck types.

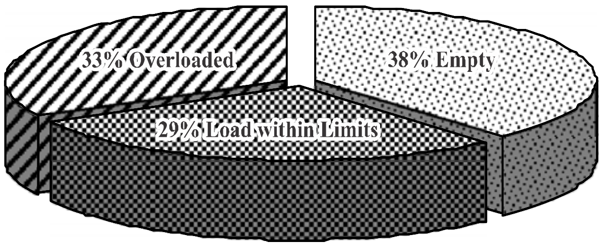


FIG. 2. TOTAL TRUCK TRAFFIC SUMMARY OF SANGHJANI (3 MONTHS DATA)

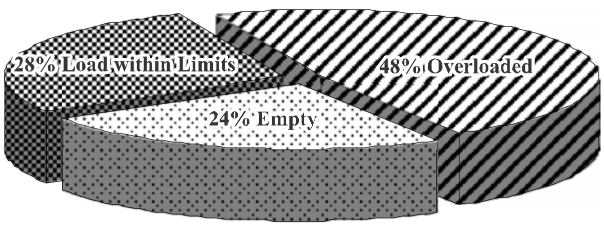


FIG. 3. TOTAL TRUCK TRAFFIC SUMMARY OF MULLAH MANSOOR (6 MONTHS DATA)

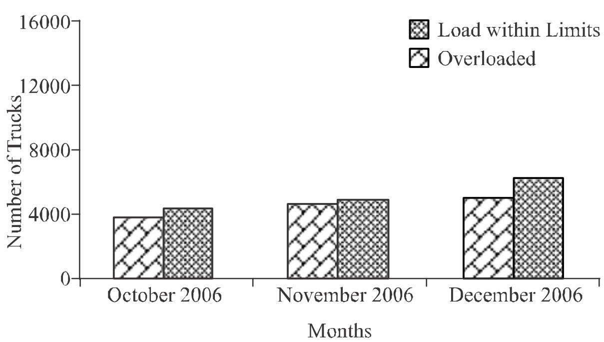


FIG. 4. LOADED VERSUS OVERLOADED (SANGHJANI WEIGHING STATION)

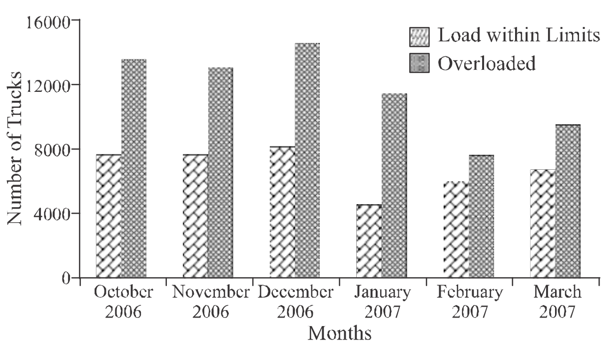


FIG. 5. LOADED VERSUS OVERLOADED (MULLAH MANSOOR WEIGHING STATION)

9. STATISTICAL ANALYSIS

Two types of statistical methods were used ANOVA (Analysis of Variance) and regression analysis. ANOVA was used to measures the relative importance in different axle types of trucks. ANOVA also identify the most damaging axle type of truck. Regression analysis was used to get an individual relationship between the summation of axle group EALF (Truck Factor) and GVW for the specified heavy vehicle types. Different types of models were tested e.g. linear, quadratic, cubic, exponential, power and polynomial. Both analyses are explained in the proceeding sections

9.1 Analysis of Variance

The null hypothesis (H_o) that all axle truck types have equal average EALF (H_o: $\mu_2=\mu_3=\mu_4=\mu_5=\mu_6$) at significance

TABLE 3. NUMBERS OF DATA POINTS (TRUCKS) USED FOR MODELING

Axle Type	Total Loaded Trucks	Data used for Model	Data used for Validation
2	72642	55355	17287
3	24090	18068	6022
4	4636	3477	1159
5	2535	1901	634
6	5121	3841	1280

level (a) of 0.05 was tested against alternative hypothesis (H_1) that there is a significant difference between averages of EALF of axle truck types. ANOVA results are shown in Tables 4-5. It is clears that average EALF of axle type of trucks were significantly different from each other. Significance level (a) equals to 0.05 or p-value <0.05 means at most a 5% chance that this difference is due to random uncertainty and not real whereas higher value of ratio of variability (F) indicates that there are large variations among EALF of axle truck types.

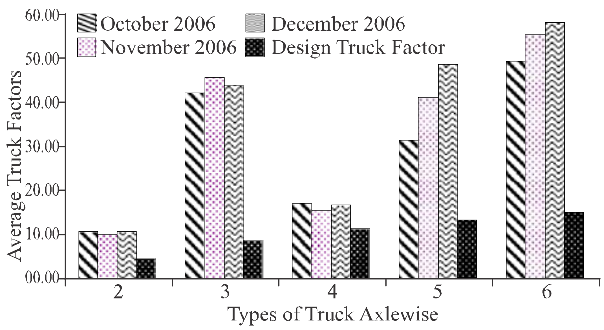


FIG. 6(a). COMPARISON OF AVERAGE TRUCK FACTOR AND DESIGN TRUCK FACTOR MULLAH MANSOOR WEIGHING STATION, OCTOTOBER TO DECEMBER 2006

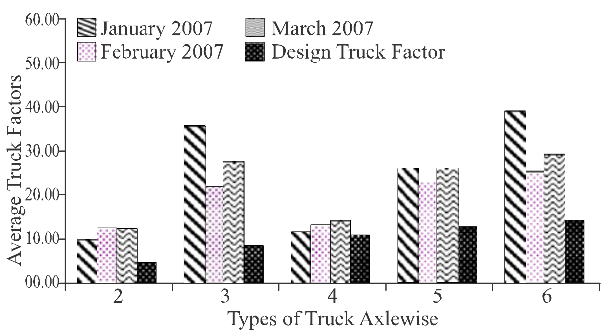


FIG. 6(B). COMPARISON OF AVERAGE TRUCK FACTOR AND DESIGN TRUCK FACTOR MULLAH MANSOOR WEIGHING STATION, JANUARY TO MARCH 2007

9.2 Most Damaging Truck Type

Comparison between design EALF and summation of axle group EALF is given in Table 6. Summation of axle group EALF of all truck types is very high than design EALF. It also clearly suggested that the most damaging axle type of truck is 3 as the actual EALF is 6.4 times greater than design EALF which mean overloading trend in 3 axle type of trucks is highest.

9.3 Regression Analysis

Regression analysis was done to develop a relationship between EALF and GVW. As describe before, to ensure compatibility and fair comparison of different models, 75% of original randomly selected data was used to develop models and remaining 25% data used for validation. Minitab as well as Curve Expert software used for modeling. Different types of regression models were tested e.g. linear, quadratic, cubic, exponential, power and polynomial.

TABLE 4. AXLE WISE TRUCKS SUMMARY FOR MULLAH MANSOOR WEIGHING STATION

Truck Types	Count	Sum	Average	Standard Deviation
2-Axle	72642	10247776	13.7	15.3
3-Axle	24090	1048178	43.5	29.1
4-Axle	4636	89433.6	19.3	20.2
5-Axle	2533	96097.0	37.9	34.8
6-Axle	5121	232332	45.4	37.6

TABLE 5. ANOVA TABLE

Source of Variation	SS	df	MS	F	P-value	F-crit
Between Groups	17989235	4	4497309	9021.06	0	2.37204
Within Groups	45553556	91375	498	-	-	-
Total	63542791	91379	-	-	-	-

9.2.1 Axle Truck Type-2

For axle truck Type-2 (single axle) 75% (55355) trucks data was randomly selected and used to develop the regression model, having GVW ranges from 8.55-35.26 tons. Polynomial regression model of degree 4 was selected based on higher R^2 value. Equation (2) shows the expression for model and graphically shown in Fig. 7(a). The model developed enables GVW to account for more than 96% of the variance in EALF for most of the sample of single axle trucks.

$$EALF = -21.32 + 5.4GVW - 0.48GVW^2 - 0.0177GVW^3 - 0.00016GVW^4 \quad (2)$$

For validation, model shown in Equation (2) was applied on 25% (17287) remaining data and results show higher R^2 value (0.93). Fig. 7(b) shows the scatter plot between actual EALF and predicted EALF.

9.2.2 Axle Truck Types 3-6

Similarly, regression models were development for axle truck Types 3-6. Table 7 shows the predictive equations developed to estimate EALF for axle truck Types 3-6.

Figs. 8-11 shows regression plots and their application on 25% validation data for axle Types 3-6, respectively. Each model shows high R^2 value for both actual (data used for developing models) and validation data.

TABLE 6. COMPARISONS BETWEEN DESIGN AND SUMMATION OF AXLE GROUP EALF

Axle Type Trucks	Design EALF	Summation of Axle Group EALF	Times Increased
2	4.88	13.7	3.00
3	6.81	43.5	6.40
4	11.49	19.3	1.68
5	13.42	37.9	3.00
6	14.95	45.4	3.00

10. CONCLUSIONS

This paper presents a comparison of actual and design truck factor in Pakistan and also shows models to estimate truck factor from gross vehicular weight. The following are the conclusions and recommendations based on the results thus far:

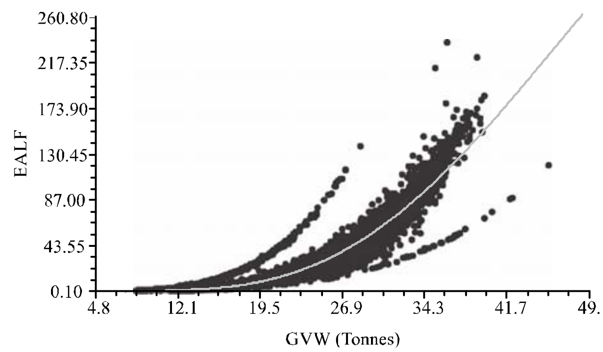


FIG. 7(a). REGRESSION PLOT OF AXLE TRUCK TYPE-2

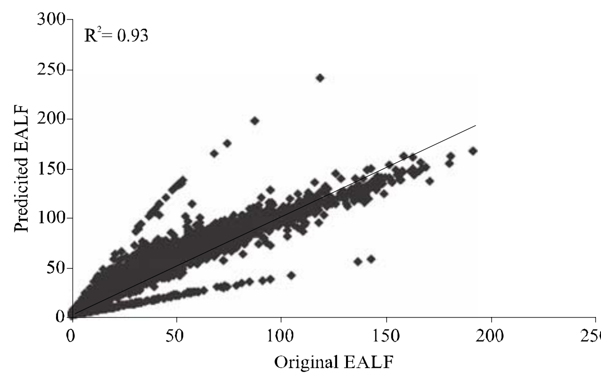


FIG.7(b). ILLUSTRATION OF ACTUAL VERSUS PREDICTED, VALIDATION DATA OF AXLE TRUCK TYPE-2

TABLE 7. REGRESSION EQUATIONS FOR AXLE TRUCK TYPES 3-6

Axle wise Truck Type	Regression Equation
3 Axle	$EALF = -41.74 + 4.91\ GVW - 0.13\ GVW^2 + 0.00072\ GVW^3 - 0.0000178\ GVW^4$
4 Axle	$EALF = -61.87 + 7.82\ GVW - 0.35\ GVW^2 + 0.0065\ GVW^3 - 0.000037\ GVW^4$
5 Axle	$EALF = 118 - 10.09\ GVW + 0.32\ GVW^2 - 0.0039\ GVW^3 + 0.00002\ GVW^4$
6 Axle	$EALF = 6.79 - 1.32\ GVW + 0.089\ GVW^2 - 0.00154\ GVW^3 + 0.000009\ GVW^4$

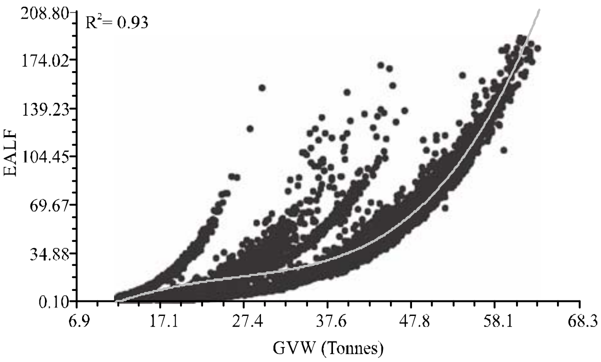


FIG. 8(a). REGRESSION PLOT OF AXLE TRUCK TYPE-3

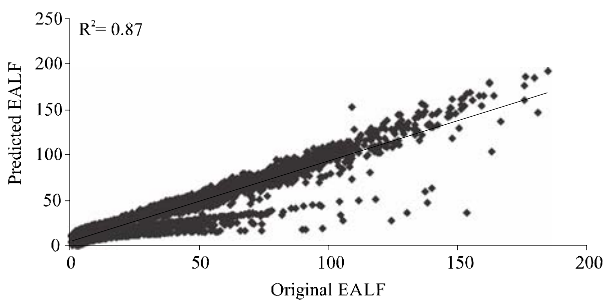


FIG. 8(b). ILLUSTRATION OF ACTUAL VERSUS PREDICTED, VALIDATION DATA OF AXLE TRUCK TYPE-3

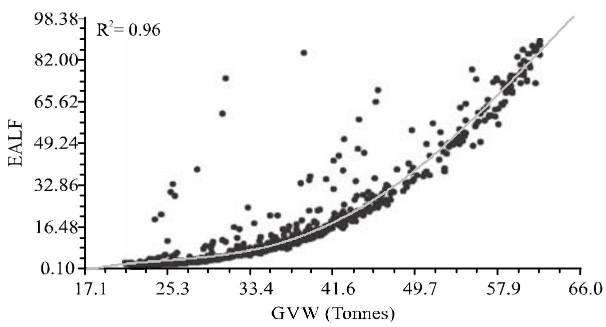


FIG. 9(a). REGRESSION PLOT OF AXLE TRUCK TYPE-4

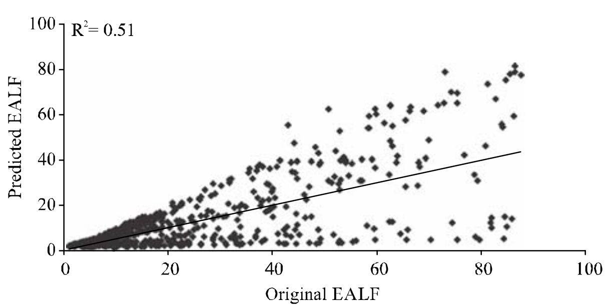


FIG. 9(b). ILLUSTRATION OF ACTUAL VERSUS PREDICTED, VALIDATION DATA OF AXLE TRUCK TYPE-4

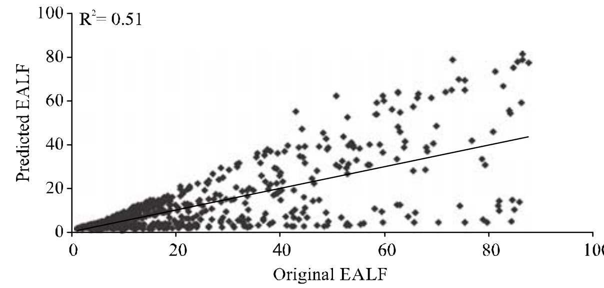


FIG.10(a). REGRESSION PLOT OF AXLE TRUCK TYPE-5

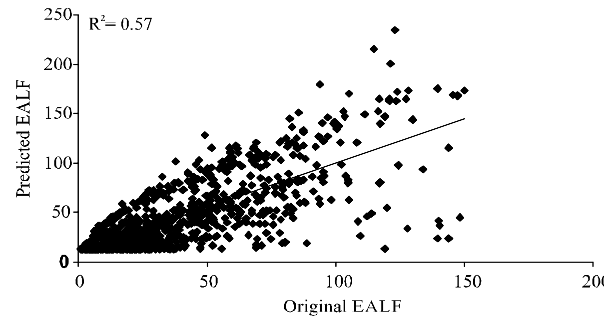


FIG. 10(b). ILLUSTRATION OF ACTUAL VERSUS PREDICTED, VALIDATION DATA OF AXLE TRUCK TYPE-5

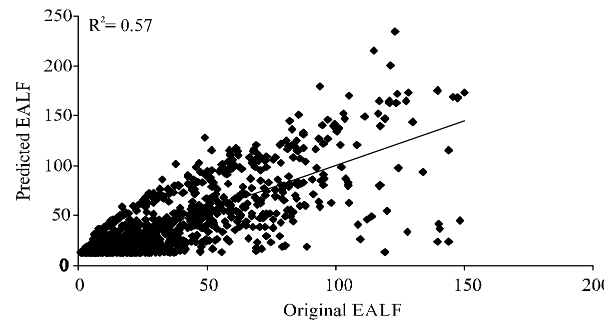


FIG. 11(a). REGRESSION PLOT OF AXLE TRUCK TYPE-6

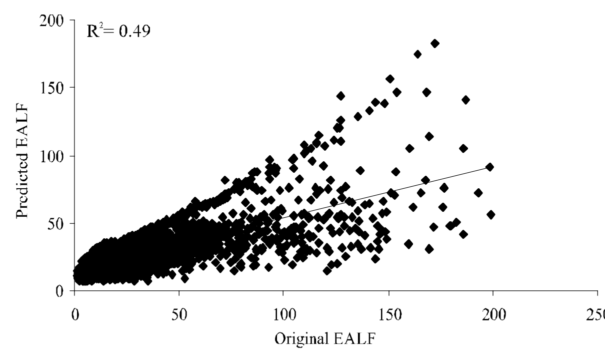


FIG. 11(b). ILLUSTRATION OF ACTUAL VERSUS PREDICTED, VALIDATION DATA OF AXLE TRUCK TYPE-6

(i) Axle type 3 trucks are more damaging to pavement as compare to other truck types.

(ii) In order to overcome the overloading issues there are two ways either increase the ELAF while designing the pavements or strictly enforce the allowable limits.

(iii) Actual truck factor is much higher than the design truck factor

(iv) Most of the truck traffic carrying loads more than allowable limits.

(v) Application of global average EALF factor is not appropriate for pavement design of individual roads. It is necessary to determine equivalent standard axles for each road by weighing axle loads of individual vehicles.

(vi) Relationship between pavement damage and axle load is required to be determined for each set of axle load data in order to access the average load impact on any particular road.

(vii) In the recent past, the legal axle load limits could not be implemented in true sense, each time the authorities tried to enforce the limits, it was strongly resisted by the transporters and resulted in countrywide strikes by the trucks owners associations. Thus, we have to come up with a solution which should satisfy both sides.

(viii) The existing truck factor limits in the Pakistan needs to be revised, and work is underway to extent this research and determine the optimum truck factor for Pakistan road network.

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