Study on Impact of Vehicle Overloading on National Highways in Varying Terrains

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***Abstract* - Pavement damage is mainly due to factors such as poor quality of materials used, poor construction practices, temperature variations, weather conditions, environmental changes, *etc*. One of the most important factors in the recent years is the pavement damage due to the overloaded trucks and the overloading effects caused by the increased truck traffic volume. Government of India has framed certain standards based on various research publications for the loads to be carried by the trucks with respect to their axle configuration. But the truck operators seldom follow these standards and regulations. This practice of overloading the trucks will have a direct impact on the pavements getting more damaged. It is expected that the impact of overload on roads in hilly terrain is more vulnerable than that in the plain terrain. This is mainly due to the change in gradient and thereby the load distribution in the vehicle.**

The impact caused by different classes of truck over the pavement is determined by the Vehicle Damage Factor (VDF). An attempt has been made in this study to determine the impact of vehicle damage factor caused by the overloaded vehicle on National Highways passing through varying terrain conditions. The major objectives of this work is to analyze the impact of overloaded trucks on flexible pavements and to study the variations in VDF in detail for various class of trucks with respect to varying loading and terrain condition. The scope of the work is limited to National Highway stretches NH-66 (Plain terrain) and NH-744 (Hilly terrain) in Kanhangad and Kollam districts of Kerala. VDF was calculated considering two scenarios in both the terrain conditions. Scenario 1 implies the actual VDF values obtained and in scenario 2, the VDF value is determined by distributing the additional load from overloaded trucks to a new vehicle class. The result shows that the VDF values calculated shows a higher variation in both the scenarios in varying terrain conditions. As the VDF value increases, the pavement life will be reduced. Higher VDF values necessitate thicker pavements and hence the pavement construction and maintenance costs will be increased. Pavement damages due to very high VDF value impose the need for frequent overlays before the design life period. This means that the design period of the pavement get attenuated before the actual design life and hence frequent strengthening measures such as overlay should be done in order to keep them in good condition. Therefore thickness and cost variation analysis is also performed as part of this study to estimate the varying cost.

Keywords: Legal Load Limit, Gross Vehicle Weight, Equivalent Standard Axle Load, Vehicle Damage Factor, Truck Overloading, Cumulative Standard Axles.

INTRODUCTION

Highways are vitally important to a nation’ s economic development. The construction of a high quality road network directly increases a nation’ s economy by reducing journey time, vehicle operating costs and easing the mobility of people and goods making a region more attractive. India, like most developing countries is facing the dilemma of vehicle over loading. The vehicle loads flying on the highways are much heavier than the strength of the infrastructure actually designed. Nowadays, the situation has entirely changed and goods transportation by railways has been mostly shifted to road due to the end to end service offered by road. Pavement design is performed by accounting various factors such as traffic data, growth rate, lane distribution of vehicles, and the vehicle damage factor. Vehicle Damage Factor which is a representing parameter for traffic load is one of the predominant components on pavement design. The local truck body makers are producing wider and elevated truck bodies which enable the truck owners to reduce haulage cost. The over loaded trucks stress the road structure beyond its safe bearing capacity. This causes a drastic reduction in the pavement service life and gets destroyed before its design life. IRC-3-1983 clearly specifies the maximum amount of load that a truck’ s axle can carry based on the axle configuration. Due to lack of strict enforcement, these rules and regulations are getting violated most of the time. For getting more profit in less time, the truck owners overload their trucks exceeding their maximum carrying capacity thereby ignoring the rules. A detailed study on the overloading of trucks and its impact on pavement structure and the economy is performed in this study.

Scope and Objectives

The scope of work is limited to the National Highways passing through varying terrain condition in Kerala. The major objectives of this work is

- To analyze the behavior of truck overloading on flexible pavements.
- To study the VDF in detail for various class of trucks with respect to varying loading condition.
- To analyze the variations in thickness and cost of a flexible pavement subjected to truck overloading.
- To explore the severity of overloaded vehicles on pavement service life

Literature Review

This section discusses the previous studies carried on impact of overloading on road performance and the damaging effects of overloading.

Impact of overloaded trucks

Gatot Rusbintardjo (2013) made a sensitivity analysis to measure the influence of overloading to level of road damage. The factors considered for sensitivity analysis includes traffic load, stress at the surface layer cause by excessive of tyrepressure, pavement materials, pavement layers thickness, roadbed or sub grade soil, and environment. In addition to the analysis of sensitivity, calculation using vehicle damage factors (VDF) was also used to determine the capacity of single, dual, or triple axle trucks on damaging of pavement. The result of analysis of

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sensitivity show that 150% overloading of single, dual, and triple axle truck, will bring about 500, 135, and 122% level of damage respectively. The results of calculation using VDF also have the similar result namely 47.20, 10.30, and 7.99 times the capacity to deteriorated pavement respectively. Paise *et al*,.(2013) investigates the impact of overloaded vehicles on road pavements by studying the truck factors for different vehicle cases applied to a set of pavements composed of five different asphalt layer thicknesses and five different subgrade stiffness moduli. The analysis of the impact of the overloads in the pavement performance was carried out by studying the truck factor for overloaded vehicles, truck factor for legal vehicles, Truck factor for all vehicles (overloaded and legal loads) and Influence of asphalt layer thickness and subgrade stiffness modulus on truck factor. The analysis concluded that the truck factors for all classes of vehicles are almost identical and no significant differences can be found among the vehicle with the maximum legal load per axle, the average truck factor observed and a vehicle with the average load in each axle. However, there are vehicles with very high loads, which lead to very high truck factors. The study carried out in this paper concluded that the effect of vehicle loads is diminished by increasing the asphalt layer thickness. The influence of the subgrade on the vehicle loads effect is very low when the primary pavement distress is the fatigue cracking. The study revealed that, for consideration in pavement design, if vehicles are considered to be at their maximum legal weights, the effect of overloaded vehicles on the pavement performance is clearly reduced. However, the presence of overloaded vehicles can increase costs by more than 100% compared to the cost of the same vehicles with legal loads.

Cost variations due to overloading

The cost of pavements is highly related to the degree of overloading. Pais *et al*., (2013) in their study found out that about 30 percentage extra cost was needed for an overloaded pavement than a legally loaded pavement. The pavement damage was found to be increasing an exponential rate. The pavement designed for 15 years was found to be reduced its life to 12.3, 10.27 and 7.25 years due to 5%, 10% and 20% overloading respectively. This study also concluded that by increasing the asphalt layer thickness of the pavements, the effect of overloading can be reduced. Chhoeuy Roeun et al.,(2008) had conducted a study on overloading and found that 10% overloaded truck can damage road pavement greater than 40% comparing to the same load limited truck. 21 tons legal loaded truck is overloaded to 30 tons loaded truck; it reduced life span of road from 15 years to only 3.16 years. Vertical contact stress under tyre-road contact is found 2 to 3 times of inflated tyre pressure induced by under-inflated and overloaded tyre pressure. Vertical contact stress alone is greater than approximately 30% of inflated tyre pressure. The service life of the pavements can be significantly improved by implementing strict enforcements for restricting overloading which was analyzed by Sharma *et al*., (1995). The study also found out that by adopting strict enforcements, the maintenance and rehabilitation costs of roads can be reduced; maintenance can be done at desired serviceability levels and also availability of funds for the preservation of pavements.

Pavement condition index and overloading

The Pavement Condition Index (PCI) is a measure of the condition of the pavement, which will be seriously affected due to overloading. Wahid *et al*., (2013) had conducted a study on the impact of overloading and found out that that pavement condition index on the national road West Sumatra Border to Jambi City has reached the terminal pavement condition index (IPt) in the 4th year whereas it was designed for 10 years. It means the deficit design life was about 60%. The study also concluded that subgrade improvement and replacement of pavement type by rigid pavement were the best pavement repair alternatives for that location.

Influence depth of overloading

The effect of depth of loading on pavement is not same for normal loaded and overloaded condition. Huang Chuansheng *et al.*, (2008) had used Boussinesq solution and layer-wise summation method, to analyze the infection degree of the road bed' s load influence depth under the vehicle loading. The study had concluded that roadbed' s influence deep is 6 -14 m in the condition of overloading, otherwise it is about 6 -8 m, the influential depth of vehicle loads increased as parabola with the increase of overloading degree of vehicle.

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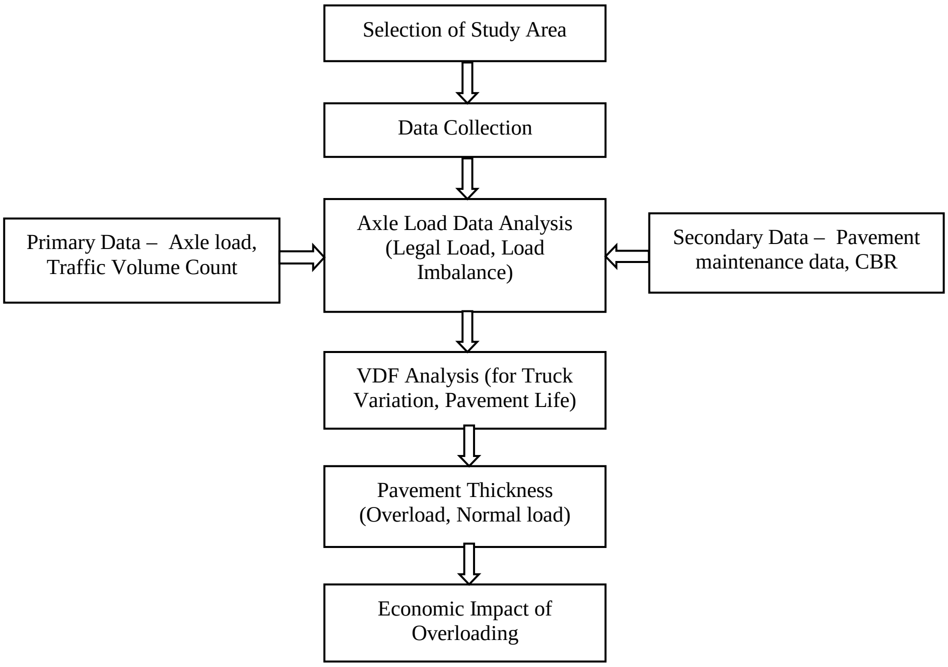
METHODOLOGY

The methodology adopted for the study is represented using a flowchart.



Study Area

The major data requirement is the axle load data of truck traffic. Hence, considering the need, study area was chosen accordingly. It is expected that the truck movement will be more in the border roads connecting Kerala with nearby states such as Tamilnadu and Karnataka and therefore two locations of varying terrain and topographic condition is finalized for the study. The road characteristics are almost similar in both the location except the terrain condition. The study area listing the survey locations is provided in Table 1. The map showing the study area locations shown in Figure 1

Table 1. Study locations.

Sl. No.	Road Name	Road stretch	Survey location	Terrain type
1	NH 17	Kannur - Kasaragod	Kanhangad	Plain
2	NH 744	Kollam – Thenkasi	Ariyankavu	Hilly Terrain

Figure 1. Map showing study locations.

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Data Collection

Primary Data Collection

The primary data was collected by conducting traffic surveys on the selected locations. Direction-wise data was collected for all the study locations. The data collection procedure adopted for each of the survey is explained below:

Axle load survey

Axle Load Survey is used to determine the axle load of vehicles. For this study the axle loads are checked and surveyed with the help of a portable Axle Weigh pad. Figure 2.1 and 2.2 shows the picture of the Axle weigh pad used for the survey and the axle load survey.

Figure 2.1. Axle weigh pad.

Figure 2.2. Axle load Survey.

Volume count survey

The total number of vehicles passing the particular location for the particular day of axle load survey was counted. The data was collected for a 24 hours time period on both direction of traffic movement.

Secondary Data

The secondary data required for the work is traffic growth rate, CBR value of the subgrade soil and existing pavement layer. These data were collected for determining the pavement thickness.

Data Analysis

Vehicle Composition

The volume count data obtained from both the location were analysed to get the individual percentage composition of vehicle. Figure 3(a) and 3(b) shows the vehicle composition data for Kanhangad and Aryankavu locations respectively. It can be seen that the truck traffic share a higher percentage followed by car and two wheeler traffic. The composition of commercial vehicles or trucks based on volume count survey at each location also for both the location is shown in Figure 4.

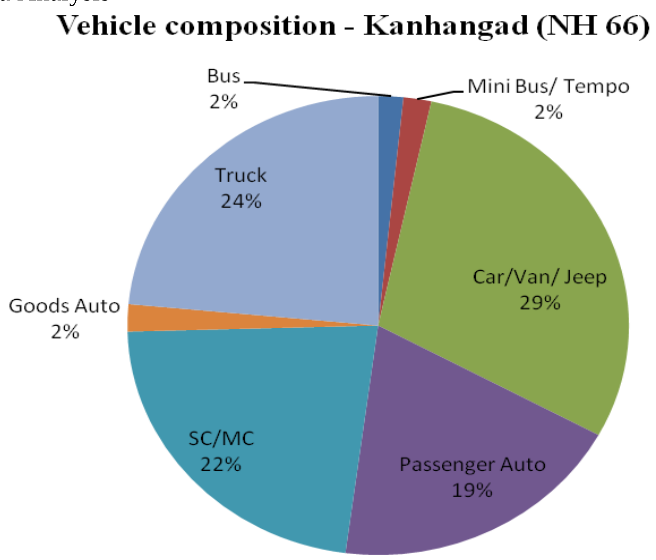

Figure 3(a) Vehicle Composition at Kanhangad.

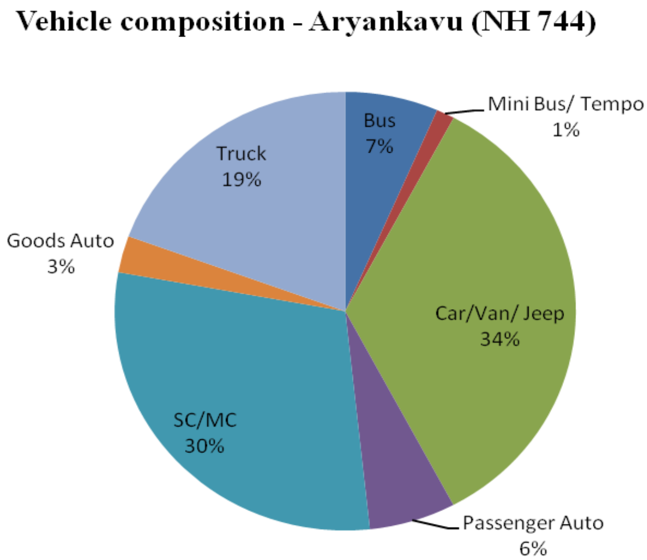

Figure 3(b) Vehicle Composition at Aryankavu.

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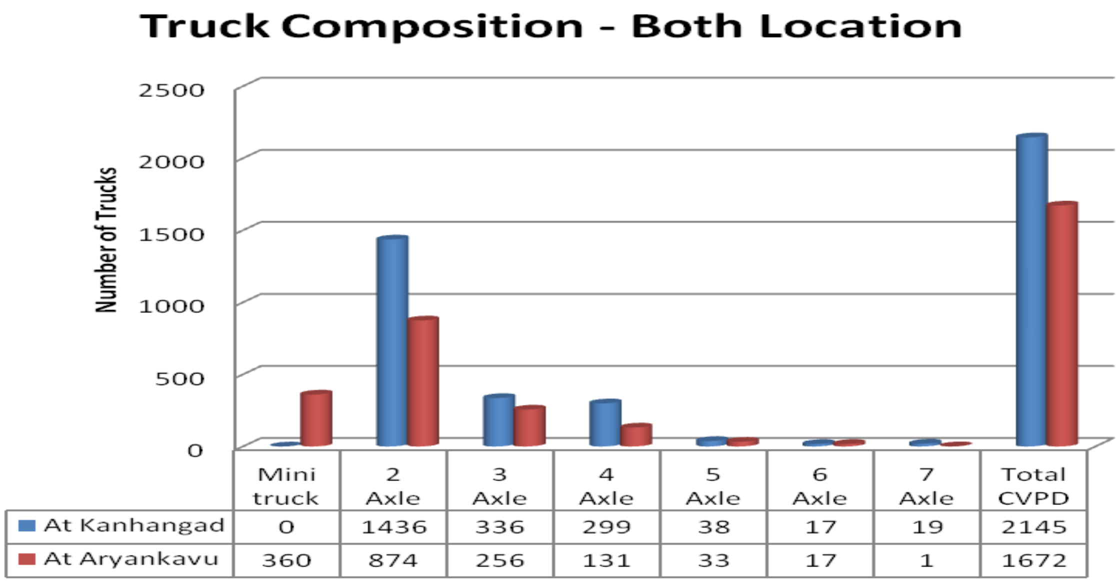

Figure 4. Comparison of various Truck Composition at both location

From Figure 4 it can be seen that for both the locations heavy vehicles contribute to 20% of total traffic. Also, Kanhangad location was observed to have higher truck traffic volume. Two axle trucks contribute the higher percentage of truck traffic in both the location which is followed by LCVs, three axle and Multi axle trucks.

Sample size for Axle Load Survey

The details regarding the number of trucks subjected to axle load survey out of the total volume passed for the current study in both the locations is summarized in Table 2.

Table 2. Sample size for axle load survey

Location	Number of vehicles surveyed	Total Number of Vehicles passed	Sample Size (%)
Aryankavu	980	1672	58.61
Kanhangad	1340	2592	51.70

It is observed that in both location the total number of CVPD is calculated to be less than 3000 and hence it will be sufficient to have a sample size of 20%.

DETERMINATION OF OVERLOADING

The total amount of overload was determined by truck factor method [10, 13] for both the study location. From studies it has been inferred that there are two methods for calculating the overload of a vehicle. Truck factor method is one in which the total load carried by the vehicle is accounted as a whole. In axle load factor method individual axles will be considered for analysis of load. Axle load factor is mainly used to determine the damage effect of axle in pavement structure. In truck factor method the overloading of vehicle is valued based on the total gross weight of the loaded vehicle.

For the current study, each type of truck and its corresponding number of overloaded trucks were analyzed based on the surveyed data. The Total load exceeding the legal limit, the number of additional trucks required to satisfy the freight transport demand in each category was also computed. Considering both the directions together the severity of overloading on that location was analyzed for the study stretches. The result of the analysis performed at each location is briefed in subsequent paras.

Location1: Aryankavu

The trucks passing through the NH-744 towards Tenkasi direction and Thenmala direction was analyzed individually and the details are furnished in Table 5 and 6.

Table 5. Truck movement towards Tenkasi direction

Truck type	Number of trucks Surveyed	Number of overloaded trucks	Percentage of overloaded trucks	Total loads exceeding Legal load limit (kg)	No of additional trucks required
LCV	17	0	0.00	0	0
2 Axle	198	19	9.60	44260	3
3 Axle	197	24	12.18	107040	5
4 Axle	91	7	7.69	29156	1
5 Axle	1	0	0.00	0	0
Total	504	50	9.92	180456	9

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A total of 504 vehicles were surveyed of which approximately 10% (50 numbers) of the trucks were found to be overloaded. Three axle vehicle contributed the major share of overloaded vehicles followed by two axle and four axle trucks. Also, the percentage of overload carried by three axle truck is more. It was determined that an additional nine trucks is necessary to handle the additional load carried.

It can be observed from Table 6 that out of 476 vehicles surveyed; approximately more than 60% (288 numbers) of the trucks were found to be overloaded. Three axle trucks contribute the huge amount of overloaded truck which is followed by two axle and four axle trucks. Also, all the multi axle truck passing through this section is found to be overloaded. It was determined that an additional 57 trucks is necessary to handle the additional load carried. Figure 5 provide a graphical representation of percentage share of overloaded vehicles plying in both directions. From the graph it can be observed that the trucks going towards Thenmala are heavily overloaded than that to Tenkasi direction.

Table 6. Truck movement towards Thenmala direction

Truck type	Number of trucks Surveyed	Number of overloaded trucks	Percentage of overloaded trucks	Total loads exceeding Legal load limit (kg)	No of additional trucks required
LCV	19	0	0.00	0	0
2 Axle	186	56	30.11	109870	7
3 Axle	150	119	79.33	588156	25
4 Axle	108	101	93.52	688642	23
5 Axle	10	10	100.00	81470	2
6 Axle	3	2	66.67	20030	0
Total	476	288	60.50	1488168	57

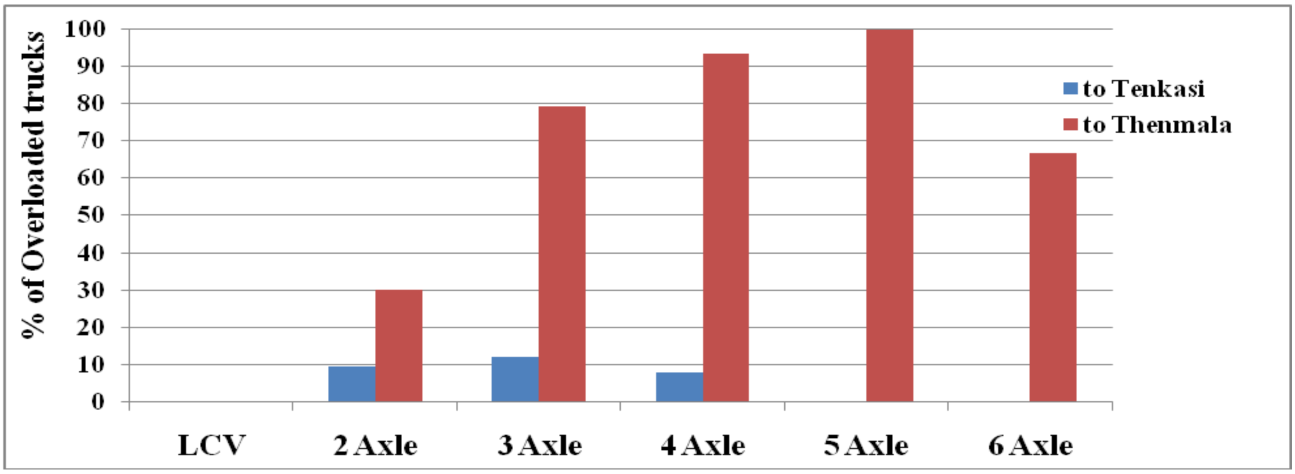

Figure 5. Percentage share of overloaded trucks in Tenkasi and Thenmala direction

Location 2: Kanhangad

The trucks passing through Kanhangad on NH66 towards Kannur direction and Mangalore direction was analyzed individually and tabulated below in Table 7 and 8.

Table 7. Truck movement towards Kannur direction

Truck type	Number of trucks Surveyed	Number of overloaded trucks	Percentage of overloaded trucks	Total loads exceeding Legal load limit (kg)	No of additional trucks required
LCV	27	0	0.00	0	0
2 Axle	329	68	20.67	149450	10
3 Axle	152	86	56.58	322686	14
4 Axle	143	99	69.23	529330	16
5 Axle	5	1	20.00	1332	1
6 Axle	3	3	100.00	47132	1
Total	659	257	39.00	1049930	42

Form Table 7 it can be revealed that out of 659 vehicles surveyed, approximately 39% (257 numbers) of the trucks were found to be overloaded. Four axle trucks contribute the huge amount of overloaded truck which is followed by three axle trucks. Also, the percentage of overload carried by four axle truck is more. It was determined that an additional 42 trucks is necessary to handle the additional load carried.

It can be observed from Table 8 that out of 681 vehicles surveyed; approximately more than 15% (104 numbers) of the trucks were found to be overloaded. Three axle contribute the huge amount of overloaded truck which is

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followed by four axle and two axle trucks. Also, almost 75% of the multi axle truck passing in this direction is found to be overloaded. It was determined that an additional 16 trucks are necessary to handle the additional load carried. Figure 6 provide a graphical representation of percentage share of overloaded vehicles plying in both directions. From the graph it can be observed that the trucks going towards Kannur are heavily overloaded than that to Mangalore direction.

Table 8. Truck movement towards Mangalore Direction

Truck type	Number of trucks Surveyed	Number of overloaded trucks	Percentage of overloaded trucks	Total loads exceeding Legal load limit	No of additional trucks required
LCV	17	1	5.88	2980	1
2 Axle	344	29	8.43	35402	3
3 Axle	171	38	22.22	141950	6
4 Axle	145	33	22.76	140492	5
5 Axle	4	3	75.00	8960	1
Total	681	104	15.27	329784	16

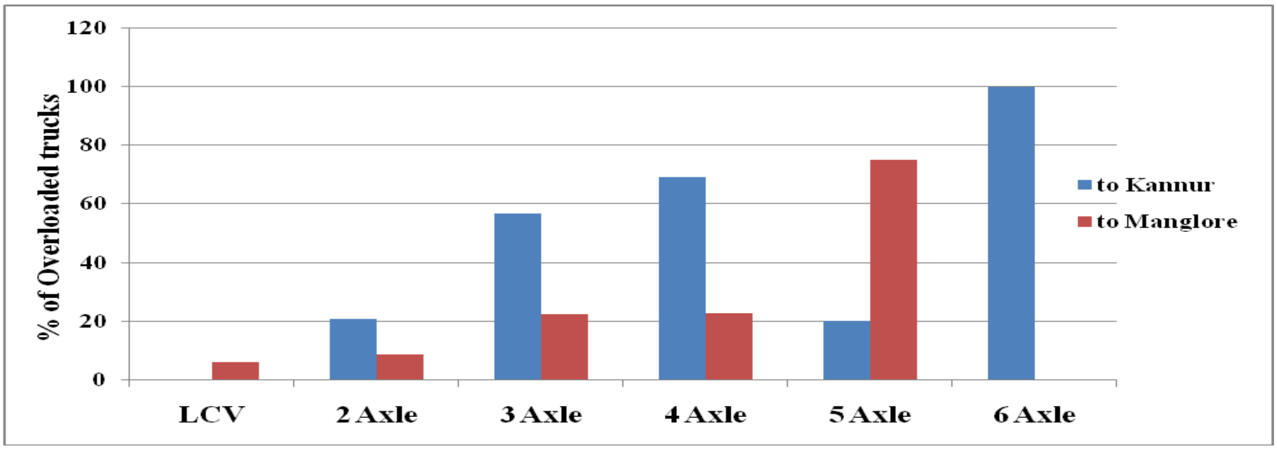

Fig 6. Percentage share of overloaded of trucks to Kannur and Mangalore

Critical direction of overloaded vehicle movement

The truck-wise overloading analysis indicates that in every location the percentage of overloading in any one direction is comparatively higher than the other direction. It can be observed that the vehicles approaching the Kerala state in all the location is fully loaded than the vehicles moving out of the state. During the OD survey, it is observed that vehicles moving in the downward movement i.e., towards Kerala at Aryankavu carry goods such as vegetables, fruits, dairy products, steel, rice and cement. The vehicles carrying steel, rice and cement are observed to be overloaded. Similarly the vehicles reaching Kerala at Kanhangad location mostly carries petroleum products and industrial goods.

The road lane leading towards the state gets damaged much quicker than the other lane as most of the heavy vehicles entering the state are in overloaded condition. The critical directions at each location based on the above analysis are listed below in Table 9

Table 9. Critical direction of Overload vehicle movement

Location	Critical direction	Percentage of Overloading	
		In critical direction	In opposite direction
Aryankavu	Thenmala	60	10
Kanhangad	Kannur	39	15

From the above table it is can be visualized that the road leading towards Thenmala at Aryankavu location is facing a severe overloading issues as the 60 percentage of truck passing through this road is observed to be overloaded.

Load Spectrum

Based on the results of axle load survey, the trucks plying on the two locations were classified into different classes based on the load spectrum. The percentage distribution of vehicle load with respect to the various load spectrums is shown in Table 10 below.

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Table 10. Percentage distribution of vehicles in load spectrum

Load Spectrum (tones)	Percentage of Vehicles	
	Aryankavu	Kanhangad
0 - 10	25.66	29.18
10 - 20	42.16	41.04
20 - 30	15.07	17.61
30 - 40	13.24	10.29
40 - 50	3.56	2.31
50 - 60	0.20	0.07
60 - 70	0.10	0.15

The Table 10 shows the percentage of vehicles at each location corresponding to GVW varying from 0 to 80 tones. It can be seen that about 40 percentages of vehicles plying in Aryankavu and Kanhangad falls in the load range of 10-20 tones. Also both the locations show a similar pattern of load distribution.

IMBALANCE LOAD DISTRIBUTION

Truck manufacturer' s technical specifications and highway agencies general concept is that the loading of trucks should be distributed in a ratio so that the all the axle of trucks will have equal load distribution. If the surface area of load distribution increases the pavement will sustain for a longer life. For a two axle truck, the loading ratio of 1:2 on front and rear axles seem to be a safe loading pattern and for a four axle truck it is 1:2:2:2. Truck operators should follow this loading pattern which will provide mutual benefits. Overloaded trucks violate this load distribution. Even if the gross weight of a truck is within the legal load limit, if the load distribution pattern is varying, say, for a two axle truck if the load distribution pattern of 1:2 is varied the heavier loaded axle will cause much impact on the road surface than which it is meant to withstand. As VDF is the measurable parameter of the damage caused by vehicle on pavement, the change in loading pattern will gradually increase the VDF. This can be well studied by considering a 2 Axle truck, in which the loads were assumed to be distributed in the ratio 1:2, 1:3, 1:4 and 1:5 as shown in Table 11.

Table 11. Impact of imbalance loading pattern on VDF values (2-Axle Truck)

GVW in tones	VDF for 2Axle Truck			
	1:2	1:3	1:4	1:5
10	0.51	0.79	1.00	1.18
15	2.79	4.02	5.10	5.96
20	8.82	12.71	16.14	18.91
25	21.54	31.03	39.41	46.16
30	44.66	64.34	81.73	95.72

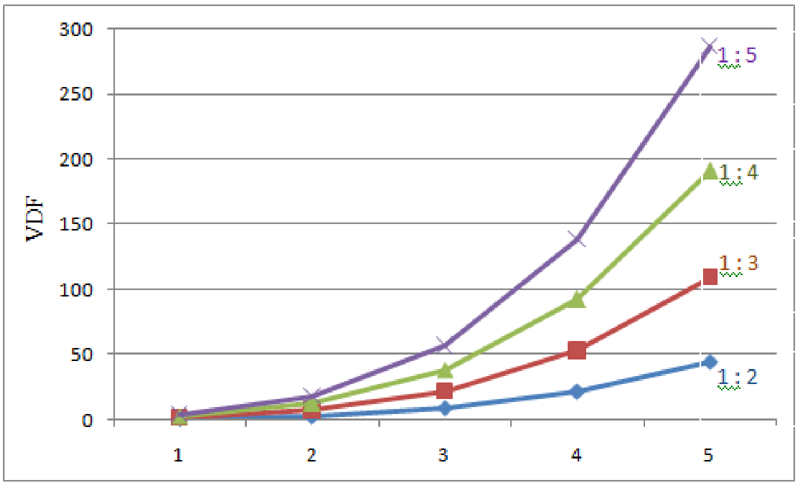

Figure 7. Graph showing Increase in VDF due to varying load Distribution

From Figure 7 it can be understand that the variation in load distribution between front and rear axles of a 2 Axle truck has a drastic change in the VDF values. For the other truck types also the same pattern is found to be continuing. It was determined that for the vehicle surveyed in Aryankavu location the load distribution pattern was as high as in the ratio of 1:4.5.

An analysis was performed in the study location considering the load distribution pattern for two axle trucks. It was observed that 24% of 2 axle trucks have improper load distribution at Aryankavu and 23% at Kanhangad location. This practice of load distribution increases the damaging effect of vehicle over the pavement. The corresponding VDF values obtained for balanced and unbalanced state are provided in Table 12.

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Table 12. Comparison of VDF values based on 1:2 load Distribution (2-Axle Truck)

Location	Aryankavu		Kanhangad	
Load Distribution	Balanced	Unbalanced	Balanced	Unbalanced
Two Axle truck (nos)	291	93	661	192
VDF values	1.2	1.69	0.506	4.33

VDF Analysis

Direction-wise observed VDF at each Location

The Axle load survey conducted at the survey locations provide the axle load values of the trucks surveyed. These axle loads were converted into its Equivalent Axle Load Factor (EALF) values as per the equations given by IRC: 37-2012 mentioned in the previous section of this chapter. Then these EALF values were added up to get the Equivalent Standard Axle Load (ESAL) value of that truck. From the ESAL values, VDF was calculated. This analysis was done for the trucks plying in both the directions at the selected locations and the higher VDF value was selected from each category of trucks for further analysis. The direction-wise VDF at each location is summarized as shown below:

Location-1: Aryankavu

Table 13 shows the VDF values for different types of trucks plying towards Tenkasi and Thenmala directions at Aryankavu.

Table 13. VDF values at Aryankavu

Truck type	VDF Values	
	Towards tenkasi	Towards thenmala
LCV	0.02	0.14
2 Axle	1.57	2.97
3 Axle	1.15	5.75
4 Axle	2.25	15.00
5 Axle	0.26	11.77
6 Axle	0.00	8.93

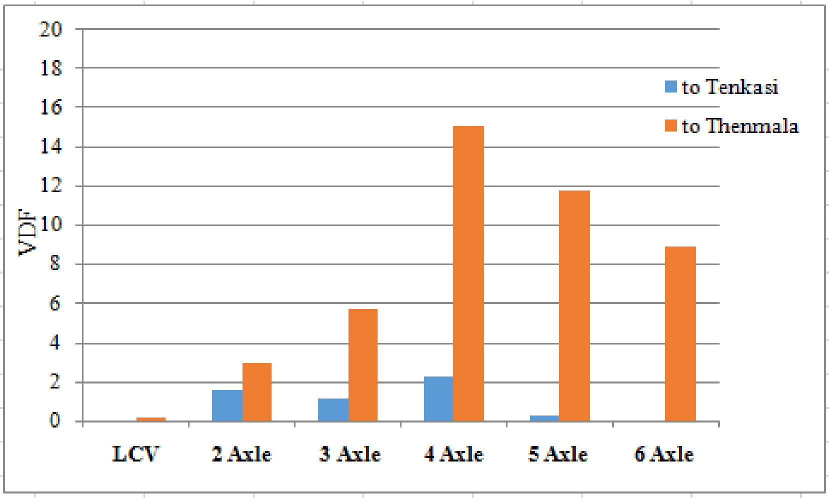

Figure 8. Graph showing variation of VDF at Aryankavu in both directions

From the graph depicted in the Figure 8, it can be seen that the trucks plying in the Thenmala direction is having more VDF values. The maximum VDF is caused by the 4 Axle tucks. This indicates that the damaging effect to the pavement by the trucks is more in Thenmala direction than Tenkasi direction.

Location-2: Kanhangad

Table 14 specifies the variation in VDF values for different types of trucks plying towards Mangalore and Kannur at Kanhangad. It is observed from Figure 9 that the trucks plying in the Kannur direction are having more VDF values than in Mangalore direction. This indicates that the damaging effect caused by the vehicle in pavement is more in Kannur direction than Mangalore direction.

Table 14. VDF values at Kanhangad

Truck type	VDF Values	
	Towards kannur	Towards mangalore
LCV	0.05	0.41
2 Axle	2.75	1.30
3 Axle	4.12	1.89
4 Axle	9.43	4.97
5 Axle	4.59	6.75
6 Axle	12.84	0.00

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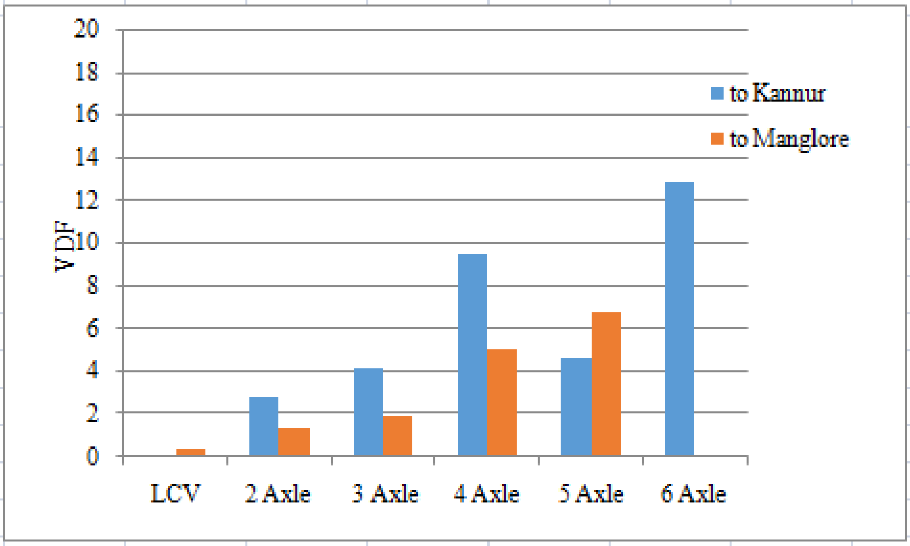

Figure 9. Graph showing variation of VDF at Kanhangad in both directions

Direction-wise Normalised VDF at each location
The observed values are the overloaded VDF values. For comparing these values with the values specified by IRC, it has to be normalized by reducing all the overloads to normal loads. For this each axle was considered individually. If the axle load was above legal load limit it was restricted to legal load limit value and then VDF was computed as earlier. The results are provided in Table 15.

Table 15. Direction-wise normalized VDF at each location

Type of Truck	VDF values			
	Aryankavu		Kanhangad	
	Towards tenkasi	Towards tenmala	Towards kannur	Towards mangalore
LCV	0.02	0.14	0.05	0.16
2 Axle Truck	0.73	1.93	1.57	0.97
3 Axle Truck	0.61	2.62	2.40	1.14
4 Axle Truck	1.45	4.90	4.73	2.13
5 Axle Truck	0.26	4.05	4.48	5.38
6 Axle Truck	-	3.52	3.99	-

Analysis of Pavement Thickness
The variation in pavement thickness for Aryankavu location considering various loading cases is calculated and the same is summarized in Table 16.

Table 16. Summary of Difference in Pavement Thickness

Pavement Layers	Thickness mm		
	Overload case	Normal load case	Normal load (introducing additional axle)
BC	50	44.6	45.6
DBM	100	71.9	73.4
G. Base	250	250	250
GSB	200	200	200
Total Thickness	600	566.5	569

Analysis on Cost Variations
Overloading accelerates the pavement damage and reduces the pavement life to a great extent. This causes wastage of huge amount of funds invested in road projects. Overloading of pavements only benefits a small percent of population while the others also have to suffer its impacts. Numerical calculations were done to express the loss in economy due to the overloading effect. The rate of materials used for the evaluation of different layers is adopted from CPWD. These rates vary from place to place. To compensate this variation, CPWD specifies a cost index value for different places and it varies accordingly based on economy fluctuation. For Aryankavu and Kanhangad location, the suggested cost index values are 1.55 and 1.43 respectively.

A Typical 1km road stretch is considered for cost estimation. The road characteristics are similar in both locations and have a two lane carriageway, and hence the road width is considered as 7.5 m. Height of each layer varies according to different loading conditions. It was observed that there is not much thickness variation between normal loading condition and Normal loading condition after introducing additional trucks; however these two cases

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show a considerable variation from Overloaded condition. The existing pavement at Aryankavu is designed by adopting the IRC specified VDF values. But, the current scenario of vehicle overloading will make the pavement to deteriorate at a faster rate and hence additional overlay may require for fulfilling the gap in reduction of service life.

A reverse calculation was performed using the obtained VDF values with similar traffic condition for determining the reduction in service life. The reduction in service life in comparison with the design life (15 years) for Aryankavu and Kanhangad location was obtained as 4.5 and 7.4 years. This indicates that even if the pavement was constructed for 15 years, it will show severe distresses and will get pre mature damage due to the overloaded vehicles passing through it. Hence to protect the pavement from excess damage and to preserve it in a well serviceable condition, overlays should be done at proper time. This must be done by arriving Benkelman beam deflection values and as per the guidelines given by IRC: 81-1997.

Since the pavement is designed for 15 years and due to high VDF the pavement life for Aryankavu and Kanhangad locations reduced to 4.5 years and 7.4 years respectively. Therefore, minimum 2 overlays (50 mm DBM and 40 mm BC) for Aryankavu location and 1 overlay for Kanhangad location must be given to make the pavement sustain until 15 years as designed.

The summary of cost estimation for pavement designed by VDF obtained through axle load survey, design adopting VDF values recommended in IRC 37:2012 and the additional cost required to extend the design life till 15years is shown in Table 17.

Table 17. Summary of Cost Estimate

Pavement Design		Construction Cost	
		Aryankavu	Kanhangad
Overloaded condition	Considering overloaded condition VDF values	3.7	3.6
	Additional Overlay	2.4	1.1
	Total	6.1	4.7
Design	As per IRC specified VDF value	3.1	3.6
Cost variation		3	1.1

CONCLUSION

The paper discuss about the impact of overloading vehicles on flexible pavement. The conclusions derived from the study are highlighted below

- Preliminary analysis shows that Kanhangad is facing huge truck traffic than Aryankavu. 2-Axle truck contributes a higher traffic volume both the survey locations.
- 60% of vehicles moving towards Thenmala is found to be overloaded, in which, 3-Axle and 4-Axle truck contribute a huge ratio. Also, 40% of vehicles moving towards Kannur at Kanhangad location is found to be overloaded.
- It is determined that an additional 7% and 5% of the truck traffic is needed to distribute the overloads carried by the trucks.
- It was observed that 24% of 2 axle trucks have improper load distribution at Aryankavu and 23% at Kanhangad location. This imbalanced loading condition especially at Aryankavu will make a high distress in pavement as it has a hilly terrain.
- With every 5% increase in overloading, 2-Axle truck shows a higher VDF values when compared to 3-Axle and 4-Axle truck. This implies that the damage caused to the pavement by an overloaded 2-Axle truck is more.
- Pavement thickness analysis at Aryankavu location shows that there is a 5cm additional thickness to be maintained for overloaded condition than the normal loaded condition.
- Financial analysis of pavement construction at Aryankavu(hilly) and Kanhangad(plain) location shows that if the overloading of vehicle persists an additional cost of Rs. 3 crore and Rs. 1.1 crore per km is need to be spend to maintain the design life of pavement.

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