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# Flexible Pavement Thickness

## (A Comparative Study Between Standard and Overloading Condition)

Krishna Nath Ojha*

*Senior Divisional Engineer, Ministry of Physical Infrastructure and Transport, Department of Roads (DoR),*
*Lalitpur, Nepal*
*Email: knojha256@gmail.com*

## Abstract

The ability of a pavement structure in carrying out its function reduces in line with the increase of traffic load, especially if there are overloaded heavy vehicle passing through the road. Most of the road pavement is designed considering the legal load limit of the vehicles. But that may not be the actual condition and most of the transport enterprenures want to minimize the transport cost making the heavy vehicles overloaded. The impact of overloaded truck traffic includes economic, social and environmental losses. In this study, the effect of overloaded vehicles on the road pavement thickness was analyzed using the AASHTO 1993. Traffic load (ESAL) and Structural Number (SN) were calculated on standard and overloading conditions. The difference due to overloading condition was also presented. Study was done taking the traffic data on Narayanghat-Mugling road (AH42) segment which is a link between Prithvi Highway and East-West Highway, located in Chitawan district of Narayani zone, state 3, Nepal in which the composition of traffic seen to be 83.76% heavy vehicles, 9.18% Medium vehicles and 7.05% light vehicle. The presence of overloaded vehicles, particularly heavy vehicles resulted in traffic load (W18) value found to be greater than that of standard condition. The impact of overload conditions on the road pavement showed increase in the layer thickness than that of thickness at the legal axle load limit. From the results, it can be concluded that overloaded vehicles on the road are very influential to the reduction in pavement service life and require higher thickness. For S-N direction, the pavement thickness seems to be increased upto 22.81% due to overloading with respect to standard condition, while for the opposite direction; the thickness seems to be more than sufficient in standard condition.

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* Corresponding author.

The total pavement thickness required for overloaded condition seemed to be 43.25 inch in which 30.735 inch subbase, 7.797 inch base and 4.718 inch bituminous wearing course but in standard condition total thickness required seemed to be 36.856 inch with 26.659 inch subbase, 6.355 inch base and 3.842 inch bituminous wearing course. Road infrastructure is used by various types of vehicles among which heavy vehicles imposes the most critical loading, causing damage in pavement structure, which ultimately leads to an increased maintenance and rehabilitation costs. Therefore, it is expected that road users to comply with existing regulations in the conduct of transportation.

***Key words:*** Standard and overloading vehicle; equivalent single axle load; pavement design; pavement service life; pavement layer thickness.

## 1. Introduction

### *1.1. General*

Road network plays an important role in any country’s transport and communication. Pavement condition is one factor to access the efficiency of road network. Design life and bearing capacity of pavement are dependent on the construction materials and the type of highway. Design life of new flexible pavement is frequently taken as 5 to 20 years which includes regular maintenance and rehabilitation within its service period [1]. Thus annual average daily traffic (AADT) of each class is a key input to the schedule of Design for New construction, maintenance and rehabilitation plan. However, the occurrence of overloaded truck traffic induces incorrect estimation in total equivalent single Axle Loads (ESALs). Therefore the frequency of maintenance and rehabilitation within the service period are corrupted by overloaded truck traffic. The pavement deterioration over time is caused by a combination of factors; however, traffic loads play a key role in consumption of pavement service life. Magnitude and configuration of vehicular loads together with the environment has a significant effect on induced tensile stresses within flexible pavement [2]. Overloaded truck traffic is an untenable problem around the world. This phenomenon occurs in not only developing countries, but also in developed countries. Extremely high enforcement and inspection are applied to ensure this. Impact of overloaded truck traffic includes economic, social and environmental losses [2]. The major economic impact by overloaded truck traffic is unexpected expenditure on pavement investment. Because pavement design is based on normal traffic load and total ESAL. Overloaded truck traffic is not the expected traffic load in pavement design. As a result, the bearing capacity of pavement is lower than the actual design. Pavement service life has a direct relationship with net present value of investment [3]. Construction cost for a new pavement is the most direct cost, which occurs when pavement service life is reduced. On the other hand, increase in annual maintenance and rehabilitation costs at the most evident economic loss is induced by overloaded truck traffic.

### *1.2 Overloading and Pavement Service Life* [5]

Design life of new flexible pavement is frequently taken as 5 to 15 years (Nepal Road Standard 2045 BS), which includes regular maintenance and rehabilitation within its service period. Thus annual average daily traffic (AADT) of each class is a key input to the schedule of maintenance and rehabilitation plan. However, the occurrence of overloaded truck traffic induces incorrect estimation in total equivalent single Axle Loads (ESALs). Along Narayanghat-Mugling Road section (AH42), for the direction of Narayanghat – Mugling (S-N), the pavement service life might be reduced by 59.90% due to overloading condition, while for the opposite direction, the service life would not reduced caused by the same factor. Comparison between ESAL with overloaded and standard truck traffic is the important factor to estimate the reduction in pavement service life, because pavement service life is directly driven by traffic load. The impact of overload conditions on the road pavement showed premature failure, that is, a condition which the damage reduced the life of roads before the design life of the road is reached. Bituminous pavements undergo premature failure much before their design life. The reason may be inappropriate selection of materials, lack of dependable traffic and axle load data and limited information related to distresses for analysis. From the results, it can be concluded that overloaded vehicles on the road are very influential to the reduction in pavement service life. Figure 1 shows the load – road life relation in standard and overloaded condition.

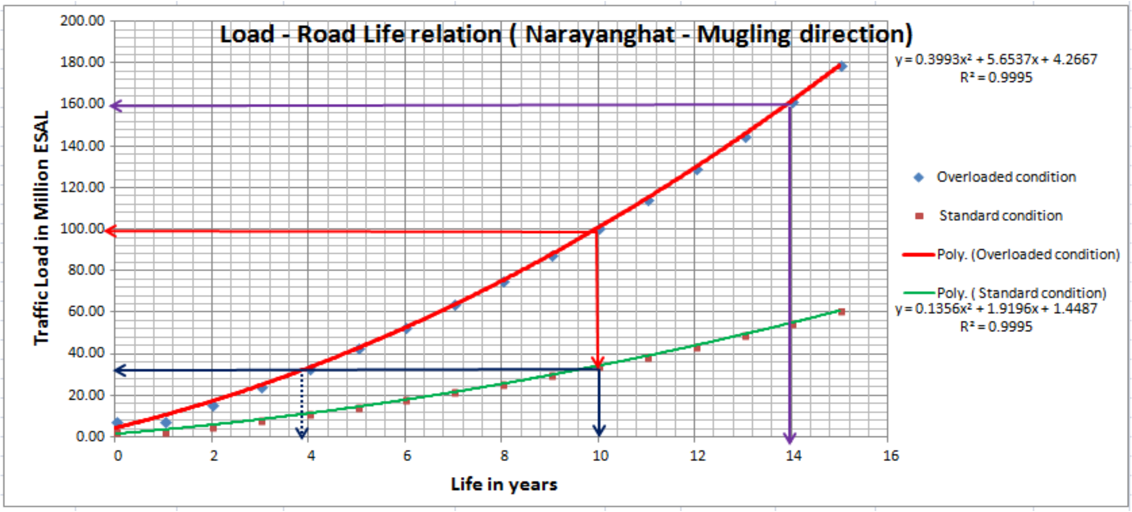

**Figure 1:** Load – Pavement life relation in standard and overloaded condition

### *1.3 The impact of overweight vehicles on pavement life* [6]

The impact of overweight vehicles on pavement life was analyzed using WIM data and mechanistic-empirical pavement analysis. Different distribution patterns were observed between the overweight and non-weight traffic in terms of truck classes and axle load spectra. The reduction ratio of pavement life was used to normalize the effect of overweight truck at different conditions. A linear relationship was found between the overweight percentage and the reduction ratio of pavement life regardless of the variation in traffic loading and pavement structure. In general, it shows that 1% increase of overweight truck may cause 1.8% reduction of pavement life. The effect of truck overloading is studied to estimate its impact on the deformability of road pavement on compacted gravel lateritic soils. For that purpose, various loading conditions were tested to measure the impact on the critical response parameters of road pavement design. The results show a linear variation of deflections and deformations at the road layers according to the variation of the axle overload. This overload seems to have more effects on deflections for the top layers level (asphalt layer and base layer) than the lower layers.

### ***1.4 Analysis of damage due to overloading*** [7]

Overloading is the most important cause of the deterioration of flexible pavements. In developing countries this is very critical, where transportation of heavy vehicles on city roads and highways is increasing. By studies it is found that this problem causes a great damage to road networks and results in high maintenance and repair costs. To overcome this problem one has to develop other branches of transportation such as rail roads, increase the bearing capacity of pavement for the heavier traffic loads, and improve the axle load distribution of overweight vehicles. The stress-strain response of a bituminous pavement depends on the properties of materials used in different layers, traffic on the pavement and the environmental conditions prevalent in the location. In IRC: 37, rutting in subgrade and fatigue cracking initiated at the bottom of the bituminous layers are considered as the two important distresses. The pavements in India experience high temperature around 60°C and above.

### ***1.5 The effect of overload on axle load distribution*** [8]

Premature deterioration of pavements not only occurs on relatively new roads but also prevails on roads that have just been repaired. The premature damage on roads is allegedly caused by the overloaded heavy trucks. It was found that the effect of overloaded heavy vehicle are: (a) higher axle-load distribution for the rear wheels (b) higher average ESAL value per type of truck (c) higher tire pressures for heavy trucks. Heavy vehicles are overloaded lead to changes in the axle load distribution of vehicles. The results showed that the axle load distribution for the rear wheel is greater than the standard of Bina Marga (1987). The results showed that the EAL value of research results greater than EAL based on Bina Marga (1987, 2005) which is 2.2 to 8.3 times. The value of tire pressure for single axle single wheel (SASW ), tandem and triple axle dual wheel (TADW and TrDW), and single axle duwal wheel (SADW) are 130-140 psi, 160-185 psi and 140-150 psi.

### ***1.6 Impact of axle overload*** [9]

Road infrastructure is used by various types of vehicles among which heavy vehicles imposes the most critical loading, causing damage in pavement structure, which ultimately leads to an increased maintenance and rehabilitation costs. During the design of road pavements, each type of vehicle is converted into equivalent standard axle load (ESAL) to consider their impact on road structure. A road structure is subjected to various types of loading during its life. These include traffic load and environmental actions producing stresses and strains in road structure. The response of pavement structure to these loads depends on the stiffness of subgrade, type of pavement, pavement thickness and type of traffic the pavement carries. The magnitude of damage depends on axle configuration (single, tandem or tridem), number of axles in the vehicle (large number of axles ensures distribution of axles load over a large length of pavement), suspension system, tire pressure and the magnitude of overload. The damaging effects of overloaded axles on a pavement include fatigue, which reduces the design life of a pavement, and rutting, which causes the serviceability problem in the pavement. The latter can be structural or non-structural depending upon the design of different pavement layers, anticipated loads and ground moisture conditions.

### ***1.7 The Influence of Overloading Truck to the Road Condition*** [10]

Traffic load is dominant function on pavement design because the main function of pavement is to resist traffic load. Efforts to repair of the road damages have been done; but almost meaningless since the overloading trucks keep in progress, even reach twofold from the normal load. Analysis of sensitivity and vehicle damage factors (VDF) were used to measure the influence of overloading to level of road damage. The result of analysis of sensitivity found was 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 deteriorate pavement respectively. The detrimental effect of single axle trucks is high compare to dual or triple axle trucks. Relative strength of pavement structure caused by overloading of single axle truck decrease much more than caused by overloading of dual or triple axle truck. Higher the overloading higher will be the decreasing rate of relative strength of pavement structure. Anticipation occurring of early damage on pavement structure caused by overloading truck, especially single axle truck, is needed. Strict on quality control during construction period to insure that all specifications are met the requirement is required and is very important. Strict control on overloading truck by controlling limited truck load is required. Regulation to call for using multi-axle truck instead of single-axle truck is needed to be considered.

### ***1.8 Influence of Axle Overload on the Performance*** [11]

The deterioration in pavement life is caused by many combinations of factors. The traffic loads take a highest role in consumption of pavement life. Tensile strain and compressive strain increased with increasing axle loads and these strains decreased with increasing asphalt layer resilient modulus. Rutting and fatigue of pavement surface increases dramatically with the increase in axle load of the vehicles. allowable maximum load limits per each axle type that should not be exceeded. Different axle loads are considered (8, 9, 10, 11, 12, 13, 14, 15, and 16) tons for single axle dual tire. Also, two pavement resilient moduli are taken into consideration in the analyses that represent summer season and winter season to reflect the climate condition of the pavement under service condition. The result showed that the maximum allowable single axle load during the summer season is 9 tons and 15 tons during winter season. Therefore, the permitted 13 tons load for single axle load with dual tire as per the current local specification instead of 9 tons could be approximately result in a loss of one quarter the pavement design life.

### ***1.9 Impact of Traffic Overload on Road Pavement Performance*** [12]

Traffic on a road pavement is characterized by a large number of different vehicle types, and these can be considered in pavement design by using truck factors to transform the damage they apply to the pavement to the damage that would be applied by a standard axle.The truck factors to convert trucks into standard axles or the load equivalent factors to convert axles into standard axles are defined by considering the average loads for each axle. This process includes the vehicles that travel with axle loads above the maximum legal limit. There are also a substantial number of overloaded vehicles in terms of total vehicle weight. These axles/vehicles cause significant damage to the pavements, increasing the pavement construction and rehabilitation cost. The study revealed that the presence of overloaded vehicles can increase pavement costs by more than 100% compared to the cost of the same vehicles with legal loads. The study of the traffic information allowed the conclusion that heavy vehicles do not circulate with the maximum load defined by law. On average, and depending on the axle position, the load of each axle ranges from 20 to 90% of the maximum legal load. The study 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.

### *1.10 Vehicle classification in Nepal* [13]

Vehicles are at present classified into three categories under Vehicles and Transportation Management Act, 2049, Nepal. They are:

a. Heavy Vehicle:- Gross vehicle weight > 10 ton

b. Medium Vehicle:- Gross vehicle weight 4 to 10 ton

c. Light Vehicle:- Gross vehicle weight < 4 ton

### *1.11 Legal load provision in Nepal* [14]

Maximum allowable axle load is the axle load as specified by the manufacturer within safe axle load as specified below and described thereafter:

| | |
|---|---|
| a. Single axle fitted with 2 tires: | 6 ton |
| b. Single axle fitted with 4 tires | 10.2 ton |
| c. Tandem axle fitted with 8 tires | 19 ton |

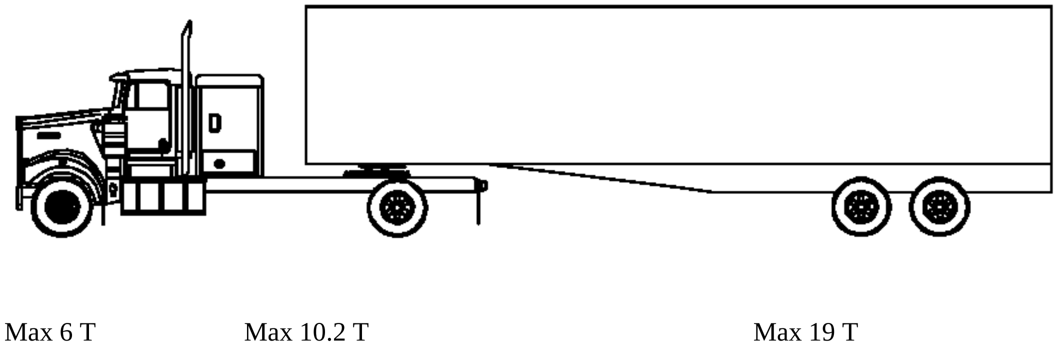

**Figure 2:** Typical Heavy Vehicle [14]

### *1.12 AASHTO 1993 Design Guide* [15]

### *1.12.1 Fundamental Equations*

The 1993 AASHTO Design Guide is the current standard used for designing flexible pavement for many transportation agencies. In the AASHTO design methodology, the subgrade resilient modulus (MR), applied ESAL ($W_{18}$), reliability (with its associated normal deviate, $Z_R$), variability ($S_o$), loss in serviceability (ΔPSI), and structural number (SN) are used in the nomograph (Figure 2) and the corresponding Equation (1) to design thickness of flexible pavements [15].

$$logW18 = Zr(So) + 9.36\log(SN+1) - 0.20 + \frac{\log(\frac{\Delta PSI}{4.2-1.5})}{0.40 + \frac{1094}{((SN+1))^{5.19}}} + 2.32logMR - 8.07 \ldots\ldots(1)$$

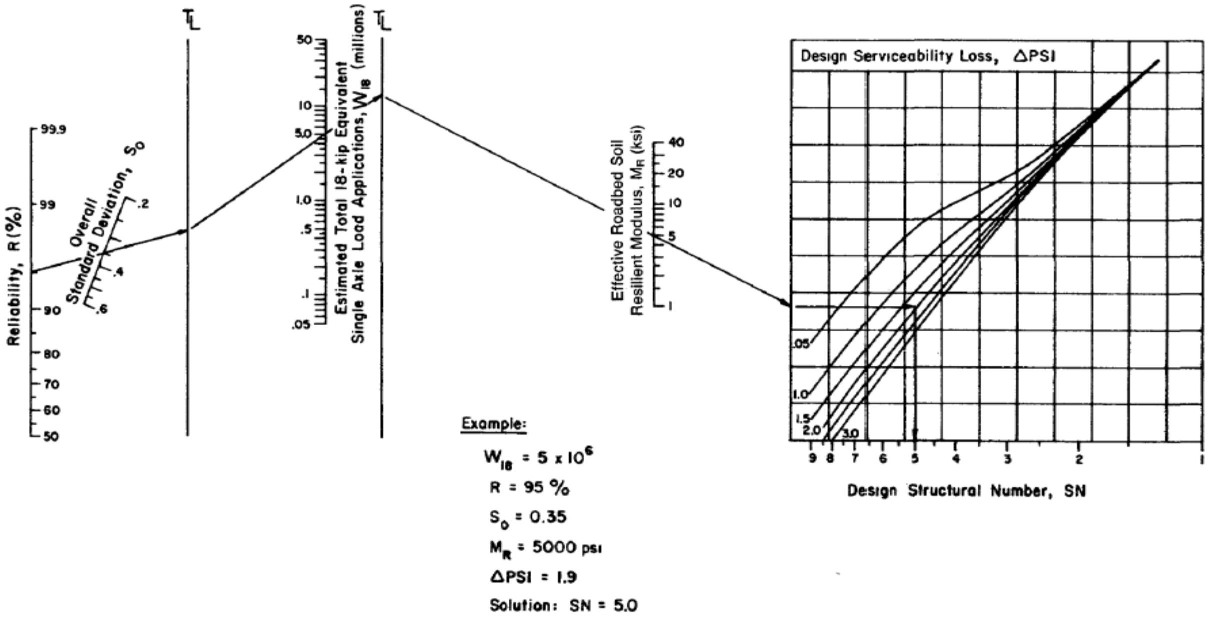

**Figure 3:** AASTHO Flexible Pavement Design Nomograph [15]

### *1.12.2 Traffic Load, W18 and Growth Rate, GRi*

$W_{18}$ is the number of single-axle load applications to cause the reduction of serviceability to the terminal level ($p_t$), and the standard deviation ($S_o$) is typically assumed to be 0.49 for flexible pavements based upon previous research [15]. Traffic load that used for determining flexible pavement design thickness is the cumulative traffic load during design life. The magnitude of the traffic load for two ways is obtained by summing the multiplication of three parameters, i.e. average daily traffic, axle load equivalency factor, and annual growth rate, for each type of axle load. Numerically, the formulation of cumulative traffic load is as follows:

$$W_{18} = \sum_i (AADT_i \times E_i \times G_{Ri}) \times 365 \ldots\ldots\ldots\ldots(2)$$

$$G_{Ri} = \frac{(1+g_i)^n - 1}{g_i} \ldots\ldots\ldots\ldots(3)$$

Where, $W_{18}$ = cumulative standard single axle loads for two ways, ESALs

$AADT_i$ = average annual daily traffic for axle load i

$E_i$ = axle load equivalency factor (or vehicle damage factor VDF) for axle load i

$G_{Ri}$ = annual growth rrate for vehicle i, %

$g_i$ = traffic growth for vehicle type i, %

n = service life, year

To obtain traffic on design lane, following formula can be used:

$$W_{18} = D_D \times D_L \times W_{18} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where, $W_{18}$ = cumulative standard single axle load on design lane, ESAL

$D_D$ = direction distribution factor

$D_L$ = lane distribution factor

### *1.12.3 Structural Capacity*

To calculate the structural capacity of road pavement, as represented by structural number (*SN*), it is necessary to determine several parameters as Loss of Serviceability (ΔPSI), resilient modulus ($M_R$), Traffic Load (ESAL or $W_{18}$), $Z_r$, $S_o$, and can found from equition (1) by trial and error method.

## 2. Materials and Methods

The 1993 AASHTO Design Guide procedures were adopted during the analysis of flexible pavement layer thickness as following procedure;

a. Determine the volume of traffic (AADT) from survey data, existing CBR, IRI and $M_R$

b. Calculate vehicle damage factor (VDF)

c. Calculate cumulative equivalent single axle load (CESAL) using actual VDF based upon design and existing condition.

d. Calculate the Structural Number (SN) for different pavement layers by trial and error method.

d. Calculate pavement thickness of different layers based upon SN.

The methodology was as per following flowchart;

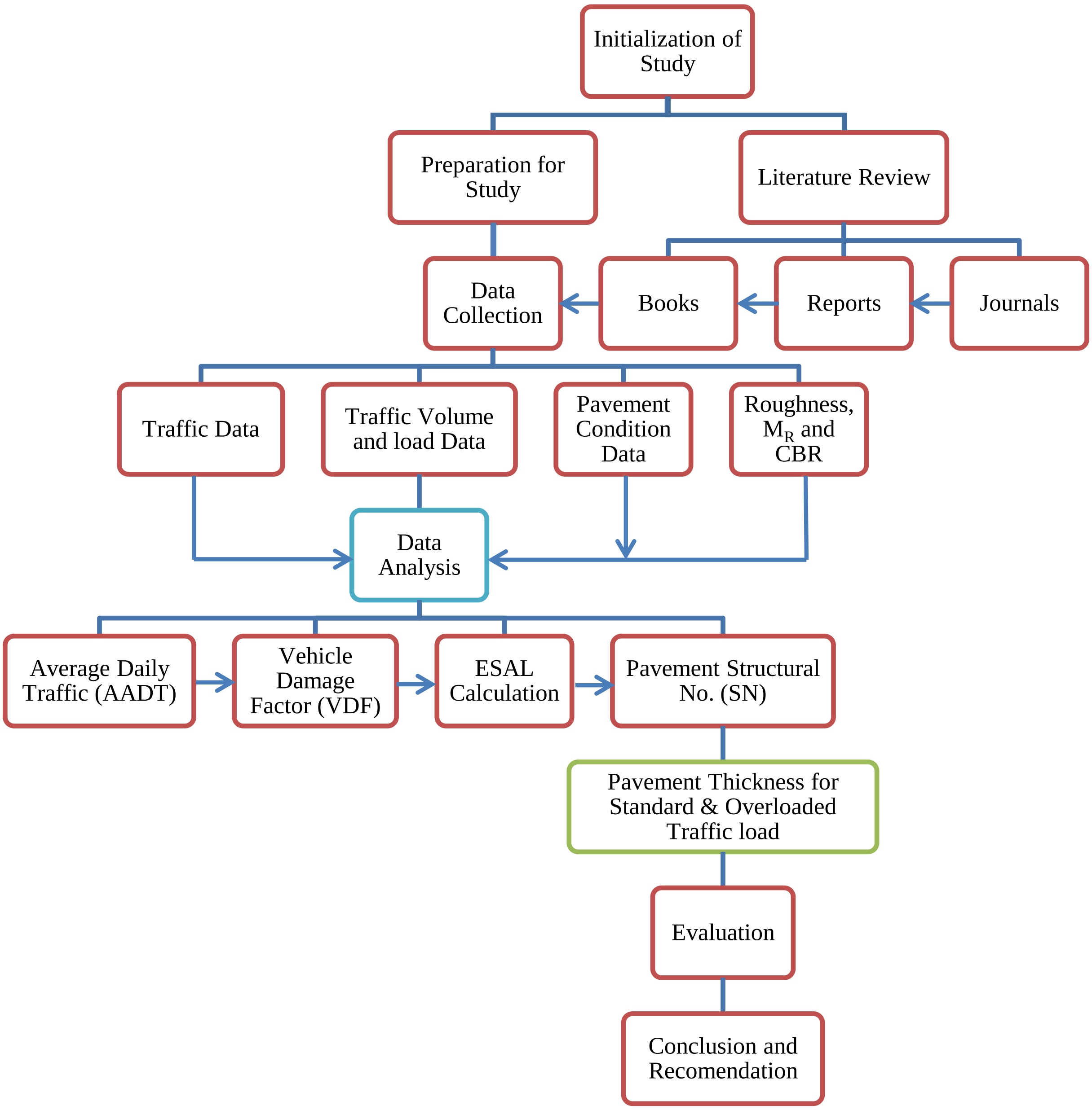

**Figure 3:** Flowchart for methodology of the study

## 3. Results and Discussion

### *3.1 Loss of Serviceability (ΔPSI)*

The loss of serviceability can be determined by following the procedure below.

a. Average *IRI* was calculated from the existing data for different stations of each direction. The *IRI* for all stations can be seen in Tables 1 and Table 2 below.
b. PSI (in this case, PSI was referred to terminal serviceability, $p_t$) can be obtained by using the relationship between *PSI* and *IRI*, as follows.

$$PSI = 5-0.2937X^4+1.1771X^3-1.4045X^2-1.5803X \text{ ……………………… (5)}$$

Where, $X = \log(1+SV)$ and $SV = 2.2704\ IRI^2$

Initial serviceability $p_o = 4.2$

c. Loss of serviceability could be calculated using the following equation.

$$\Delta PSI = Po - Pt \text{ ……………………………………………………….. (6)}$$

$p_t$ is terminal serviceability index 2 to 3.5. The use of $p_t = 3.0$ is caused by the minimum terminal serviceability for medium traffic highway.

The calculation result *ΔPSI* for two directions are depicted in Table 1 and Table 2 in which road sections having high IRI values that cause the initial serviceability ($p_o$) is less than terminal serviceability ($p_t$). To overcome this problem, all initial serviceability; that was less than two, was equated to two.

### ***3.2 Pavement Design Guideline (Flexible Pavement)*** [16]

Pavement is most important component of highway section. The overall functioning of highway system greatly depends on the performance of its pavement. Furthermore, vehicle operating cost, entire highway economics and life cycles are interrelated to the pavement design practices.

The design procedure of flexible pavement involves the interplay of several veriables, such as wheel loads, traffic, climate, terrain and subgrade soil conditions. The values of elastic moduli of Asphalt Concrete (AC), Dense Bituminous Macadam (DBM), and Bituminous Macadam (BM) meeting the requirements of the standard specifications of DoR are given table 3.

### ***3.3 Resilient modulus (MR)***

The value of resilient modulus could be measured according to AASHTO procedure or based on relationship with other parameter, such as California Bearing Ratio (*CBR*). This relationship is represented by the following equation. 1 Mpa ~ 145.03774 psi [17]

$$M_R \text{ (Mpa)} = 10.3 * CBR \text{ or, } M_R \text{ (psi)} = 1500 * CBR \text{ …………………. (7)}$$

The CBR for every single station on the road and its corresponding $M_R$ is shown in Table 4. It was assumed that the resilient modulus is similar for both directions.

**Table 1:** Loss of Serviceability for Narayanghat - Mugling Direction [4]

| Chainage Km | | IRI m/km | SV | X | $P_t$ | code value $P_t$ | $P_o$ code value | ΔPSI |
|---|---|---|---|---|---|---|---|---|
| From | To | | | | | | | |
| 0+000 | 1+000 | 11.48 | 299.217 | 2.477435 | -0.701 | 3.000 | 4.200 | 1.200 |
| 1+000 | 2+000 | 11.2 | 284.799 | 2.456061 | -0.601 | 3.000 | 4.200 | 1.200 |
| 2+000 | 3+000 | 6.45 | 94.4543 | 1.979796 | 0.988 | 3.000 | 4.200 | 1.200 |
| 3+000 | 4+000 | 6.05 | 83.1023 | 1.924808 | 1.117 | 3.000 | 4.200 | 1.200 |
| 4+000 | 5+000 | 7.57 | 130.105 | 2.117619 | 0.627 | 3.000 | 4.200 | 1.200 |
| 5+000 | 6+000 | 9.35 | 198.484 | 2.299908 | 0.039 | 3.000 | 4.200 | 1.200 |
| 6+000 | 7+000 | 7.78 | 137.424 | 2.14121 | 0.559 | 3.000 | 4.200 | 1.200 |
| 7+000 | 8+000 | 9.15 | 190.084 | 2.281223 | 0.106 | 3.000 | 4.200 | 1.200 |
| 8+000 | 9+000 | 11.15 | 282.262 | 2.452188 | -0.584 | 3.000 | 4.200 | 1.200 |
| 9+000 | 10+000 | 10.52 | 251.266 | 2.401859 | -0.363 | 3.000 | 4.200 | 1.200 |
| 10+000 | 11+000 | 10.49 | 249.835 | 2.399388 | -0.352 | 3.000 | 4.200 | 1.200 |
| 11+000 | 12+000 | 8.06 | 147.493 | 2.171707 | 0.467 | 3.000 | 4.200 | 1.200 |
| 12+000 | 13+000 | 8.06 | 147.493 | 2.171707 | 0.467 | 3.000 | 4.200 | 1.200 |
| 13+000 | 14+000 | 11.92 | 322.593 | 2.509999 | -0.859 | 3.000 | 4.200 | 1.200 |
| 14+000 | 15+000 | 17.91 | 728.272 | 2.862889 | -3.145 | 3.000 | 4.200 | 1.200 |
| 15+000 | 16+000 | 11.71 | 311.327 | 2.494609 | -0.783 | 3.000 | 4.200 | 1.200 |
| 16+000 | 17+000 | 10.65 | 257.514 | 2.412485 | -0.408 | 3.000 | 4.200 | 1.200 |
| 17+000 | 18+000 | 11.26 | 287.859 | 2.460685 | -0.623 | 3.000 | 4.200 | 1.200 |
| 18+000 | 19+000 | 10.6 | 255.102 | 2.408413 | -0.390 | 3.000 | 4.200 | 1.200 |
| 19+000 | 20+000 | 13.06 | 387.248 | 2.589109 | -1.275 | 3.000 | 4.200 | 1.200 |
| 20+000 | 21+000 | 16.49 | 617.367 | 2.791247 | -2.583 | 3.000 | 4.200 | 1.200 |
| 21+000 | 22+000 | 10.37 | 244.152 | 2.389435 | -0.310 | 3.000 | 4.200 | 1.200 |
| 22+000 | 23+000 | 16.84 | 643.853 | 2.809461 | -2.721 | 3.000 | 4.200 | 1.200 |
| 23+000 | 24+000 | 15.68 | 558.206 | 2.747572 | -2.267 | 3.000 | 4.200 | 1.200 |
| 24+000 | 25+000 | 14.23 | 459.74 | 2.663456 | -1.712 | 3.000 | 4.200 | 1.200 |
| 25+000 | 26+000 | 13.34 | 404.03 | 2.607488 | -1.378 | 3.000 | 4.200 | 1.200 |
| 26+000 | 27+000 | 15.22 | 525.935 | 2.721757 | -2.090 | 3.000 | 4.200 | 1.200 |
| 27+000 | 28+000 | 11.97 | 325.305 | 2.513624 | -0.877 | 3.000 | 4.200 | 1.200 |
| 28+000 | 29+000 | 14.58 | 482.633 | 2.684516 | -1.845 | 3.000 | 4.200 | 1.200 |
| 29+000 | 30+000 | 15.68 | 558.206 | 2.747572 | -2.267 | 3.000 | 4.200 | 1.200 |
| 30+000 | 31+000 | 12.75 | 369.082 | 2.568298 | -1.161 | 3.000 | 4.200 | 1.200 |
| 31+000 | 32+000 | 15.78 | 565.349 | 2.753084 | -2.306 | 3.000 | 4.200 | 1.200 |
| 32+000 | 33+000 | 10.42 | 246.512 | 2.393596 | -0.328 | 3.000 | 4.200 | 1.200 |
| 33+000 | 34+000 | 9.05 | 185.951 | 2.271729 | 0.140 | 3.000 | 4.200 | 1.200 |

**Table 2:** Loss of Serviceability for Mugling – Narayanghat Direction [4]

| Chainage Km | | IRI | SV | X | $P_t$ | code value $P_t$ | $P_o$ code value | ΔPSI |
|---|---|---|---|---|---|---|---|---|
| From | To | | | | | | | |
| From | To | 10.87 | 268.263 | 2.430177 | -0.485 | 3.000 | 4.200 | 1.200 |
| 0+000 | 1+000 | 13.82 | 433.629 | 2.638119 | -1.558 | 3.000 | 4.200 | 1.200 |
| 1+000 | 2+000 | 10.87 | 268.263 | 2.430177 | -0.485 | 3.000 | 4.200 | 1.200 |
| 2+000 | 3+000 | 10.77 | 263.35 | 2.42218 | -0.450 | 3.000 | 4.200 | 1.200 |
| 3+000 | 4+000 | 11.63 | 307.087 | 2.488674 | -0.754 | 3.000 | 4.200 | 1.200 |
| 4+000 | 5+000 | 10.89 | 269.252 | 2.431768 | -0.492 | 3.000 | 4.200 | 1.200 |
| 5+000 | 6+000 | 13.03 | 385.471 | 2.587116 | -1.264 | 3.000 | 4.200 | 1.200 |
| 6+000 | 7+000 | 12.60 | 360.449 | 2.558047 | -1.106 | 3.000 | 4.200 | 1.200 |
| 7+000 | 8+000 | 10.44 | 247.459 | 2.395255 | -0.335 | 3.000 | 4.200 | 1.200 |
| 8+000 | 9+000 | 13.71 | 426.754 | 2.631194 | -1.517 | 3.000 | 4.200 | 1.200 |
| 9+000 | 10+000 | 16.03 | 583.404 | 2.766713 | -2.403 | 3.000 | 4.200 | 1.200 |
| 10+000 | 11+000 | 11.17 | 283.275 | 2.453739 | -0.591 | 3.000 | 4.200 | 1.200 |
| 11+000 | 12+000 | 14.86 | 501.349 | 2.701005 | -1.952 | 3.000 | 4.200 | 1.200 |
| 12+000 | 13+000 | 11.17 | 283.275 | 2.453739 | -0.591 | 3.000 | 4.200 | 1.200 |
| 13+000 | 14+000 | 9.98 | 226.133 | 2.35628 | -0.176 | 3.000 | 4.200 | 1.200 |
| 14+000 | 15+000 | 10.39 | 245.094 | 2.391102 | -0.317 | 3.000 | 4.200 | 1.200 |
| 15+000 | 16+000 | 9.50 | 204.904 | 2.313664 | -0.012 | 3.000 | 4.200 | 1.200 |
| 16+000 | 17+000 | 10.44 | 247.459 | 2.395255 | -0.335 | 3.000 | 4.200 | 1.200 |
| 17+000 | 18+000 | 15.54 | 548.283 | 2.739796 | -2.213 | 3.000 | 4.200 | 1.200 |
| 18+000 | 19+000 | 11.89 | 320.971 | 2.507817 | -0.848 | 3.000 | 4.200 | 1.200 |
| 19+000 | 20+000 | 8.25 | 154.529 | 2.191812 | 0.405 | 3.000 | 4.200 | 1.200 |
| 20+000 | 21+000 | 8.31 | 156.785 | 2.198066 | 0.385 | 3.000 | 4.200 | 1.200 |
| 21+000 | 22+000 | 10.74 | 261.885 | 2.419766 | -0.439 | 3.000 | 4.200 | 1.200 |
| 22+000 | 23+000 | 11.40 | 295.061 | 2.471381 | -0.672 | 3.000 | 4.200 | 1.200 |
| 23+000 | 24+000 | 10.11 | 232.062 | 2.367472 | -0.221 | 3.000 | 4.200 | 1.200 |
| 24+000 | 25+000 | 9.75 | 215.83 | 2.336119 | -0.097 | 3.000 | 4.200 | 1.200 |
| 25+000 | 26+000 | 8.99 | 183.494 | 2.265982 | 0.160 | 3.000 | 4.200 | 1.200 |
| 26+000 | 27+000 | 10.79 | 264.329 | 2.423785 | -0.457 | 3.000 | 4.200 | 1.200 |
| 27+000 | 28+000 | 9.29 | 195.945 | 2.294345 | 0.059 | 3.000 | 4.200 | 1.200 |
| 28+000 | 29+000 | 7.92 | 142.414 | 2.156592 | 0.513 | 3.000 | 4.200 | 1.200 |
| 29+000 | 30+000 | 7.87 | 140.622 | 2.151129 | 0.530 | 3.000 | 4.200 | 1.200 |
| 30+000 | 31+000 | 9.50 | 204.904 | 2.313664 | -0.012 | 3.000 | 4.200 | 1.200 |
| 31+000 | 32+000 | 9.22 | 193.003 | 2.287809 | 0.083 | 3.000 | 4.200 | 1.200 |
| 32+000 | 33+000 | 7.39 | 123.991 | 2.09688 | 0.685 | 3.000 | 4.200 | 1.200 |

**Table 3:** Elastic Modulus (Mpa) of Bituminous Materials [16]

| Mix type | Temperature, $^{o}$C | | | | |
|---|---|---|---|---|---|
| | 20 | 25 | 30 | 35 | 40 |
| AC and DBM 80/100 Bitumen | 2300 | 1966 | 1455 | 975 | 797 |
| AC and DBM 60/70 Bitumen | 3600 | 3126 | 2579 | 1695 | 1270 |
| AC and DBM 30/40 Bitumen (75 | 6000 | 4928 | 3809 | 2944 | 2276 |

**Table 4:** Modulusof resilient of pavement layers

| Chainage | Subgrade | | Subbase/Base | | Surface Layer | |
|---|---|---|---|---|---|---|
| | *CBR % [4] | MR (psi) | CBR % [4] | MR (psi) | MR (Mpa) [16] | MR (psi) |
| 2+650 | 11.70 | 17550 | 80.30 | 120450 | 2300 | 333586.79 |
| 6+000 | 11.00 | 16500 | 80.30 | 120450 | 2300 | 333586.79 |
| 9+100 | 15.90 | 23850 | 80.30 | 120450 | 2300 | 333586.79 |
| 12+000 | 15.10 | 22650 | 75.00 | 112500 | 2300 | 333586.79 |
| 15+000 | 16.20 | 24300 | 75.00 | 112500 | 2300 | 333586.79 |
| 18+000 | 16.50 | 24750 | 74.00 | 111000 | 2300 | 333586.79 |
| 21+000 | 15.00 | 22500 | 74.00 | 111000 | 2300 | 333586.79 |
| 25+000 | 17.00 | 25500 | 74.00 | 111000 | 2300 | 333586.79 |
| 27+000 | 14.00 | 21000 | 74.00 | 111000 | 2300 | 333586.79 |
| 30+000 | 12.00 | 18000 | 74.00 | 111000 | 2300 | 333586.79 |
| 32+900 | 14.50 | 21750 | 74.00 | 111000 | 2300 | 333586.79 |
| 35+850 | 15.50 | 23250 | 74.00 | 111000 | 2300 | 333586.79 |

### *3.4 Traffic Data*

In this study, analysis of traffic data in the means of calculating average annual daily traffic (AADT) was taken from survey report provided by Road Sector Development Project. The data survey period was 3 days for each direction in 2010 AD [4]. Therefore, all traffic analyses in this study were based upon these 3-day traffic data. According to Heavy Vehicle Management Policy 2064, vehicles could be categorized in to 3 classes, as light, medium and heavy vehicle.

**Table 5:** AADT of heavy vehicles for both directions [4]

| Direction | AADT of vehicle classes | | | | | |
|---|---|---|---|---|---|---|
| | Light | Medium | Heavy vehicles | | | Total |
| | | | 2- Axle | 3- Axle | 4- Axle | |
| Narayanghat – Mugling(S-N) | 1191 | 209 | 1076 | 643 | 40 | 3151 |
| Mugling – Narayanghat(N-S) | 1190 | 180 | 840 | 574 | 39 | 2812 |

### *3.5 Determination of Vehicle Damage Factor (VDF)*

VDF or axle load equivalency factor (LEF or E) of each heavy vehicle was determined using Nepal Road Standard 2047 [1] as follows for individual axle,

$$VDF = \left(\frac{Axle\ Load}{8.16}\right){}^\wedge 4.5 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

The VDF of front and rear axles for every type of vehicle were calculated based upon the configuration specification defined by Heavy Vehicle Management Policy 2064.

**Table 6:** VDF of different classes of vehicles [4]

| Direction | VDF of vehicle classes | | | | |
|---|---|---|---|---|---|
| | Light | Medium | Heavy vehicles | | |
| | | | 2- Axle | 3- Axle | 4- Axle |
| Narayanghat - Mugling | 0.002 | 0.123 | 6.14 | 15.23 | 28.89 |
| Mugling - Narayanghat | 0.002 | 0.101 | 4.04 | 1.76 | 0.49 |

As seen in Table 6, the total VDF of Narayanghat – Mugling direction is higher than the opposite direction. The deviation of VDF is mainly contributed by VDF of 2-Axle, 3-Axle and 4-Axle vehicle.

### 3.6 Calculation of Traffic Load

The calculation of traffic load $W_{18}$ in equivalent standard axle load (ESAL) should be based on the actual VDF and AADT. AASHTO Design Guide gives the following formula to determine the traffic load for design lane ($W_{18}$).

$$W_{18} = \sum(AADTi * Ei * GRi) * 365$$

$$W_{18} = \overline{W}_{18} * D_D * D_L$$

$$G_{Ri} = \frac{(1+g_i)^n - 1}{g_i}$$

Road section Narayanghat – Mugling or Mugling - Narayanghat is a Two-lane two- direction undivided road, therefore, in this case, $D_D$ and $D_L$ equal to 0.5 and 1.0, respectively. The traffic load on Narayanghat – Mugling or Mugling - Narayanghat road section was assumed to increase 6.2% per anuum [4] and the road could serve traffic load for the next 10 years. $D_D$ is generally taken 0.5. In some special cases, $D_D$ varies from 0.3 to 0.7 depending on which direction that considers as major and minor (AASHTO 1993). The magnitude of $D_L$ is determined based on the number of lanes in one carriageway as per table 7.

**Table 7:** Lane Distribution factor (DL) [15]

| Number of lane direction | % Standard axle load in design lane |
|---|---|
| 1 | 100 |
| 2 | 80 -100 |
| 3 | 60 -80 |
| 4 | 50 -75 |

### 3.7 Calculation of Equivalent Single Axle Load

The equivqlent single axle load (ESAL) was calculated using equition 2, 3 and 4 and values are tabulated in table 8, 9 and 10. ESAL for both directions of the road in standard and overloaded conditions for 10 years pavement life are presented for design of pavement layers.

**Table 8:** ESAL values in overloaded condition

| **Average Vehicle** | **AADT** | **Growth rate** | **$G_{Ri}$ for 2014** | **$G_{Ri}$ for 2014** | **Lane Distribution Factor** | **Directional Distribution Factor** | **A Year** | **N-S Direction** | | **S-N Direction** | | **Design Loads (10 years life)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Vehicle** | **2010** | **g%** | **4 Years** | **14 Years** | **$D_L$** | **$D_D$** | **Days** | **VDF** | **2014 ESAL** | **VDF** | **2014 cum ESAL** | **2024 cum ESAL** |
| Light | 247 | 6.2 | 4.388 | 21.312 | 1.00 | 0.50 | 365 | 0.002 | 396 | 0.002 | 396 | 1,921 |
| Medium | 389 | 6.2 | 4.388 | 21.312 | 1.00 | 0.54 | 365 | 0.101 | 33977 | 0.101 | 33977 | 165,040 |
| Heavy 2-Axle | 1358 | 6.2 | 4.388 | 21.312 | 1.00 | 0.59 | 365 | 2.980 | 3823749 | 2.98 | 3823749 | 18,573,411 |
| Heavy 3-Axle | 1756 | 6.2 | 4.388 | 21.312 | 1.00 | 0.55 | 365 | 4.220 | 6527110 | 4.22 | 6527110 | 31,704,673 |
| Heavy 4-Axle | 79 | 6.2 | 4.388 | 21.312 | 1.00 | 0.50 | 365 | 6.940 | 439014 | 6.94 | 439014 | 2,132,457 |
| Total | 3829 | | | | | | **Total ESAL** | | **10,824,245** | | **10,824,245** | **52,577,502** |

**Table 9:** ESAL values in overloaded condition

| **Average Vehicle** | **AADT** | **Growth rate** | **$G_{Ri}$ for 2014** | **$G_{Ri}$ for 2024** | **Lane Distribution Factor** | **Directional Distribution Factor** | **A Year** | **N-S Direction** | | | **S-N Direction** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Vehicle** | **2010** | **g%** | **n=4 Years** | **n=14 Years** | **$D_L$** | **$D_d$** | **Days** | **VDF** | **2014 ESAL** | **2024 ESAL** | **VDF** | **2014 cum ESAL** | **2024 cum ESAL** |
| Light | 247 | 6.2 | 4.388 | 21.312 | 1.00 | 0.50 | 365 | 0.002 | 396 | 1921 | 0.002 | 396 | 1,921 |
| Medium | 389 | 6.2 | 4.388 | 21.312 | 1.00 | 0.54 | 365 | 0.101 | 33977 | 165040 | 0.123 | 41378 | 200,989 |
| Heavy 2-Axle | 1358 | 6.2 | 4.388 | 21.312 | 1.00 | 0.59 | 365 | 4.040 | 5183874 | 25180061 | 6.140 | 7878462 | 38,268,706 |
| Heavy 3-Axle | 1756 | 6.2 | 4.388 | 21.312 | 1.00 | 0.55 | 365 | 1.760 | 2722207 | 13222802 | 15.230 | 23556373 | 114,422,315 |
| Heavy 4-Axle | 79 | 6.2 | 4.388 | 21.312 | 1.00 | 0.50 | 365 | 0.490 | 30997 | 150562 | 28.890 | 1827536 | 8,877,042 |
| Total | 3829 | | | | | | **Total ESAL** | | **7,971,451** | **38,720,386** | | **33,304,145** | **161,770,974** |

**Table 10:** Traffic load (standard and overloaded condition) for 2024

| Direction | $W_{18}$ (In Million ESAL) | |
|---|---|---|
| | Standard Condition | Loaded Condition |
| Narayanghat – Mugling (S-N) Direction | 52.577 | 161.770 |
| Mugling – Narayanghat (N-S) Direction | 52.577 | 38.720 |

Table 10 shows that there is no different on traffic load for both directions in standard condition, but in overloaded condition, traffic load of Narayanghat – Mugling direction is 4.18 times higher than opposite direction. Although N-S direction traffic load is less than in standard condition and design is done taking Standard traffic load in N-S direction.

### *3.8 Calculation of Structural Number (SN)*

The structural capacity of road structure, represented by SN, is determined by the following procedure.

a. $SN_3$, $SN_2$ and $SN_1$ were determined based on resilient modulus of subgrade; base and surface layer, respectively, using AASHTO design thickness equation (1).

The three values of SN were calculated using data from the following input parameter which is corresponding with standard and overloaded conditions: traffic load, $W_{18}$ as shown in Table 10, and loss of serviceability ($\Delta$PSI) Tables 1 and Table 2. Other parameters, R or $Z_R$ and $S_o$, were assumed to be similar for the two conditions, that are, R = 90% or $Z_R = -1.282$ and $S_o = 0.49$

b. Coefficient of Relative Strength (*a*) and Drainage Coefficient (*m*) were taken from AASHTO 1993. The coefficients of relative strength (*a*) for standard and overloaded conditions had similar values.

The $a_1$, $a_2$ *and* $a_3$ were determined based on the resilient or elastic modulus as table 4. The drainage coefficient (*m*) was assumed to equal to 1.0 as the quality of drainage was flowing the water from the pavement structure within one day or it is categorized as “good”

**Table 11:** The Definition of Drainage Quality [15]

| Drainage Quality | Time for water dispered |
|---|---|
| Excellent | 2 hours |
| Good | 1 day |
| Fair | 1 week |
| Poor | 1 month |
| Very poor | Water will not drain |

**Table 12:** Drainage Coefficient (m) [15]

| Quality of drainage | Percentage of time pavement structure is exposed to moisture level approaching saturation | | | |
|---|---|---|---|---|
| | < 1% | 1 – 5% | 5 – 25% | >25% |
| Excellent | 1.40 – 1.35 | 1.35 – 1.30 | 1.30 – 1.20 | 1.20 |
| Good | 1.35 – 1.25 | 1.25 – 1.15 | 1.15 – 1.00 | 1.00 |
| Fair | 1.25 – 1.15 | 1.15 - 1.05 | 1.00 – 0.80 | 0.80 |
| Poor | 1.15 – 1.05 | 1.05 – 0.80 | 0.80 – 0.60 | 0.60 |
| Very poor | 1.05 – 0.95 | 0.95 – 0.75 | 0.75 – 0.40 | 0.40 |

c. The layer thickness was calculated using the following equations

$$SN_3 = a_1D_1 + a_2D_2\, m_2 + a_3D_3m_3 \quad (9)$$

$$SN_2 = a_1D_1 + a_2D_2m_2 \quad (10)$$

$$SN_1 = a_1D_1 \quad (11)$$

Where: $a_1$, $a_2$, $a_3$ = layer coefficients of surface, base, and sub base courses respectively.

$D_1$, $D_2$, $D_3$ = actual thicknesses (in inches) of surface, base and subbase courses, respectively

$m_2$, $m_3$ = drainage coefficients for base and sub base layers, respectively

Based on the procedure above, the structural number and thickness of each layer for two conditions (standard and overloaded) can be determined as in Tables 13 & Table 14.

**Table 13:** SN and Thickness in Overloaded Condition

| S-N Direction | | | | | Trial and error Value | | | Measured/Code Value | | | | | | | | Thickness of pavement | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chainage | $W_{18}$ | $\log W_{18}$ | $Z_r$ | $S_0$ | $SN_3$ | $SN_2$ | $SN_1$ | $\Delta PSI$ | $MR_3$ | $MR_2$ | $MR_1$ | $a_1$ | $a_2$ | $a_3$ | $m_2$ | $m_3$ | $D_1$ | $D_2$ | $D_3$ |
| 2+650 | 161,770,974 | 8.2090 | -1.282 | 0.49 | 5.9280 | 2.744 | 1.793 | 1.2 | 17550 | 120450 | 333586.79 | 0.38 | 0.135 | 0.084 | 1.0 | 1.0 | 4.718 | 7.044 | 37.905 |
| 6+000 | 161,770,974 | 8.2090 | -1.282 | 0.49 | 6.0470 | 2.744 | 1.793 | 1.2 | 16500 | 120450 | 333586.79 | 0.38 | 0.135 | 0.082 | 1.0 | 1.0 | 4.718 | 7.044 | 40.280 |
| 9+100 | 161,770,974 | 8.2090 | -1.282 | 0.49 | 5.3500 | 2.744 | 1.793 | 1.2 | 23850 | 120450 | 333586.79 | 0.38 | 0.135 | 0.092 | 1.0 | 1.0 | 4.718 | 7.044 | 28.326 |
| 12+000 | 161,770,974 | 8.2090 | -1.282 | 0.49 | 5.4450 | 2.826 | 1.793 | 1.2 | 22650 | 112500 | 333586.79 | 0.38 | 0.130 | 0.090 | 1.0 | 1.0 | 4.718 | 7.946 | 29.100 |
| 15+000 | 161,770,974 | 8.2090 | -1.282 | 0.49 | 5.3150 | 2.826 | 1.793 | 1.2 | 24300 | 112500 | 333586.79 | 0.38 | 0.130 | 0.092 | 1.0 | 1.0 | 4.718 | 7.946 | 27.054 |
| 18+000 | 161,770,974 | 8.2090 | -1.282 | 0.49 | 5.2820 | 2.843 | 1.793 | 1.2 | 24750 | 111000 | 333586.79 | 0.38 | 0.130 | 0.093 | 1.0 | 1.0 | 4.718 | 8.077 | 26.226 |
| 21+000 | 161,770,974 | 8.2090 | -1.282 | 0.49 | 5.4580 | 2.843 | 1.793 | 1.2 | 22500 | 111000 | 333586.79 | 0.38 | 0.130 | 0.090 | 1.0 | 1.0 | 4.718 | 8.077 | 29.056 |
| 25+000 | 161,770,974 | 8.2090 | -1.282 | 0.49 | 5.2270 | 2.843 | 1.793 | 1.2 | 25500 | 111000 | 333586.79 | 0.38 | 0.130 | 0.094 | 1.0 | 1.0 | 4.718 | 8.077 | 25.362 |
| 27+000 | 161,770,974 | 8.2090 | -1.282 | 0.49 | 5.5870 | 2.843 | 1.793 | 1.2 | 21000 | 111000 | 333586.79 | 0.38 | 0.130 | 0.088 | 1.0 | 1.0 | 4.718 | 8.077 | 31.182 |
| 30+000 | 161,770,974 | 8.2090 | -1.282 | 0.49 | 5.8800 | 2.843 | 1.793 | 1.2 | 18000 | 111000 | 333586.79 | 0.38 | 0.130 | 0.084 | 1.0 | 1.0 | 4.718 | 8.077 | 36.155 |
| 32+900 | 161,770,974 | 8.2090 | -1.282 | 0.49 | 5.5220 | 2.843 | 1.793 | 1.2 | 21750 | 111000 | 333586.79 | 0.38 | 0.130 | 0.089 | 1.0 | 1.0 | 4.718 | 8.077 | 30.101 |
| 35+850 | 161,770,974 | 8.2090 | -1.282 | 0.49 | 5.3980 | 2.843 | 1.793 | 1.2 | 23250 | 111000 | 333586.79 | 0.38 | 0.130 | 0.091 | 1.0 | 1.0 | 4.718 | 8.077 | 28.077 |
| $D_1,a_1,SN_1$ | for surface Layer | | $D_2,a_2,SN_2$ | | for base Layer | | | $D_3,a_3,SN_3$ | | for subbase Layer | | | | | | Inch | 4.718 | 7.797 | 30.735 |

**Table 14:** SN and Thickness in Standard Condition

| S-N Direction/N-S Direction | | | | | Trial and error Value | | | Measured/Code Value | | | | | | | | | Thickness of pavement | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chainage | $W_{18}$ | $\log W_{18}$ | $Z_r$ | $S_0$ | $SN_3$ | $SN_2$ | $SN_1$ | ΔPSI | $MR_3$ | $MR_2$ | $MR_1$ | $a_1$ | $a_2$ | $a_3$ | $m_2$ | $m_3$ | $D_1$ | $D_2$ | $D_3$ |
| 2+650 | 52,577,502 | 7.7210 | -1.282 | 0.49 | 5.025 | 2.237 | 1.46 | 1.2 | 17550 | 120450 | 333586.79 | 0.38 | 0.135 | 0.084 | 1.00 | 1.00 | 3.842 | 5.756 | 33.190 |
| 6+000 | 52,577,502 | 7.7210 | -1.282 | 0.49 | 5.137 | 2.237 | 1.46 | 1.2 | 16500 | 120450 | 333586.79 | 0.38 | 0.135 | 0.082 | 1.00 | 1.00 | 3.842 | 5.756 | 35.366 |
| 9+100 | 52,577,502 | 7.7210 | -1.282 | 0.49 | 4.476 | 2.237 | 1.46 | 1.2 | 23850 | 120450 | 333586.79 | 0.38 | 0.135 | 0.092 | 1.00 | 1.00 | 3.842 | 5.756 | 24.337 |
| 12+000 | 52,577,502 | 7.7210 | -1.282 | 0.49 | 4.567 | 2.302 | 1.46 | 1.2 | 22650 | 112500 | 333586.79 | 0.38 | 0.130 | 0.090 | 1.00 | 1.00 | 3.842 | 6.477 | 25.167 |
| 15+000 | 52,577,502 | 7.7210 | -1.282 | 0.49 | 4.443 | 2.302 | 1.46 | 1.2 | 24300 | 112500 | 333586.79 | 0.38 | 0.130 | 0.092 | 1.00 | 1.00 | 3.842 | 6.477 | 23.272 |
| 18+000 | 52,577,502 | 7.7210 | -1.282 | 0.49 | 4.410 | 2.315 | 1.46 | 1.2 | 24750 | 111000 | 333586.79 | 0.38 | 0.130 | 0.093 | 1.00 | 1.00 | 3.842 | 6.577 | 22.527 |
| 21+000 | 52,577,502 | 7.7210 | -1.282 | 0.49 | 4.578 | 2.315 | 1.46 | 1.2 | 22500 | 111000 | 333586.79 | 0.38 | 0.130 | 0.090 | 1.00 | 1.00 | 3.842 | 6.577 | 25.144 |
| 25+000 | 52,577,502 | 7.7210 | -1.282 | 0.49 | 4.358 | 2.315 | 1.46 | 1.2 | 25500 | 111000 | 333586.79 | 0.38 | 0.130 | 0.094 | 1.00 | 1.00 | 3.842 | 6.577 | 21.734 |
| 27+000 | 52,577,502 | 7.7210 | -1.282 | 0.49 | 4.702 | 2.315 | 1.46 | 1.2 | 21000 | 111000 | 333586.79 | 0.38 | 0.130 | 0.088 | 1.00 | 1.00 | 3.842 | 6.577 | 27.125 |
| 30+000 | 52,577,502 | 7.7210 | -1.282 | 0.49 | 4.978 | 2.315 | 1.46 | 1.2 | 18000 | 111000 | 333586.79 | 0.38 | 0.130 | 0.084 | 1.00 | 1.00 | 3.842 | 6.577 | 31.702 |
| 32+900 | 52,577,502 | 7.7210 | -1.282 | 0.49 | 4.639 | 2.315 | 1.46 | 1.2 | 21750 | 111000 | 333586.79 | 0.38 | 0.130 | 0.089 | 1.00 | 1.00 | 3.842 | 6.577 | 26.112 |
| 35+850 | 52,577,502 | 7.7210 | -1.282 | 0.49 | 4.520 | 2.315 | 1.46 | 1.2 | 23250 | 111000 | 333586.79 | 0.38 | 0.130 | 0.091 | 1.00 | 1.00 | 3.842 | 6.577 | 24.231 |
| $D_1$, $a_1$, $SN_1$ | for surface Layer | | | | | | | | | | Average Thickness | | | | | Inch | 3.842 | 6.355 | 26.659 |
| $D_2$, $a_2$, $SN_2$ | for base Layer | | | | Comparision on Thickness with respect to standared condition in percentage | | | | | | | | | | | | 22.81 | 22.69 | 15.29 |

$D_3$, $a_3$, $SN_3$ for subbase Layer

It can be seen from the analysis that there are significant differences between the structural number and thickness of subbase/base and surface layers for standard and overloaded conditions. The effect of overloading in designed total thickness was found as 17.35 % with 15.29% increase in sub-base layer, 22.69% increase in base layer and 22.81 % increase in surface layer.

## 4. Conclusions and Recommendations

### *4.1 Conclusions*

From the study and analysis of traffic data following points can be concluded:

1. From sample survey data, and traffic listed in survey report the composition of traffic was heavy vehicle 83.76 %, medium vehicle 9.18 % and light vehicle 7.05 %( in average). The composition of heavy vehicle was found as: 2-Axle 42.53%, 3-Axle 55% and 4-Axle 2.72% and damaging effect (VDF) of different vehicles is as: Light 0.002, Medium 0.123, 2-Axle 6.14, 3-Axle 15.23 and 4-Axle 28.89. Percentage of overloaded vehicles against standard loading are as 2-Axle: 62.77, 3-Axle: 79.34 and 4-Axle: 100.00 and overloading is higher in S-N direction than in N-S direction.
2. Cumulative ESAL on Narayanghat- Mugling direction for year 2024 found to be 161.77 million ESAL in overloaded condition but it was only 52.577 million ESAL in standard condition
3. The total pavement thickness required for overloaded condition seemed to be 43.25 inch in which 30.735 inch subbase, 7.797 inch base and 4.718 inch bituminous wearing course. But in standard condition total thickness required seemed to be 36.856 inch with 26.659 inch subbase, 6.355 inch base and 3.842 inch bituminous wearing course.
4. The reduction of service life of the pavement surface due to overloading along Narayanghat-Mugling direction was found to be 59.90% [5] where as the effect of the same in designed total thickness was found as 17.35 % increase with 15.29% in sub-base layer, 22.69% in base layer and 22.81 % in surface layer.
5. From the study it can be concluded that flexible pavement surface is more sensitive in service life than in design thickness due to overloading. Rutting and fatigue effect on pavement surface may play vital role in the reduction of service life and damaging the road pavement.

### *4.2 Recommendations*

Following recommendations can help to control the overloading.

1. Design of the road pavement should be done with actual traffic loading rather than in standard loading. Rutting and fatigue criteria should be considered during the design of the flexible pavement surface and regular maintenance should be carried out to prolong the pavement service life of the road.
2. As overloading is increasing, it has to be controlled by rules and regulations. Effective means of managing truck overloading is not unitary. It must be combined with monitoring, inspection, enforcement and punishment as a complete. Regular monitoring, inspection and enforcement are the effective ways to control overloading. So fines must be associated with intensified enforcement when

considered in further strategy recommendations.

3. Use of networking technology should be encouraged for better effectiveness to control overloading.

## 5. Constraint and Limitations

Study area was limited to a road section from Narayanghat to Mugling, Nepal. This study was done taking 3 days traffic survey data provided by Department of Roads, Road sector development project. Sub-grade CBR data were taken from Survey report at the rate of 3 km interval. Pavement structure misture levels were assumed. Field survey and investigations were not done by the auther. Some datas that were not obtained from field and survey report were taken from different codes and manuals.

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## 6. Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

## 7. Abbreviations

AADT = Annual Average Daily Traffic

AASHTO = American Association of State Highway Transportation Officials

AH42 = Asian Highway 42

CBR = California Bearing Ratio

CESAL = Cumulative Equivalent Single Axle Loads

DoR = Department of Roads, Nepal

E = Modulus of Elasticity

ESALs = Equivalent Single Axle Loads

HMA = Hot Mix Asphalt

IRI = International Roughness Index

M&R = Maintenance and Rehabilitation

MPa = Megha Pascal

MR = Resilient Modulus

NRS = Nepal Road Standard

N-S = North-South Direction

PCU = Passenger Car Unit

PSI = Pavement Serviceability Index

Psi = Pounds per Square Inch

RSDP = Road Sector Development Project

S-N = South-North Direction

SN = Structural Number

VDF = Vehicle Damage Factor

$W_{18}$ = Traffic Load for Design Lane

$\Delta$PSI = Loss of serviceability

## References

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