

Analysis and Design of Bituminous Pavements

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Lecture -18

Traffic Analysis - Examples

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TABLE - 1A: AXLE LOAD SURVEY DATA													
Form: Road, Sr.: Changanassery, Date: 16/02/2011													
Sr.No	No. of Axles	Vehicle Type	Wheel Loads	Front 1	Front 2	Middle 1	Middle 2	Middle 3	Middle 4	Rear 1	Rear 2	Rear 3	Total
51	2	Auto	Bus	1.7						3			
104	2	Auto	Bus	1.7						2.8			
477	2	Auto	Bus	1.6						3.5			
100	2	Auto	Bus	1.6						3.5			
213	2	Auto	Bus	1.6						3.5			
260	2	Auto	Bus	1.6						3.5			
367	2	Auto	Bus	1.6						3.5			
408	2	Auto	Bus	2.5						3.2			
414	2	Auto	Bus	2.3						3.2			
432	2	Auto	Bus	2.3						3.5			
482	2	Auto	Bus	1.5						2.5			
526	2	Auto	Bus	1.7						2.5			
57	2	Auto	LGV	1.2						3.5			
58	2	Auto	LGV	1.5						3.5			
104	2	Auto	LGV	1.4						2.5			
105	2	Auto	LGV	0.9						3.7			
104	2	Auto	LGV	1.4						2.4			
136	2	Auto	LGV	1.2						3.5			
135	2	Auto	LGV	1.2						2.4			
183	2	Auto	LGV	0.9						3.7			
188	2	Auto	LGV	0.9						3.7			
212	2	Auto	LGV	1.4						3.5			
214	2	Auto	LGV	1.3						3.8			
218	2	Auto	LGV	1.3						2.7			
222	2	Auto	LGV	1.4						3.7			
227	2	Auto	LGV	2.0						4.5			
239	2	Auto	LGV	1.4						3.5			
248	2	Auto	LGV	1.5						3.5			
264	2	Auto	LGV	1.2						3.8			
267	2	Auto	LGV	1.4						3.5			
266	2	Auto	LGV	1.6						3.5			
264	2	Auto	LGV	1.6						3.5			
119	2	Auto	LGV	2.0						4.7			
114	2	Auto	LGV	2.0						4.5			
119	2	Auto	LGV	1.6						3.5			
146	2	Auto	LGV	1.5						3.5			
116	2	Auto	LGV	1.7						2.7			
403	2	Auto	LGV	2.3						4.5			
411	2	Auto	LGV	1.4						3.5			

Hello everyone. Using a template, I will show you how this truck factor method and the vehicle damage factor method is used to determine the equivalent standard axle loads. So, what you see here is the template in which you actually mark the axle load data that is being collected. You can see here, there is the serial number and the number of axle. You can read the serial number part. This is a traffic which comprises of 2 axle truck, 3 axle, 4 axle and 5 axle. We will see what the different classes are. For the different classes or the vehicle types, you measure the wheel loads. Here, a portable small weigh pad was used wherein you will note the wheel loads essentially and not the axle load as such. So, you can see here that the wheel load is noted here as 1.7 and for the rear wheel it is noted as 3. Likewise, you have commercial vehicles, bus, etc.

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And when you go to three axles, there is a front axle and in the rear, you have a tandem axle. In the tandem axle, you note the load on the first wheel of the front axle and the second wheel of the front axle and so on. The data is collected like this.

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Single Wheel Loads (Front)		Single Axle Dual Wheel Loads (Rear)			
3 (mm)	Axle Load (Tonnes)	kN	Wheel Load (Tonnes)	Axle Load (Tonnes)	kN
3	3.30	33	2.95	5.90	59
4	3.60	36	2.75	5.50	55
5	3.90	39	3.00	6.00	60
6	3.90	39	3.50	7.00	70
7	3.90	39	3.50	7.00	70
8	3.90	39	3.50	7.00	70
9	3.90	39	3.00	6.00	60
10	4.00	40	2.90	5.80	58
11	5.00	50	3.20	6.40	64
12	5.00	50	3.20	6.40	64
13	4.20	42	3.50	7.00	70
14	3.80	38	2.50	5.00	50
15	3.80	38	2.50	5.00	50
16	2.80	28	3.00	6.00	60
17	3.50	35	2.50	5.00	50
18	2.80	28	2.50	5.00	50
19	1.80	18	0.70	1.40	14
20	2.80	28	2.40	4.80	48
21	2.80	28	1.50	3.00	30
22	2.80	28	2.40	4.80	48
23	1.80	18	0.70	1.40	14
24	1.80	18	0.70	1.40	14
25	2.80	28	3.80	7.60	76
26	3.40	34	2.75	5.50	55
27	2.60	26	2.70	5.40	54
28	2.80	28	1.70	3.40	34
29	4.00	40	4.50	9.00	90
30	2.80	28	2.45	4.90	49

Once the data is collected, you can see that in this excel sheet I have marked it as different pages. One is the 2 axle truck, the other is named as 3 axle truck, 4 axle truck, then 5 axle truck and so on. So, if you see there is a 2 axle truck, this is an example of the 2 axle truck that you are considering. There is a front axle with a single axle single wheel and a rear axle with a single axle dual wheel. This class is categorized as a 2 axle truck in the study.

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The screenshot shows an Excel spreadsheet with a table of data for 2-axle trucks. The table has columns labeled Q, R, S, T, U, V, W, X, Y, Z, AA, AB, AC, AD, AE, AF, AG, AH. The data rows are numbered 1 through 47. The first four columns (Q, R, S, T) contain numerical values. An image of a white truck with a brown container is displayed in the center of the spreadsheet. The truck has a single front wheel and a dual rear wheel. The NPTEL logo is visible in the top right corner of the spreadsheet window. A small inset image of a woman is visible in the bottom right corner of the overall image.

We will move on to the next one which is a 3 axle truck. As you see here in this picture, there is a front axle with single axle single wheel and at the rear there is a tandem axle. But for convenience it is written as 2 axles. Altogether, there are 3 axles. This is why this class is named as 3 axle truck.

(Refer Slide Time: 02:48)

The screenshot shows an Excel spreadsheet with three main columns: 'Single Axle Dual Wheel (SADW)', 'Single Axle Single Wheel (SASW)', and 'Tandem Axle Dual Wheel (TADW)'. Each column contains a list of vehicle configurations with their respective axle counts. An inset image shows an orange truck with four axles labeled 1, 2, 3, and 4. The NPTEL logo is in the top right corner.

And then you have a 4 axle truck here, you see that at the front there is a single axle single wheel assembly and then you have a single axle dual wheel assembly and then there is a tandem axle which is counted as 3 and 4. So, there are 2 axles. Altogether there are 4 axles. So, this class of vehicle is classified as a 4 axle truck.

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The screenshot shows an Excel spreadsheet with three main columns: 'Single Axle Dual Wheel (SADW)', 'Single Axle Single Wheel (SASW)', and 'Tandem Axle Dual Wheel (TADW)'. Each column contains a list of vehicle configurations with their respective axle counts. An inset image shows a white truck with five axles labeled 1, 2, 3, 4, and 5. The NPTEL logo is in the top right corner.

And then comes the 5 axle truck. You see here that there is a front axle which is single axle single wheel and there is a single axle dual wheel which is your axle number 2 and there is a tridem axle with dual wheels. So, altogether there are 5 axles. This class of truck is named as 5 axle for convenience. So accordingly, I have all these axle sheets here.

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Single Axle Single Wheel Loads (Front)			Single Axle Dual Wheel Loads (Rear)		
Wheel Loads (Tonnes)	Axle Load (Tonnes)	kN	Wheel Loads (Tonnes)	Axle Load (Tonnes)	kN
1.65	3.30	33	2.95	5.90	58
1.70	3.40	34	2.75	5.50	55
1.75	3.50	35	3.00	6.00	60
1.75	3.50	35	3.50	7.00	70
1.60	3.20	32	3.50	7.00	70
1.75	3.50	35	3.00	6.00	60
3.81	6.02	60.2	2.90	5.80	58
2.50	5.00	50	3.20	6.40	64
2.70	5.40	54	3.20	6.40	64
2.80	4.20	42	3.50	7.00	70
1.50	3.00	30	2.50	5.00	50
1.70	3.40	34	2.50	5.00	50
1.70	2.40	24	3.00	6.00	60
1.55	3.10	31	2.50	5.00	50
1.40	2.80	28	2.50	5.00	50
0.90	1.80	18	4.20	8.40	84
1.40	2.80	28	2.40	4.80	48
1.20	2.40	24	1.50	3.00	30
1.20	2.40	24	2.40	4.80	48
0.51	1.02	10.2	4.20	8.40	84
0.51	1.02	10.2	4.20	8.40	84
1.40	2.80	28	3.90	7.80	78
1.70	3.40	34	2.75	5.50	55
1.50	2.60	26	2.20	4.40	44
1.40	2.80	28	1.70	3.40	34
2.00	4.00	40	4.50	9.00	90

Let us see how the data is tabulated in this table. This is the original data as you see here. So, this is the data in which the single axle single wheels of all those loads are presented. So, this is a wheel load in tons as 1.65, 1.7 and so on for each of the vehicle and it is multiplied by 2 to get the axle load. So, in the single axle single loads, you have the load in tons, it is then converted into kN. This is the axle load data that you have collected for the front axle of this 2 axle truck. And similarly, on the rear axle, you have a single axle dual wheel. For all the trucks that you have surveyed, you see that the wheel has the wheel loads are 2.95, 2.75 and so on, which is multiplied by 2 to get the axle load, which is then converted to kN. So, you get the axle loads on the rear.

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The screenshot shows an Excel spreadsheet with the following data tables:

2-Axle Vehicles

Sl. No.	From	To	Mid	No. of Axles	% of Each Category	Cumulative %	Equivalency Factor	No. of Equivalent Std. Axles	% Damaging Effect
1	0	10	5	1	0.55	0.55	0.000035	0.000035	0.004
2	10	20	15	8	3.85	4.35	0.000136	0.000136	0.013
3	20	30	25	21	10.08	14.43	0.00043	0.00043	0.043
4	30	40	35	32	15.05	29.48	0.00166	0.00166	0.166
5	40	50	45	47	22.05	51.53	0.00279	0.00279	0.279
6	50	60	55	49	23.05	74.58	0.00281	0.00560	0.560
7	60	70	65	23	10.95	85.53	0.00100	0.00660	0.660
8	70	80	75	4	1.90	87.43	0.00013	0.00673	0.673
9	80	90	85	1	0.55	88.00	0.000035	0.00676	0.676
Total				208	100.00			70.85514	

Single Axle Single Wheel Loads (Front)

Wheel Loads (Tonnes)	Axle Load (Tonnes)	kN	Std
1.65	3.30	33	
1.70	3.40	34	
1.75	3.50	35	
1.79	3.58	35	
1.80	3.60	36	
1.82	3.64	36	
1.85	3.70	37	
1.88	3.76	37	
1.90	3.80	38	
1.92	3.84	38	
1.95	3.90	39	
1.98	3.96	39	
2.00	4.00	40	
2.02	4.04	40	
2.05	4.10	41	
2.08	4.16	41	
2.10	4.20	42	
2.12	4.24	42	
2.15	4.30	43	
2.18	4.36	43	
2.20	4.40	44	
2.22	4.44	44	
2.25	4.50	45	
2.28	4.56	45	
2.30	4.60	46	
2.32	4.64	46	
2.35	4.70	47	
2.38	4.76	47	
2.40	4.80	48	
2.42	4.84	48	
2.45	4.90	49	
2.48	4.96	49	
2.50	5.00	50	
2.52	5.04	50	
2.55	5.10	51	
2.58	5.16	51	
2.60	5.20	52	
2.62	5.24	52	
2.65	5.30	53	
2.68	5.36	53	
2.70	5.40	54	
2.72	5.44	54	
2.75	5.50	55	
2.78	5.56	55	
2.80	5.60	56	
2.82	5.64	56	
2.85	5.70	57	
2.88	5.76	57	
2.90	5.80	58	
2.92	5.84	58	
2.95	5.90	59	
2.98	5.96	59	
3.00	6.00	60	

A total of 208 vehicles were surveyed and you have measured the front axle load and the rear axle load for all vehicles. Now, let us see how the equivalent standard axle loads are calculated. This is a 2 axle vehicle as you see here. Now, the front axle as I said is a single axle with single wheel on either side. The standard axle load is taken as 65 kN for single axle single wheel and the equivalency factor can be computed.

$$\text{Equivalency factor} = \left(\frac{\text{Axle load}}{65} \right)^4$$

This data has to be grouped into different axle groups. IRC suggests that for single axle dual wheels, you can have a bin size of 10 kN. As the single axle single wheel load is not mentioned in the code, we have taken a bin size of 10 kN. This is a class interval. From 0 to 90, you have divided into 9 class intervals based on what is the minimum and the maximum values that comes in this data. Now, this gives you the mid value of each bin. For 0 to 10, the mid value is 5 and for 10 to 20, the mid value is 15 kN and so on. Now, you find what the frequency of each one of these load groups is. From this data, you have counted how many fall in the 0 to 10 category, how many axle loads are in the 10 to 20 kN category and so on. This is the frequency table. This gives you the frequency distribution of the load.

You can say what is the percentage of each one of these loads in this category. You see that 29.8% of the load comes in the 30 to 40 kN category in this group. And also a cumulative percentage is calculated so that you can just see whether all the vehicles are included in the analysis. Just for the sake of convenience, we find the cumulative percentage or if you want to draw a cumulative frequency chart, you can use this information.

Next you have to get the equivalency factor by considering the mid value of each load group. So, for the first class from 0 to 10, 5 is the mid load group.

$$\text{Equivalency factor} = \left(\frac{\text{Mid load value}}{\text{Standard axle load}} \right)^4$$

$$\text{Equivalency factor for single axle single wheel} = \left(\frac{\text{Mid load value}}{65} \right)^4$$

For the next class 15 is the mid value. So, 15 divided by 65 raised to 4 will give you the equivalency factor. Likewise, for each load group you have determined the equivalency factors. Now you have to convert the number of axles in each of these groups to the equivalent standard axle by multiplying the number of axles in that group with the equivalency factor. So, as you see here in the first category 0 to 10 kN, you had only one axle. So, that one axle multiplied by 0.000035 was the equivalency factor, you got the total number of equivalent standard axles. Likewise, for each load group you have the equivalency factors and multiply with the frequency in that load group or the number of axles in that load group to get the equivalent standard axles. You add all of them together to get the equivalent standard axles that is formed from all the front axles of this 208 vehicles that you have surveyed. And the purpose of this is that the equivalent standard axle essentially tells you how damaging this axle was. So, it contributes to around 70.85 of which you can see that, 32% is due to the vehicles which come with a load range of 60 to 70 kN. You have found out the equivalent standard axles due to the front axle for all the vehicles.

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Sl. No.	Class (kN)	No. of Axles	% of Each Category	Cumulative %	Equivalency Factor	No. of Equivalent Axles	Damaging Effect
21	0-10	5	0.5%	0.5%	0.000015	0.000015	0.001
22	10-20	7	3.5%	3.5%	0.000136	0.000136	0.001
23	20-30	10	4.8%	8.3%	0.000512	0.000512	0.001
24	30-40	11	5.3%	13.6%	0.000636	0.000636	0.001
25	40-50	14	6.7%	20.3%	0.000811	1.401911	0.291
26	50-60	15	7.2%	27.5%	0.221884	3.353793	6.201
27	60-70	16	7.7%	35.2%	0.415806	6.927900	1.401
28	70-80	24	11.5%	46.7%	0.72479	7.22479	1.601
29	80-90	25	11.8%	58.5%	1.274479	10.505369	6.351
30	90-100	32	15.4%	73.9%	1.85741	49.56911	14.521
31	100-110	32	15.4%	89.3%	2.967245	50.44132	16.531
32	110-120	25	11.8%	101.1%	4.20915	106.250820	22.181
33	120-130	13	6.3%	107.4%	5.960484	77.486038	16.171
34	130-140	3	1.4%	108.8%	8.109146	24.327438	5.081
35	140-150	6	2.9%	111.7%	10.792152	44.25320	13.511
36	150-200	1	0.5%	112.2%	100.0%	35.300308	7.171
37	Total	208	100.0%			479.388984	

40	Total No. of Axles (X)	416	(Single)
41	Total No. of Vehicles (Y)	208	
42	Total Damaging Effect (Z) (E _{MA})	550.01	
43	Axle Equivalency (Z/X)	1.322	
44	Track Factor (Z/Y) for 2 Axle Trucks	2.644	

Now, moving on to the rear axle which is a single axle dual wheel for which the standard axle load is 80 kN. You can see that the load is grouped into 10 kN groups. You can see that the ranges are 0 to 10, 10 to 20, 20 to 30 and so on. It is divided into class groups and the mid value is taken as the load for that particular class group. The number of axles or the frequency is estimated from the data as I have already shown here. Then you see the percentage of each category and its cumulative percentage of all also is marked here.

Let us consider the 50 to 60 load range for which 55 is the mid value. The equivalency factor will be 55 by 80 raised to the power of 4. The equivalency factor multiplied with the number of axles in that group which is 15 will give you the total equivalent standard axles of that load group. Likewise, you find out the equivalent standard axles of all the rear axle of all the 208 vehicles that you have surveyed. You get a sum which is 479. So, the damaging effect that is caused by the rear axles is 479. Now, you have counted 416 axles because there were 208 front axles and 208 rear axles or the total number of vehicles is 208. The total damaging effect is due to the front axle plus that due to the rear axle, which comes to around 550. Now, you can find the truck factor for this two axle truck is given by the total damaging effect.

$$\text{Truck factor} = \frac{\text{Total damaging effect}}{\text{Total number of vehicles}}$$

$$\text{Axle equivalency factor} = \frac{\text{Total damaging effect}}{\text{Total number of axles}}$$

Truck factor is 550 divided by the number of trucks that you have considered (208). Suppose, you want to find the axle equivalency factor, you can divide this total damaging effect divided by the number of axles. So, this 1.322 is essentially like of an axle equivalency factor. But what you need is a truck factor, which is the total equivalent single axle loads from the front and the rear put together and divided by the number of vehicles that are counted. The truck factor is 2.644 for two axle trucks.

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The screenshot displays an Excel spreadsheet with the following structure:

Single Axle Single Wheel Loads (Front)			Tandem Axle Dual Wheel Loads (Rear)				
Wheel Loads (Tonnes)	Axle Load (Tonnes)	kN	Wheel on Axle (Tonnes)	Wheel on Axle (Tonnes)	Total Wheel Load (Tonnes)	Total Axle Load (Tonnes)	kN
3.8	7.6	79	5.8	5.7	11.5	21.8	218
3.5	7.0	72	5.8	5.8	11.6	22.4	224
3.0	6.0	60	5.8	5.3	11.1	21.0	210
3.2	7.4	76	5.7	5.7	11.4	21.8	218
3.2	7.4	76	6.2	5.9	12.1	23.1	231
3.0	6.0	60	5.9	5.7	11.6	22.0	220
3.4	6.8	68	5.7	5.9	11.6	22.0	220
3.2	6.4	64	5.8	5.5	11.3	21.6	216
3.3	6.6	66	5.9	5.8	11.7	22.4	224
3.0	6.0	60	5.5	5	10.5	20.0	200
3.2	6.4	64	5.5	4.8	10.3	19.6	196
3.5	7.0	70	5.4	4.9	10.3	19.6	196
3.0	6.0	60	5.5	4	9.5	18.0	180
3.5	7.0	70	6.5	7	13.5	27.0	270
3.0	6.0	60	6	5.5	11.5	22.0	220
3.0	6.0	60	6	5	11.0	21.0	210
3.5	7.0	70	5.5	5.8	11.3	21.6	216
3.0	6.0	60	5.5	5.2	10.7	21.4	214
3.2	6.4	64	6	5.8	11.8	23.0	230
3.2	6.4	64	4.7	4.6	9.3	18.0	180
3.0	6.0	60	4.5	5.7	10.2	19.0	190
3.5	7.0	70	5.2	5.5	10.7	21.0	210
3.0	6.0	60	6	5	11.0	21.0	210
3.8	7.6	76	6.5	6.2	12.7	25.4	254
3.2	6.4	64	6.2	5.8	12.0	24.0	240
3.4	6.8	68	6.2	6.2	12.4	24.8	248
3.4	6.8	68	5.7	5.7	11.4	22.8	228
3.0	6.0	60	5	6.5	11.5	23.0	230
3.5	7.0	70	6.5	6	12.5	25.0	250
3.2	6.4	64	6	5	11.0	22.0	220
3.6	7.2	72	5.4	6	11.4	22.8	228
3.4	6.8	68	5.8	6.5	12.3	24.6	246
3.0	6.0	60	5.8	5.8	11.6	23.0	230

Now, let us move on to the three axle truck. As you see here in the three axle truck, there is a front single axle single wheel and the rear which is a tandem axle. In the case of the tandem axle, the weight on the first axle, the one wheel of the first axle and the weight on one wheel on the second axle is noted. The weight on one wheel multiplied with two will give you the weight on that particular axle. So, you get the axle load on one axle of the tandem wheel and the other axle of the tandem wheel and it is summed together to get the total tandem axle load. So, this is how you collect the data from the field and you sum it up together to get the axle load. So, you can

see that 216 kN is the axle load of the first vehicle, 224 is the tandem axle load of the second vehicle and so on.

(Refer Slide Time: 13:29)

The screenshot displays a software interface with two main tables. The first table, titled '2-Axle Vehicles', lists axle load classes (30, 40, 50, 60, 70, 80, 90 kN) and their corresponding axle loads, frequencies, and equivalent axle loads. The second table, titled 'Single Axle Single Wheel Loads (Rear)', lists axle load classes (30, 40, 50, 60, 70, 80, 90 kN) and their corresponding axle loads, frequencies, and equivalent axle loads. The NPTEL logo is visible in the top right corner, and a presenter is visible in the bottom right corner.

So, again, the truck has two classes of axles. The first is the front axle which is a single axle single wheel with the standard load of 65 kN so that the equivalency factor can be calculated. In the rear you have the tandem axle where the standard load is 148. As per IRC, for the tandem axle, you can get the equivalency factor as axle load divided by 148 raise to 4. The frequency is put into the load groups. We have started from 30 to 100 kN and in between there could be some load ranges where there are no vehicles, so which is omitted from this table. The mid values are written here and then the number of axles or the frequency is noted. Equivalency factor for each of those mid values of load is noted and then multiplied with the frequency will give you the total number of standard axles. So, the front axles will give you a total damaging effect of 224.

(Refer Slide Time: 14:40)

The screenshot displays an Excel spreadsheet with the following data tables:

Sl. No.	Class (kN)	From	To	Mid	No. of Axles	% of Each Category	Cumulative %	Equivalency Factor	No. of Equivalent Std Axles	% Damaging Effect
22	1	50	70	60	1	0.13	0.13	0.022002	0.022002	0.001
23	3	70	90	80	2	0.26	0.39	0.050000	0.100000	0.003
24	3	110	120	115	2	0.26	0.65	0.050000	0.200000	0.003
25	4	120	130	125	35	4.53	0.99	0.070000	0.270000	0.005
26	5	130	140	135	29	3.75	1.28	0.080000	0.350000	0.005
27	6	150	160	155	25	3.23	1.53	0.090000	0.440000	0.005
28	7	170	180	175	46	5.95	2.00	0.100000	0.540000	0.006
29	8	190	200	195	32	4.14	2.32	0.110000	0.650000	0.006
30	9	220	230	225	3	0.39	2.71	0.110000	0.760000	0.006
31	10	230	240	235	2	0.26	2.97	0.110000	0.870000	0.006
32	11	270	280	275	1	0.13	3.10	0.110000	0.980000	0.006
33	12	300	350	325	1	0.13	3.23	0.110000	1.090000	0.006
34	13	350	400	375	3	0.39	3.63	0.110000	1.200000	0.006
35					273	100.00			1482	

	Single	Tandem	Total
Total No. of Axles (X)	773	773	1546
Total No. of Vehicles (Y)	273	273	546
Total Damaging Effect (Z) (kN)	1482	224	1706
Axle Equivalency (Z/X)	1.92	0.29	2.21
Truck Factor (Y/Z) for 2-Axle Trucks	0.25	0.38	0.63

Likewise for the tandem axle, you see that the load range is taken in the range of 20 kN since it is a tandem axle you can take a larger range. And then the mid value, the frequency, the percentage of frequency in each category and the cumulative frequency is also noted here. Then the equivalency factors are computed using the equation and each equivalency factor multiplied with the corresponding frequency will give you the total equivalent standard axles which is summed together which comes out to 1482. You get the vehicle damage factor for this category by summing up the damaging effect due to the front single axle and the tandem axle. You get the truck factor by dividing the total damaging effect (1482+224) divided by the number of vehicles surveyed (273), which is 6.25.

(Refer Slide Time: 15:50)

The screenshot displays an Excel spreadsheet with multiple columns of data, likely representing axle configurations and their equivalent single axle loads. An inset image shows a 4-axle truck with axles numbered 1, 2, 3, and 4. The NPTEL logo is visible in the top right corner.

The next truck category is a 4 axle truck. First of all you have data for the single axle single wheel, and then you have data for the single axle dual wheel, then tandem axle. So, equivalency factor can be obtained for the first one using a standard axle load of 65 kN, the second one with a standard axle load of 80 kN and the third which is a tandem axle, with a standard load of 148 kN.

(Refer Slide Time: 16:32)

The screenshot displays an Excel spreadsheet with detailed data for 4-axle vehicles, categorized into front, middle, and rear wheels. The NPTEL logo is visible in the top right corner.

4-Axle Vehicles									
All the Front Wheels are Single Axle Single Wheel Equivalency Factor - (Axle Load) 65 kN									
Shk.	From	To	Mid	No. of Axles	% of Each Category	Cumulative %	Equivalency Factor	No. of Equivalent Std Axles	% Damaging Effect
1	30	80	75	1	1.25	1.25	0.084066	0.084066	0.05
2	80	50	65	3	3.75	5.00	0.379719	0.463785	0.30
3	50	60	55	24	27.00	32.00	0.305812	11.67960	7.50
4	60	70	65	12	13.50	45.50	1.000000	12.000000	7.50
5	70	80	75	79	89.25	94.75	1.779442	33.57790	22.50
6	80	90	85	2	2.25	97.00	2.934167	36.51206	2.25
Total				100	100.00			75.87249	

All the Middle Wheels are Single Axle Dual Wheel Equivalency Factor - (Axle Load) 80 kN									
Shk.	From	To	Mid	No. of Axles	% of Each Category	Cumulative %	Equivalency Factor	No. of Equivalent Std Axles	% Damaging Effect
1	40	50	45	3	3.75	3.75	0.300000	0.300000	0.25
2	50	60	55	3	3.75	7.50	0.333333	1.000000	0.25
3	60	70	65	16	18.00	25.50	0.433000	6.328000	4.00
4	70	80	75	16	18.00	43.50	0.774167	10.396167	6.50
5	80	90	85	25	28.25	71.75	1.724419	30.861233	19.00
6	90	100	95	9	10.25	82.00	1.081818	11.294051	6.50
7	100	110	105	2	2.25	84.25	2.982500	5.306818	3.25
8	110	120	115	1	1.25	85.50	8.720000	8.720000	3.75
9	120	130	125	1	1.25	86.75	10.292500	9.972500	3.5
10	130	140	135	1	1.25	88.00	11.895000	11.167500	3.2
Total				100	100.00			109.84092	

All the Rear Wheels are Tandem Axle Dual Wheel Equivalency Factor - (Axle Load) 148 kN									
Shk.	From	To	Mid	No. of Axles	% of Each Category	Cumulative %	Equivalency Factor	No. of Equivalent Std Axles	% Damaging Effect
1	40	100	70	1	1.25	1.25	0.300000	0.300000	0.25
2	100	140	120	2	2.50	3.75	0.395833	0.791667	0.50
Total				3	3.75			1.095833	

The data is divided into different axles, and then the damaging effects for each one of them are calculated as before.

(Refer Slide Time: 17:12)

Class (kN)	From	To	Total	No. of Axles	% of Each Category / Cumulative %	Equivalency Factor	No. of Equivalent Std Axles	Damaging Effect
1	100	120	100	7	1.05	0.305182	0.305182	21.373
2	120	140	130	7	1.35	0.339187	0.339187	21.373
3	140	160	170	7	1.85	0.402800	0.402800	21.373
4	160	180	170	7	2.55	0.446889	0.446889	21.373
5	180	200	200	7	3.55	0.500576	0.500576	21.373
6	200	220	200	7	4.85	0.554263	0.554263	21.373
7	220	240	200	7	6.45	0.607950	0.607950	21.373
8	240	260	200	7	8.45	0.661637	0.661637	21.373
9	260	280	200	7	10.85	0.715324	0.715324	21.373
10	280	300	200	7	13.65	0.769011	0.769011	21.373
11	300	320	200	7	16.85	0.822698	0.822698	21.373
Total				81	100.00		609.0000	609.0000

	Single	Tandem	Total
Total No. of Axles (X)	81	81	162
Total No. of Vehicles (Y)	81	81	162
Total Damaging Effect (Z) (X*Y)	6561	6561	13122
Axle Equivalency (Z/X)	81	81	162
Track Factor (1/X) for 4 Axle Trucks	0.0123	0.0123	0.0246

The total damaging effect is computed which comes to 609 and 81 vehicles were there in this category. So, 609 divided by 81 will give you the vehicle damage factor for this category as 7.5.

(Refer Slide Time: 17:27)

2. (a) Axle Dual Wheel Loads (Middle)	Tridem Axle Dual Wheel Loads (Rear)				
3. Axle Load (Tonnes)	Wheel on Axle (Tonnes)	Wheel on Axle (Tonnes)	Wheel on Axle (Tonnes)	Total Wheel Load (Tonnes)	Total Axle Load (Tonnes)
13.8	2.0	5.5	5.5	13.0	26.0
3.0	5.5	6.0	5.5	17.0	34.0
10.0	6.5	5.0	5.5	17.0	34.0
5.2	5.5	5.2	6.0	16.7	33.4
8.0	5.0	6.0	5.0	16.0	32.0
8.0	5.2	6.0	5.5	16.7	33.4
8.0	5.8	6.0	6.4	18.2	36.4
5.4	5.5	5.0	5.2	15.7	31.4
3.4	5.2	5.0	5.2	15.4	30.8
10.0	5.5	6.0	5.0	16.5	33.0
6.8	5.5	6.0	6.5	18.0	36.0
8.0	5.0	6.0	5.5	16.5	33.0
3.8	5.8	5.5	6.2	17.5	35.0
8.0	5.4	5.2	6.0	16.6	33.2
7.0	6.0	5.0	5.5	16.5	33.0
6.0	6.0	5.2	6.2	17.4	34.8
3.0	5.0	5.0	6.0	16.0	32.0

The next category is the 5 axle truck. 18 five axle trucks were there in this group. Let us see how the data was collected for the tridem axles. In the tridem axle you have 3 axles. The weight of one wheel is measured for each axle. So, this is wheel number 1, wheel number 2 on the second axle and wheel number 3 on the third axle. Now, each one of them will be multiplied with 2 to get the axle load on the first, second and third axle. Add them together to get the total tridem axle load which is 380 kN for the first vehicle and likewise for all the 18 axles.

(Refer Slide Time: 18:24)

The screenshot displays a spreadsheet with three main sections for 5-axle vehicles:

- Front Axles:** All the Front Wheels are Single Axle Single Wheel Equivalency Factor = (Axle Load/56.7)⁴. The table shows 3 categories of axle classes (50-80, 80-70, 70-80) with a total of 18 axles.
- Middle Axles:** All the Middle Wheels are Single Axle Dual Wheel Equivalency Factor = (Axle Load/80)⁴. The table shows 5 categories of axle classes (80-70, 70-80, 80-80, 100-100, 100-100) with a total of 18 axles.
- Rear Axles:** All the Rear Wheels are Tridem Axle Dual Wheel Equivalency Factor = (Axle Load/224)⁴. The table shows 4 categories of axle classes (150-300, 300-300, 300-370, 370-800) with a total of 18 axles.

On the right side, a table titled "Single Axle Single Wheel Loads (Front)" shows wheel loads in kN for front, middle, and rear axles. The "Single Wheel Loads (Tridem)" table shows a total load of 380 kN for the tridem axle.

These five axles are divided into 3 axle groups. There are 18 front axle, which is single axle single wheel, then middle axles which are single axle dual wheel and that the last one which is a tridem axle, wherein the equivalency factor is computed as axle load divided by 224 raise to 4 because for tridem axle the standard load is taken as 224.

(Refer Slide Time: 18:57)

The screenshot displays an Excel spreadsheet with the following data tables:

All the Middle Wheel are Single Axle Dual Wheel Equivalency Factor - (Axle Load) 30/32

SN.	Class (kN)	No. of Axles	% of Each Category	Cumulative %	Equivalency Factor	No. of Equivalent Std Axles	% Damaging Effect
1	80	20	5%	5%	0.437500	8.750000	0.54%
2	70	80	20%	25%	0.771429	15.428571	1.91%
3	60	100	25%	50%	0.952381	19.047619	2.38%
4	50	130	32.5%	82.5%	1.369048	27.380952	3.42%
5	40	140	35%	100%	1.904762	38.095238	4.73%
	Total	400	100%			99.000000	

All the Rear Wheel are Tridem Axle Dual Wheel Equivalency Factor - (Axle Load) 22/24

SN.	Class (kN)	No. of Axles	% of Each Category	Cumulative %	Equivalency Factor	No. of Equivalent Std Axles	% Damaging Effect
1	180	300	75%	75%	3.000000	30.000000	3.75%
2	200	300	75%	100%	4.670000	46.700000	5.84%
3	220	300	75%	100%	6.300000	63.000000	7.98%
4	240	300	75%	100%	8.000000	80.000000	10.13%
	Total	400	100%			229.700000	

Summary Statistics:

Total No. of Axles (N)	400	Single	38	Tridem	362
Total No. of Vehicles (V)	100		100		100
Total Damaging Effect (D) (MSA)	34.18		100.32		134.50
Axle Equivalency (E)	1.000				
Truck Factor (TF) for 4 Axle Trucks	8.700				

Likewise, all the damaging effects are summed together and divided by the number of vehicles to get a truck factor of 8.70. So, for all the 4 truck categories we have determined the truck factor separately.

(Refer Slide Time: 19:12)

The screenshot displays an Excel spreadsheet with the following data tables:

Line Distribution Factor

Line Distribution Factor	0.4	✓	MSA/yr 2008	(1 lane single carriageway)
Design Period	75	✓		

Base Year Traffic Data (per Day)

Category	Truck Factor	No. of Veh	% Occurrence	2 Axle (Bus+CV)	3 Axle Truck	4 Axle	5 Axle	Total
2 Axle	2.544	308	31.3%	1893	2894	382	889	3794
3 Axle	6.753	773	62.5%	3448	8753	2518	8700	30399
4 Axle	2.328	81	14.0%	1925	1890	382	1420	3039
5 Axle	8.700	48	3.5%	405	85	85	53	548
Total		510	100%	22005	27320	20053	45313	100798

Annual Growth Rate

Annual Growth Rate	4%	✓				
Cumulative No. of Std. Axles for 15 yrs	220053	✓	27320	20053	45313	100798
Cumulative No. of Std. Axles for 15 yrs in millions (million standard axles, MSA)	22.00	✓	2.73	2.00	4.53	10.08

Handwritten Formula:

$$365 \times \frac{(1+r)^n - 1}{r} \times \text{ESAL} \times L$$

Now, let us see how the equivalent standard axle load is computed. Let us assume that you know this is a 4 lane single carriageway, for which you can take a lane distribution factor of 0.4. Let us say you have assumed a design period of 15 years. Now, the base year traffic data, the annual average daily traffic is computed for all the 4 classes of vehicles. Let us say, the base year traffic for the 2 axle vehicle is 1859 per day and the 3 axle trucks are 2894, the 4 axle vehicles are 782 and 169 is the base year traffic data of the last category of vehicles. Now, the truck factors that you have measured for all the 4 categories are here which is 2.6, 6.2, 7.5 and 8.7 respectively. By multiplying the base year traffic with the corresponding truck factor, you can find the equivalent standard axle for each of these categories per day. We can convert this per day traffic to ESAL by assuming a growth factor separately for different vehicles. Different growth rates are assumed here, say, first type of vehicle has a growth rate of 10%, the next has 8%, the next has 6% and last one has 5% growth factor. You can use the equation to compute the ESAL for a design period of 15 years.

$$\text{ESAL or } N_{\text{des}} = 365 \times \left[\frac{(1 + r)^n - 1}{r} \right] \times A \times D \times L \times \text{VDF}$$

Now, divide it with 10^6 , you can express it in terms of million standard axles. The result is 22.8 million standard axles of first category, 71 from the second category, 20 from the third and 4 from the fourth category of trucks. So, the total equivalent standard axle loads or the design traffic as you say is 190 ESALs. This is how we can use this template to input the data and calculate the truck factors for each of these categories and the advantage is that you can consider different growth rate for each of the categories and then the total ESALs for the design can be calculated.

(Refer Slide Time: 22:32)

2-Axle vehicles		Wheel Loads		Axle Loads		Equivalency Factor		Equivalent number of std. axles
Truck No.	Front (kN) Single axle single wheel	Rear (kN) Single axle dual wheel	Front (kN)	Rear (kN)	Front (kN/65) ² *4	Rear (kN/80) ² *4		
1	16.5	29.5	33	59	0.6644	0.2958	0.3613	
2	12	22.5	34	55	0.6289	0.2234	0.2983	
3	12.5	30	35	60	0.6841	0.3064	0.4009	
4	12.5	35	35	70	0.6841	0.5861	0.6303	
5	16	35	37	70	0.6987	0.5861	0.6489	
6	12.5	30	35	60	0.6841	0.3064	0.4009	
7	30.1	29	60.2	58	0.7758	0.7263	1.0130	
8	25	30	50	64	0.7071	0.4096	0.7297	
9	22	32	54	64	0.6283	0.4096	0.6359	
10	21	35	62	70	0.7141	0.5861	0.7609	
11	15	25	30	50	0.6154	0.1536	0.5980	
12	12	25	34	50	0.6289	0.1536	0.7275	
13	12	30	34	60	0.6886	0.3064	0.3358	
14	15.5	25	31	50	0.6917	0.1536	0.2843	
15	14	25	28	50	0.6344	0.1536	0.3820	
16	9	7	18	14	0.0099	0.0009	0.0068	
17	14	24	28	48	0.6344	0.1296	0.3642	
18	12	15	24	30	0.6086	0.0096	0.2084	
19	12	24	24	48	0.6086	0.1296	0.1482	
20	9.1	7	18.2	14	0.0064	0.0009	0.0071	
21	9.1	7	18.2	14	0.0064	0.0009	0.0071	
22	14	31	28	62	0.6344	0.3608	0.3952	
23	12	22.5	34	55	0.6289	0.2234	0.2983	
24	13	22	26	54	0.6736	0.2826	0.3332	
25	14	12	28	34	0.6344	0.0216	0.0671	
26	20	45	60	90	0.1434	1.6618	1.2457	
27	14	34.5	28	69	0.6344	0.1407	0.1757	
28	25	35	50	70	0.6344	0.5861	0.6318	

Now, let us see a slightly simplified or different approach wherein you can get this by truck factor method. What we have seen is that from the axle load data, you have grouped these axle loads into different load groups or different bins of 10 kN or 20 kN groups and the mid value of that is taken as the average load value for that particular group. Now this could be erroneous if the axle load data is not uniformly distributed in that bin or if it is skewed in one direction. What could be done is that, rather than dividing it into different axle, putting in different bins, you can just compute the equivalent standard axles for all the axles directly by taking the equivalency factor for each one of them.

Let us see how that is computed. We see here that you have the two axle vehicles. In the two axle vehicles, you have the front axle load as well as the rear axle load. So, I mean the first two columns or the second and third column here gives the wheel load. The wheel load multiplied with 2 will give you the axle load. Here, column D gives you the front axle load and column E here gives the rear axle load of that two axle truck that we have discussed. For the front axle which is a single axle single wheel load, its standard axle load is 65 kN and the equivalency

factor is the load divided by 65 raise to 4. So, for each one of these trucks, the equivalency factor for the front axle as well as the equivalency factor for the rear axle is computed.

For the rear axle here, it is a single axle dual wheel. So, the equivalency factor is load divided by 80 raise to 4. There is no mid value that is considered, you are straight away taking the load of that axle and then finding its equivalency factor, then multiply the front axle with its equivalency factor and add it to the rear axle and its equivalency factor. This will give you the total equivalent number of standard axles of the truck number 1. Likewise, you can calculate for all the 218 trucks. So, in this method, you have calculated the equivalent single axle loads rather than grouping them into any bins.

(Refer Slide Time: 25:12)

Truck No.	Front Axle Load	Rear Axle Load	Front Axle Equivalency Factor	Rear Axle Equivalency Factor	Total Equivalent Axles
180	177	26	0.4096	3.5245	3.9341
181	178	24	0.3924	3.5245	3.9169
182	179	30	0.7260	5.0625	5.7885
183	180	30	0.7260	5.0625	5.7885
184	181	20	0.1434	5.0625	5.2099
185	183	17	0.0389	0.0410	0.1199
186	183	25	0.3981	2.4414	2.8395
187	184	37	0.65	8.9279	9.5779
188	185	34	0.48	5.5793	6.0593
189	186	15	0.0314	0.0366	0.0780
190	187	18	0.0941	0.0366	0.1307
191	188	20	0.1434	1.9061	2.0495
192	189	18	0.0941	0.0366	0.1307
193	190	22	0.2900	1.9061	2.1961
194	191	30	0.7260	5.0625	5.7885
195	192	26	0.4096	3.5245	3.9341
196	193	30	0.7260	2.4414	3.1674
197	194	35	1.3451	5.0625	6.4076
198	195	38	1.5875	8.9279	10.5154
199	196	30	0.7260	5.7700	6.4960
200	197	30	0.7260	5.0625	5.7885
201	198	33	0.9999	3.8416	4.8415
202	199	28	0.5509	4.1234	4.6743
203	200	19	0.1168	1.6048	1.7216
204	201	20	0.1434	2.4414	2.5848
205	202	16	0.0382	0.0509	0.0891
206	203	28	0.5509	4.1234	4.6743
207	204	30	0.7260	4.7311	5.4571
208	205	25	0.3981	4.1234	4.5215
209	206	18	0.0941	1.9061	2.0002
210	207	16	0.0366	4.4305	4.4671
211	208	25	0.3981	3.5245	3.9226
212	Average				2.8978

Then take the average of all this total number of equivalent standard axle loads to get the truck factor for that category. This has come out as 2.8978. So, this is for the first category of vehicle.

(Refer Slide Time: 25:35)

The screenshot shows an Excel spreadsheet titled "TruckFactor (Metric)". The spreadsheet is divided into sections for "3-axle vehicles". The columns are labeled as follows:

- Truck No.:** 1 to 40
- Front (kN):** Values ranging from 100 to 200
- Rear (kN):** Values ranging from 100 to 200
- Equivalency Factor:** Calculated as $\frac{\text{Front (kN)}}{100}$ and $\frac{\text{Rear (kN)}}{100}$
- Equivalent no. of axles/Off Track Factor for each truck:** Calculated as $\text{Front (kN)} + \text{Rear (kN)}$

The NPTEL logo is visible in the top right corner of the spreadsheet interface.

Now similarly for the second category of vehicles, you see that this is 3 axle truck. So, equivalency factor for the front axle and the rear axle (tandem axle) is calculated. The total equivalent standard axles or truck factor for each one of the trucks is calculated.

(Refer Slide Time: 26:07)

The screenshot shows an Excel spreadsheet titled "TruckFactor (Metric)". The spreadsheet is divided into sections for "4-axle vehicles". The columns are labeled as follows:

- Truck No.:** 1 to 40
- Front (kN):** Values ranging from 100 to 200
- Rear (kN):** Values ranging from 100 to 200
- Equivalency Factor:** Calculated as $\frac{\text{Front (kN)}}{100}$ and $\frac{\text{Rear (kN)}}{100}$
- Equivalent no. of axles/Off Track Factor for each truck:** Calculated as $\text{Front (kN)} + \text{Rear (kN)}$

The NPTEL logo is visible in the top right corner of the spreadsheet interface.

The average truck factor for this category is 6.58.

(Refer Slide Time: 26:12)

The screenshot shows an Excel spreadsheet with the following columns: Front (Ax), Rear (Ax), Middle (Ax), and Truck Factor for each truck. The data is organized into two main sections: '4 axle vehicles' and 'Equivalent Factor'. The '4 axle vehicles' section lists various truck configurations with their respective axle weights and truck factors. The 'Equivalent Factor' section shows the calculated truck factors for these configurations. The final row of the spreadsheet displays the average truck factor for this category as 6.58.

Now similarly for the 4 axle truck, the average truck factor comes out to be 8.31

(Refer Slide Time: 26:28)

The screenshot shows an Excel spreadsheet with the following columns: Front (Ax), Rear (Ax), Middle (Ax), and Truck Factor for each truck. The data is organized into two main sections: '4 axle vehicles' and 'Equivalent Factor'. The '4 axle vehicles' section lists various truck configurations with their respective axle weights and truck factors. The 'Equivalent Factor' section shows the calculated truck factors for these configurations. The final row of the spreadsheet displays the average truck factor for this category as 8.93.

For the 5 axle it came out as 8.93.

(Refer Slide Time: 26:30)

The screenshot shows an Excel spreadsheet with the following data:

Category	Truck Factor	No. of Veh	Occurrence
2-Axle	1.544	208	25.20
3-Axle	6.753	773	67.55
4-Axle	2.528	81	14.05
5-Axle	3.700	48	3.15
Total		350	109.95

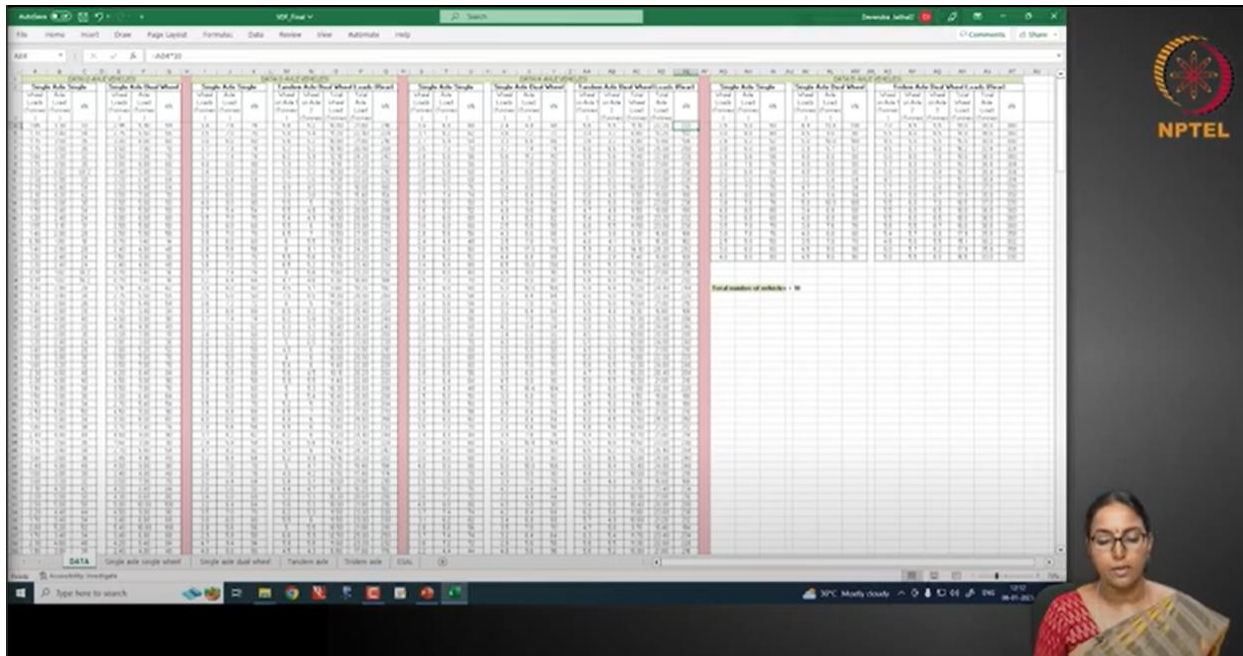
Parameter	Value
Lane Distribution Factor	0.8
Design Period	15
Base Year Traffic Data (per Day)	3794
Truck Factor	3359
ESAL (per Day)	1270
Assumed Growth Rate	6%
Cumulative No. of Std. Axles for 15 yrs	119.3
Cumulative No. of Std. Axles for 15 yrs in millions (million standard axles, MSA)	119.3

Handwritten formula: $365 \times \frac{(1+r)^n - 1}{r} \times \text{ESAL} \times L$

Then the rest of the computations are similar. You see that the base traffic data is given. You get the ESALs by multiplying the truck factor by the base traffic. Then by applying the growth rate and the direct lane distribution factors and growth factor for 15 years, you get the total equivalent standard axles, which are 127. What we have observed is that, if you apply the truck factor, you have got the design traffic as 127 million standard axles, but what we have observed from the method 1 wherein it is divided into different load groups is that the design traffic is 119 MSA only. There could be slight difference.

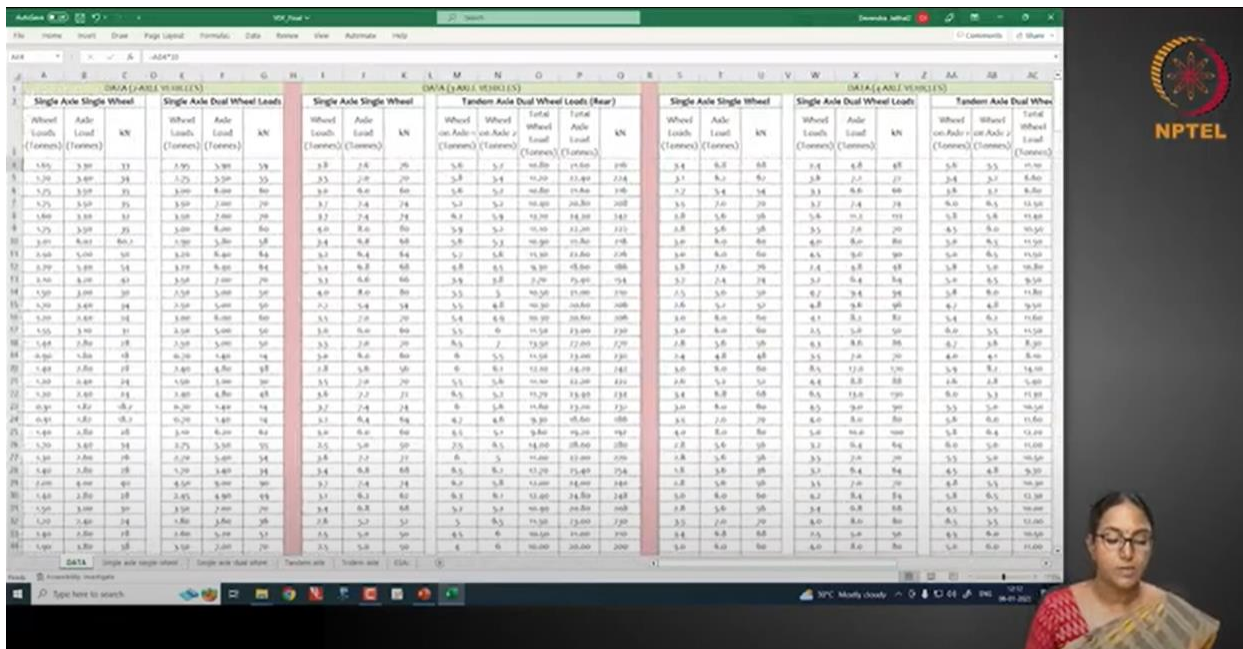
The problem associated with that is, if you put it in different bin groups, some of the traffic may get overestimated or some traffic may get underestimated. These are the two approaches by which you can calculate the truck factor for each truck category and arrive at the cumulative number of standard axles for the design. We will see how the vehicle damage factor is calculated from the axle load data and how the equivalent single axle loads or the design traffic is estimated.

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So, this is the same data that we have used for computing the truck factor and the ESALs based on the truck factor method.

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As we have already seen, there were like 4 classes of vehicles which were named as 2 axle vehicle, 3 axle vehicle, 4 axle vehicle and 5 axle vehicle for convenience. So, this is the data for 4 classes of vehicles. Compile all the single axle single wheel loads together. From all the 4 categories, single axle single wheel will be put together and you determine the equivalent standard axle loads from that category of axle.

(Refer Slide Time: 28:55)

The screenshot displays an Excel spreadsheet with four tables, each representing a different vehicle category. Each table includes columns for 'Sl. No.', 'Class No.', 'No. of Axles', '% of Each Category', 'Conversion Factor', 'No. of Equivalent Std. Axles', and 'Equivalent Effect'. The tables are titled '2-Axle Vehicle', '3-Axle Vehicle', '4-Axle Vehicle', and '5-Axle Vehicle'. Small images of vehicles are placed next to each table. The NPTEL logo is visible in the top right corner of the spreadsheet window.

The second sheet here is for the single axle single wheel. For each category of trucks, the front axle data is given here. So, from all the 4 trucks, the identical axle categories are put together in 4 tables.

(Refer Slide Time: 29:35)

The screenshot displays an Excel spreadsheet titled "2-Axis Vehicles" and "3-Axis Vehicles". The spreadsheet is divided into two main sections, each with a table of axle load data. The first section, "2-Axis Vehicles", includes a table with columns for Sl. No., Class (kN), No. of Axles, % of Each Category, Cumulative %, Equivalency Factor, No. of Equivalent Std. Axles, and % Damaging Effect. The second section, "3-Axis Vehicles", follows a similar structure. The spreadsheet also includes images of a truck and a trailer with highlighted axles. The NPTEL logo is visible in the top right corner of the slide.

2-Axis Vehicles							
All the front Wheels are Single Axle Single Wheel Equivalency Factor = (Axle Load/ 63) ⁴							
Sl. No.	Class (kN)			No. of Axles	% of Each Category	Cumulative %	Equivalency Factor
	From	To	Mid				
1	0	10	5	1	0.5%	0.5%	0.000015
2	10	20	15	8	4.0%	4.5%	0.000186
3	20	30	25	21	10.5%	14.5%	0.001881
4	30	40	35	67	29.8%	44.3%	0.084066
5	40	50	45	46	22.8%	66.1%	0.229794
6	50	60	55	43	20.2%	86.3%	0.517633
7	60	70	65	23	11.3%	97.6%	1.000000
8	70	80	75	4	1.9%	99.5%	5.772327
9	80	90	85	1	0.5%	100.0%	23.94303
				Total	208	100.0%	70.805924

3-Axis Vehicles							
All the front Wheels are Single Axle Single Wheel Equivalency Factor = (Axle Load/ 63) ⁴							
SNo.	Class (kN)			No. of Axles	% of Each Category	Cumulative %	Equivalency Factor
	From	To	Mid				
1	30	40	35	1	1.3%	1.3%	0.084066
2	40	50	45	45	16.5%	17.8%	0.229799
3	50	60	55	93	34.8%	52.6%	0.517627
4	60	70	65	95	35.9%	88.5%	1.000000
5	70	80	75	30	11.0%	99.5%	5.772327
6	80	90	85	7	2.7%	99.8%	23.94303
7	90	100	95	2	0.7%	100.0%	93.3501
				Total	273	100.0%	224.41466

You can put the axles in different class categories, the frequency can be measured. And then we can calculate the equivalency factor for this particular class of truck using the standard load. So, multiply the number of axles with the equivalency factor to get the total equivalent standard axles. So, from the first class of vehicle, you got 70, the second class of vehicles is 224, third class of vehicles is 75 and the fourth class of vehicles it is 19.

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4-axis Vehicles
All the Front Wheels are Single Axle Single Wheel Equivalency Factor = (Axle Load) 60^{2/3} k

Sl. No.	Class (kN)	No. of Axles	% of Each Category	Cumulative %	Equivalency Factor	No. of Equivalent Std Axles	% Damaging Effect
1	30-40	35	1.05	1.05	0.054966	0.019236	0.10
2	40-50	45	3.95	5.00	0.232779	1.547151	2.45
3	50-60	55	17.05	22.05	0.528217	3.006413	11.30
4	60-70	75	23.05	45.10	1.000000	7.000000	22.40
5	70-80	75	23.05	68.15	1.777111	13.277111	44.35
6	80-90	75	23.05	91.20	2.943811	21.843811	72.35
Total	300	315	100.00			79.872890	

3-axis Vehicles
All the Front Wheels are Single Axle Single Wheel Equivalency Factor = (Axle Load) 60^{2/3} k

Sl. No.	Class (kN)	No. of Axles	% of Each Category	Cumulative %	Equivalency Factor	No. of Equivalent Std Axles	% Damaging Effect
1	30-40	55	9.00	9.00	0.520812	4.666466	14.75
2	40-50	75	12.50	21.50	0.45	3.375000	10.50
3	50-60	75	12.50	34.00	1.227511	11.405489	36.75
Total	100	105	100.00			29.447955	

Total number of equivalent standard axes: 396.08133
Total number of vehicles: 316

If you sum it up together, you will get the total number of equivalent standard axes from these front axles alone and the total number of vehicles that you have counted is 550 altogether.

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4-axis vehicles
All the Middle Wheels are Single Axle Dual Wheel Equivalency Factor = (Axle Load) 60^{2/3} k

Sl. No.	Class (kN)	No. of Axles	% of Each Category	Cumulative %	Equivalency Factor	No. of Equivalent Std Axles	% Damaging Effect
1	40-50	5	0.25	0.25	0.000000	0.000000	0.00
2	50-60	5	0.25	0.50	0.223894	1.119471	0.00
3	60-70	15	0.75	1.25	0.423266	6.348989	0.25
4	70-80	25	1.25	2.50	0.721876	18.046950	0.00
5	80-90	25	1.25	3.75	1.218279	30.867711	0.00
6	90-100	35	1.75	5.50	1.985421	70.846666	0.20
7	100-120	105	5.25	10.75	2.987585	313.20879	3.00
8	120-150	105	5.25	16.00	4.220835	42.20879	1.50
9	150-170	105	5.25	21.25	6.085111	60.21175	0.75
10	170-190	105	5.25	26.50	8.693278	86.693278	0.40
Total	400	420	100.00			109.80977	

3-axis vehicles
All the Middle Wheels are Single Axle Dual Wheel Equivalency Factor = (Axle Load) 60^{2/3} k

Sl. No.	Class (kN)	No. of Axles	% of Each Category	Cumulative %	Equivalency Factor	No. of Equivalent Std Axles	% Damaging Effect
1	40-50	5	1.00	1.00	0.000000	0.000000	0.00
2	50-60	5	1.00	2.00	0.223894	1.119471	0.00
3	60-70	15	3.00	5.00	0.423266	6.348989	0.00
4	70-80	15	3.00	8.00	0.721876	18.046950	0.00
5	80-90	15	3.00	11.00	1.218279	30.867711	0.00
Total	50	50	100.00			95.140000	

Now, moving on to the second data computation, the next category of axle is your single axle dual wheels. In the 3 axle vehicle, there are no single axle dual wheels. Now, coming to the 4 axle vehicles, there was a single axle dual wheel and on the 5 axle vehicle also there was a single axle dual wheel. So, all this single axle dual wheel data are clubbed together.

(Refer Slide Time: 31:26)

The screenshot displays an Excel spreadsheet with the following data tables:

Class (kN)	From	To	Mid	No. of Axles	% of Each Category	Cumulative %	Equivalency Factor	No. of Equivalent	% Damaging Effect
1	40	54	47	5	6.25	6.25	0.000000	0.000000	0.000
2	54	68	61	5	6.25	12.50	0.000000	0.000000	0.000
3	68	82	75	16	19.75	32.25	0.000000	0.000000	0.000
4	75	89	82	18	21.75	54.00	0.000000	0.000000	0.000
5	89	103	96	25	30.38	84.38	0.000000	0.000000	0.000
6	103	117	110	3	3.75	88.13	1.960000	5.970000	0.300
7	117	131	124	2	2.50	90.63	1.960000	5.970000	0.300
8	131	145	138	1	1.25	91.88	1.960000	5.970000	0.300
9	145	159	152	1	1.25	93.13	1.960000	5.970000	0.300
10	159	173	166	1	1.25	94.38	1.960000	5.970000	0.300
Total				81	100.00			100.000000	30.000

Class (kN)	From	To	Mid	No. of Axles	% of Each Category	Cumulative %	Equivalency Factor	No. of Equivalent	% Damaging Effect
1	40	54	47	4	11.11	11.11	0.000000	0.000000	0.000
2	54	68	61	6	16.67	27.78	0.000000	0.000000	0.000
3	68	82	75	7	18.52	46.30	1.960000	5.970000	0.300
4	82	96	89	8	22.22	68.52	1.960000	5.970000	0.300
5	96	110	103	1	2.78	71.30	1.960000	5.970000	0.300
Total				36	100.00			36.000000	10.800

Summary Table:

Total number of equivalent standard axes	834.356831
Total number of vehicles with single axle dual wheel	56
Total number of vehicles	316

You see that this is from the first type of vehicle, this is from the second type of vehicle and this is from the third type of vehicle, all common type of axles with a standard axle load of 80 kN. Now, using the same approach, you find the equivalent axle loads, you sum up together. So you get the total equivalent single axle loads due to this axle type.

(Refer Slide Time: 31:34)

The screenshot shows an Excel spreadsheet titled "3 axle vehicles". The data is organized into a table with the following columns: SNo, From, To, Axle, Category, Communication, Factor, Equivalent, No. of Equivalent, and Damaging Effect. The table lists various axle configurations and their corresponding equivalent standard axle values. A total row at the bottom indicates a total of 275 standard axles. An image of a truck is shown in the middle of the spreadsheet, and another image of a tractor is shown below it. The NPTEL logo is visible in the top right corner.

Now, moving on to the tandem axle, you had like 2 vehicle classes where there were tandem axles. Find the total equivalent standard axles for those classes.

(Refer Slide Time: 31:58)

The screenshot shows an Excel spreadsheet titled "tandem axle". The data is organized into a table with the following columns: SNo, From, To, Axle, Category, Communication, Factor, Equivalent, No. of Equivalent, and Damaging Effect. The table lists various axle configurations and their corresponding equivalent standard axle values. A total row at the bottom indicates a total of 275 standard axles. An image of a truck is shown in the middle of the spreadsheet. The NPTEL logo is visible in the top right corner.

We had only one vehicle category where there were tridem axles. So, for that you will find what the damaging effect is. 102 are the total equivalent standard axles from this axle. Now, we have seen that you have computed the total equivalent standard axles for the single axle single wheels of all the categories of vehicles, which comes to 390. Then for the single axle dual wheel, it comes to 624. Then for the tandem axles from all the vehicle categories together, you get equivalent standard axles of 1906. And for the tridem axle, you get a value of 102. Now, let us see how the equivalent single axle loads or the design traffic can be estimated from this.

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Category	No. of equivalent std. axles	Design Period	Years
Single-axle single-wheel	390.12		
Single-axle Dual-wheel	624.27		
Tandem-axle	1906.61		
Tridem-axle	102.32		
Total (Y)	3023.31		
No. of Vehicles (X)	580		
VDF (Y/X)	5.2126		
Base Year Traffic Data (per Day)			5704
VDF			5.2126
ESAL (per Day)			29733
Assumed Growth Rate			10% 7%
Cumulative No. of Std. Axles for 15 yrs			137923684 109084563
Cumulative No. of Std. Axles for 15 yrs in millions (million standard axles, MSA)			137.92 109.08

This is the total number of equivalent standard axles that we have computed for single axle, single axle dual, tandem axle and tridem axle. The total equivalent single axle loads for all the vehicles put together comes to 3023. Now, you have like 580 vehicles which are considered in this study. So, the total equivalent single axle loads divided by 580 will give you one vehicle damage factor which is 5.2126 for the all categories of vehicles put together. Now, let us use this VDF to find the design traffic. Like in the previous case, here also let us assume that there is a lane distribution factor of 0.4 and the design period is taken as 15. And you just need the total vehicle volume count which is 5704 in this case. Now, the ESALs per day can be computed as the traffic on the base year multiplied by the VDF.

Once you get the ESALs, now it has to be projected to the future. You cannot use different growth rates for the different classes of vehicles however, you have to choose only one growth rate for all the vehicles put together. Let us assume that the maximum of 10% is the growth rate and you apply the growth factor multiplied with the ESAL per day into 365 into the lane distribution factor to get the cumulative number of standard axles for 15 years. This is 137.9 million standard axles. Now, we have seen that the vehicle classes have different growth factors. Now, if I take a growth factor of 7 percentage instead of 10, you see that the design traffic comes down to 109. So, it is very important that you choose a appropriate annual growth rate if you are essentially going for one growth rate for the estimation of the design traffic, as in the case of this VDF method.