A Report
On
Risk Analysis of Highway Failure

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Instructor/Advisor: Dr. Dennis Randolaf

Deepak Koirala

Introduction:

Now a day, risk analysis before starting a new construction became very important to enhance investment and provide a better service of it. Every locality has been facing a great loss in liabilities as well as lives loss due to improperly developed infrastructures. One can easily evaluate the performance of any structure on the basis of risk involving in its investment and service providing capability.

Highway can be taken as a one of the biggest construction area of the world and likewise with a highest risk involving area. Here, we have taken risk of failure of highway in the sense that encompasses its thorough design process from the beginning, and performance and longevity with least maintenance.

This paper covers four sections, in the literature we have described different features of highway with its failure modes whereas the discussion section go through fault tree and its analysis. Finally we end up with summarizing the analysis.

Literature on the state of art:

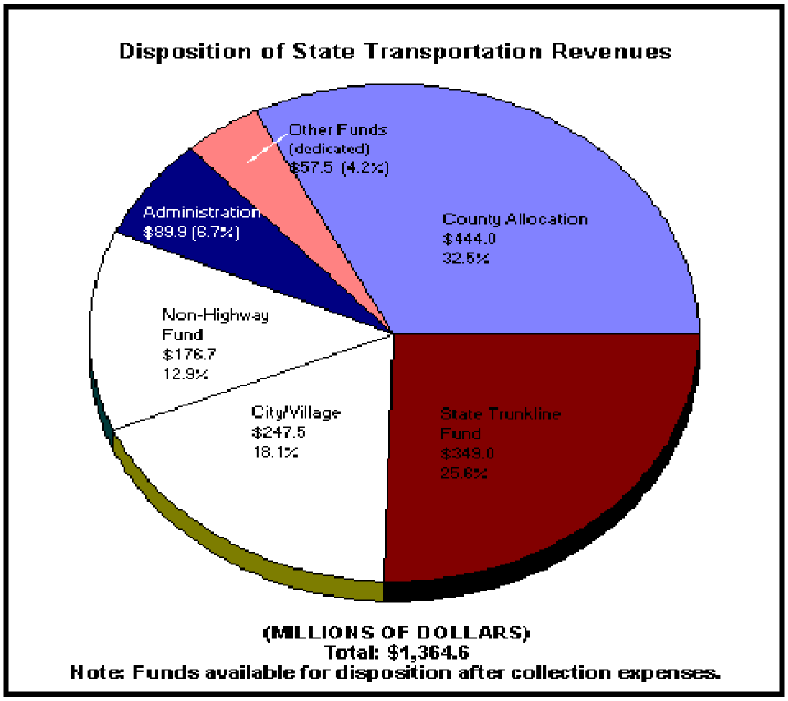
<u>Transportation in Michigan</u>

The Michigan transportation infrastructure system is crucial to the state's economical progress. The study made by Taylor, 1996 shows important findings, which we can see in two major points as:

- *Substantial repairs and improvements are necessary.*
- *Policy makers must fundamentally reinvent the planning, funding, construction and maintenance procedures in Michigan.*

The day by day increased traffic certainly help to boost revenue but also produce an increasing need for capital projects and maintenance. History shows between 1982 and 1992, Michigan transportation fund revenues rose by 46.9 percent in real terms, but in the same time period the number of miles driven on the state's roads increased by 37 % and the number of registered vehicles went up by 13.7%. The percentage of state system roads rated 'poor' increased 36% between 1982 and 1993 that is very important to understand because fixing 'poor' roads is three to five times more expensive than fixing 'fair' condition roads. It makes economic sense in the long run to invest in halting the deterioration of roads before they became 'poor'. Michigan Department of Transportation officials report shows for a total identified gross need of $656.8 million per year, an additional $281.8 million per year for city and county road investments. the total spending in transportation; construction and maintenance for the state is shown below in chart.

In the other hand, we cannot neglect the high number of road accident in Michigan. High percentage of 'poor' road and highly increased traffic are the main reasons for this high number of fatal accidents. Fatal accident presented in 2002 annual evaluation report by office of highway safety planning is shown in ***figure 2.*** below, we can see that only in year 2000, 1382 number of fatalities recorded. Whereas in 2001 the number reduced to 1328.



Source: MDOT Financial Planning and Budget, *State Flow of Funds for Transportation*, FY 1995.

Figure 1.

	Michigan			United States		
	2000	2001	% Change	2000	2001	% Change
Fatalities	1382	1328	-3.9%	41,945	42,116	0.4%
VMT (Billions)	94.9	96.5	1.7%	275	277.8	1.0%
Fatality Rate (100 million VMT) *VMT=Vehicle Miles Traveled*	1.46	1.38	-5.5%	1.53	1.52	-0.6%
Occupants Killed	348	315	-9.5%	36,348	36,386	0.1%
Non-occupants Killed* **Non-occupants=Bicyclists & Pedestrians*	194	185	-4.6%	5,597	5,730	2.4%
Alcohol-Related Fatalities	515	504	-2.1%	17,380	17,448	0.4%
Alcohol-Related (% of total)	37.3%	38.0%	1.9%	41%	41%	0.0%
Alcohol Fatal Rate (100 million VMT)	0.54	0.52	-3.8%	0.63	0.63	0.0%
Fatalities from Crashes Involving Large Trucks	172	129	-25%	5,282	5,082	-3.8%
Pedestrian Fatalities	166	159	-4.2%	4,763	4,882	2.5%
Motorcycle Under age 45	49	79	61.2%	1,714	1,925	12.3%
Motorcycle age 45 and older	31	15	-51.6%	1,178	1,254	6.5%
Total Motorcycle Fatalities	80	94	17.5%	2,897	3,181	9.8%

Figure 2.Traffic fatalities in Michigan and United states

A good facilitate highway:

A properly facilitate road or highway is one which is constructed under a good consideration of its different features that ensure a road user safe and comfort journey. Some of the important features that a well-designed road or highway should encompass are shown below:

1. Geometric features like,

    - Suitable Super-elevation on curves and bends.
    - Sufficient and safe Camber for proper surface drain.
    - Proper Location of crown
    - Sufficient number and width of lane.
    - Safe curves and bends
        - Horizontal, summit, Valley, hair pin bends etc.
    - Frontage roads if necessary.
    - Sufficient Right of way.
    - Proper extra widening.

2. Structural features:

    - Sufficient friction on top layer as per speed limit.
    - Uniformity in pavement thickness
    - Proper selection of Slope protection structures like, Retaining and revetment walls, toe walls, roadside arboriculture.
    - Less undulation in surface layer
    - Absence of ruts, potholes and jerks.
    - Kerbs, side drainage, pits and ditches, outlets, cross drainage structures like culverts, bridges
    - Islands, lane separator.
    - Safe Tunnels if required
    - Proper selection of material on different layers as per AASHTO requirement.
    - Side benching.
    - Road side development
    - Arboriculture

3. Traffic Marking post and signs
    - Regulatory and warning signs.
    - Traffic lights.
    - Pavement marking.

Highway Features

1. Geometric Feature
   - Super Elevation.
   - Camber
     # Negative
     # Zero
     # Positive
   - Crown
   - Shoulder
   - Cross walk
   - Lane width & No.
   - Curves & Bends
     # Horizontal
     # Summit
     # Valley
     # Hair Pin Bends
     Etc.
   - Frontage Roads
   - Right of Way
   - Extra Widening

2. Structural Feature
   - Friction
   - Pavement Thickness
   - Slope Protection Str.
     # Retaining Wall
     # Revetment Wall
   - Undulation in Layer
   - Cross Drainage Str.
     # Culverts
     # Bridges
     # Pits & Ditches
   - Island, Land Separator
   - Tunnels
   - Proper Material in diff. Layer as Per AASHTO
   - Side Benching
   - Road side development
   - Arboriculture

3. Traffic Marking Post & Sign Feature
   - Informatory Signal.
     # Parking
     # Hospital
     #First Aid Post
     #Public Telephone etc.
   - Regulatory & Warning Signal
     # Stop
     # Pass With Care
     # Speed Limit etc.
   - Pavement Marking
     # Solid line
     # Dotted Line
     # Cross Sign
     # Inclined line

Different features of a highway

We can see clearly typical cross sections of rural highway ***Figure B.*** and city road ***FigureB.*** In index. Showing these features. Before discussing about highway failure cases, it's important to start with the broad overview on the process of constructing it so that we can figure out different suspected area of failure along with the process. Here, we have mainly seven phases in this concept, they are:

- Reconnaissance also called Reccee
- Preliminary survey
- Detail survey
- Design
- Construction
- Commission and
- Open to traffic with maintenance.

Recee starts with the concept build up. Necessity, payback, feasibility, area covered, route visiting are the main focusing points during this period. Preliminary survey goes with a socio economical, Political, natural, tentative route selection, traffic analysis and idea of soil along that route. Detail survey covers finalizing and fixing route, prediction of traffic volume, axle load, detail soil exploration, environmental impact assessment, consents and permits etc then on the basis of detail survey the design and construction phases start. So, during this whole period of a highway construction, there might be several critical factors to be considered for preventing its failure. We can see broadly under each phase several factors that may contribute a failure. They are mentioned diagrammatically below, which clearly shows different phases of highway construction and work under each phase. So, failure in any of them may cause whole concept breakdown. This chart is the main basis for the preparation of our fault tree in the following section.

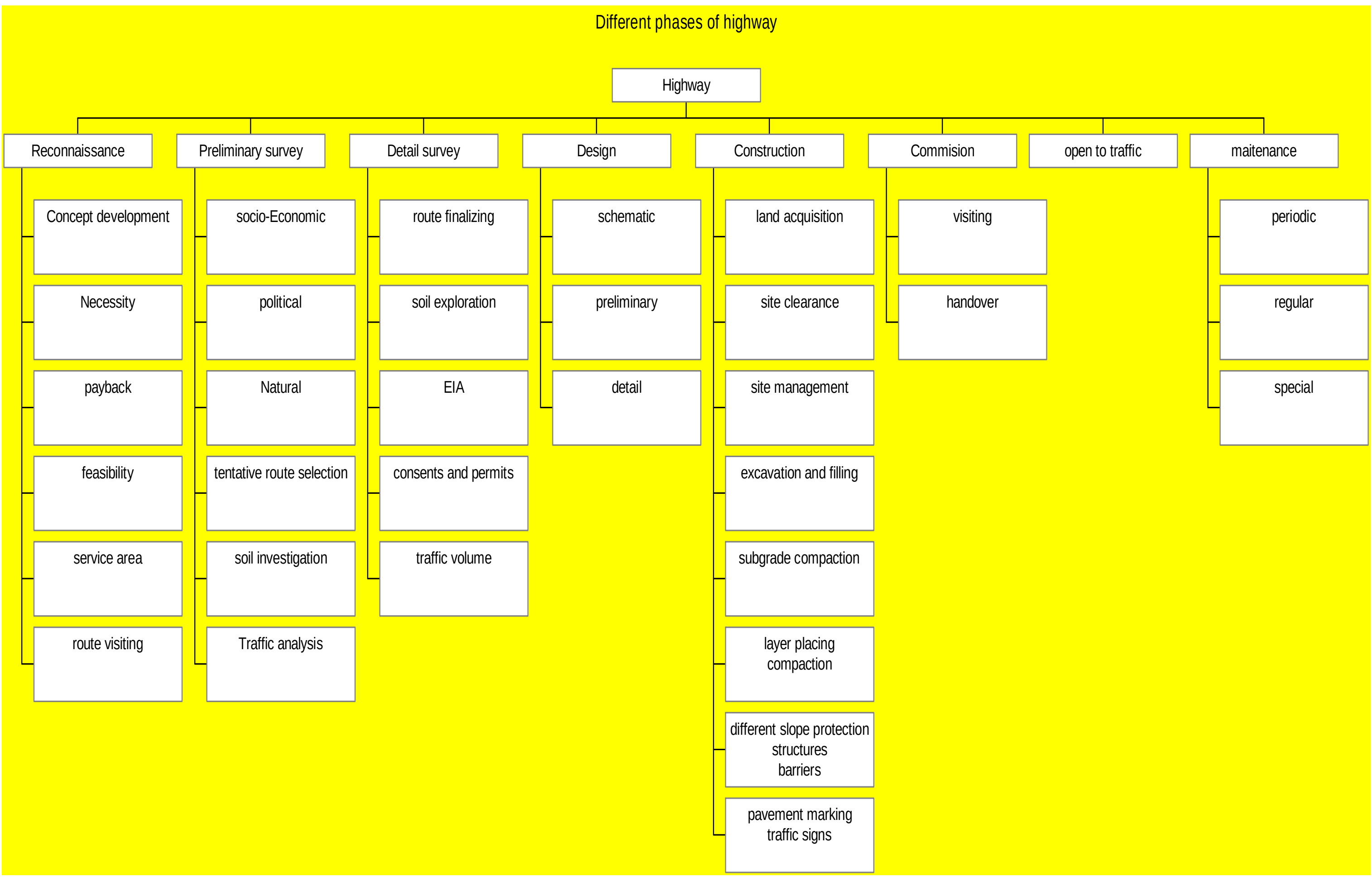


Figure 3.Different phases of highway construction

Fault tree discussion and finding of critical areas:

After overall study of construction process of highway, it is felt that the several areas or factors presented in chart below should be analyzed to get a critical one.

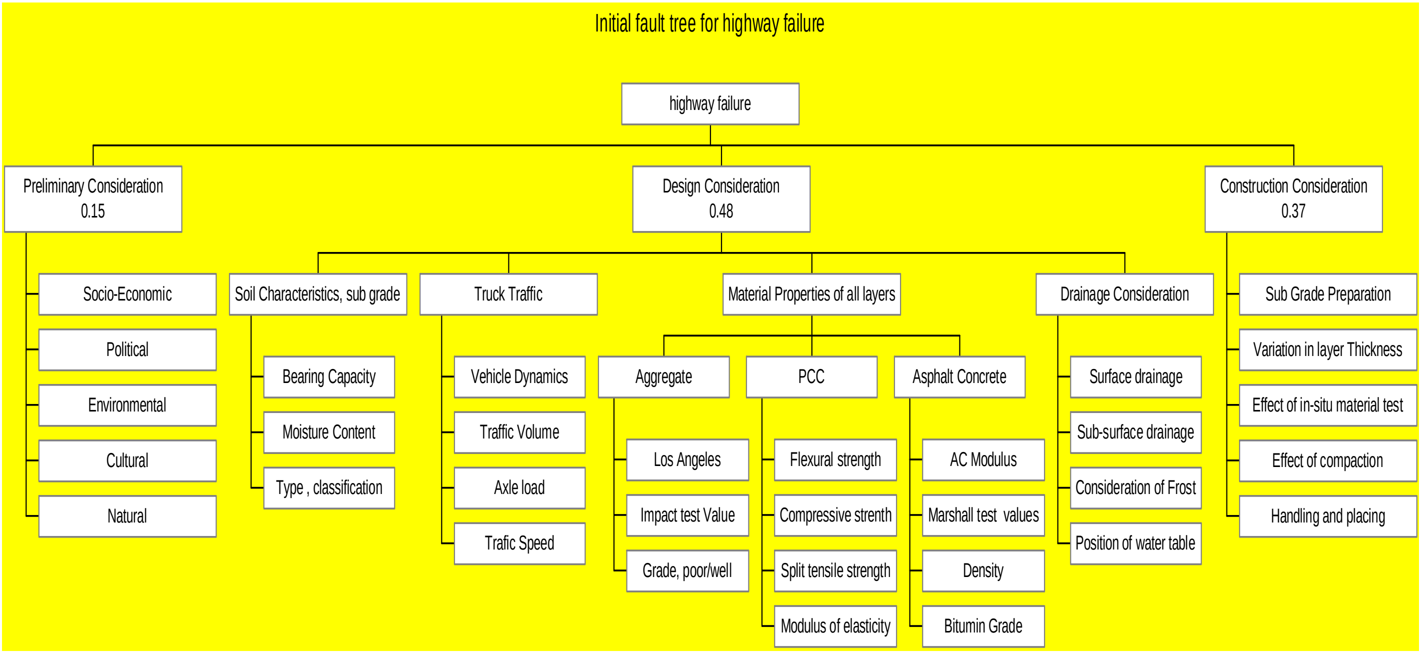


Figure 4.Priliminary fault tree.

To begin the analysis following procedures are performed:

First of all, a survey was run through 55 Civil engineers who are involving in different field of engineering with following Questioners:

1. According to your view, does the fault tree cover all risk suspected areas in highway construction? Do you have any suggested change?
2. Which one is most critical factor among top three considerations?

After this short survey, we found the rating for preliminary consideration 12%, for design consideration 68%, and for construction consideration 20%, which is shown in preliminary fault tree in ***figure 4***. Here, due to inconsistency in surveyed value we again adjusted and fixed to 15% for preliminary considerations, 48% for design considerations and 37% for construction considerations, they are shown in adjusted fault tree in ***figure 5***. Hence, design consideration is taken as a critical among three.
Most of them are focused in risk on proper selection of design parameters during design. So, we are focused on finding the variation in the value of parameter taken during design and actual in-situ tested value found after construction that lead us to figure out critical factor according to the highest chances of variation.
Here, LTPP (long –term pavement performance) data is used for purposes of defining the variability of pavement design input parameters. It includes all 50-states' pavement test section database, thus the data encompasses virtually every conceivable climatic zone possible, and the results made are depend upon these data.

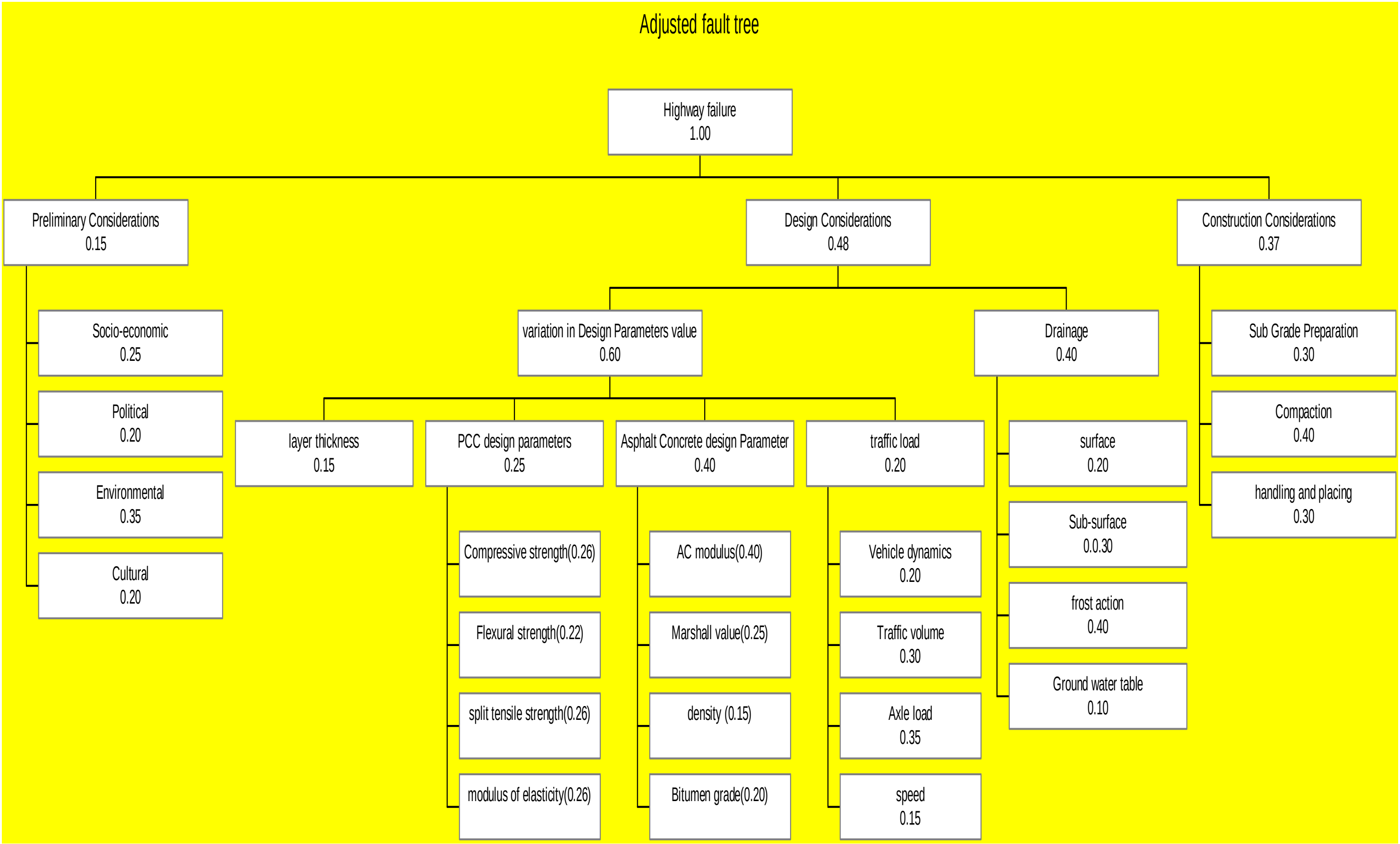


Figure 5.adjusted and final fault tree

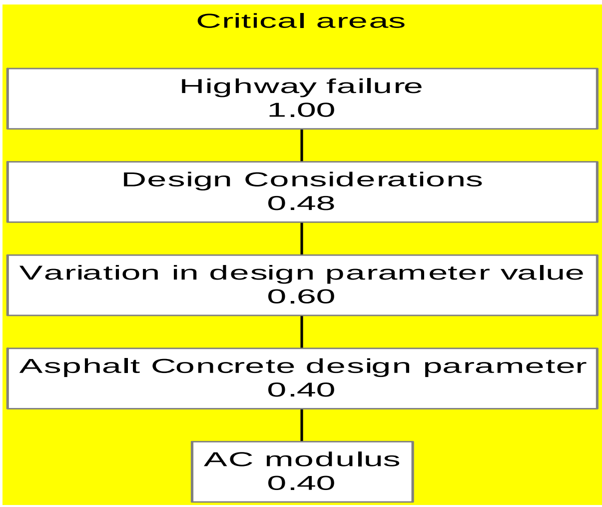
According to the database, and findings of that study the following facts are outlined:

Layer thickness:
-The overall nationwide average thickness of layers is very closed to the designed or planned thickness (from a structural point of view.)
PCC design parameters:
- The average coefficient of variation in compressive strength of PCC is found to be 15%.
-The average coefficient of variation in flexural strength is found to be 12%.
- The average coefficient of variation in split tensile strength is found to be 15%.
-The average coefficient of variation in modulus of elasticity is found to be 15%.
AC design parameters:
-There is a more significant variation in the AC moduli than all other, and the selection of these moduli depends upon construction practices of different areas, sub grade condition, investigation of pavement structure, stiffness of each layer, temperature ranges, and other many things. So, a careful study should be made for the selection of them.

Traffic load:

- *In pavement design, neither the vehicle class distribution nor the axle load spectrum can be reasonably assumed using a 'defult' or single load distribution for either the functional class of a roadway or by state/province (or region)*
- *Once the vehicle distribution and load spectra for a roadway are known through surveys for a single year, those distributions can confidently be used to pridict the distributions for other years.*

Now, evaluating these facts, flexural strength of PCC value taken during design has a little chance of deviation from in-situ value tested after construction. Whereas AC moduli (stiffness, resilient, etc) has a significant chance of deviation from the value taken during design. So, the factor that has higher chance of deviation in its in-situ value is taken as a critical one and given weightage in chart above.
After knowing weightage of all factors, we are able to find out the most critical areas as shown in figure below:



Recommendations:

While a concept of highway or road is to be developed, we need to focus on parameters to be taken during structural design. Among all, AC related design parameters should be taken as most sensitive . While fixing proper asphalt Concrete parameters, following points is to be considered:

- Look at smaller regional areas to account for construction practice differences when studying modulus variability.
- More detailed pavement structure definitions (thickness ranges, soil type etc..) must be investigated.
- Look at different groupings (e.g., group modulus values for each layer into low, medium, and high stiffness categories) to investigate variability.
- Try grouping the data by temperature ranges instead of environmental zones or seasons.
- Long-term variation analysis should include 'correcting' the moduli to a standard temperature, or temperatures, in order to investigate the change in variability over time.

Conclusion

From the above discussion and analysis we can see different critical areas in a concept of highway construction in the form of fault tree. This analysis has concluded that the design parameters should be critically considered, and asphalt concrete related parameters should be given importance among all.

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Index

***Figure A*. Typical City Road**

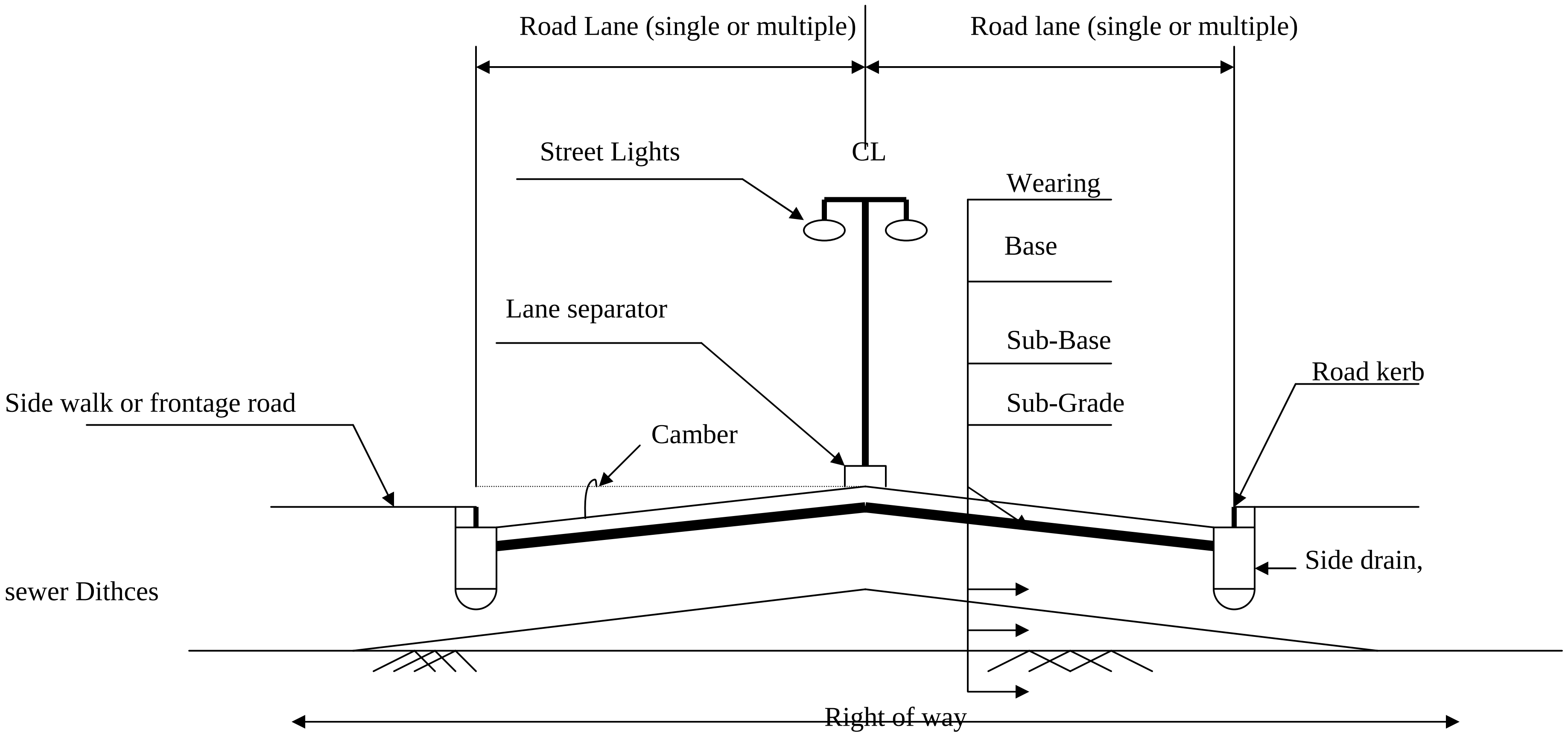

Figure B. Typical Rural Highway