प्राविधिक तर्फ, उपसचिव र सहसचिवको स्रोत सामग्री

इन्जिनियरिंग सेवा सिभिल समूह,हाइवे उपसमूह, दित्तीय पत्र , सेवा सम्बन्धि प्रविधिक विषयको स्रोत सामाग्री

- पाठ्यक्रम
- बिगत १० वर्ष भित्रका प्रश्नहरु प्रथम पत्रको खण्ड ख र दित्तीय पत्रको प्रश्नहरु
- पाठ्यक्रम अनुसारको विषयवस्तुहरू

लेखक तथा संकलनकर्ता

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8.10 Concept of Value Engineering.

9. Convention and Implementation

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हाइवे उप समूह, राजपत्रांकित दितीय श्रेणी (उपसचिव) र राजपत्रांकित प्रथम श्रेणी (सह सचिव) पदको प्रतियोगितात्मक लिखित परिक्षाको दितीय पत्र बिषय :- सेवा सम्बन्धि प्राविधिक बिषय (१००) र प्रथम, खण्ड (ख) बिषय :- सेवा सम्बन्धि सामान्य बिषय (५०)को बिगत १० बर्षका प्रश्नपत्रहरु

नेपाल इन्जिनियरिङ सेवा, सिभिल समूह, हाइवे उप समूह, राजपत्रांकित दितीय श्रेणी, उपसचिव वा सो सरह प्राबिधिक पदको प्रतियोगितात्मक लिखित परिक्षा

२०७८/११/३० गते

समय :- ३ घण्टा पूर्णाक :- १००

पत्र :- दितिय बिषय :- सेवा सम्बन्धि प्राविधिक बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

1. The concern for land compensation for road infrastructure is increasing day by day due to the limitations of the government to finance it wholly from the development budget. Discuss all the options available for financing the road projects land costs, outlining its merits and demerits. Is there a need to depart from the existing land procurement policy to ensure land availability for future road projects? 15
2. Explain the importance and requirements of highway drainage system. State the steps of design of longitudinal drain of a road to drain off surface water.
3. Describe the prioritization process/principle for road maintenance adopted by department of Roads. Explain the funding mechanism for road maintenance for roads under provincial government. 10+5
4. Why superelevation (SE) is necessary in a road? Discuss the provision of superelevation as mentioned in Nepal Road Standard, 2070. The radius of horizontal circular curve is 100 m. The design speed is 50 kmph and coefficient of lateral friction is 0.15, calculate the SE required in full friction case. 15
5. In recent times, there has been sinking or subsidence of bridge structures especially piers leading to failures of bridges structures. Narrate your view on the likely causes of such failures? How can such failures be prevented? 20
6. Describe various types of traffic control devices for urban road network. What are the different measures adopted for the safety of pedestrians at crossing of roads? State their relative merits. 20

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२०७८/७/१० गते

समय :- ३ घण्टा पूर्णाक :- १००

पत्र :- दितिय बिषय :- सेवा सम्बन्धि प्राविधिक बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

1. What is value engineering? Describe its importance in the context of Road Project? How is it used? Explain its concept as envisaged in contracts. 15

2. Road intersections are very prone to road crash. Explain the reasons for such types of road crashes.
3. What are the major types of erosion control measures used in highway drainage system of hill roads? 15
4. What are the basic requirements of an ideal alignment of highway and factors controlling the alignment in our context?
5. Monitoring and evaluating the project cycle at each stage is critical for successful project implementation. Discuss the existing practices of the project appraisal process, elaborating the role of monitoring and evaluation to be undertaken during this stage of the project cycle. How critical is the project's funding and financial and financial return and what steps are needed to bring the project's cost within an acceptable range? Discuss in detail with illustrations. 20
6. Explain the importance of highway information management system. Describe the data type useful for highway planning and project formulation. 20

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२०७६/१०/१७ गते

समय :- ३ घण्टा पूर्णाक :- १००

पत्र :- दित्तिय बिषय :- सेवा सम्बन्धि प्राविधिक बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

1. In Highway planning exercise, what are the major technical considerations to be given attentions to? In your objective view, why very often our planning exercises fail to address main issues? Critically assess and give your appropriate suggestions. 15
2. What are the different topics to be covered in carrying out the feasibility study of any road projects and how these studies are conducted and used in project preparation? 15
3. Stitching method is commonly adopted in connecting new deck to existing one in bridge widening works. What are the problems associated with this method in terms of shrinkage of concrete? 15
4. Explain the importance of highway maintenance, its challenges and inspection procedures, giving methods of repair for gravel and bituminous roads. 15
5. It is argued that outcome of development projects depends on the quality of public institutions responsible for them. Discuss analytically and suggest measures that ought to be under taken towards strengthening of institutions at various levels in the Nepalese context. 20
6. A) What are the main reasons behind the frequent road accidents in National Highways of Nepal? B) List the measures that can be taken to avoid traffic accidents and explain the measures to be emphasized in the context of road safety. 10

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२०७४/११/०५ गते

समय :- ३ घण्टा पूर्णाक :- १००

पत्र :- दित्तिय बिषय :- सेवा सम्बन्धि प्राविधिक बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

1. What are flexible and rigid pavements? Describe them with sketches. Mention suitable pavement for hill roads in Nepal with Concrete reasons. 15
2. A highway passing through rolling terrain in heavy rainfall area has a horizontal curve of radius 500m. Design the length of transition curve assuming suitable data given below. Design speed 80

kmph, pavement width 7m. Allowable rate of change of centrifugal acceleration super elevation 1 in 150. 15

3. How is road maintenance planned and executed in Nepal? How do you think the existing problems in routine maintenance including labor management can be overcome in near future? 15
4. It is generally talked that none of the bridges is designed for earthquake action. Give your opinion on what should be done with the existing bridges? 15
5. Transport system of Kathmandu valley is far below to our satisfaction. Identify and analyze the problems, suggest your recommendations for improvements with implementation strategies. 20
6. It is high time to go for public private partnership (PPP) in infrastructure development in Nepal. Discuss the possibilities and hinderances for applying PPP model in construction of road in general and particularly Kathmandu terai fast track. 20

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२०७३/०९/१३ गते

समय :- ३ घण्टा पूर्णाक :- १००

पत्र :- दितिय बिषय :- सेवा सम्बन्धि प्राविधिक बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

1. Give your appropriate suggestions to solve traffic congestion problems being faced in Kathmandu valley. Keeping in view the ever-increasing traffic and the slow pace of road widening as well as maintenance. 15
2. Enumerate and explain the methods to be adopted while tunnelling in soft ground with their advantages and disadvantages. 15
3. Critically analyse special considerations needed for design and construction of hill roads in Nepal.
4. Steel structures are widely used in bridge construction. What are the different types of steel bridges? Describe the practical difficulties faced in the fabrication and erection of steel structures?
5. Road safety is a burning issue and challenges to all of us in Nepal. Identify its issues and problems, explain laws and policies and recommend you suggestions with implementation strategies. 6+4+6+4
6. Road infrastructure requires huge investments and the budgetary allocation alone may not be adequate in meeting such requirements. Discuss how private sector can effectively contribute in road infrastructure development. 20

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२०७२/०९/०६ गते

समय :- ३ घण्टा पूर्णाक :- १००

पत्र :- दितिय बिषय :- सेवा सम्बन्धि प्राविधिक बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

1. What are the sequential and methodological steps that are to be followed in each assessment exercise that bears relevance to both environmental and the social impacts which are likely to occur in road development projects under the strategic road network programs of Nepal? 15
2. Elucidate a vegetation structure with sketches vegetative stabilization techniques together with small scale engineering techniques for slope stabilization. 8+7

3. What do you mean by California Bearing Ratio (CBR)? Determine the spacing between contraction joints for 3.5 m slab width having thickness of 20 cm for plain cement concrete and for reinforced cement concrete. Take f =1.5, w + 2400 kg/cum, Sc+1.6 kg/cm3, f.o.s =2. Total reinforcement of 6kg/sqm is provided and is equally distributed in both directions. 15
4. State the importance and feasibility of highway tunnel in Nepal. Write down the objectives of lighting in highway tunnel.
5. A) What is Mountain Risk Engineering (MRE) approach in selection and design of mountain roads? B) Differ between a front battered and back battered retaining wall in terms of implications on cost and construction in hill roads. 12
6. Through Kathmandu to terai highway construction is necessary, limited fund exists as a main constraint. Recommend the shortest route analysing the different modes of financing. How to implement this project without any time and cost overrun? Suggest. 10+10

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२०७१/०९/०६ गते

समय :- ३ घण्टा पूर्णाक :- १००

पत्र :- दितिय बिषय :- सेवा सम्बन्धि प्राविधिक बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

1. What is a national strategic road network? Discuss its significance with respect to the classification of roads adopted in Nepal.
2. What is traffic engineering? Explain how to ensure construction of safer roads? What is safety auditing? 15
3. Explain in detail with diagrams about the different technologies available for the construction of highway bridges in Nepal. Explain about their advantages and disadvantages. 15
4. Soil bioengineering is a tool for stabilizing areas of soil instability. Write down the benefits from its implementation. List out the steps to be followed for bio engineering project planning and implementation. 15
5. The concept of BOT could not move forward as desired in Road sector, Analyse the existing situation and recommend corrective measures including alternates with respect to Kathmandu Terai fast track. 7+7+6
6. Even with the establishment of road Board Nepal (RBN), the maintenance of road are not satisfactory. Identify and analyse the problems, list down your recommendations for improvements with clear implementation strategies. 6+4+6+4

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२०७८/११/२९ गते

समय :- १ घण्टा ३० मिनेट

पूर्णाक :- ५०

पत्र :- प्रथम, खण्ड (ख) बिषय :- सेवा सम्बन्धि सामान्य बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

1. Quality control is an important aspect in road construction projects. Briefly describe the issues with reference to the standard specification for road and bridge works 2073 for quality assurance plan. 10

2. What are the reasons for the current increasing trends in demands for dispute resolutions through dispute resolution mechanism such as adjudications/arbitration? Discuss with examples by identifying the causes, relevant legal provisions and contractual obligations. 10

3. Briefly explain IEE and EIA process. How Environmental Protection Act, 2076 is effective in preservation of environment in the context of road construction? 5 +5

4. Explain the provisions made by Motor Vehicles Transport Management Act, 1993 towards effective management of traffic on Nepalese roads.

5. नेपाल इन्जिनियरिङ परिषद ऐन २०५५ र यसको नियमावली संग सम्बन्धित व्यावसायिकइन्जिनियर (Professional Engineer) को दर्ता सम्बन्धि योग्यता तथा प्रक्रिया लाई सक्षेपमा लेख्नुहोस् | साथै, निरन्तर व्यावसायिक विकास (Continual Professional Development) समाबेश गर्न सकिने कुनै तीनवटा ज्ञान तथा अनुभवहरुलाई विस्तृत रुपमा उल्लेख गर्नुहोस् | 10

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२०७८/७/९ गते

समय :- १ घण्टा ३० मिनेट

पूर्णाक :- ५०

पत्र :- प्रथम, खण्ड (ख)   बिषय :- सेवा सम्बन्धि सामान्य बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

1. a) what are the role of private sector in financing road infrastructure in Nepal? 2

   b) what are the risk that are associated in PPP both for the government and private sector? List down and assign to respective entity with reasons and justifications. 8

2. Discuss the reasons that contribute to encroachment of road right of way. What steps should be taken to control it .   5+5

3. नेपालको विद्यमान् अवस्थामा सडक यातयात संग सम्बन्धित गुरुयोजना तर्जुमा, पूर्वाधार विकास निर्माण, यातायात सेवा संचालन, मर्मत सम्भार आदि पक्षहरुको प्रभावकारी रुपमा कार्यान्वयन हुनका लागि कानूनी व्यवस्था तथा संस्थागत संरचनाहरुको आलोचनात्मक विश्लेषण गर्नुहोस् |

4. सडक पूर्वाधार बिकासमा आवश्यक बैदेशिक सहायताको भूमिकालाई उल्लेख गर्नुहोस् | साथै यसको प्रभावकारीका बारेमा विश्लेषणात्मक टिप्पणी गर्नुहोस् | सडक पूर्वाधार विकास र यातायात सेवा संचालनमा निजि लगानीका पक्षहरुको Strength, Opportunity, Weakness and Threat (SWOT) विश्लेषण गर्नुहोस् |

5. Explain Four key areas which needs immediate amendment in National Transport Policy, 2058. 10

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२०७६/१०/१६ गते

समय :- १ घण्टा ३० मिनेट

पूर्णाक :- ५०

पत्र :- प्रथम, खण्ड (ख) बिषय :- सेवा सम्बन्धि सामान्य बिषय

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1. What are the main features of 20 years road plan? Whether the development of road network is being done as envisaged in the 20-year plan. 10
2. A) What are the issues on land acquisitions related to infrastructure development not covered in the prevailing act? 3
   B) How do you suggest incorporating social and environmental aspects in the forthcoming revision of “Land Acquisitions Act”? List down and discuss in detail.7
3. Highlight the objectives of Nepal Engineering Council Act. Explain 3 key challenges to implement the Act. (6+4)
4. Discuss the significance of IEE/EIA in a road infrastructure development project. Highlight the role of stake holders in these studies. 6+4
5. Explain as per Roads Board Act 2058, the provisions for road maintenance. What are the changes required in the Act to finance the provincial roads? 10

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२०७४/११/०४ गते

समय :- १ घण्टा ३० मिनेट पूर्णांक :- ५०

पत्र :- प्रथम, खण्ड (ख) बिषय :- सेवा सम्बन्धि सामान्य बिषय

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1. Proper road maintenance is inevitable for the effective, economic and safe of road transport service. Highlight the issues of poor road operating conditions and discuss the role of roads Boards Nepal in this perspective along with the implementation issues of Roads Boards Act. 10
2. Implementation of road projects in Nepal are delayed quite significantly mainly due to issues related to environment, land acquisition and social safeguards. What are your recommendations to improve the situations? 10
3. List down and discuss the role and responsibilities of 3Cs (Client, Contractor and Consultants) in executing and implementing road projects? 10
4. सवारी तथा यातायात व्यवस्था ऐन, २०४९ को उदेश्य र प्रमुख प्रवाधानहरु उल्लेख गर्नुहोस् | यस ऐनमा समयसापेक्ष रुपमा गर्नुपर्ने सुधार बारे छोटो विवेचना गर्नुहोस् |
5. What are the sources of disputes during the implementation of contract works? Describes stage wise procedures for the settlement of disputes as per provisions in public works directorate. Is any modification in your opinion is required in prevailing procedures Describe in brief? 3+5+2

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२०७३/९/१२ गते

समय :- १ घण्टा ३० मिनेट पूर्णांक :- ५०

पत्र :- प्रथम, खण्ड (ख) बिषय :- सेवा सम्बन्धि सामान्य बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

1. What are the role and functions of Nepal Engineering Council? How the capacity of Nepal Engineering’s Council can be enhanced to fulfill its objectives? 10

2. Traffic growth is rapidly increasing in urban areas especially in Kathmandu. Considering the congestion and hazards in traffic in Kathmandu, suggest options (short term and long term) for improving the transport system. Analyse critically interdependent functions of institutions responsible for the management of urban transport. 6+4
3. गरिवी निवारण तथा दिगो आर्थिक विकासको लागि देशमा वैदेशिक पुँजी प्रविधि आकर्षित गर्ने सोच अनुरुप सरकारले वैदेशिक सहायता नीति, २०५९ तयार गरी लागू गरेको लामो समय वितिसक्दा पनि नेपालको गरिवी निवारण, आर्थिक विकास र पूर्वाधारहरुको निर्माणमा वैदेशिक सहायता प्रभावकारी हुन् सकेको छैन | सो सन्दर्भमा वैदेशिक सहायता प्राप्ति र उपभोग चरणमा मौजुदा समस्याहरु के देख्न्नुहुन्छ ?सो समस्या निराकरणका उपायहरु के के हुन् सक्दछन् ? 10
4. नेपालको सडक यातायात क्षेत्रमा जलबिधुत र अन्य सेवा क्षेत्रको दाँजोमा निजि क्षेत्रको सहभागिता र लगानी अन्त्यन्तै न्यून रहेको सन्दर्भमा यसका पछाडी के कस्ता कारणहरु हुन् सक्दछन्? समस्या पहिचान गरी राजमार्ग र मुख्य सडकहरूमा निजिक्षेत्रको सहभागिता र लगानीमा विकास गर्न के कस्तो सुधारको आवश्यकता देख्न्नुहुन्छ ? विवेचना गर्नुहोस् | ५+ ५
5. Significant percentage of strategic road network is in a state of unpaved condition. Discuss a strategy to manage or upgrade these roads by categorizing them under different traffic level.

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२०७२/९/०५ गते

समय :- १ घण्टा ३० मिनेट पूर्णाक :- ५०

पत्र :- प्रथम, खण्ड (ख) बिषय :- सेवा सम्बन्धि सामान्य बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

1. सवारी दुर्घटनाको रोकथाम, पिडितपक्षलाई क्षतिपुर्ति र सर्वसाधारण लाई सरल एवं सुलभ दङ्गबाट यातायात सुबिधा उपलब्ध गरुन सवारी तथा यातायात व्यवस्था ऐन, २०४९ लागू गरिएतापनि देशमा बढ्दै गइरहेको सवारी दुर्घटना र जनधनको क्षतिलाइ कम गर्न सकिएको छैन | यसमा देखिएका कमजोरीहरु औल्याउदै समाधानका उपायहरु उल्लेख गर्नुहोस् | १०
2. How does Environmental Impact Assessment National Guidelines help the environment as well as the road network, as it is now mandatory to conduct EIA for significant roads in Nepal. Give a critical analysis. 10
3. जग्गा प्राप्ति ऐन, २०५५ अनुसार जग्गा अधिग्रहण कार्यविधि बारे उल्लेख गर्नुहोस् | समयमै जग्गा अधिग्रहण हुन् नसक्दा सडक निर्माण एवं स्तरोन्नति सम्बन्धि आयोजनाहरु लक्षित समयमा पुरा हुन् नसकिरहेको सन्दर्भमा यसका कारणहरु र निराकरणका उपायहरु बारे प्रष्ट पार्नुहोस् |
4. Discuss on the current status of road system in Nepal with reference to strategic road network. Identify the priorities for future development and the strategy to be adopted for its implementation. 5 + 5
5. Government has given permission to private sector to construct Kathmandu Hetauda fast track road. Such policy can be applied to other areas of road network also. What are the strengths and weaknesses of such policy in Nepalese perspective? 5+5

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२०७१/९/०५ गते

समय :- १ घण्टा ३० मिनेट पूर्णाक :- ५०

पत्र :- प्रथम, खण्ड (ख) बिषय :- सेवा सम्बन्धि सामान्य बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

1. Describe the existing Land Acquisition Act of Nepal. In your opinion is this act perfect? If not, what is your comments and suggestions?
2. Transport Policy is major document for streaming the decisions in transport sector. Critically analyze the existing 'National Transport Policy'. Write down/propose some strategies for the improvement of transport service sector in Nepal.
3. सडक एक महत्वपूर्ण सार्वजनिक सम्पति हो | यसको अतिक्रमण गर्नु तथा आवत जावतमा बाधा खडा गर्नु सार्वजनिक तथा दण्डनीय अपराध हो | यस पक्षका वर्तमान चुनौती एवं समस्या पहिचान गरी सरकारी नीति तथा नियमहरुको उल्लेख गर्दै के कस्ता सुधार गर्न सकिन्छ ? ५+२+३
4. State the strategy of Department of Roads. Develop action plans based on the strategy for phase-wise development of roads throughput Nepal. 4+6
5. Describe the general conditions of roads in Nepal. What are the programs that should be implemented to improve its conditions? Discuss briefly the policies and programs of roads stated in current plan. 3+3+4

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२०७८/९/१३ गते

समय :- ३ घण्टा पूर्णाक :- १००

पत्र :- दितिय बिषय :- सेवा सम्बन्धि प्राविधिक बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

1. Nepal is a very difficult country in terms of its altitude, geography and terrain to construct and operate transport infrastructures in the country. From the perspective of transport economics, present your analysis on the comparative advantages and disadvantage of various modes of transport infrastructures such as highway, railway, waterway and airways in framing national transport development plan of Nepal. 5+4+1+5
2. Describe the main causes of road accidents in Nepal. Give your opinion to lower and prevent the road accidents in Nepal. 15
3. Build, operate and transfer (BOT) has been adopted to involve private sector investor in infrastructure development. This concept is "Talk of Country" since decades but not a single investor is involved in road sector development so far. Briefly discuss the benefit of BOT and how to attract private sector investor? 15
4. Explain briefly the necessity of highway maintenance and analyze the suitability of performance-based contracting for maintaining and managing the road infrastructure in the context of Nepal.
5. Some major development transport projects are going on and some are being lunched to connect Kathmandu valley with Terai. Analyze critically the various modes of transport which can be selected. 10 +10
6. Sustainability of infrastructure like road and bridges up to its designed life period is depend upon the quality of product. 8+12

a) “Quality cost more, but lack of quality cost even more” Elaborate this statement.
b) Explain quality control (QC), Quality Assurance (QA) and Total Quality Management (TQM). Also discuss whether TQM in infrastructure development is achievable or not.

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२०७८/४/२९ गते

समय :- ३ घण्टा पूर्णाक :- १००

पत्र :- दितिय बिषय :- सेवा सम्बन्धि प्राविधिक बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रदद् हुनेछ |

1. What are the principal components of a bridge? What are the main factors affecting the selection of type of the bridge with respect to cost and quality? 15
2. It is a public opinion that “Road Projects are not completed within time, cost and quality”. Explain in detail about their issues and problems and suggest your recommendation to solve the problems.
3. Road transport sector has been considered as the major indicator of economic growth in Nepal. This sector shall be managed by the scientific and rational institutional arrangement. Review the existing road transport sector institutional provisions in the context of federal hierarchy of governance, and recommend a robust organizational framework for this sector to handle the issues of planning, designing, construction and maintenance. 15
4. Major contributing factors and sequence of road crash are important information for crash reduction activities. Explain this aspect with the help of “Haddon Matrix” Explain the traffic control devices for an urban for leg intersection. 5+5+5
5. What are the various factors of “Vehicle Operating Cost” and how it relates with total system cost in relation with the driving speed of the vehicle? Suggest your recommendation with the help sketches how the Optimum Axle Load Limit are derived? 8+7+5
6. The road condition and traffic congestion of Kathmandu valley calls for urgent attention of decision makers without any further delay. Discuss in detail about the origin of the problems with reference to the data, current institutional, legal arrangement and suggest your recommendation for its sustainable improvements with its implementation strategy. 4+3+3+7+3

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२०७६/९/६ गते

समय :- ३ घण्टा पूर्णाक :- १००

पत्र :- दितिय बिषय :- सेवा सम्बन्धि प्राविधिक बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रदद् हुनेछ |

7. Highway maintenance is crucial aspect for road transport infrastructure. Review the existing practice and propose some alternative approaches to overcome the present problems. 15
8. Construction of highway in mountains is very challenging due to various topographic as well as geological conditions. Construction of tunnels and viaduct could be taken as new approach in road transport sector in Nepal. Explain the issues and challenges for the construction of tunnel and viaduct in Nepal. 15
9. Discuss the functions of road management and finance reform implementation committee. Explain the concept of build operate and transfer (BOT). How can it be made more effective in Nepal? 8+3+4

10. With the opening of number of Northsouth and East West corridors in various parts of Nepal, the Feeder Road Standard, 1997 is become absolute. Analyze in detail about it and propose various criteria for its revision. 4+4+7
11. Road asset management will be further challenging due to the fact that preventing road maintenance should follow the actions as demanded by pavement deterioration curve by the respective governments of Federal Nepal. Identify the problems in this context and suggest your recommendation based on User Pay Principles. 6+6+8
12. The social and Environmental safeguards issues in relation to rehabilitation and Resettlement of displaced people due to the development and widening of various road projects are getting very challenging in these days. Discuss in detail about its national policies in comparison with the international best practices. 20

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२०७४/९/२३ गते

समय :- ३ घण्टा पूर्णाक :- १००

पत्र :- दितिय बिषय :- सेवा सम्बन्धि प्राविधिक बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

1. Use of forest lands in the construction of physical infrastructures in Nepal is a time taking and complex exercise for all agencies of Nepal including DoR. What are the issues, problems and challenges in this respect and suggest your recommendation to maintain the balance between brown and green agencies.
2. What are the problems of design and construction of a 4-lane express way such as Kathmandu Nijgadh express way, also called the Fast Track, in Nepal?
3. Terai Roads (Hulaki Roads) of Nepal is being talked since long time in Nepal. Describe in detail about its various components and explain in detail about the issues, problems and challenges of the project. Recommend your doable suggestions to complete the project as soon as possible.
4. What do you understand by road asset management? Explain in detail how the bituminous pavement can be taken under preventative road maintenance. 8+7
5. Urban road infrastructure and transport system are the major causes of dust and air pollution in Kathmandu valley. Identify the problems in this context, describe the current GoN polices and laws, recommend your suggestion to solve the problems and propose a sound and practical implementation strategy. 6+4+6+4
6. What do you understand by road construction technology? Describe in detail the material requirement, equipment requirement, construction steps for quality control for construction of asphalt concrete pavement. Identify the problems; describe the current policies and laws with your recommendations for further improvements. 20

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२०७३/८/४ गते

समय :- ३ घण्टा पूर्णाक :- १००

पत्र :- दितिय बिषय :- सेवा सम्बन्धि प्राविधिक बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

1. Explain the economic importance of Mid-Hill Highway. Describe the tentative alignment and highlight its progress status. 5+5+5

2. What are the environmental consequences of highway construction in hilly areas? Suggest mitigation measures to overcome these problems. 5+10
3. Discuss and review Road Safety Action Plan – 2012, for improvement of road safety in Nepal. 5+10
4. Describe the types of pavement structure and method of construction practiced in Nepal. 15
5. Explain the present status of bridge construction in Nepal. Recommend solutions for timely completion of bridges under construction. Discuss the appropriate technology in the context of Nepal. 5+5+10
6. Describe the types of road maintenance practiced in Nepal. Highlight its short comings and recommend suitable measures of sustainable road maintenance system. 5+7+8

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२०७२/८/८ गते

समय :- ३ घण्टा पूर्णाक :- १००

पत्र :- दितिय बिषय :- सेवा सम्बन्धि प्राविधिक बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

1. What are the various types of failure in flexible pavement? What is the purpose of pavement evaluation? Explain in details various approaches and methods of pavement evaluation in Nepal.
2. Enumerate and explain the methods which can be adopted while tunnelling in soft ground with their advantages and disadvantages. 15
3. Effective monitoring and evaluation (M&E) are considered to be the key features of successful project anywhere. Express your opinion on above statement linking with Nepalese experience of project delays, cost over runs and effective M and E to overcome them. 15
4. What are the important features of Priority Investment Programme (PIP) of Department of Road of Nepal? How and why this document is followed?
5. Why "Road safety" is a matter of concern in national, regional and international level? What are the measures can be taken on short-, medium- and long-term basis in order to improve in the present situations? 20
6. The concept of Build operates and transfer (BOT) adopted successfully across the global could not proceed effectively in Nepal. Critically analyse the situation in transport sector with special reference to Kathmandu -Nijgadh expressway and suggest workable model including necessary improvement law and process. 20

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२०७१/८/१२ गते

समय :- ३ घण्टा पूर्णाक :- १००

पत्र :- दितिय बिषय :- सेवा सम्बन्धि प्राविधिक बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

1. There are many soil bio engineering systems used as slope stabilization techniques. What is its basic concept? Selection of the appropriate techniques, or techniques, is critical to successful restoration. What are the points to be considered for the appropriate selection? 15
2. Failures of roads are related with quality control activities. What is the difference between quality control and the assurance? Write down the quality assurance procedure and planning and validation process.

3. What kind of road traffic safety surveillance are currently used in Nepal? What are your suggestions to enhance its level and what agencies should be made responsible to implement them? 5+5+5
4. With view of fast-track roads connecting Kathmandu and terai, discuss various methods to ensure private sector participation in construction of highways. 15
5. Road widening program has been started in Kathmandu valley two years ago with the objectives of fulfilling the mission with blacktopping within two years' time frame. But the mission could only accomplish less than 15 % blacktopping. Critically analyze the progress and suggest stepwise programmable activities to complete the mission within short period. 20
6. Guide bunds are meant to confine and guide the river flow through the bridge without causing damages to it and its approaches. Nevertheless, the result is negative due to improper shape and design features. What should be the shape and the design features? What are activities that you suggest to carry out for the maintenance and repair of guide bund? 10

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२०७८/७/१० गते

समय :- ३ घण्टा पूर्णाक :- १००

पत्र :- दितिय बिषय :- सेवा सम्बन्धि प्राविधिक बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

1. What are the basic problems faced in land acquisition for development projects? Recommend practical solution to 3 of those problems. 6+4
2. A) What are the fundamental challenges that the road sector is facing toady in implementing road sector programs? List down and discuss. 5

   B) Road sector development offers various opportunities to scale up the people and society's economic and social environment. In the Nepalese context, specify these opportunities and discuss on its applicability in the project design framework. 5
3. State each mode of transport used in Nepal with its characteristic features. Railway transport is considered is very advantages, but in Nepal, this mode of transport could not be developed with time, what are factors responsible for this? Explain. Do you agree that modification in transport policy is required to accelerate the Railway transport? Suggest your views. 10
4. What are the institutional issues encountered during the implementation of road projects? List your actions to minimize issues for timely completion of road project with intended qualities of works. 10

नेपाल इन्जिनियरिङ सेवा, सिभिल समूह, हाइवे उप समूह, राजपत्रांकित प्रथम श्रेणी, उपसचिव वा सो सरह प्राबिधिक पदको प्रतियोगितात्मक लिखित परिक्षा

२०७८/४/२८ गते

समय :- ३ घण्टा पूर्णाक :- १००

पत्र :- दितिय बिषय :- सेवा सम्बन्धि प्राविधिक बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

1. सडक दुर्धटना कम गर्ने सन्दर्भमा नेपाल विभिन्न अन्तर्राष्ट्रिय मन्चमा प्रतिबद्ता ब्यक्त गर्ने तर कुनै पनि अभिसन्धि, सम्झौताको पक्ष राष्ट्र नभएको वर्तमान सन्दर्भमा ति प्रतिबद्धताहरु पुरा गर्न एवं नेपालमा बर्षेनी सडक दुर्घटनाबाट भैरहेको क्षति न्यूनीकरण गर्ने के कस्ता नीतिगत, कानूनी तथा संस्थागत प्रबन्ध गर्नुपर्ने देख्नुहुन्छ ? १०

2. What are the sources used for the financing of highway development in Nepal? Explain Public-Private- Partnership (PPP) for the development of highway projects with its common types. State briefly reasons behind the non-implementation of PPP in Nepal so far and suggest measures to attach investors. 10
3. How would you evaluate the current status of transport infrastructure in the country? What are the actions that are needed to link the investment in the transport infrastructure to its service delivery for an effective outcome? Discuss in detail. 10
4. State the purpose of establishment of Road Board and its functions, duties and powers as documented in Road Board Act, 2058. What are the sources prescribed to establish separate fund of its own to meet the expenditure? Asses critically its coordination with Department of Road and suggest for the modification if required in Act. 10
5. विद्‌यमान सार्वजनिक खरिद कानुनको निर्माण कार्य सम्बन्धि खरिद प्रबन्धमा नियोक्ताको डिजाइनमा आधारित पद्‌धतिलाई आधार मानि कानूनी प्रवन्ध गरेको पाइए तापनि ठुला पूर्वाधार संरचना निर्माणको कार्यान्वयन स्तरमा धैरै जटिलताहरु देखिन्छ| निर्माण व्यवसायी लाई गुणस्तरीय पूर्वाधार निर्माणमा जिम्मेवार तथा जवाफदेही बानि ठुला पूर्वाधार संरचनाहरु स्वीकृत लागत, समय तथा गुणस्तरमा सम्पन्न गर्ने विद्‌यमान कानुनमा के कस्ता सुधार गर्नुपर्ने देख्नुहुन्छ? १०

नेपाल इन्जिनियरिङ सेवा, सिभिल समूह, हाइवे उप समूह, राजपत्रांकित प्रथम श्रेणी, सहसचिव वा सो सरह प्राबिधिक पदको प्रतियोगितात्मक लिखित परिक्षा

२०७६/९/५ गते

समय :- १ घण्टा ३० मिनेट

पूर्णाक :- ५०

पत्र :- प्रथम, खण्ड (ख) बिषय :- सेवा सम्बन्धि सामान्य बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्‌द हुनेछ |

1. What are the current issues and challenges for timely availability of land parcels for road development and management? Considering the provisions of re-settlement and rehabilitation principles. Give your suggestions to improve land acquisition process. 10
2. A) What do you understand by road asset management? Explain in brief. 4
   B) What is the basic preparation/tools needed to introduce and effectively manage road asset in Nepal Road System? Discuss illustrating examples.
3. What are the common issues and challenges for both MoPIT and DoR to fulfill its role as central federal agencies for managing strategies road network (SRN). What should be done to strengthen the road ownership for the sustainable transport infrastructure and effective transport delivery in Nepal. 10
4. State the types of financing for the construction of highways Nepal? What do you understand by public private partnership (ppp) in development projects? What are common types outline the advantages of PPP for the development of highway projects. 2 +2+3+3
5. In the context of “Prosperous Nepal: Happy Nepali” how would you see the role of transport sector in accelerating economic growth? List down and discuss the priority within the transport

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२०७४/९/२२ गते

समय :- १ घण्टा ३० मिनेट

पूर्णाक :- ५०

पत्र :- प्रथम, खण्ड (ख) बिषय :- सेवा सम्बन्धि सामान्य बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

1. Explain the reasons why most of the contracts are not getting completed on schedule date and go under extensive time and cost variation? What measures GON can take to ensure construction of such projects within cost, time and quality?
2. A) Why are road sector has been unable to attract private investment in Nepal so far? discuss with examples. 3
   B) To attract or solicitate private investment in road sector, what is to be done by the government and the private sector. List down and discuss. 7
3. State the strategy for promotion of electric vehicles in Nepal as provisioned by National Transport Policy, 2058. What further actions are necessary to enforce the policy? 5+5
4. A) List down and discuss the current issues and challenges that are hindering effective transport mobility in Kathmandu valley. B) In selecting different mode/type for transport in Kathmandu urban transport, what are the choices and preferences? List down and discuss comparative advantages and disadvantages of each mode/type considered.
5. State the objective of 20 years road plan point out the financial resources envisaged for the implementation of plan during its preparation critically review the implementation status of the plan so far and suggest actions required to improve the implementation activities, considering the problems encountered in past; in remaining period of the plan.

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२०७३/८/३ गते

समय :- १ घण्टा ३० मिनेट

पूर्णाक :- ५०

पत्र :- प्रथम, खण्ड (ख) बिषय :- सेवा सम्बन्धि सामान्य बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

१. नेपालमा विद्यमान सार्वजनिक सडक ऐन, २०३१ अनुसार जग्गा विकास कर सम्बन्धि व्यवस्थाको विवेचना गर्नुहोस् | १०

२. नेपालमा इन्जिनियरिंग पेशालाई व्यवस्थित गर्न नेपाल इन्जिनियरिंग परिषद ऐन, २०५५ मा के कस्ता प्रावधान राखिएका छन् ? तिनको कार्यान्वयन र नियमन गर्न नेपाल इन्जिनियरिंग परिषद कति प्रभावकारी भएको छ ? विशलेषण गर्नुहोस् | ५+५

३. नेपालमा सद्खारुको मर्मत सम्भारमा देखिएका समस्या र चुनौतीबारे व्याख्या गर्दै त्यसका लागि विद्यमान्सडक बोर्ड नेपालको क्षमता वृद्धि गर्न के कस्ता उपाय गर्नुपर्दछ? स्पष्ट गर्नुहोस् |

४. सार्वजनिक निजि साझेदारी अन्तर्गत सडक पूर्वाधार निर्माणमा नेपालमा देखिएका सम्भावना र समस्या बारे विवेचना गर्नुहोस् | १०

५. बैदेशिक लगानी संचालनमा रहेका विकास आयोजनामा देखिएका समस्याहरु के हुन् ? नेपालको पूर्वाधार विकासमा बैदेशिक ऋण र अनुदानको प्रभावकारिता कस्तो छ / व्याख्या गर्नुहोस् | १०

नेपाल इन्जिनियरिङ सेवा, सिभिल समूह, हाइवे उप समूह, राजपत्रांकित प्रथम श्रेणी, सहसचिव वा सो सरह प्राबिधिक पदको प्रतियोगितात्मक लिखित परिक्षा

२०७२/८/७ गते

समय :- १ घण्टा ३० मिनेट

पूर्णाक :- ५०

पत्र :- प्रथम, खण्ड (ख) बिषय :- सेवा सम्बन्धि सामान्य बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

१. What do you understand by public private partnership (3P) and how it differs with private sector participation and private sector outsourcing? Describe the different characteristics of ppp.
२. निजामती सेवा ऐन, २०४९ र नियमावली २०५० मा हालै भएको २०७२ को संशोधनले राजपत्रांकितविशिष्ट श्रेणी , सचिव पदको समूहीकरणको व्यवस्था गरेको छ | उक्त व्यवस्थाले निजामती सेवामा पार्ने प्रभावबारे समिक्षात्मक टिप्पणी गर्नुहोस् |
३. नेपालमा केही बर्ष यता सडक दुर्घटना अत्यधिक वृद्धि भइ धनजनको ठुलो क्षति बहिरहेको छ | यस्तो दुर्घटनाका कारक तत्वहरु के के हुन्? सडक दुर्घटनालाई न्यूनीकरण गर्ने तपैका सुझावहरु के के छन् ?
४. What are the planning considerations to be followed while preparing the strategic plan of national highway network? Analyze it's constraints and opportunities in the present context. 4+3+3
५. सडक यातायात क्षेत्रम बैदेशिक ऋणको दायित्व दिन प्रति दिन बढिरहेको सन्दर्भमा सडक विकास तथा मर्मत पनि गर्नुपर्ने र ऋणको दायित्व पनि कम गर्ने गरि सडक विकास तथा मर्मत कार्यमा कसरी लगानी गर्नु उपयुक्त हुन्छ ? सुझाव दिनुहोस् | १०

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२०७१/८/११ गते

समय :- १ घण्टा ३० मिनेट

पूर्णाक :- ५०

पत्र :- प्रथम, खण्ड (ख) बिषय :- सेवा सम्बन्धि सामान्य बिषय

तलका प्रश्नको उतर छुटाछुटै उतरपुस्तिकामा लेख्नुपर्नेछ अन्यथा उतर पुस्तिका रद्द हुनेछ |

१. परियोजना चक्र भन्नाले के बुझ्नुहुन्छ? परियोजना चक्रका विभिन्न चरणहरु प्रस्तुत गर्नुहोस् | परियोजना पहिचानलाई प्रष्ट पार्दै केन्द्रीयस्तरका परियोजना निर्धारण गर्ने प्रक्रिया बारे व्याख्या गर्नुहोस् | १०
२. निजामती सेवा ऐन (दोस्रो संशोधन), २०६४ मा व्यवस्था गरिएको आचरण भन्नाले तपैले के बुझ्नुहुन्छ? नेपाल सरकारका निजामती कर्मचारीहरु ले आफ्नो कार्यसम्पादन गर्दा आचरण अनुरुप काम गरेको/नगरेको प्रति तपाईकोधारणा के छ ? निजामती कर्मचारीले आचरण पालना गर्नुपर्ने बाध्यता हो कि हैन ? निजामती सेवा eन २०४९ अनुसार निजामती कर्मचारीले पालना गर्नुपर्ने अचारन्हारू उल्लेख गर्नुहोस् |
३. Write short notes on: i) National Transport Policy, 2058 5

ii) The department of road strategy, 1997 A.D. 5

४. विभिन्न उमेर, मोडेल, परिवर्तित आकारप्रकार , रुप रंग र अनियन्त्रित संख्याका प्रदुषणकारी सवारी साधनहरुको बाहुल्यता एवं रुट कार्टेलिंग भाडादर कार्टेलिंग र सिण्डिकेट प्रणाली आदि जस्ता समस्या निराकरण गर्ने बारे मौजुदा सवारी तथा यातयात व्यवस्था ऐनमा भएका प्राबधानलाई विश्लेषण गरीसमस्या समाधानका लागि सुझावहरु सहित लेख्नुहोस् | १०

५. What are the transport sector agencies of Nepal in South Asia Subregional Economic Cooperation (SASEC) coordinated by Asian Development Bank? What are the contributions made by ADB for the promotion of SASEC transport corridors in Nepal? 5+5

CHAPTER-1

INTRODUCTION

1.1/1.2 National Strategic Road Network / Road classification:

The needs for which roads are classified i.e., **the importance of classification** of roads is as follows:

- To provide a framework for policy formulation in road administration and management.
- To make the perspective road plans like master plan, Rolling plan clear and comprehensive,
- To develop road management information systems,
- Acts as a guide for budget allocation on priority basis,
- Acts as a guide to prioritize roads for construction, upgrading, rehabilitation etc,
- On the basis of roads level of services (LOS) are assigned and LOS governs the geometric design,
- Helps to promote Public-Private-Partnership (PPP) models of investment for huge projects like on NH.
- Helps to develop institutions responsible for maintaining the particular type of roads keeping them serviceable,
- Influences road user expectations, behaviour, and traffic performance, increase their level of confidence for the efficient and worthwhile continuity of service.
- Helps to develop institutions who works after and responsible for particular roads.
- Provide consistency in road design and construction.

- **National Strategic Road Network,**

  According to NRS 2070, roads in Nepal are classified as follows:
  a.) Administrative classification.
  b.) Technical/ Functional classification.

A.) Administrative classifications:

Administrative classification of road is intended for assigning national Importance and the government level is responsible for overall management and methods of financing. According to this classification roads are of:

→ National Highways (NH), which are main strategically important roads connecting East-West and North-South of the country. They are the main arterial routes that pass through the length and breadth of the country and they:

- Serve directly the greater portion of the population for long distance travel,
- Provide consistently higher level of service in terms of travel speeds, and bear inter-community mobility,
- Are main lifeline of the road network,

DESIGNATION: Alpha Num
H 00

→ Feeder Roads, (CR) which are (as clear from their name itself) important roads of localized nature that feed the wide interest of community from District Headquarters (DHQ) ,major economic centres, tourism centres to National Highways or other Feeder Roads of larger scale.

DESIGNATION: Alpha Num
F 000

→ District Roads, which are important roads within a district serving areas of production and markets and connecting with each other or with main highways (NHs).

→ Urban Roads, which are the roads serving within the urban municipal network.

Note: NH & FR are collecting called as SRNs. In the context of Nepal, the overall management of SRN lies under MOPIT while District & Urban Roads are managed by DOLIDAR under Ministry of Local Development (MoLD).

B**.) Technical/Functional classification:**

Technical /Functional classification of roads is done for assigning various geometric and technical parameters for design. These classifications are as follows:

→ Class-I: are the highest standard roads with divided carriageway/multiple lanes and expressways (Ex Access Control) with ADT of 20,000 PCU or more in 20 years perspective period. Design speed adopted in these types of roads are 120kph.

→ Class-II: are those with ADT of 5000-20,000 PCU in 20 years perspective period. Design speed of 100kph is adopted in plain terrain.

→ Class-III: are the roads with ADT of 2000-5000 PCU in 20 years perspective period. Design speed of 80kph is adopted in plain terrain.
→ Class-IV: are the roads with ADT of less than 2000 PCU in 20 years perspective period. Design speed of 60kph is adopted in plain terrain.
For the design of roads, the class of roads is taken as the traffic deciding factor, which is ascertained based on the traffic on the roads. However, an approximate correlation can be established between the administrative and functional classifications of the roads as follows:

RoadsPlain/Rolling	TerrainMount / Step Terrain	
- National Highways	Class - I, II	II, III
- Feeder Roads	Class – II, III	III, IV

- **General/Theoretical Classification of Roads:**
In general, roads classification is taken as a broad concept wherein various aspects are consider for the road categorization. So roads are classified as in:
a.) Seasonal Usages: Based on serviceability of roads as per different seasons of the year. These are of:
→All weatherroads, which are operal and negotiable at all weathers throughout the year except major river crossing where bridges are required.
b.) Pavement Status: Based on status of pavement and types of carriageway roads are classified as:
→Paved Roads: which are provided with a hard pavement courses where continuous / frequent traffic is required to be catered. They are of:
- Water Bound Macadam (NBM) Flexible Pavement
- Bituminous Roads
- Concrete Roads Rigid Pavement

→ Unpaved Roads: are provided where limited fair weather traffic is observed without hard surface finish. Eg: Earthern & graved roads.
c.) Based on road surfacing:
→ Surfaced Roads, which are provided with a bituminous or cement concrete.
→ Unsurfaced Roads, surfacing not present.
d.) Urban Road classification:
→ Arterial roads, → Collector streets,
→ Sub-arterial roads, → Local streets,
e.) National Administrative Classification:
→ National Highways, → District Roads,
→ Feeder Roads, → Urban Roads,
→ Regional Roads,

- **Methods of Road classification (How??):**
The roads are generally classified on the following basis:
→ Traffic volume (ADT in PCUs)
→ Load / Tonnage,
→ Location & Function

Recommended Design Parameters

Design Parameter	Road Class				Remarks
	I	II	III	IV	
1. Design capacity (PCU per day, ADT)	Greater than 20,000.00	5000-20,000	2000-5000	<2000.00	
	120				
2. Design Speed P	100	100		60	
R	80	80	80	40	

M	60	60	60	30	
S		40	40	20	
	Min. of 4		30		
3. No. of lanes		≥2	2	<2	
	3.5m				
4. Lane width, m		3.5	3.5	3.75 to 5.5	3.75
	3.75				for
5. Min Shoulder P	3.75	2.5	2.0	1.50	singe
Width (m) R	2.5	2.5	2.0	1.50	5.5
M	2.5	2.0	1.0	0.75	total
S	4	2.0	1.0	0.75	for
6. Ma^{m} Long P	5	5	6	7	double
R	6	6	7	9	Both
M	7	7	9	10	sides
S		9	10	12	

Comment of NRS 2070

- Stipulate radius, visibility, super elevation etc.
- Minimum radius such as SD in hill roads not complied with respect to significant important to safety, no intervention on marking/signage etc.
- Minimum geometry not feasible due to cost, political issue etc. but no intervention to warn for speed limit which result Head on collision at blind/BB curves and RE and SS at steep gradient
- Safety risk at Hairpin bends but vehicle do not limit to 20 kmph so avoid the hairpin may be fruitful
- Risk at high gradient segments and blind curves

Rural Road Classification

According to the Department of Local Infrastructure Development and Agriculture Roads (DoLIDAR) , approach for the development of agriculture and rural roads (1990) are classified as follows.

1. Based on the importance of Road
   a. District Road or Rural Road 'A' or Gramin Sadak 'Ka' shreni
      - All rural roads which connect one or more main markets, tourist spots, industrial area etc.
      - All rural roads which connect different VDC of same or neighbored district headquarter.
      - All rural roads which connect NSRN i.e. national strategic roads network.

   b. Village Road or Rural Road 'B' or Gramin Sadak 'Kha' shreni
      - All rural roads which connect village centre to other VDC/SNRN /District Road / same or neighbored district market center.
      - All agriculture roads which connect agriculture pocket area to market center.
      - All rural roads which connect one of the special place in the village such as small market center, school, health post, community forest, panni ghatta, etc to VDC center/ other place of VDC/ one place of neighbored VDC/SNRN/District road.

   c. Main Trail or Rural Road 'C' or Gramin Sadak 'Ga'

- All Goreto/Ghoreto Bato which connect VDC center to District headquarter of same or neighbored District/SNRN/District Road/ Village road/ market center of same or neighbored District.

   d. Village Trail or Rural Road 'D' or Gramin Sadak 'Gha'

- All Goreto/Ghoreto Bato which connect one place of VDC to VDC center/other place of same or neighbored VDC /SNRN/village road/main trail/rural road/other road of village .

- e. Rope way or Rural Road ‘E’ or Gramin Sadak ‘agna’

2. Based on Service
   - a. All weather Road
   - b. Fair weather Road
3. Based on Grade of Road
   - a. Earthen Road
   - b. Gravel Road
   - c. Black top Road
4. Based on Repair and maintenance
   - a. Maintainable Road
   - b. Non maintainable Road

Rural Road Design Standards (Only for Rural road A, B, C, D)

S. N	Design Parameters	RRA		RRB		RRC	RRD
		Pahad	Terai	Pahad	Terai		
1	Design capacity - Two way Vehicles number per day	400	800	200	400		
2	Design Speed in Km	20	40	15	30		
3	Right way from center of road in m	10	10	7.5	7.5	2.5	1.5
4	Width of road in m	5	6	4	4.5	2	1.2
5	Vehicle track width in m	3	3	3	3	2	1.2
6	Shoulder with on both side in m	1	1.5	0.5	0.75	0	0
7	Surface of road in m	Gravel	Gravel	-	-	-	-
8	Curve radius in m	10	20	10	20		
9	Max. average gradient up to 75m	8	5	8	5		
10	Max. gradient	12	7	12	7		
11	Comfort width in length for increase height in per 500m	0.5	-	0.5	-		
12	Min. gradient	1	-	1	-		
13	Free board on bridge	0.5	0.5	0.5	0.5	0.5	0.5
14	Stopping sight distance	20	40	15	30		
15	Vehicle track’s camber in %	4	4	5	5		
16	Shoulder’s camber in %	5	5	5	5		
17	Culvert or Bridge width in m	3	3	3	3	2	1.2
18	Size of Lay bypass in m	3*20	3*20	3*20	3*20		
19	Interval of bypass in m	300	500	300	500		
Load for Rural Road							
1	Average daily annual traffic in number	40		20			
2	Axel load in ton	8		6			
3	Additional width in case of less than 20m curve (m)	2		2			

1.3 Concept and Significance of Highway Planning:

- Planning is considered as a pre-requisite before any development programme is attempted. As such , it is considered as a basic requirement to undertake any new project or for upgrading/extending existing one.
- Transportation occupies a very important space in modern life since it advancement in all spheres is to a large extent influenced by transportation. On this light , transport planning is a science that arise in providing the transport facilities in an urban, regional or national level so as to prepare a systematic basis to provide such facilities.
- Planning is a set of activities done before the execution of any work (say project planning) or simultaneously with the work (say construction planning) so as to perform the tasks sequentially and orderly with optimization of resources available and avoid delays.
- Planning is very important since the success and timely completion of a project along with economic advantages solely depends upon how soundly the planning phases has been executed.
- The aspect of highway planning finds its special importance in a developing country like Nepal where sources are limited, yet the demands/requirement being higher.

- **Objectives of Highway Planning:**

  Highway planning is carried out for following objectives:
- To plan a road network for safe, efficient and economical traffic operation giving due consideration to the cost of construction, maintenance, rehabilitation and vehicle-operation.
- To arrive at a road network that provides maximum utility within the available resources during the planning period taken into consideration.
- To work out financing system,
- To study and research present situations of the transport sector to forecast future requirements.
- To fix the date wise priorities for the development of each road link based on its utility and make that the basis for phasing of road development program.
- To plan the future requirements and improvements of roads w.r.t. anticipated advancement in new trends.

  National Planning Commission (NPC) of Nepal defines planning objectives as:
- It should translate the objectives and goals of National Development Plan,
- It should aim at conserving scarce resource like oil, fuels, coal and electricity,
- Should aim at balanced development of the country keeping in view the needs of inaccessible areas and
- Transport plan should facilitate the growth of new industries, agricultural productions and other development with minimum hazard to environment leading to sustainable development of infrastructure.

- **System Approach to Planning:**

  The planning process begins with the establishment of an overall framework by the central government that include strategic goals and policy objectives for economic development and transportation plans are of :

  →Long -Term Plan (Rolling Business Plan)

  →Short- Term Plan (Implementation Plan)

1. Long Term Plan (20 years plan in prospect of Nepal) identifies general needs and choices thereby establishing the framework for the project and programming decisions.

2. Once the long-term plan (20 years) is established, the capital programming process identifies and evaluates specific road and highway projects and make trade-off among programme areas.

3. The output of capital programming process is short term plan which lists all the projects that need to be undertaken within 1-5 years period making them consistent with local and national program objectives and budget constraints.

<u>Hierarchy of Plans:</u>

National Plan

↓

National Transport Plan

↓

Regional Transport Plan

↓

Local Transport Plan

(District, City, Town)

System Approach To Planning (Flowchart)

Decision to Adopt Planning

↓

Problem Definitions, Goal Formulation

↓

Problem, Constraints, Potentials, Forecasting

↓

Generation of Solutions

↓

Solution Analysis

↓

Evaluation of possible Alternatives sand choices

↓

Implementation

↓

Operation

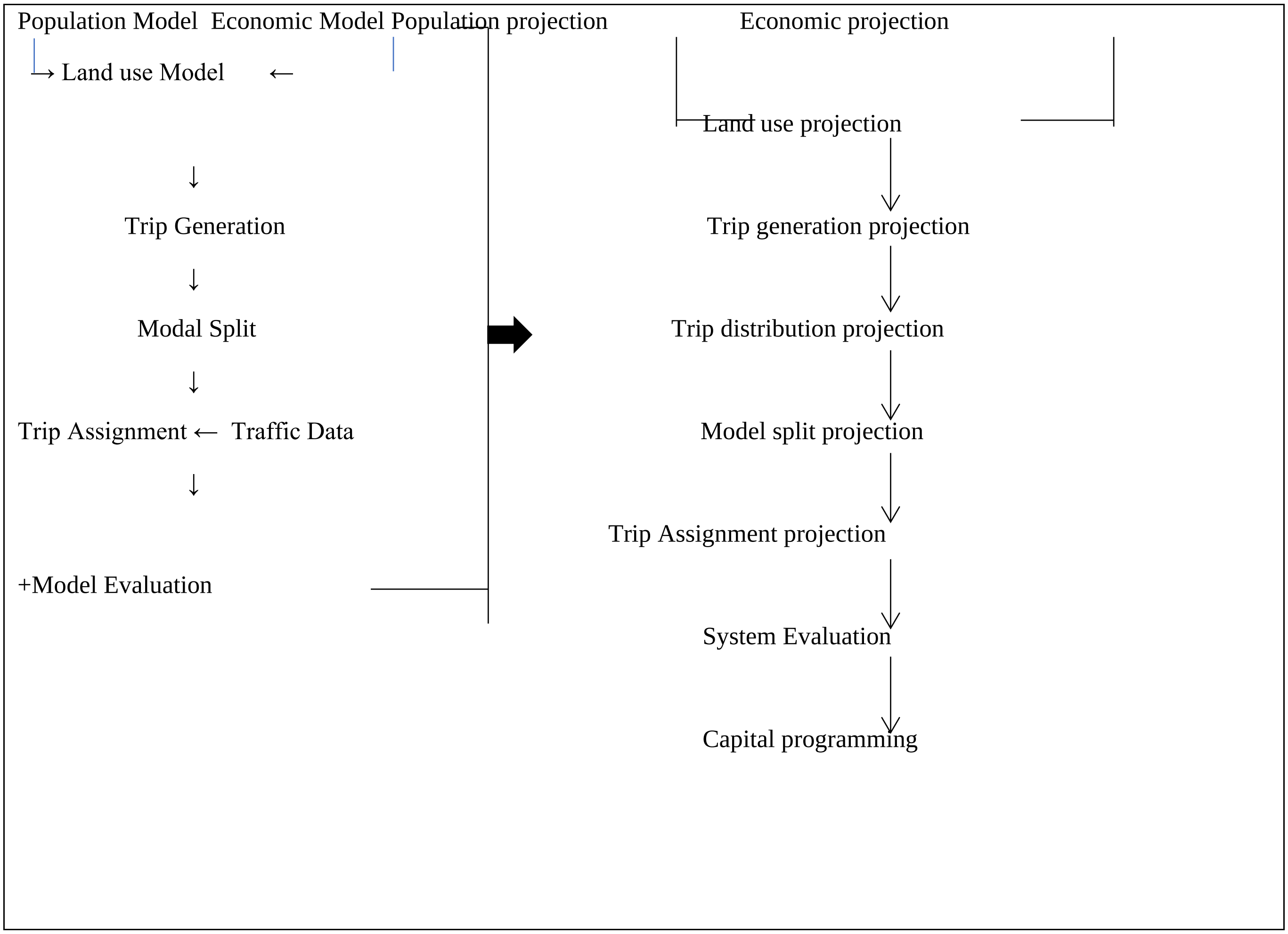
↓

Performance Assessment and Review

Fig: System Approach to Planning

- **Principle Model for Strategic Transport Planning:**
  Strategic transport planning incorporates following models:
  1. Population model
  2. Economic activity model
  3. Land use model
  4. Trip generation model
  5. Modal split model
  6. Trip assignment model

Calibration Phase in the base year data	Projection Phase on the design year data



- **Planning Stages / Steps:**

  Planning of transport facilities is said to have followed the following steps:

  1.) Survey and Analysis of exiting conditions:

  To survey and analyse the existing conditions of an area under study is divided into smaller units to study the movement pattern. The goals are so set as that all the relevant social ,legal ,economics ,technical and aesthetic factors are very comprehensively weighed, evaluated and reconciled. The following inventories and studies are done:

  a) Inventory of existing travel pattern
  - O&D surveys
  - Rail & Bus surveys
  - Household interviews
  - Goods vehicles interview
  - Coach surveys
  - Cordon & screen line surveys

  b) Inventory of existing transport facilities:
  - Street Inventory
  - Bus Inventory
  - Rail Inventory
  - Parking Inventory
  - Travel time studies

  c) Land use and economic activities:
  - Zoning
  - Land use
  - Population structure
  - Household structure

- Employment pattern
- Income etc

2.) Analysis after Inventory:

After the studies and inventories are done following analysis are made:

a.) Trip Generation / Attraction: is concerned with the estimation of number of trips produced in or attracted to a given zone under study. These studies are done by multiple regression analysis and category analysers.

b.) Trip Distribution: is the stage where trips generated / attracted are distributed to any other zone. This analysis is done by Gravity Model method according to which:

Trips between any two zones 'i' and 'j' are:

- Directly proportional to no. of trips generated in zone 'i' and no. of trips attracted to zone 'j'
- Inversely proportional to fx^n of distance or separation bet zones.

c.) Modal split: the proportional of total trips that can be shared between private and public transport facilities between any 2 zones is studied in modal split.

d.) Traffic Assignment: is the assignment of various trips between two O-D pairs on different highways routes to identify shortest, safe, economical and comfortable route wherein final traffic assignment is done.

3.) Forecast/Analysis of future conditions and plan Synthesis:

Based on the surveys and studies conducted at various stages forecast / analysis of probable future conditions is done and plan synthesis is carried out correspondingly.

Following activities are involved:

- Network planning that tentatively prepares the networks of transport facilities.
- Planning forecast based on projection of population, households, employment and future land use pattern
- Future trip generation, distribution and assignment
- Formulation of available and feasible alternatives.

4.) Evaluation of Alternatives/planned Evaluation:

For a predefined set of goal and polices various feasible alternatives are evaluated and best is selected as follows:

- Preliminary cost estimates
- Benefits/cost Analysis
- Other consideration

5.) Program Adoption and Implementation:

The best alternative related after evaluation is put forward for adoption and implementation. It involves:

- Selection of network plans
- Development of transport polices.
- Staging the execution process
- Preparing the financial resources
- Setting out the organization for implementation
- Find implementation and execution

6.) Continuing studies and Research:

Transport planning being a dynamic and complex process there cannot be any end in the plans. Uncertainity is always associated with the system because technology and preferences of people are liable to change with time. As such plans and polices very effective and relevant today might not be the same in future. This needs constant iteration and feedback by periodic surveys and thus calculating reviews, studies and researches there by updating plans continuously.

Biogrmetical Representation of Long-term Planning

Philosophical values

Goals

Objectives

Criteria

~~Re-examination~~ of Goals Objective

land use transport model

Re-define Alternatives

Impacts

Evaluation

- Highways Planning an Overview of Nepal:
  The concept of highways planning in Nepal came into account after:

  1.) Department of Roads (DOP) strategy, 1995:
  The main motive of this strategy was to introduce network planning as the basis for allocating resources to the strategic network and to make the best use of the available resources.

  2.) 20 years road plan (2058 or 2002):
  After DOR strategy was formed, 20 years road plan was prepared in 2058 (2002) whose main objectives were:

- To provide access to 17 remaining district headquarters by 11th plan.
- Total of 4040km road will be constructed

According to 20yrs plan, the expected status of SRN having different surfaces at the end of the next 20yrs will be as follows:

Road Types

Year	BT (km)	GR(km)	ERC(km)	Total(km)
- Present (2002)	3257	1254	655	5166
- After 20yrs (addn)	190	1939	1911	4040
Total in km (after 20yrs)	3447	3193	2566	9206

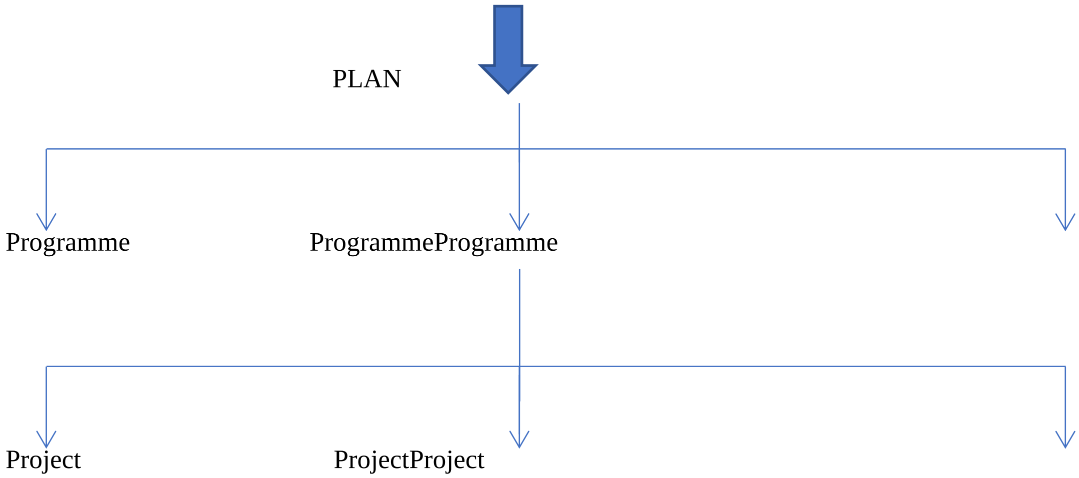
As per SSRN 2011/12:

	BT (kms)	GR(kms)	ERC(kms)	Total(kms)
At the end of 2011/12	5574	1888	4174	11636

3.) After that master plan for SRN(20yrs) in 2005.
4.) Vision paper, 2007
5.) PIP and sector wide Road Programme (SWRP), 2006

1.4) Highways Projects:

Project Formulation



PLAN : Investment exercise to drive the economy in a desired direction through an idea,

PROGRAMME : Set of activities/projects to attain certain goals,

PROJECT : A proposal for an investment to create, expand and take plan/programme into reality.

Technical Analysis of a project:

- Size of Investment,
- Location of project,
- Plan layout,
- Civil structure,
- Supply of materials,
- Production plan,
- Distribution system

Project Selection Techniques:

1.) Undiscounted techniques:

- Ratio methods – B | c   Ratio > 1.

2.) Discounted Techniques:

NPV -   +ve,   IRR> Borrowing rate (usually10%)

EIRR   Economic   IRR

Financial Analysis:

It is done to access the commercial profitability and to formulate the sound financial plan of a project.

Cost & Return → Financial IRR

Economic Analysis:

To access the analysis worth to the overall economy regards of whom the befits occurs particularly by:

- Efficient utilisation of resources,
- Growth of resources over time.

Public projects are selected on the basis of their contribution to national economy.

Need:

- To attain the optimum allocation of scare resources,
- To access the feasibility of project from national economic view point,
- To minimum the chances of duplicate of roject,
- To minimum the chances of investment risks,

Process

- Identification of costs and returns/benefits,
- Quantification of costs and benefits,
- Valuation of costs and benefits,
- Assessment of costs and benefits of alternative projects,
- Selection of projects

Problems in a Project

Generally following types of problems can be seen in a project:

1.) Policy problems:
- traditional working framework
- lack of participatory approach
- cultural and environmental factor not considered,

2.) Organizational problems:
- weak organization
- insufficient authority to PM,
- institutional bottleneck
- absence of organisational development

3.) Managerial Problem:
- Traditional managerial practices
- Insufficient utilisation of human resources,
- Lack of discipline and effectiveness,
- Lack of coordination among organization/team
- Incapable PM

4.) Procedural problems:
- Controlling acts and directions,
- Complexity in budgeting systems and budget release,
- Corruption and leakage,
- Late decision
- Impractical information system
- Working schedule not followed

5.) Behaviour Problems:
- Negativity about development/project or everything.
- Lack of motivation,
- Low morale,
- Lack of accountability, transparency, responsiveness and awareness.

6.) External Problems:
- Insufficient infrastructure,
- Low utilisation of resources
- Lack of construction materials
- Continual blockage in works, quarry sites,
- Political influence in works.

- **Feasibility study of Highway Project**

A highway projects to be attempted needs to be physically, socially, economically and environmentally viable in order to be a success. Therefore, there is a need to study the feasibility of highway projects beforehand on the following grounds:

→ Development of project objective – scope
→ Data collection
→ Development of project works

→ Participation of stakeholders
→ Preliminary design (Eng., design)
→ Preliminary cost estimate,
→Economic-financial analysis,
→ Identification of institutional and training requirements,
→ Proposed funding modalities,
→ Assessment of project risks,
→ Initial implementation plan and schedule
→ Feasibility report

Basic Requirement to decide Feasibility of highways:
1.) General Requirement:
→ Contribution to national objective adopted by national 3-5 years planning/National periodic plan,
→Regional balance,
→ Need of government role,
→ Sustainability of project
→ Participation of stakeholders,
→ Clear and concise objective,
→ Involvement of foreign experts (specially in projects under foreign aids/ loans)
→ Environmental impact assessment (EIA)
→ Equity in resource distribution
→ Support to gender equality issues.

2.) Technical Requirements:
- Financial Benefits
- Benefits/Cost Analysis

3.) Regional Priority Requirements:
→ Contribution/Support to Regional Development plan
→Regional Resource balance,
→ Support to National development goals,

Regional development goal

Sectoral development goal

Environmental issues,

Social issues

- **Criteria for feasibility study:**

General criteria that need to be fulfilled for the feasibility study are as follows:
1.) Achievement of planned goals and objectives,
2.) Cost effectiveness
3.) Economic viability
4.) Financial viability,
5.) Technical viability,
6.) Operational viability,
7.) Environmental viability/Impact
8.) Operational cost,
9.) Multi-model transfer,
10.) Sustainability,
11.) Resettlement impact,
12.) Social impact
13.) Support to regional development

GAM Index = Goal Achievement Method index is often used to weigh the various parameters,
From 1-3:
N_i = weightage range = 0-100 finalised in a participatory workshop
C_i = Each criteria have to be ranked bet^{h} 1-10

GAM Index = $\sum W_i C_i$

- Criteria for feasibility study of Highway projects

Usually for feasibility study of highway projects the following criteria have to be usefully studied:
1.) Technical
2.) Economic – 3 sets,
3.) Financial
4.) Sensitivity,
However, the basic governing criteria for carrying out feasibility study of highway project are:

1.) Technical Criteria
The technical criteria judge the technically feasible/unfeasible status of various alternatives alignments of highway with judgement of following technical aspects:
- Geology and geomorphology of the site,
- Preliminary alignment surveys and feature details,
- Traffic studies / forecasts,
- Availability of construction material at local level as well local manpower availability,
- Social Issues / political issues,
- Environmental issues
- Property acquisition / resettlement,
- Construction technology,
- Hydrology and metrological factors
- Sustainability and other design factors.

2.) Economical Criteria:
After a project is technically feasible, economic analysis is done by assessing cost and benefit issues to judge the project feasibility under economic criteria.
Five-step Cost-Benefit Analysis process:
1.) Identification of cost-benefit,
2.) Quantification of cost-benefit,
3.) Validation of cost- benefit,
4.) Assessment of cost-benefit and alternatives,
5.) Selection of project.

Total Transport Costs:
1.) Study and Research cost,
2.) Property acquisition cost,
3.) Construction cost,
4.) Maintenance cost,
5.) Road user costs, -accidents +VOC
6.) Environmental costs,

Benefit-Analysis:
All direct and indirect benefits that can be converted to money are benefits. They can be analysed as:
1.) Socio-economic studies

- Demographic picture
- Land use pattern
- Trade, Industry and commerce,
- Transportation and communication facilities/Network
- Administrative facilities

Economic projection:

Then the economic projection within the zone q influence of the various alternatives is done with at least 3 basic settings:

i.) Proposed project is not undertaken and existing trends continue and development plan carried out,

ii.) Proposed project is undertaken and existing trends continue & development plan carried out,

iii.) Proposed project is undertaken and appropriate accelerated development with cost, benefit and economic activity projection.

.

Discounted Technique:

- Present worth(PW) Net present value (NPV), IRR, EIRR are stipulated,
- B|C ration >1 ; project feasible,
- NPV +ve, project feasible
- IRR > Borrowing rate project feasible
- FIRR/EIRR> project feasible

Undiscounted Technique:

- Ratio method - B|C ratio method

  B|C ratio >| - project feasible.

1.6 Highway Management Information System.

To manage data related to highways, various models are created. But before we select any model, we need system selection i.e. modular system is required. System are of:

1.) Information system: network information production function,

2.) Decision support system: planning, programming, preparation and operation.

The output of the system is produced from a combination of data and model which needs to have

- Relevance
- Appropriateness
- Reliability
- Affordability

Usually HDM_4 system is used for highway management system:

- Road Inventory
- Pavement
- Structures
- Traffic
- Finance
- Activity
- Resources

Database processing

- Network Information
- Planning
- Programming
- Preparation
- Operation

Inputs (Private) Sub	Model Output	Inputs (Private) Sub
Vehicle type, volume Growth, loading, physical Parameter	Traffic	volume by vehicle type equivalent standard axles
Terrain material rainfall Geometry thickness unit cast	Highway construction	Construction quantities New condition ,type
Pavement type and strength ESA age condition maintenance strategy	Pavement Deterioration &Maintenon Vehicle	Cracking, ravelling Pothades ,rut depth gravel thicknen roughness etc.

Highway geometry and roughness, vehicle speed Type, unit cost	operating cost	Fuel, lubricants, types, Maintenance, fixed cost, speed, travel time
Developmental traffic delay accident, environmental	Exogenous benefit 4 Cost	Costs and benefits.
Above outputs for the analysis year	Annual Record	Condition quantities costs by components for each year required
Annual Reads	Summary Records	Total costs by component, net present Values and rates of return by like.

Fig.: Structure of HOM –iii Model

Highway Design and Maintenance (HDM) Model:

HDM model can predict the total life cycle costs, cost of construction, maintenance and road-user costs as a function of road design, maintenance standards and other policy options which may have to be considered. Although the model doesn't provide a formal mathematical optimisation, it can provide the results of economic analysis.

Concept:

- Three interacting sets of cost relationships are added together overtime in discounted present values.
- Costs are determined first by consumption which are then multiplied by unit cost or price.

Set-1: Construction cost: f Terrain, soil, rainfall, geometric
Design standards, pavement design,
Unit cost

Set-2 : Maintenance cost: f Road deterioration, pavement design
Climate, time, traffic, unit cost,
Maintenance standards

Set-3 : Road-user cost: f Geometric design, condition of road
Surface, vehicle speed, vehicle type
Unit costs

Three phase operation:

1.) Data Input and Diagnostic phase:
The input data are examined for possible format and numerical errors and internal consistencies.

2.) Simulation:
Simulation of the traffic flows and of the changes in the roads as they go from initial construction through annual cycles of use, deterioration and maintenance, with possible construction projects to upgrade them.

3.) Analysis:
Economic analysis and comparison of alternatives of construction and maintenance polices for selected group of road links is carried out. Reports are generated to give difference between the financial, economic and foreign exchange cost of pair of alternatives.

- The coefficients used in the function of HDM models varies on local conditions.

HDM-4:

HDM-4 is a software system used for evaluating options for investing in load transport infrastructures. Most common use of HDM is for feasibility study but it is most comprehensively used for network evaluation. The model is used for planning and programming of capital activities such as reseal, overlay, reconstruction, widening and new construction.

Application of HDM-4:

- Project Appraisal : New construction, upgrading, economic evaluation.
- Project Formulation: Surface type, thickness.
- Maintenance policy optimisation: Funding.
- Road work programming: Plan development.
- Network strategic analysis: Assess funding needs.
- Standards $ Policies: Road price, axle load limits.

- Periodic Maintenance Planning:
  Periodic maintenance planning is done in five stages:

1. Data collection and road register updating:

Data collected from HMIS are:
- Updated read register.
- Traffic data of road links.
- SDI and IRI of road links.
- Terrain.
- Surface type.
- Road width and length.

2. Determination of time for Resurfacing:

- Maintenance cycle of 5-6 years is set based in terrain in which read exists and the traffic it caters.
- Then age correction factors are applied W.R.T present surface condition (SDI, IRI values)
- Following are resurfacing frequencies in year set up by DOR system for given traffic (veh/day)

Terrain/Traffic(vpd)	<250	250-1500	>1500
Plain	8	7	6
Rolling	7	7	6
Hill	6	6	5
SDI →	0-1.7(Good)	1.7-3 (Fair)	3.1-5.0 (Poor)

Then time for resurfacing = Previous resurfacing year + Maintenance cycle + Age Corr factor

If the output value is less than recent time format, resurfacing is needed otherwise the value shows the year when resurfacing has to be done.

3. Screening and Ranking Process:

During the screening process, it must be noted that the service life of a road can only be extended by periodic maintenance is the underlying layers are sound. This test can be done by there ways:

i) Visual Screening:
If a road section is free of ruts, extensive deformation and/or dense cracking, its suitable for resurfacing.

ii) Estimated Remaining Pavement Life:
If the pavement design axle loading and traffic history is known or can be reasonably be infer a residual pavement life can be computed. This can later be modified by visual pavement condition assessment.

iii) Pavement Deflection Survey:
After screening the road links, prioritisation of roads for surfacing is done with reference to 3 indices.

Contd:

The three indices used for prioritisation are:

a) Traffic Index - 0.15 to 0.90

Traffic Group (veh/day)	<250	250-1500	>1500
Index value	0.15	0.50	0.90

b) Road condition Index: - 0 to 1.0

SDI value	0-1.7(Good)	1.8-3.0 (Fair)	3.1-5.0(Poor)
Index value	0	0.30	1.0

c) Strategic Importance Index: 0-0.6

Strategic Importance	Low	Medium	High
Index value	0.0	0.30	0.60

» Ranking Index = TI+RCI+SII = R.I
Road having highest value of R>I are prioritized for resurfacing.

4. Compilation of Priority and Needs:

Regional priority list is prepared from the divisional priority list which is finally integrated with national priority.

5. Budget Allocation:

Based on integrated national priority list and available funds, budget allocation is done rationally to implement at division level.

Highway Management Information System : (HMIS)

HMIS is a system which is capable of generating and providing comprehensive highway data by introducing and operating a unified location reference system in connection with existing highway related systems thereby establishing a linkage between the highway digital maps and a variety of highway related data.
For an efficient HMIS, there must be integration of:
i) Pavement maintenance management system
ii) Bridge maintenance system
iii) Traffic management system
iv) Highway drawings & registers
v) Cut slope maintenance system

HMIS has two systems:

1. Client System: Important for highway policy makers, engineers and serves following functions:
- Database management
- Comprehensive data analysis

2. Web-based System: For highway engineers and others with following functions:
- Highway information query
- Easy data access

Advantages of HMIS:

1. Efficient resources planning management
2. Unified location reference system guarantees consistency of highway management and user convenience.
3. More accurate data can be obtained on highways by the provision of locational information.
4. Effective tool for policy update.
5. Integrated database leads to better utilization of data and resources in highways.

In the context of Nepal DOR has established HSIM unit in 1994 which currently runs PMEU. HSIM has been since then conducting pavement condition surveys, annual traffic count and SRN datas and publishing status of SRN (SSRN) document every 2 years. Thus, HMIS plays vital role by assisting the Roads Board by updating road status every year. However, an integrated HMIS has yet to be developed.

Objectives of HMIS unit:
- Efficient management of SRN,
- Act as information centre of DOR
- Enhance central highway database management and information system of DoR

Strategies of HMIS unit:

- Prepare, store and update network level inventory, road condition, road maps and traffic related data.
- Develop, update and maintain construction and maintenance cost data bank,
- Install, develop and maintain analytical methods like HDM-4 for project proposals, annual and rolling periodic maintenance program.

Activities of HMIS unit:

- Conduct annual pavement condition surveys on SRN i.e. SDI, road roughness survey etc.
- Conduct manual classified traffic count survey on SRN annually,
- Collect and update SSRN in every two-year interval,
- Produce and distribute maps having geographic information of roads, links, district, zonal and regional boundaries.
- Conduct road inventory survey of SRN
- Publish half yearly HMIS newsletter ,
- Maintain and update the official website of DOR i.ewww.dor.gov.np

CHAPTER-2

HIGHWAY DESIGN & GEOMETRICS.

2.1. Road Geometrics and general considerations:
2.2. Design Parameters and criteria of selection:

Highway Alignment:
Highway alignment is the position or layout of various points of the centre-line of a road through which it is supposed to pass. The utmost need for good alignment is justified because of the following disadvantages that can be experienced in a poorly aligned roads/highways.

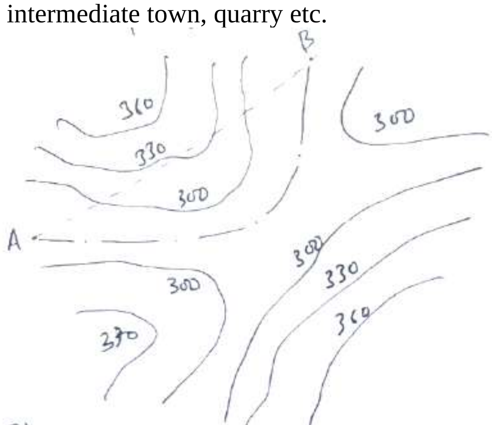
- Increase in construction cost,
- Increase in maintenance cost,
- Increase in vehicle operation cost,
- Increase in accident rate

The various requirements of highway alignment are:

1.) Short: shortest alignment between two terminals and hence preferably straight. However, several practical considered cause deviations from straight path.
2.) Easy: Easy to construct and maintain with minimum problems. Also easy for vehicle operation.
3.) Safe: Safe for construction and maintenance from view point of stability of natural slope, act slope and embankments. Also, safe enough for vehicle operation with safe
4.) Economical: the total cost including initial construction cost, maintenance cost and vehicle operating cost.

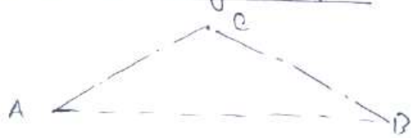
- Factors Controlling Highway Alignment:

The various factors that govern the choice of a highway alignment are as follows:
1.) Obligatory Points:
These are the control points governing the alignment of a highway. They are of two types:
i.) Points through which the alignment is to pass:
For various regions, an alignment often deviates from the shortest path or easiest path like in bridge site, mountain pass, intermediate town, quarry etc.



a) Alignment along hill pass

b.) bridge site



c.) Connecting intermediate town C.

etc..

ii.) Points through which alignment should not pass:
sometimes road alignment deviates from the shortest/easiest path in view of various points through which alignment shouldn't pan like ponds, depressions, religion areas, marshy/water-logged areas, costly structures, unsuitable lands etc.

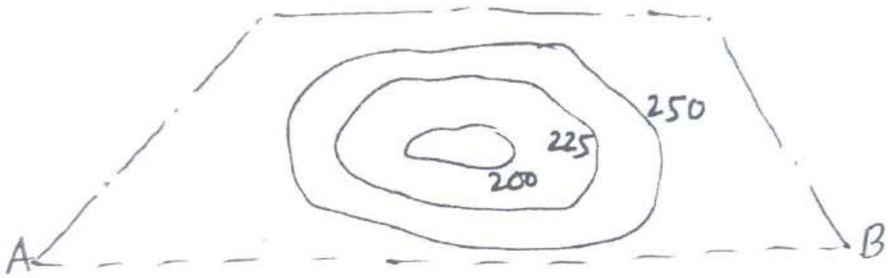


fig: Alignment avoiding a pond:

2.) Traffic:
With respect to traffic flow trend, desired lines have to be drawn after conduction 0-0 surveys recalling into an alignment fitting to traffic requirement at present and projected future requirements.

3.) Geometric Designs:
Geometric design factors such as gradients, radius of curves, sight distance etc. also govern the final alignment of highway. Adjustments might be necessary in view of design speed, maximum allowable super-elevation, coefficient of lateral friction, minimum radius of curves, transition curves etc. minimum sight distance equal to safe stopping distance should be available at every road section to avoid accidents.

4.) Economy:
Economics for the road in regard of initial construction cost, maintenance cost and vehicle-operation cost. Balanced cutting-filling approach should be used to avoid high initial costs. Also, social issues should be considered.

5.) Other Factor:
Other factor include:

- Drainage considerations,
- Hydrological factors,
- Political consideration
- Monotony.

In the case of hill roads, special considerations need to be given to:

- Stability: Align the road on stable side avoiding slide-prone areas and other unstable areas.
- Drainage: Attempts should be made to reduce the crossing over small natural drains to minimise costs of cross drainage works.
- Geometrics: Ruling gradient should be provided in every possible length minimising steep grade, hair pin bends, needles rise and falls.
- Resisting length: Should be kept as low as possible i.e., ineffective rise and executive fall kept min.

Factor controlling the choice of route depends up on

1. Construction cost
2. Cost to future traffic
3. Maintenance cost
4. Social cost and benefits
5. Water shed route

GEOMETRIC DESIGN OF HIGHWAYS.

- Deals with the dimensions and the layout of visible features of the highway such as right distance, super-elevation, alignment, intersections etc.
- To provide optimum efficiency in traffic operations with maximum safety at seasonable cost.
- If not design properly and constructed at the initial stage, improvements in geometric elements at a later date is rather expensive and very difficult.

Geometric design deals with the following elements:

1.) Gross-sectional elements,
2.) Sight distance considerations,
3.) Horizontal alignment details,
4.) Vertical alignment details,
5.) Intersection elements.

Basic principle of Geometric Design

1. For road safety and comfort: a uniform application of design standard is most necessary
2. Geometric features of highway except cross section elements do not lead to stage construction like grade and curve
3. The design standard recommends further as their absolute minimum, so effort should exceed the minimum value as far as possible.
4. Optimum efficiency in traffic operation with respect to traffic safety and comfort
5. The NRS, passenger car is considered as design vehicle and having 1 unit of PCU.

Design Control and Criteria/Parameters:

Following are the factors that control geometric design:

i.) Design Speed:

It's the safe speed that can be maintained over a specified section of highway under favourable conditions. It's the most important factor since almost all the geometric design elements of a road depend on speed.
The 95th percentile speed and the 98th percentile speed are often taken as design speed. In Nepal different standards have be assigned depending upon the importance or the class of road i.e. NH, FR, district roads etc.
According to NRS 2070:

Road class	Design Speed (kph) in terrain below			
	Plain	Rolling	Mountains	Steep
I	120	100	80	60
II	100	80	60	40
III	80	60	40	30
IV	60	40	30	20

In very difficult terrain and at unavoidable situations design speed may be taken as 75% of the above values.

ii.) Design vehicle

Design vehicle is a selected motor vehicle the weight, dimensions and operating characteristics of which are used to establish highway design controls to accommodate vehicles of a designated type. Radius of curves, pavement widths, clearness, parking geometric etc. are controlled on this regard.
Also, the weight of vehicles, axle configurations affect the structural design of pavement and structures as well as the operating characteristics of vehicle in grades.
As per NRS2070, a standard traffic unit " Passenger car unit (PCU)" is assigned (Equivalent to normal passenger car or light van or pick-up) and equivalency factors are assigned to other vehicle to maintain uniform unit to all vehicles.

Vehicle Types	Equivalency Factor
Bicycle, motorcycle	0.50
Car,lightvan,pick-up,auto-rickshaw	1.0
Tractor, light min truck	1.50
Truck,bus,minibus	3.0
Non-motorized carts	6.0

iii.) Topography

Topography influences the geometric design of highways. The terrain are classified based on the general slope of the country across the alignment.

Terrain	Cross-slope
- Plain	0-10

- Rolling 10-25
- Mountainous 25-60
- Steep >60

The design standards specified for different classes of road are different depending on the terrain classification. Due to variation of design speed on the different terrain, geometric design is influenced. In addition to this, exceptional gradients have to be provided at some sbetches due to topography and sharp curves are also required at some places due to construction problems.

iv.) Traffic Factors

Human and the vehicular characteristics are the traffic factor that influence the geometric design of roads. Traffic factors affect the highway capacity and level of service (LOS) of a particular road. These factors include different types of vehicles in the vehicle stream, distribution of lanes, variations in traffic flow and traffic interruption. It is difficult to decide the design vehicle or the standard traffic lane under the mixed traffic flow condition prevalent on especially urban roads which is main problem.

v.) Traffic volume and Capacity

The traffic flow/volume keeps fluctuating with time, from a low value during off-peak hours to the highest value during peak hours. It is uneconomical to design for the peak flow or the highest hourly traffic volume. As such, a reasonable values of traffic volume is decided for the design and is called design hourly volume. It also thus affects the geometric features such as width, alignment, gradient etc. and has unit of Average Annual Daily Traffic (AADT) which is:

AADT= Total Annual traffic volume/No. of days in a year.

AADT, however, doesn't represent the variations in traffic flow during various months of year, days of the months and hours of the day. As such "30th highest hourly volume" is a common unit used for geometric design which is the hourly volume which is not exceeded more than 29 times in a year such that all other hourly volumes will be less than this value.

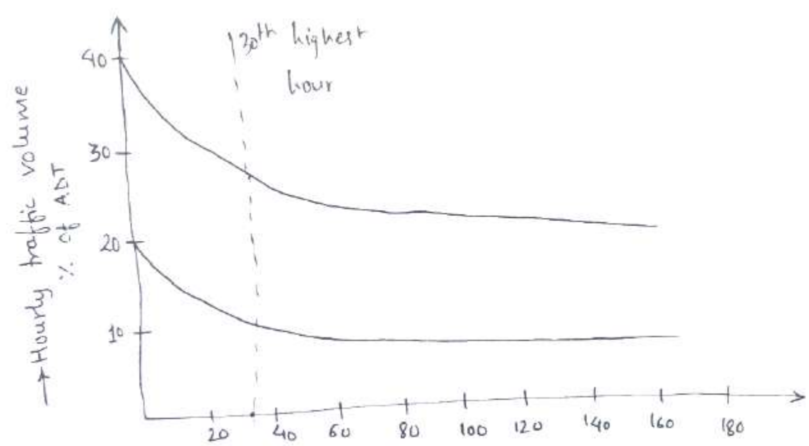


Fig: Hourly Traffic Volumes

Capacity

Traffic capacity of a highway is the ability of a roadway to accommodate the maximum flow in a highway facility. It is the total number of vehicles that can pass a given a point in a unit period of time for a given traffic condition. Unit is given as veh/hr/lane.

The LOS of road sets the traffic capacity design and the traffic capacity design governs geometrics.

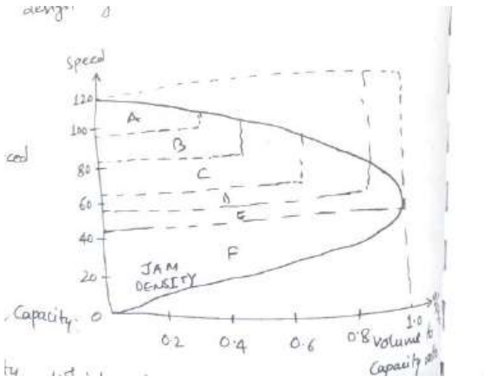
Los

A = capacity>volume

High speed

F= capacity<volume-forced flow operation,

Low speed, traffic jam



These are their types of capacity:
i.) Basic/Theoretical capacity, which is the max^{m} capacity in ideal traffic conditions and roadway conditions.

BC=c= $\frac{1000v}{S}$ v= speed in kph
s= average spacing of successive moving Vehicle

S=length of vehicle + SSD = L+vt+v^2/2gf (v in m/s)

ii.) Possible Capacity is capacity at prevailing situations as conditions never ideal. Equal to zero at worst cane and equal to BC at ideal cane.

iii.) Road user behaviour
It is a subjective parameter and depends upon the knowledge level, awareness, traffic sense, physical and mental capacity and conditions. The important human factors which effect traffic behaviour include the physical, mental and psychological characteristics of drivers and pedestrians.

iv.) Environment and other factors:
The environment factors such as aesthetics, landscaping, air pollution, noise pollution and other local conditions should be given due considerations in the design of road geometrics.

Basic Principles of Geometrics Design
i.) For road safety and comfort, a uniform application of design standards is most necessary,
ii.) Geometric feature of a highway expect cross-sectional-elements don't allow stage construction eg: grade, curvature etc.
iii.) If stage construction is unavoidable, better strategy will be to use dry masonry in drains, wall, pitching, culverts etc.
iv.) The design standards recommended are absolute minimum. So effort should be to exceed the minimum value as far as possible.
v.) Optimum efficiency in traffic operations leading to maximum status at reasonable overall cost.

Special consideration for alignment for Hill Roads
- Stability
- Drainage
- Geometric standard of hill roads
- Resisting length etc

Route Selection/Location on Hill Roads
1. River or valley Route
    - Most adopted
    - Serve rural settlement
    - Low VoC and initial cost
    - Numerous horizontal curves
    - Extensive earthwork and special structure etc
2. Ridge /Mountain Route
    - Vary steep gradient and sharp curve, hairpin bend etc
    - High cost

A mountain pass route is the necessity for developing in artificial increasing length of the road.
Best alignment is one which has sum of ascends and descends between extreme points is the least.

Highway Cross-Section Elements:
The various elements of highway cross-section are:

1.) Pavement Surface Characteristics:
The important pavement surface characteristics that play a vital role on geometric design are:

a.) Friction
- Friction between vehicle tyres and road surface determines the operating speed of a vehicle and distance required for stopping and overtaking operations of a vehicle .
- Following factors effect the friction:
→ type of pavement surface,
→ Macro-texture of pavement or relative roughness,
→ Condition of pavement, wet or dry,
→ Type and conditions of tyre
→ Speed of vehicle
→ Brake efficiency
→ Load and tyre pressure,
→ Temperature effect
→ Gradient,
→ Type of skid (if any)

NRS 2070:

Design speed (kph)		coeff. Of lateral friction (f)
30	Interpolate the in between values (linear variation)	0.39
120		0.35

'f" governs super elevation ≫ $e + f = \frac{v^2}{2gr}$ | $\frac{v^2}{2g(e+f)}$

b.) Unevenness:
Measured by unevenness index which is the cumulative measure of vertical undulations of the pavement surface recorded per unit horizontal length of the road. It is measured by using a 'Bump-Indicator'
- Effects design effect
- Effects vehicle operation cost, comfort and safety,
- Effects fuel consumption, wear and tear of vehicle parts.

Good pavement surface (on high speed highways) should have pavement unevenness less than 150cm/km.
A/C to NRS, it is given as interaction roughness index (IRI)

IRI value	Status
<3.5	Good
3.5-8.5	Fair
>8.5	Poor

c.) Light Reflecting Characteristics:
- Night visibility depends upon light reflecting characteristics.
- Light coloured/white pavement (Rigid) gives good visibility at night particularly rains while produce glare and eye strain during bright sunlight.
- Black top pavements provide very poor visibility at night especially when the surface is wet.

d.) Drainage of surface water:

2.) Camber/Gross slope:
It is the slope provided to the road surface in the transverse direction to drain off the rain water from the road surface
Importance:
- Prevent entry of surface water into the subgrade soil through pavement and to other layers as well.
- Prevent the skid by allowing rain water to remove from the pavement surface as quickly as possible.

Depends on:
- Type of pavement surface,
- Amount of rainfall.

Disadvantage of Heavy camber
- Transverse tilt causing discomfort and wear of tyres and road.
- Discomfort due to throw of vehicles while crossing crown.

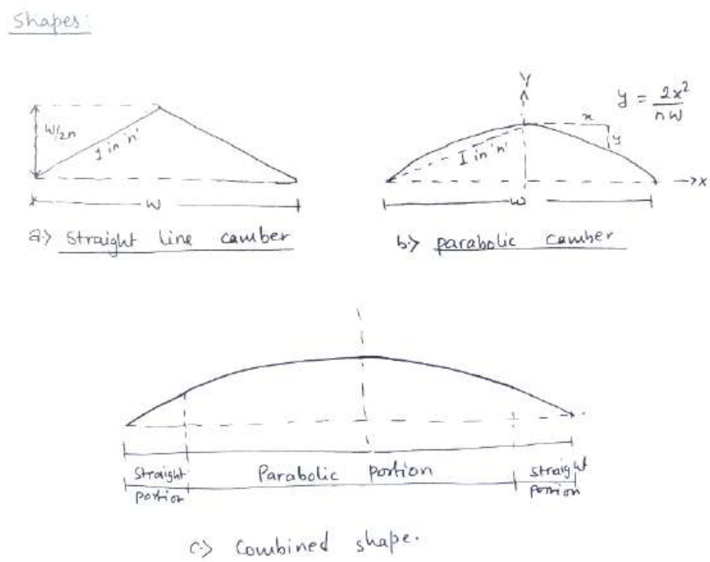
- Toppling of highly laden bullock carts and trucks,
- Formation of Gross-ruts sue to rapid water flow,
- Tendency of vehicle to move along the centre-line.

NRS 2070:

Type of road→	Rigid	Bituminous	Gravel	Earthern.
Camber →	1.5-2.0	2.50	4.0	4.50

- On straight section additional cross fall of shoulder = 0.50%

Shapes:



In hills roads cross-slope in any one direction can be adopted for easy drainage of surface water. In such cases, curves should be carefully designed to avoid negative super-elevation.

3.) Carriageway width:
- Depends upon the no. of lanes and their width,
- No. of lanes depend upon the width of the traffic lane number of lanes.
- Also no. of lanes depends upon predicted traffic volume and design traffic volume for each lane and its Los
- The lane width is determined on the basis of width of vehicle and the minimum side clearance for safety.
  → Standard vehicle width = 2.44m to 2.50m

Width

No. of lanes	As per IRC	As per NRS-2070
- Single	3.75m (2*0.625+2.5=3.75)	3.75m (upto 3m in difficult terrain)
- Intermediate	5.50m	5.50
- Double	7.5(=2*3.75)	7.50
- Multi lane	3.5m/lane	3.5m/lane

In a single lane road, it is recommended to have two treated shoulders with 1m width on either side so that the total width of surface rums up to 5.50m.

Traffic separators/medians:
They primarily serve for:
- Protecting collision between vehicles moving in the opposite directions on adjacent lanes,
- Channelize the traffic into streams w.r.t the directions they are moving at intersections,
- Shadow the crossing and turning traffic,
- Segregate the slow traffic an protect pedestrians.

4.) Kerbs:
Kerbs indicates the bounding between the pavement and shoulder or sometimes islands/footpath/kerb parking spaces. They are most desirable on urban roads. They also provide lateral confinement and stability to the granular materials placed at different pavement layers.

Types:
i.) Low/Mountable type:
- Height = 10cm above pavement edge,
- Provided at medians and chhanelised schemes. Useful for longitudinal drainage.

ii.) Semi-Barrier Type:
- Used where pedestrial traffic is high,
- Height = 15cm above pavement surface edge as shown.

iii.) Barrier Type:
- Provided in built-up areas where pedestrian traffic is huge. Placed adjacent to footpath with a height 20cm above pavement edge. Batter 1v:0.25H

5.) Road Margins:
Elements include in road margins are shoulder, parking, lane, frontage road, driveway, cycle track, footpath, guard rail, embankment slope etc.
The minimum width of shoulder as per NRS-2070 is 0.75m (even in hills) while that of IRC is 2.50m. As per NRS-2070, minimum width of shoulder on either side of pavement for different road classes are:

Road Class	Class I	Class II	Class III	Class IV
Shoulder width	3.75	2.50	2.0	1.50

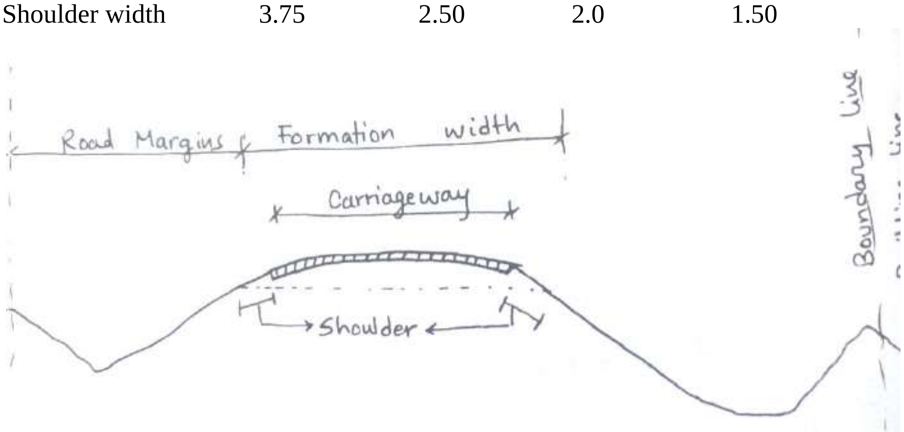


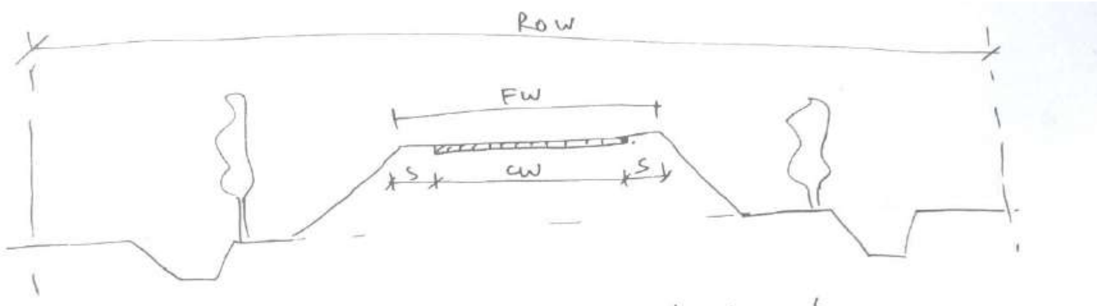
Fig: A typical road cross-section.

6.) Formation Width:
- It is the sum of width of carriageway and pavement medians and shoulders.
- Pavement width is the top width of embankment of highway or the bottom width of highway cutting excluding side drains.
- Total load taking portion of a pavement.

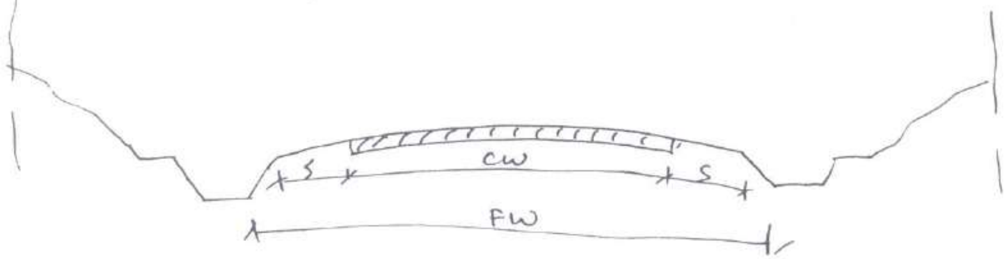
7.) Right of Way:
It is the area of land acquired for road along its alignment. The total width of right of way depends upon the importance of the road and possible future development.
As per NRS 2070:

Road Type	Row	Bet^n Building lines
NH	50m	62m
FR	30m	42m
Dist. Roads	20m	32m

8.) Typical Road Cross- Sections:



a.) C/S of a road in Embankment



b.) C/S of a road in cutting.

- **SIGHT DISTANCE**

Sight distance available from a point is the actual distance along the road surface, which a driver from a specified height above the carriageway can see the stationary or moving objects. As such, sight distance is the actual length of the road visible ahead to the driver at any instance which is very important for safe vehicle operation in a highway.
Restrictions to sight distance may be caused at horizontal curves by obstructions present at the inner side of the road or at vertical summit curves or at intersections. Sight distance required by driver applies to both geometric design and for traffic control. The standards for sight distance should satisfy the following three conditions:
1.) Driver travelling at the design speed has sufficient sight distance to stop the vehicle without collision. This is called as the minimum or stopping sight distance (SSD).
2.) Driver travelling at design speed should be able to overtake the slow-moving vehicles at reasonable intervals without causing obstruction or hazard to traffic in the opposite direction. This is called as safe passing or safe overtaking sight distance (OSD).
3.) Driver entering an uncontrolled/unsignalized intersection has sufficient visibility to enter and cross that intersection without collision. This is sight at intersections.

IRC Recommendations:
Apart from above mentioned situations, IRC considers the following sight distances for exceptional situations:
a.) Intermediate Sight Distance:
It is taken as twice the stopping sight distance (SSD) and is provided at certain sections to give limited overtaking opportunities to fast vehicle where overtaking sight distance (OSD) cannot be provided.

b.) Head Light Sight Distance:
It's the distance available to a driver during night driving under the illumination of the vehicle head light from opposite direction. This sight distance is critical at up-gradients and at the ascending stretch of valley curves.

Stopping Sight Distance (SSD)
The minimum length or signal distance available on a highway at any spot to sufficiently stop a vehicle travelling at a design speed safely without collision with any other obstruction is called as "Stopping Sight Distance (SSD)". Its also known as "Non-passing Sight Distance" SSD depends upon:
i.) Features of the road ahead: IRC recommends object height 0.15cm can above road surface.
ii.) Height of driver's eye above road surface: IRC recommends = 1.20m
iii.) Height of object above road surface: As (i).

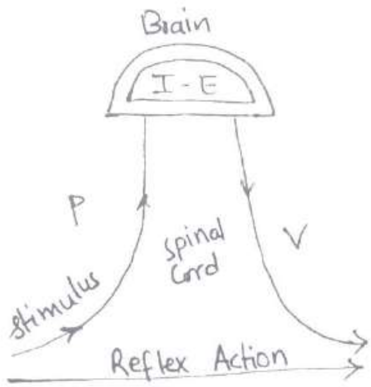
Hence, we can alternatively define "SSD at a summit curve" as the distance along the road surface visible to a driver with eye level @1.20m from the road surface such that an object @ height 0.15cm can be clearly seen to the driver.

Factors affecting SSD:
The distance within which a motor vehicle can be stopped depends upon:
a.) Total Reaction Time:
Reaction time of a driver is the time consumed from the instant the object is visible to the driver to the instant the object is visible to the driver to the instant the brakes are effectively applied. More the reaction time, more will be required sight distance.
It can be split into two parts:
→ " Perception Time" which is the time required for a driver to realise that the vehicle must be stopped i.e. from the time the object becomes visible to the time brakes are applied. It depends on speed of vehicle, object distance, factors related to environment and psychology.
→ "Brake Reaction Time" i-e the time from which the brakes are applied to the time the vehicle actually stops. It depends upon the driver skill, type of problem and various other environmental factors.
The reaction phenomenon is better explained by PIEV theory.

PIEV Theory
According to PIEV theory, the total reaction time of the driver is split into four categories:
I.) Perception Time (p): is the time required by a driver to perceive an object or a situation. Hence it is the time required for the sensations received by eyes/ears to be transmitted via the nervous system/spinal cord to the brain for taking decision.
II.) Intellection Time (I) : is the time required for understanding the situation. Also, it's the time elapsed in comparing regrouping and registering new situations/thoughts
III.) Emotional Time (E) : is the time elapsed during the emotional sensations and disturbance w.r.t any situations like anger, fear, emotions etc. Varies w.r.t problems involved.
IV.) Volition Time (V) : is the time taken for final action.

The PIEV time depend upon:
- Physical/psychological features of driver involved, types of problems, environment conditions,
- Temporary factors like motive of trip, travel speed, fatigue, consumption of alcohol etc.

As per practice, total reaction time = 0.5sec (simple situations)



b.) Speed of vehicle:
Braking distance and the total stopping distance is always proportional to the speed of vehicle before the brakes are applied. Higher the speed, higher will be the required stopping distance.
c.) Efficiency of Brakes:
Braking efficiency is said to be 100% if the wheels are fully locked after applying the brakes preventing them from rotating which results in skid and is normally undesirable. Hence to avoid skid, braking force shouldn't exceed the fictional force between the tyre and road surface. Braking efficiency depends upon the following factors:
- Age of vehicle
- Condition of vehicle
- Friction of road surface
- Skill of driver
- Psychology of drivers etc.

d.) Frictional/Skid Resistance:
Frictional or skid resistance depends upon the type and condition of road surface and the tyres.Braking distance increase with decrease in skid resistance. IRC recommends a value of coefficient of friction from 0.35-0.40 for design

Analysis of SSD

Stopping Sight Distance (SSD) of a vehicle is the sum of:

→ Distance travelled at Design Speed (v) by the vehicle during the total reaction time, called "Lag Distance".

→ Distance travelled by a vehicle after the application of brakes to a dead stop position, called "Braking Distance".

Lag Distance:

If v = Design speed of vehicle in m/s

T = PIEV reaction time,

Lag Distance = v.t [when v is in m/s]

L_{lag} = 0.278 vt [when v is in kph]

IRC recommends a value of t = 2.5sec reasonable for most situations.

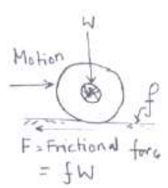
Braking Distance:

Assuming a level road, braking distance may be computed by equating the kinetic energy of the vehicle to work done by frictional force to stop the vehicle.

→ Then, frictional force (f) = F=f.w

Work done = fw * braking distance (L_b)

→ Kinetic energy = $\frac{1}{2} mv^2 = \frac{wv^2}{2g}$



Equating a and b,

$Fw*L_b = \frac{wv^2}{2g}$

» $L_b = \frac{V^2}{2gf}$

Hence, from 1 and 2

Stopping Distance (SD) = $L_{lag}+L_b$

» SD = $Vt + \frac{V^2}{2gf}$[v in m/s]

» SD = $0.278Vt + \frac{V^2}{254f}$[V in kph]

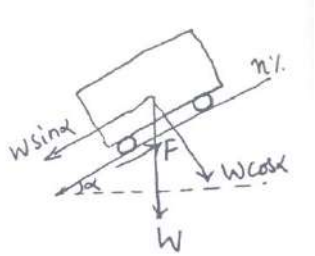
For road with gradients:

If n = Gradient of the road,

The work done in stopping the vehicle is the sum of frictional force plus the component of gravity parallel to the surface. Then,

Work done = $[F_{frict}+F_{comp}]*L_b$ F_{frict} = f.wcos

= [f.wcos+wsin]*L_b F_{comp} = W sin



For small angles, cos=1, sin=tan=n%

Work done = $W.L_b$ [f+n%] = W. L_b (f+0.01n)

» $L_b = \frac{V^2}{2g(f+0.01n)}$ [+for upward grad and vice verse)

»$SD = 0.278\ Vt+V^2/254[f+0.01n]$

SUMMARY:
For level Roads:

$SD = vt+\frac{v^2}{2gf}$ [v in mps]

$SD = 0.278\ vt+\frac{V^2}{254f}$ [V in kph]

For Roads with Gradients:

$SD = vt+\frac{v^2}{2g[f+0.01n]}$ [v in m/s]

$SD = 0.278\ vt+\frac{v^2}{254(f+0.01n)}$ [v in kph]

SSD required on descending gradients is higher as the component of gravity oppose the braking force along the direction of motion. Hence, it is necessary ti determine the critical value of the SSD for the descending gradients on the roads.

Min^m SSD = SD 1- way traffic lanes
2- way traffic lanes with two or more lanes
Min^m SSD = 2*SD – single-lane roads with two-way traffic.

Value of f:

V(kph)	20-30	40	50	60	65	80	100

Overtaking Sight Distance (OSD)

In case of mixed traffic conditions, where all vehicles don't move at the designed speed "Overtaking Sight Distance (OSD)" are provided at frequent intervals for the fast moving vehicles to overtake the slower ones. In such case, the minimum distance open to the vision of the driver intending to overtake a slow vehicle ahead with safety against the traffic moving from the opposite direction is known as the minimum "Overtaking Sight Distance (OSD)" or the "Safe Passing Sight Distance".

Thus OSD is the distance measured along the centre of the road which a driver with his eye level 1.20m above the road surface can see the top of an object 1.20m above the road surface which enables him to decide whether or not to undertake overtaking operatio

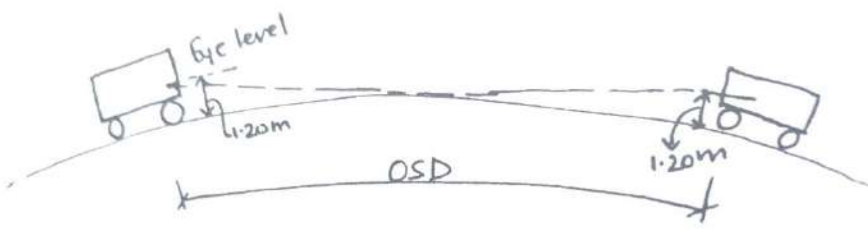


Fig: Measurement of OSD

For safe overtaking manoeuvre, the safe OSD required depends upon the following factors:

- Speeds of overtaking vehicle, overtaken vehicle and the vehicle coming from opposite direction,
- Distance between the overtaking vehicle and the overtaken vehicle, the min^m space depends on speeds.
- The reaction time of the driver,
- The rate of acceleration of the overtaking vehicle,
- Gradient of the road, if any.

Analysis of OSD

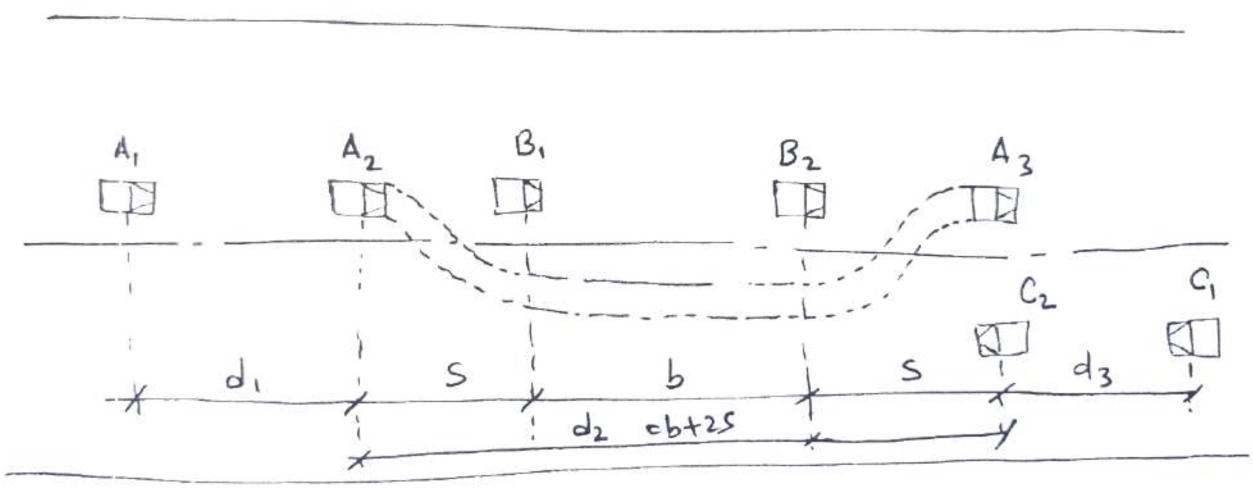


Fig: Overtaking Maneouvre

Figure above shows on overtaking manoeuvre of a vehicle 'A' travelling with design speed, another slow vehicle 'B' that is being overtaken and the third vehicle 'C' coming from the opposite direction on a two lane road with two-way traffic. In such a case, the overtaking manoeuvre can be split up into three operations. Now, overtaking sight distance is divided into three parts:

Part I : d_1 is the distance travelled by vehicle 'A' during the reaction time at which driver makes up his mood to overtake vehicle 'B'. During this time vehicle 'A' is forced to travel at speed of vehicle B (say, v_b) behind it allowing a space 'S' until the overtaking operation starts.

Hence,

$d_1 = v_b * t$ in m/s

or, $d_1 = 0.278\ V_b\ t$ in kph

where,

$v_b V_b$ = velocity of vehicle 'B'

t = reaction time (In average t = 2sec)

Part II: From A_2, the vehicle 'A' starts overtaking operation by acceleration, shifting to the other lane, overtaking the vehicle 'B' and then coming back to its own lane at a safe distance 'S' from vehicle B. During this time, say,

d_2 = Distance moved by A as it travels from A_2 to A_3

b = Distance moved by B from B_1 to B_2 at the same time,

s= Minimum clearance between vehicle A and B before the start of overtaking operation and after its complete.

T = Time taken during overtaking operation by 'A'.

→ from empirical formula,

$S = 0.7\ v_b + 6$

Here, $d_2 = b+2s$ where $b = v_b.\ T$

$d_2 = v_b.T+2s$

To calculate T which is a period in which vehicle 'A' travelling with initial speed of V_b and acceleration 'a' travels from A_2 to A_3 covering distance 'd_2'. Then from motion of uniformly accelerating body,

$D_2 = V_b.T + \frac{1}{2}aT^2$

Equating 3 and 4,

$V_bT + \frac{1}{2}aT^2 = V_bT + 2s$

$\rightarrow T = \sqrt{\frac{4s}{A}}$

As such,

$D_2 = V_b.T + 2s$,

Where,

$S = 0.7v_b + 6$

$T = \sqrt{\frac{4s}{A}}$

Part III:

'd_3' is the distance travelled by vehicle 'C' coming from the opposite lane, during the overtaking operation at which it moves at speed sayV_c, from c, to c_z

$d_3 = V_c.T$ in m/s

$d_3 = 0.278V_c.T$ in kphv_c is often design speed 'v'

Then,

$OSD = d_1+d_2+d_3$

→ $OSD = V_b.t+V_b.T+2s+V_c.T$, $s = 0.7v_b+6$ $T = \sqrt{\frac{4s}{a}}$ in m/s

→ $OSD = 0.278V_bt+0.278V_b.T+2s+0.278V_c.T$

Note : if speed of overtaken vehicle is not given it can be assumed to be (V-16)k/n or (V-4.5)m/s.

Notes:

→ When two-way traffic exists,

Min. $OSD = d_1+d_2+d_3$

→ On divide highways/roads with one-way taffic,

Min. $OSD = d_1+d_2$

→ On divide highways with four or more lanes, its not necessary to provide the usual OSD. However, the sight distance should be greater than SSD.

» Effects of Gradients on OSD:

- At descending grade, the overtaking vehicle might have easy acceleration and pass. OSD is a bit more than level surface. However, in some cause, the overtaken one also may speed-up and cover up a greater distance 'b'.
- At ascending grades, the acceleration of overtaking vehicle will be less and hence greater distance will be reqd. for overtaking opeertaions.
- Hence for both ascending and descending gradients, OSD reqd. is always more than at level surface.

» Overtaking Zones:

- Whenever sufficient length for safe overtaking can't be provided at all places, "overtaking zones" are provided at frequent intervals such that vehicles moving at design speed get to overtake slow vehicles.
- The minimum length of the overtaking zone should be three time to five times of the safe OSD as far as possible. So,

  Length of Overtaking zone: (3to5)*$(d_1+d_2+d_3)$ - 2-way traffic

  (3-5)*(d_1+d_2) – one-way traffic.
- Sign posts should be installed at a sufficient distance (equal to OSD) before the start of overtaking zone and at the end of overtaking to OSD from the start point) as shown below:

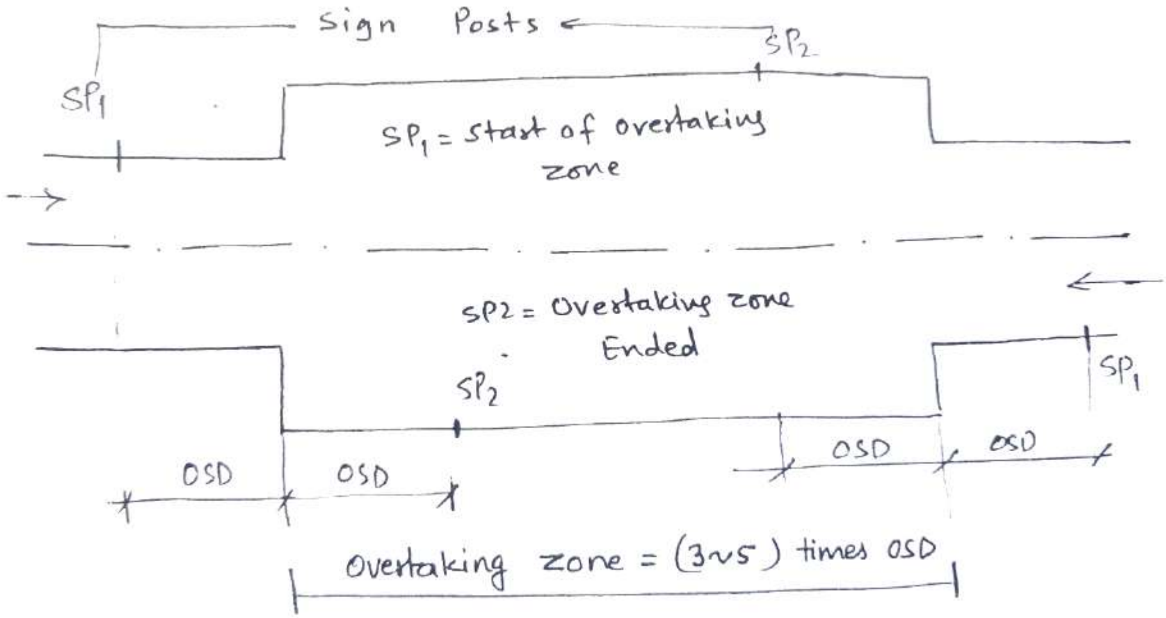


Fig: Overtaking zones.

- On horizontal curves the required minimum OSD may not be always fulfilled specially on sharp curves. In such cases sign posts should be installed indicating the "Overtaking Restricted Zone". In such cases, where min^m OSD can't be provided. Intermediate Sight Distance equal to 2*SSD has to be provided.

Sight Distance at Intersections:

In all approaches of intersecting roads, it is important to have a clear view across the corners from a sufficient distance so as to avoid chances of collision specially at uncontrolled junctions. The area of unobstructed sight formed by the lines of vision is called as the "Sight Triangle".

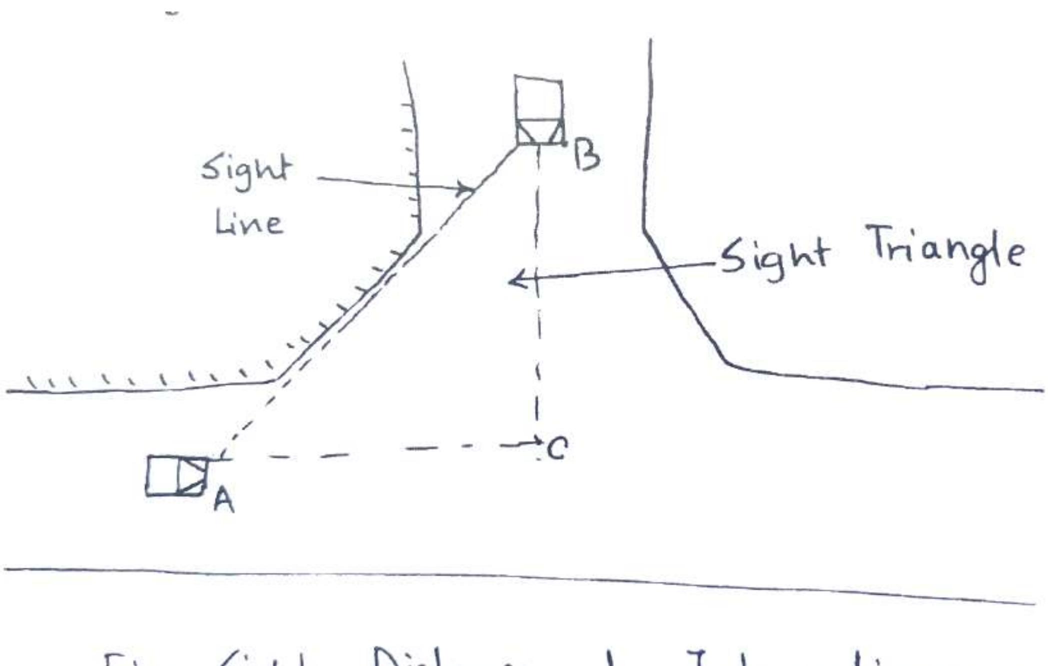


Fig: Sight Distance at Intersections.

The design of sight distance an intersection may be based on three possible conditions:

a.) Enable Approaching Vehicle to Change Speed:

The sight distance should be sufficient to enable either on or both the vehicles to change speed to avoid collision. Vehicle approaching from minor end often slows down wherein the reaction time of 2 sec to analyse and 1 sides AC and BC of sight triangle should be at least equal to distance covered by vehicle A and B in 3 sec. resp. while in design speed. However, these distance AC and BC

b.) Enabling Approaching Vehicle to Stop:

The distance between approaching vehicle should be sufficient to bring either one or both the vehicle to stop before reaching a point of collision. Hence the two sides AC and BC should be at least equal to SSD.

c.) Enabling Stopped Vehicle to Gross a Main Road:

For a vehicle entering an intersection from a minor road and controlled by a stop sign, the sight distance available from the stopped position should be sufficient enough to enable the stopped vehicle to start, accelerate and cross the main road before another vehicle moving along the main road at required for stopped vehicle depends on:

- Reaction time of the driver,
- Width of the main road,
- Acceleration and
- Length of the stopped vehicle.

Thus, the sight distance required to fulfil this condition is the distance travelled by a vehicle in the main road at design speed during time 'T'. All three of the above conditions should be fulfilled from safety considerations in case of sight distance at uncontrolled/unsignalized intersections at grade and he higher of three values should be taken.

Design of Horizontal Alignment

Horizontal alignment consists of a series of twists and turns which necessitates the change in directions. Various factors that need to be considered for design of horizontal alignment include design speed, radius of circular curves, types and length of transition curves, superelevation and widening of pavement at curves. The various components are discussed in detail as under:

» Horizontal curves:

Horizontal curves are provided in the plan of the alignment so as to provide change in direction of the vehicles w.r.t. the center line of the road. While traversing a horizontal curve, centrifugal force (p) is developed through the C.G. of the vehicle acting horizontally outwards which is counteracted by the lateral frictional resistance developed between the tyres and the pavement enabling the vehicle to change its directions with stability. The centrifugal force developed depends upon the radius of curve, weight and speed of the vehicle. The centrifugal force developed is given by the equation:

$$P = \frac{mv^2}{R} = \frac{wv^2}{Rg}$$ symbol having usual meaning

$$P/W = \frac{v^2}{Rg}$$

The ratio p/w as in eq^n(1) is called "Centrifugal Ratio" or the "Impact factor".

The centrifugal force 'P' acting on a vehicle negotiating a horizontal curve has two effects:

I.) overturning Effect:

It’s the tendency of the vehicle to overturn outwards about the outer wheels.

As in fig: say,

P= Centrifugal force developed during curve traversing,

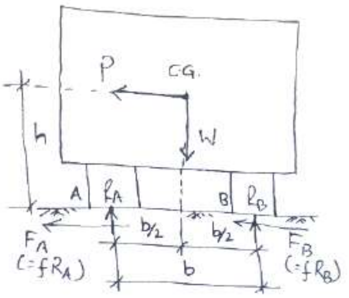
W= weight of the vehicle,

b= width of wheel base,

h= height of C.G. from road surface,

→ Overturning Moment (M_o) = P.h

→ Resisting Moment (M_R) = w.b



For equillibrium, $M_o = M_R$

» $P.h = w.\frac{b}{2}$ » $\boxed{p/w = \frac{b}{2h}}$

This implies chance of overturning exists whenever the centrifugal ratio (p/w) exceeds b/2h

II.) Transverse Skidding Effect:
The centrifugal force also pushes the vehicle in the outward direction resulting in transverse skid if the force exceeds max^m resistance to skid due to friction. Let,
R_A, R_B = Reactions developed at tyre points A&B
For eqillibrium, $p = F_A + F_B = f(R_A + R_B) = f.w$

$\boxed{» P/W = f}$

Analysis of Super-Elevation
In order to counteract the effect of centrifugal force on a vehicle traversing a curve, the outer edge of the pavement is raised w.r.t the inner edge thereby providing a transverse slope throughout the length of the curve. This provision protects the vehicle from the chances of overturning or lateral skid. Such a provision is called super-elevation.

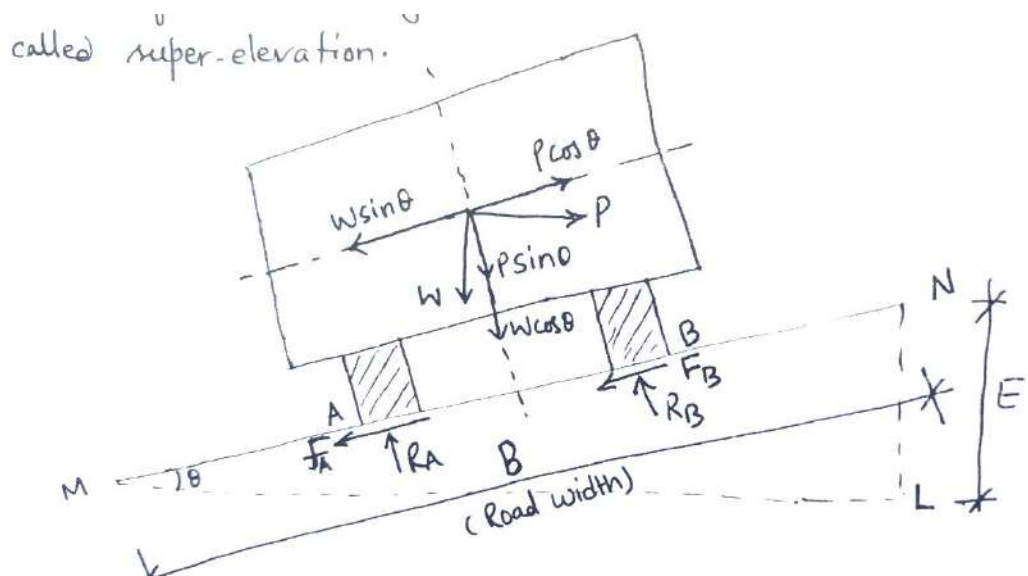


Fig: Analysis of Superelevation

As shown in fig. above, the transverse slope provided to the pavement surface is called as super elevation or cant or banking. It is expressed as 'e', as the ratio of height of outer edge w.r.t. horizontal width.

» $e = \frac{NL}{LM} = \tan Q$

Since Q is very small &tanQ<0.07, tanQ_SinQ

» e= $\frac{NL}{MN}$ [sinQ] = $\frac{E}{B}$ » E=eB

When a vehicle moves in a circular path with a speed of v m/s, there are following forces acting as shown in fig.

i.) Centrifugal force 'P' acting horizontally outwards through C.G,
ii.) Weight of vehicle 'W' acting vertically downwards through C.G,
iii.) Wheel reactions R_A&R_B acting perpendicular to plane,
iv.) Frictional force F_A&F_B developed at tyre points acting towards the center of the curve.

These forces are resolved along and perpendicular to the road surface. For equilibrium,

→ Resolving along the plane

P cosQ = W sinQ + F_A+F_B

At limiting equilibrium, full frictional forces are developed

i.e. F_A=f R_A, F_B=f R_B

» P cosQ = W sinQ + f(R_A+R_B) 1

→ Resolving perpendicular to the plane,

R_A+R_B = W cosQ + P sinQ 2

Substituting R_A+R_B in eq^ni,

P cosQ = W sinQ+f(w cosQ+PsinQ)

Or, p(cosQ-f sinQ)= w(sinQ+fcosQ)

Or, p(1-f tanQ)= w (f+tanQ) (Divided by cosQ or both sides

Generally f_{max}= 0.15, tanQ<0.07 » f tanQ~ 0, &tanQ=e

» P/W = e+f, Since p/w = v^2/gR,

» e+f = v^2/gR -v in m/s.

Equillibrium Super-Elevation

It is the value of super elevation that is required to fully counteract the centrifugal force without taking into account the friction of the road surface. In such a case, the pressure on outer and inner wheels will be equal but it results in very high value of super-elevtion.

» $e_{eq.} = \frac{V^2}{gR}$

Zero Super-elevation:

In some cases super-elevation cant be provided due to practical difficulties and then the frictional force has to fully counteract the centrifugal force produced on curves.

Such a case is zero- super elevation.

» $f = \frac{V^2}{gR}$

However, frictional force may not be able to fully counteract centrifugal force at high speeds. As such , there is a need to restrict speed to a limit V_a i.e. the allowable velocity for maximum friction.

» $V_a = \sqrt{fgR} = \sqrt{fgR}$

$V_a = \sqrt{fgR}$

Maximum Super elevation:

$E+f = \frac{V^2}{gR}$

This equation suggests that for a constant value of 'f' the value of required super elevation increase with increase in speed and with decrease of radius of curve. However, if a road is supposed to cater mix traffic consisting of both fast and slow moving vehicle maximum allowable superelevation has to be limited.

Specially for heavily loaded vehicles and very slow moving bullock carts, high super elevation may lead to overtoppling which further necessitates the need of restricting 'e' to a certain max^m value. As per IRC:

Terrain ^{e}max

- Plain & rolling snow bound areas 7%
- Hill roads not bound by snow 10%
- Urban roads with frequent intersections 4%

Minimum Super elevation:
If the calculated value of super elevation works out to be equal to or less than usual camber, then from the drainage considerations, the minimum value of super elevation should be limited to the camber of the road surface. Thus after crown is eliminated, a uniform cross-slope equal to camber should be maintained from outer edge to inner edge of the curve.

Design of Super elevation
For a road catering vehicle having wide range of speed, design of super elevation becomes complex. Maximum value of super elevation is not good/safe for slow moving vehicles and vice-versa. As such, there's practice to provide the super elevation to counteract the centrifugal force due to 75% of the design speed neglecting the lateral friction developed and then the maximum value of super elevation is limited to 0.07.

Design steps:
I.) Super elevation required for 75% of design speed neglecting lateral friction.

$$E_{75\%} = \frac{(0.75v)^2}{gR}$$

II.) Check if $e_{75\%} \leq 0.07$
If $e_{75\%} < 0.07$, adopt $e = e_{75\%}$-o.k.

III.) If $e_{75\%} > 0.07$, provide $e_{max} = 0.07$
Check friction developed , $f = \frac{V^2}{gR} - 0.07$

IV.) If f >0.15, adopt e = 0.07, f= 0.15. Then the allowable speed should be restricted to V_a, where,

$$\frac{V_a^2}{gR} = 0.07+0.15 = 0.22$$

$$V_a = \sqrt{0.22gR}$$

Attainment of Super elevation:
At straight portion, the c/s of road is usually cambered with the crown at the center of the pavement and sloping down towards the edges. At horizontal curves, the c/s is super elevated with slope tilting from outer edge of the pavement to the inner edge. This crowned section just at the start of transition curve should be changed at a gradual uniform rate throughout the transition curve to reach a single cross-slope equal to desired super-elevation at the beginning of circular curve. Super elevation is attained by following steps:

1.) Elimination of Crown:
The crown of cambered section is eliminated by two methods:

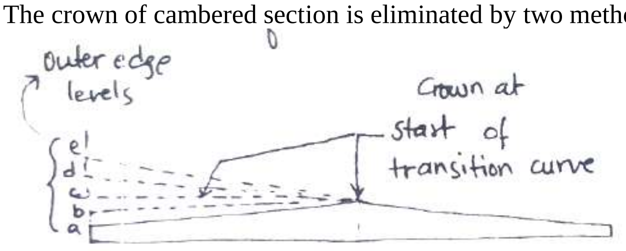


fig. a) Outer edge rotated about crown

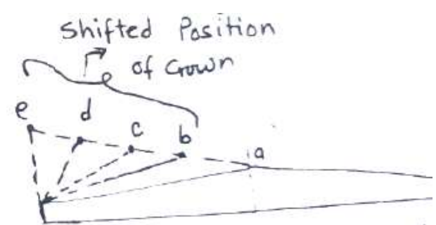
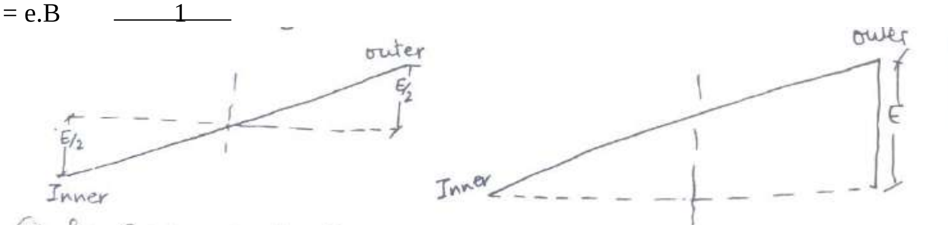


fig b: Crown shifted Outward

- First method raising of the outer edge by rotating w.r.t crown at a desirable rate. Outer half is brought to horizontal level at the start of transition curve and then subsequently further rotated to obtain desired slope.
- In second method, known as diagonal crown method, the crown is progressively shifted outwards to positions a, b, c, d & e as in fig. to attain desired super elevation.

2.) Rotation of Pavement:
The first method is applicable only for super elevation of min^m value of camber. For larger values, this method is used. If ,
e = required super elevation, B = total pavement width,
Then, total banking of outer edge (E) w.r.t inner is,
$E = e.B \qquad \underline{\quad 1 \quad}$



① fig: Rotation about ℄ ② fig: Rotating about inner edge

- In the first method, the desired super elevation is obtained by depressing the inner edge & raising the outer edge by equal amount E/2. Q thus remains unchanged.
- In the second method, full raise of outer edge is done to attain required super elevation. Q is raised by E/2.

» Radius of Horizontal Curve:
The centrifugal force experienced by a vehicle moving on a horizontal curve of radius 'R' with speed 'V' are related by:

$$e+f = \frac{V^2}{gR} \qquad R = \frac{V^2}{g(e+f)}$$

Hence, if the decided speed for a certain highway is 'v'; the minimum radius to be adopted is called Ruling minimum radius & is given by:

$$\boxed{R\ \text{ruling} = \frac{V^2}{g(e+f)}}$$

WEDENING ON HORIZONTAL CURVES
On horizontal curves, especially when they are not of very large radii (for R<300m), pavement width has to be widened by calculated amount for one or more of the following reasons:
1.) To prevent "off-tracking" of vehicles, i.e., when steered on curves, the front wheels only turn while the rear ones doesn't follow the same path due to having rigid wheel base. When extra widened, the vehicles thus don't off-track from the road when turned on such curves.

2.) At high speeds, lateral skidding might take place when super elevation and lateral friction are not able to counteract the centrifugal thrust. Thus, extra widening is provided to keep the vehicle in track even if lateral skidding occurs.

3.) In case of trailer units, the wheels are on either side of the centre line. And for other vehicles that have the tendency to follow the outer side for greater visibility extra width is provided. This gives the vehicles the larger radii & better visibility at beginning of curves.

4.) While vehicles cross or overtake on curves, there is a psychological tendency to keep more clearance against collision. This ensures more safety than on straight path.

The extra width (we) depends upon:
- Length of the wheel base of the vehicle (l)
- Radius of the curve (R)
- Psychological factor → f(V,R).

Analysis of Extra widening

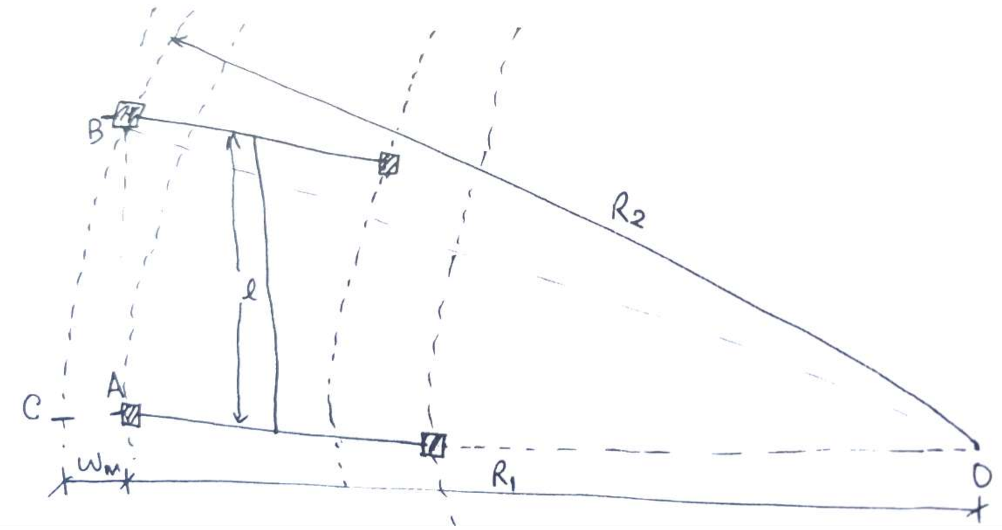


Fig.: Mechanical Widening on horizontal corves

Analysis for extra widening required on horizontal curves is divided into two parts:
1.) Mechanical widening (W_m):
- counts for off-tracking due to rigidity of wheel base.
From fig: w_m= OC-OA = R_2-R_1 (1) ________
From OAB, $AB^2=OB^2-OA^2$ => $l^2= R_2^2-R_1^2$
Or, $l^2= (R_2-R_1)(R_2+R_1) = w_m(R_1+R_2)$ (from 1)
Here, $R_1=R_2$= R (say), :. $R_1+R_2=2R$.

2.) Psychological Widening (wp):

These are providing to allow for extra space requirements to give greater clearance for crossing or overtaking at horizontal curves. This is often the function of speed of vehicle and radius of curve and is given by:

$$W_p = \frac{V}{9.5\sqrt{R}}$$

Hence, total widening required (W_e) is given by:

$$W_e = W_m+W_p$$

$$\boxed{W_e= \frac{nl^2}{2R} + \frac{v}{9.5\sqrt{R}}}$$ n= no. of lanes

Methods to Introduce Extra widening in Curves:
1.) In curves with transition curves, extra width is provided gradually from zero at straight portion to $w_e/2$ on either side to give full extrawidth throughout the -----curve, in case of large radius. In sharp curves, total extra width may be provided at the inner side only.

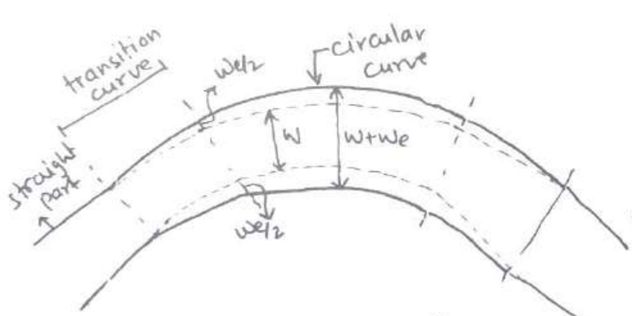


fig: Curve with large Radius

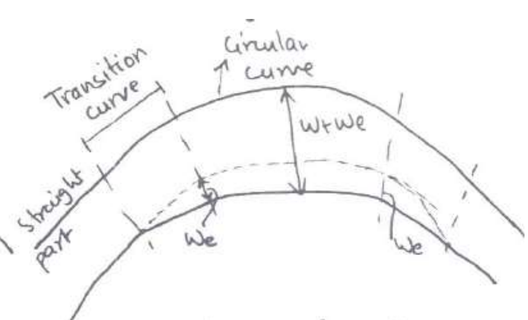


fig: Sharp Curves

2.) For curves without transition curves, $2/3^{rd}$ of w_e is provided at straight portion before start of curve and remaining is provided beyond the tangent point. The total extra width

Horizontal Transition Curve

Transition curves are provided at the deviation points from the straight alignment to horizontal curve so as to enable the smooth entry by introducing the effect of centrifugal force gradually by adopting a suitable shape of the transition curve the best fits to the alignment.

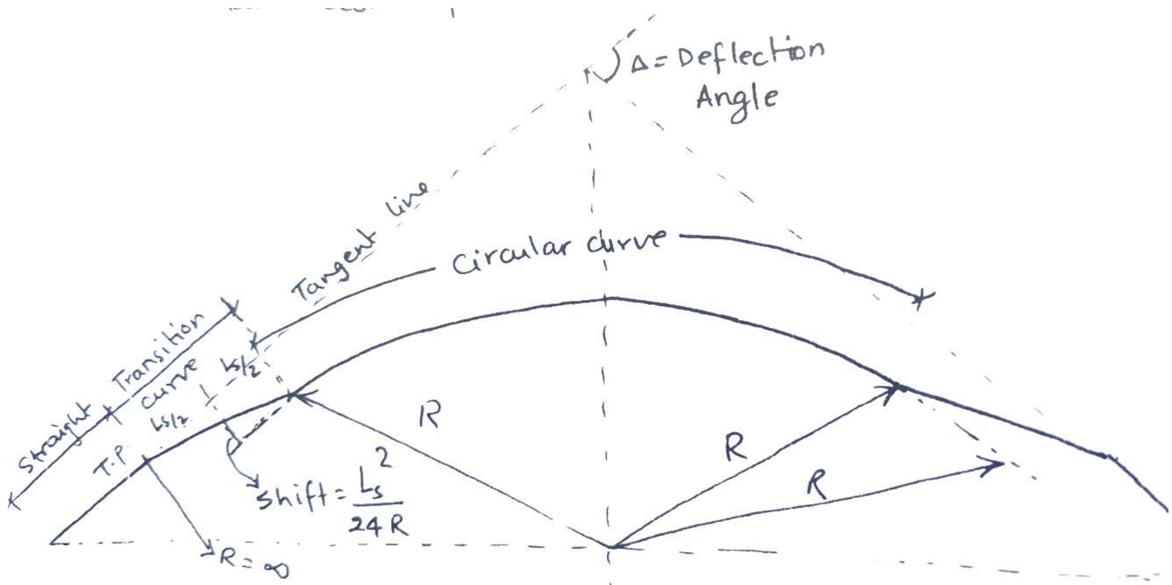


fig: Transition curve in Horizontal Alignment

As shown in fig. above, the radius of the transition curve decrease from infinity at the tangent point to designed radius at the beginning of the circular curve. The rate of change of this radius from straight portion to BC of the horizontal curve depends upon the shape adopted i.e. eq^n of curve.

Objectives

- To introduce the centrifugal force gradually between TP and BC avoiding sudden jerks on vehicles,
- To enable the driver to steer the vehicle gradually ensuring safety and comfort to himself & passengers,
- To enable the gradual introduction of super elevation and extra widening at desirable rate in horizontal curves,
- To provide aestheticity to the road surface.

In an ideal transition curve, the length (l_s) is always inversely proportional to the radius (R) of the horizontal curve.

i.e. $L_s x \frac{1}{R}$ $\Rightarrow L_s.R$= constant

The spiral transition curve fulfils this requirement.

Types of Transition Curves

The various types of transition curves commonly adopted in the horizontal alignment are:

a.) Spiral or Clothoid,

b.) Lemniscates and

c.) Cubic Parabola.

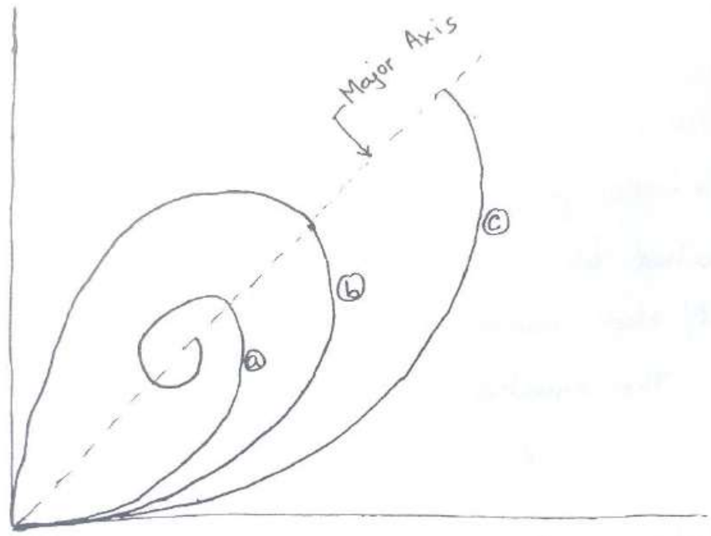


Fig Different shape of transition curves

- All three of the shapes almost follow the same path uptodelefection angle of 4° having no practical difference in shapes even upto 9°.
- In all these curves, the radius of curvature decreases as the length increases. However in the case of leminiscate and cubic parabola, the rate of change of centrifugal acceleration and rate of change of radius is not constant, especially for deflection angles with values >4°.
- In the case of spiral curves, the radius is inversely proportional to the length and the rate of change of centrifugal acceleration is uniform throughout the curve.

IRC recommends spiral curve as an ideal curve to use in horizontal alignment due to following reasons:
→ The spiral satisfies the requirement of an ideal transition curve i.e.

- Radius being inversely proportional to length,
- Rate of change of centrifugal acceleration is uniform throughout the length of the curve.

→ It has an easy geometry i.e. calculation and setting out the curve in field is simple and easy.
The equation of spiral is given by:
$L.R = L_s.R_c$= constant
Hence, $L_s = m\sqrt{Q}$ where,
m = constant = $\sqrt{2RL_s}$ & Q = Deflection angle

Calculation of Length of Transition Curve

The length of the transition curve is designed in such a way that the following three conditions are fulfilled:
1.) Gradual application of rate of change of centrifugal acceleration:
At design speed, centrifugal acceleration developed at curves on vehicle shouldn't cause discomfort to passengers. Let,
L_s= length of the transition curve for a curve of radius 'R',
t= time taken to traverse the curve,
v= design speed (m/s)
c = rate of change of centrifugal acceleration,
Then,

$$C = \frac{\text{centrifugal acceleration}}{\text{Time}} = \frac{V^2}{R.t}$$

Here, $t = L_s/v \Rightarrow c = \frac{V^2}{R.\frac{L_s}{V}} = \frac{V^3}{Ls.R}$ (m/s)

$$\boxed{L_s = \frac{V^3}{RC}}$$ is the required expression for length of the transition curve.

Where, value of c thus varying with speed & inversely varying with radius of curves, should be such that no discomfort or unnecessary oscillations are produced.
As per IRC guidelines,

$$C = \frac{80}{75+V} \quad \text{(V in kpn)}$$

Such that C = [0.50 to 0.80]   i.e. $0.50<c<0.80$

2.) Rate of Introduction of Super elevation:

Super elevation is provided in the curves either by rotating the pavement about the inner edge or the center line. It is said that the outer edge shouldn't be raised at a rate larger than 1 in 150 w.r.t the grade of center line. Literatures suggest, the length of the transition curve should be 'N' times the value by which outer edge of the pavement is raised where 1 in N is the rate by which the super elevation is applied.

→ If B = total width of the pavement = $w+w_e$

E = raise of outer edge

⇨ $E = e(w+w_e)$

$L_s = \{e(w+w_e)\}*N$ - for raise of outer edge by rotation w.r.t. inner edge.

→ If rotation to raise the outer edge is done w.r.t. centre-line,

$E = e.\frac{(w+w_e)}{2}$

⇨ $L_s = \{e.\frac{(w+w_e)}{2}\}*N$

N = 150 (General)
= 100 (Buit-up area)
= 60 (Hill roads)

3.) Empirical Formula:

As per IRC recommendation,

$L_s = 2.7\frac{V^2}{R}$ - For plain & rolling terrain

$L_s = V^2/R$ - For mountains & steep terrain.

- Max[m] of three methods is adopted.

Hence, the length of the transition curve depends upon:

→ Radius of circular curve, (R),
→ Design speed (V),
→ Allowable rate of change of Centrifugal Acceleration (c),
→ Maximum amount of super elevation (E), which depends on rate of super elevation (e)& pavement width ($B=w+w_e$),
→ Rotation of pavement w.r.t. or inner edge to attain the required super elevation.
→ Allowable rate of introduction of super elevation (1 in N) which depends upon terrain location & environment factors.

Design Summary:

1.) Find out the length of the transition curve based on allowable rate of change of centrifugal acceleration (L_s),

2.) Find out the length of the transition curve based on the rate of change of super elevation , (L_s)

$$L_{s1} = \frac{v^3}{CR}, \left[C\frac{80}{75+V_{kph}}\right] - (1)$$

$$\left.\begin{aligned} L_{s2} &= \frac{eN}{2}(w+w_e) \\ L_{s2} &= e(w+w_e)xN - inner\ edge \end{aligned}\right\} - (2)$$

3) Find out L_{s3} W.r.t. empirical formula,

$$L_{s3} = \left[2.7\frac{v^2}{R}\ (Terrain\ on\ plan, rolling), \frac{v^2}{R} - other\ step)\right] - (3)$$

Adopt Max[m] of L_{s1}, L_{s2}, L_{s3}

$$\boxed{\rightarrow \text{Shift} = \frac{Ls^2}{24R}}$$

Set Back Distance on Horizontal Curves:

At every section of the horizontal alignment of a highway, the required minimum safe SSD should be provided. Hence " Set Back Distance " is the clearance required from the centre line of a horizontal curve to any obstruction on the inner side to provide adequate sight distance. It depends on:

i.) Required sight distance S,

ii.) Length of the curve, L_c

iii.) Radius of the curve, R

There are following two cases:

a.) When length of curve > SSD reqd. (L_c>S)

Here,

L_c, R = Length, radius of curve,

S = SSD required

= Angle subtended at centre (rad)

Then,

Here,

L_c, R = Length, radius of curve,

S = SSD required

α = Angle subtended at centre (rad).

Then,

$\alpha = \frac{S}{R} \Rightarrow \frac{\alpha}{2} = \frac{S}{2R}$

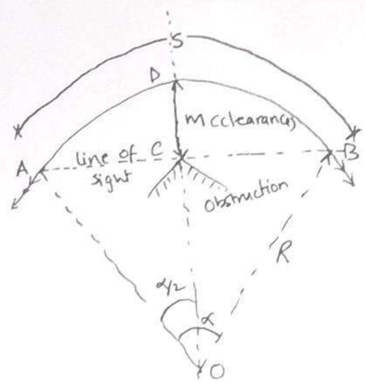


Fig: Curve with $L_c > S$

If m = Reqd. set back distance,

$m = OD - OC$

Here in ΔOAB & OAC/OBC,

$OD = R$, $OC = R\cos\alpha/2$

$\Rightarrow m = R - R\cos\alpha/2$ $\boxed{\Rightarrow m = R(1-\cos\alpha/2)}$

In case of multiple lanes, if 'd' is the distance between road ℄ and ℄ of the innermost lane,

$\alpha/2 = \frac{S}{2(R-d)}$ (rad) $\Rightarrow$ $\boxed{m = R - (R-d)\cos\alpha/2}$

b) When L_c < reqd SSD ($L_c < S$):

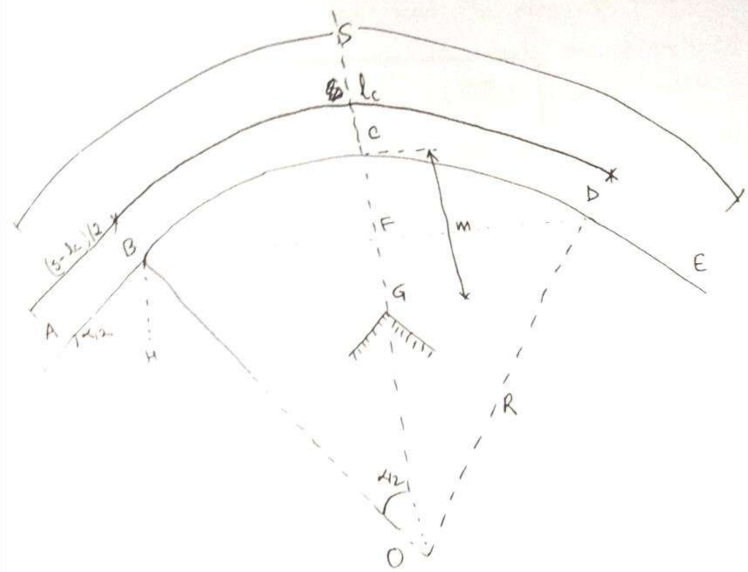


Fig Curve with L_c<SSD

Here, set back distance Required.

$m = CF + GF$ $\qquad \alpha/2 = \frac{l_c}{2R}$

$\Rightarrow CF = OC - OF = R(1-\cos\alpha/2)$

$\Rightarrow GF = BH = AB \sin\alpha/2 = \left(\frac{S-l_c}{2}\right)\sin\alpha/2$

Hence, $\boxed{m = R(1-\cos\alpha/2) + \left(\frac{S-l_c}{2}\right)\sin\alpha/2}$

In case of multiple lanes, $\qquad \alpha/2 = \frac{l_c}{2(R-d)}$

$\boxed{m = R-(R-d)\cos\alpha/2 + \left(\frac{S-l_c}{2}\right)\sin\alpha/2}$

Fig.: Curve with L_C<SSD

Here, set back distance required.

M=CF+GF

GF=OC-OF=R(1-cos$\frac{\alpha}{2}$)

GF=BH=AB sin$\frac{\alpha}{2}$ =($\frac{s-Lc}{2}$) sin $\frac{\alpha}{2}$

Hence,

m=R(1-cos$\frac{\alpha}{2}$)+($\frac{s-lc}{2}$) sin $\frac{\alpha}{2}$

In case of multiple lanes,

m=R-(R-d) cos$\frac{\alpha}{2}$+($\frac{s-lc}{2}$) sin $\frac{\alpha}{2}$

$$\frac{\alpha}{2} = \frac{lc}{2r}$$

$$\frac{\alpha}{2} = \frac{lc}{2(R-d)}$$

CURVE RE

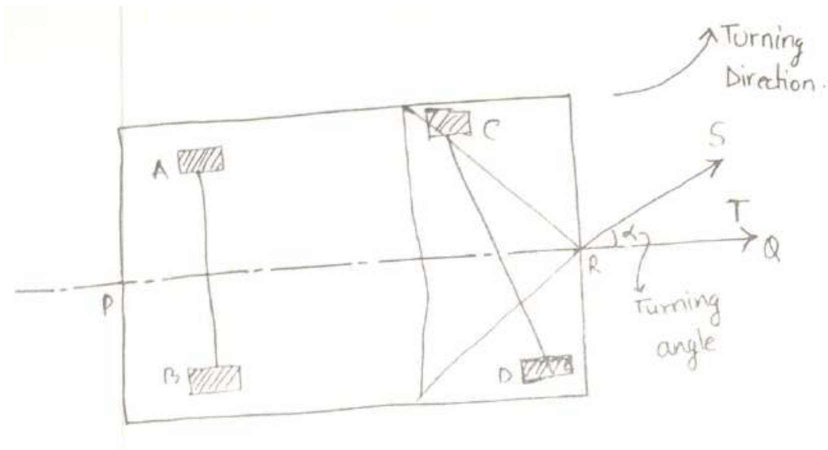


Fig.: curve resistance for turning vehicles

Whenever vehicles traverse a horizontal curve, they are steered by turning the front wheels since the rear wheels are not turned accordingly, the direction/path of front and rear wheels are not the same due to having a rigidity in wheel base thereby causing some loss in the tractive force. This mechanism is described hereunder:

- A & B are rear wheels that produce tractive force 'T' in the direction PQ.
- C & D are rear wheels used to steer the vehicle along the curve, the tangential direction of which is Rs.
- Thus, tractive force along Rs would be TCosϴ which is obviously less than T applied and is called tractive resistance.
- : tractive loss/curve resistance=T(n-cosϴ)
- For large radius & small ϴ values loss is less & vice versa.

DESIGN OF VERTICAL ALIGNMENT

The vertical alignment refers to the elevation or profile of the centre line of the road. In order to have the smooth vehicle movements on the road, the changes in the grades should be smoothened by vertical curves.

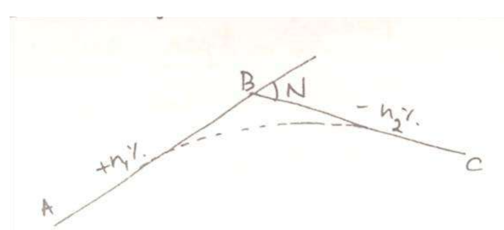
Thus, the vertical alignment consists of grades and vertical curves that influence the vehicle speed, acceleration, deceleration, SSD, OSD and comfort for high-speed vehicles.

Gradients:

Gradients is the rise or fall along the length of the road w.r.t. horizontal. It is expressed as 1in x (1v:xH) or n%('n' in 100). Ascending gradients are denoted by +ve (+n%), while descending are –ve (-n%). The angle measured at the change in grades at the intersection point of two grades is called deviation angle 'N' which is the algebraic difference bet^{n} the two grades.

In the fig. shown an ascending grade AB(+n%) is followed by descending grade BC (-n%). Then, deviation Angle (N) = $n_1-(-n_2)= n_1+n_2$

Thus while aligning a highway, the design engineer should consider all aspects such as construction cost, practical problems in construction and vehicle operation costs before any gradients is finalised.



Types of Gradients:

The gradients are divided into following categories:

- Ruling Gradient,
- Limiting Gradient,
- Exceptional Gradient and
- Minimum Gradient

1.) Ruling Gradient:

The maximum gradients with which a designer attempts to design a vertical profile of the road is called ruling gradient. As such it also called as "Design Gradient" upto which an alignment is adopted as a normal course of design based on type of terrain, grade length, vehicle power, presence of horizontal curves etc.

2.) Limiting Gradient:

When the topography of a place compels adopting steeper gradients than ruling gradients because of which enormous savings in cost of construction can be made, limiting gradients are adopted. However, the length of such grade should be limited & followed by wither a level or easy grade.

3.) Exceptional Gradient:
In some extra-ordinary situations, even larger steeper grades than limiting grade may be unavoidable, at least for a very short stretch which are called exceptional gradients. They shouldn't be provided for a length exceeding 100m.

As per IRC recommendations, the values for these grades are as tabulated below:

Terrain Type	Ruling Grade	Limiting Grade	Exceptional Grade
Plain/Rolling	1 in 30 (33%)	1 in 20 (5%)	1 in 15 (67%)
Mountains	1 in 20 (5%)	1 in 16.7 (6%)	1 in 14.3 (7%)
Steep	1 in 16.7 (6%)	1 in 14.3 (7%)	1 in 12.5 (8%)

4.) Minimum Gradients:
Minimum gradients find essence especially on plain/Terai areas from drainage point of view as favoured by the topology. The minimum gradient thus depends upon rainfall run-off, type of soil, topology and other site conditions. IRC recommendation for:

- Concrete drains – (1 in 500)
- Interior surfaced drains – 1 in 200
- Earthen (katcha) drains – 1 in 100.

Grade Compensation:
Due to turning angle of vehicle on horizontal curves the curve resistance of T(1-cos) is developed. In addition, in the addition of a horizontal curve with an ascending grade there will be increased resistance due to grade and curve. Thus, when a sharp horizontal curve is to be introduced in a road already having maximum permissible grade, ease in grade is required to compensate the tractive loss.
This reduction in grade at the horizontal curve is called grade compensation and its main objective is to offset the extra tractive effort involved at the curve.
Grade Compensation is given by:
Grade Compensation (%) = $\frac{30+R}{R}$ (R= Radius of curve)

With max^{m} value = $\frac{75}{R}$

As per IRC guidelines, grade compensation is not required for gradients flatter than 4%. As such, gradients need no to be eased 4% while applying grade compensation.

VERTICAL CURVES
Vertical curves are introduced at the intersection of different grades due to change of gradients in the vertical alignment to smoothen out the vertical profile thereby easing off the change in gradients for the fast-moving vehicles. They are of two types:
I.) Summit Curves:
These are the ones having convexity upwards are provided when:

- An ascending grade meets another ascending grade,
- An ascending grade meets a level surface,
- An ascending grade meets a descending grade,
- A descending grade meets another descending grade

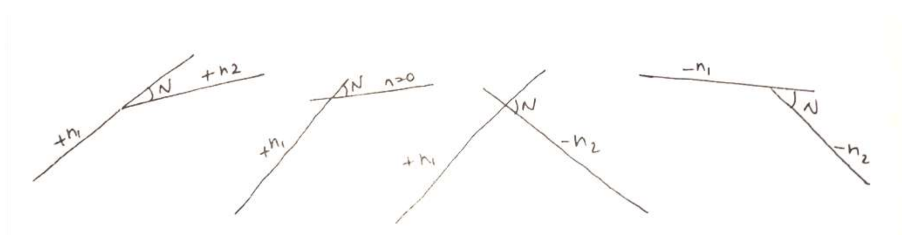


Fig.: Various cases of Summit Curve.

We can see that the deviation angle is the algebraic sum of the gradients of the two intersecting gradients which is maximum when an ascend meets a descend.

⇨ Length of Summit Curves:

Summit curves can either have a shape of a circular are or a simple parabolic one. But parabolic shapes are preferred due to having good siding comfort, simple calculation and layout. The eq^n of parabolic summit curve is given by:

$Y = kx^2$ where, $k = \frac{N}{2L}$ where

N = Deviation angle

L= Length of the curve

While designing the length of the parabolic summit curves, there are two considerations:

a.) Length for SSD,

b.) Length for OSD,

a.) Length of Summit Curve for SSD:

There are two cases:

a.1) When L>SSD: The general equation is given by:

N= Deviation Angle,

L= Length of the summit curve,

H, h= Height of driver's eye and object respectively from read surface.

Deriv^n

$$\boxed{L = \frac{Ns^2}{2(\sqrt{2H} + \sqrt{2h})^2}}$$

Since,

H=1.20, h=0.15m

$$\boxed{L = \frac{Ns^2}{4.4}}$$

a.2) When L<SSD: The general eq^n is given by:

$$\boxed{\begin{aligned} L &= 2s - \frac{2(\sqrt{2H} + \sqrt{2h})^2}{N} \\ \Rightarrow L &= 2s - \frac{4.4}{N} \end{aligned}}$$

b) Length curve for OSD:

b.1) When L>OSD:

$$L=\frac{Ns^2}{8h}$$

$$L=\frac{Ns^2}{9.6}$$

b.2) When L<OSD:

$$L=2s-\frac{8H}{N}$$

$$L=2s-\frac{9.6}{N}$$

- Higher of the values from case a art in taken.
- Minimum length should be taken from graph.

VALLEY CURVES

Valley curves are the areas that have convexity documents formed when:

- A descending grade ($-n_1$) meets an ascending grade ($+n_2$)
- A descending grade ($-n_1$) meets another descending grade ($-n_2$)
- A descending grade ($-n_1$) meets at level (n_2=0)
- A descending grade ($+n_1$) meets another ascending grade ($+n_2$)

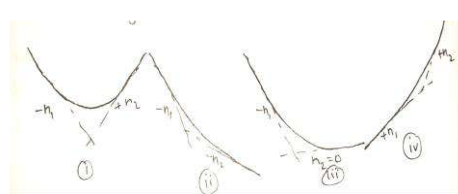


Fig.: Situations of valley curves.

The most important factors considered in the design of valley curves are:

- The impact- free movement or the comfort condition of passengers of vehicle in design speed,
- Availability of SSD under headlights during night driving.

At valley curves, the centrifugal force acts downwards adding the pressure on the springs and the suspension of the vehicle in addition to the weight of the vehicle. Hence to gradually introduce this centrifugal force, a transition curve is used with shape of cubic parabola.

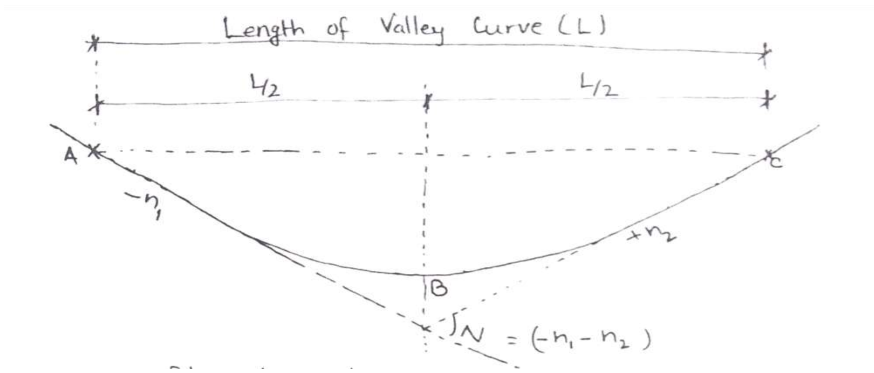


Fig.: A valley Curve

As shown in fig. above, a valley curve is made fully transitional by providing two similar transition curves of equal lengths (without any circular curve in between).
If L = Length of the curve in total,
Length of each transition curve = L , with minimum radius R at common point B. 2
Length of valley curves:
As discussed earlier, there are two cases:

1) For comfort condition:
2) Length of transition curve from comfort condition, is:

$$L_s = \frac{v^3}{cr} \text{ Where } R = \frac{L_s}{N} = \frac{L}{2N}\left[\theta\frac{l}{r}, r\frac{l}{\theta}\right]$$

$$L_s = \frac{v^3}{c \cdot \frac{L_s}{N}} = \frac{N v^3}{C L_s}$$

$$L_s^2 = \frac{N v^3}{c} \Rightarrow L_s = \left(\frac{N v^3}{c}\right)^{1/2}$$

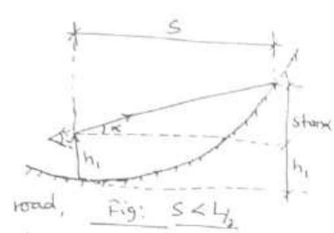
Total Length of the curve (L) $= 2L_s$

$$= 2\left(\frac{NV3}{C}\right)^{1}/_{2} = L$$

Min[n] radius of valley curve(R) $R = \frac{L_s}{N} = \frac{L}{2N}$

2) For head light sight distance:
Sight distance in valley curves is not a problem in day light. For night driving sight distance is a major issue.
There are two cause:

i) Total length of curve L>S→(ssd):



The length of the valley curve (L), is assumed to be greater than the head light sight distance 9s), which should be equal to ssd.
Let, h_1= height of headlight above road, ∝inclination of forussed position of light beam.
Available sight distance will be minimum when the vehicle is at the lowest point on the sag curve. The shape is assumed to be of parabolic with equation.

$y = kx^2$, where $k = \frac{N}{2L}$

Then, @ $x = s$, $y = h_1 + s\tan\alpha$

$\Rightarrow h_1 + s\tan\alpha = k s^2$

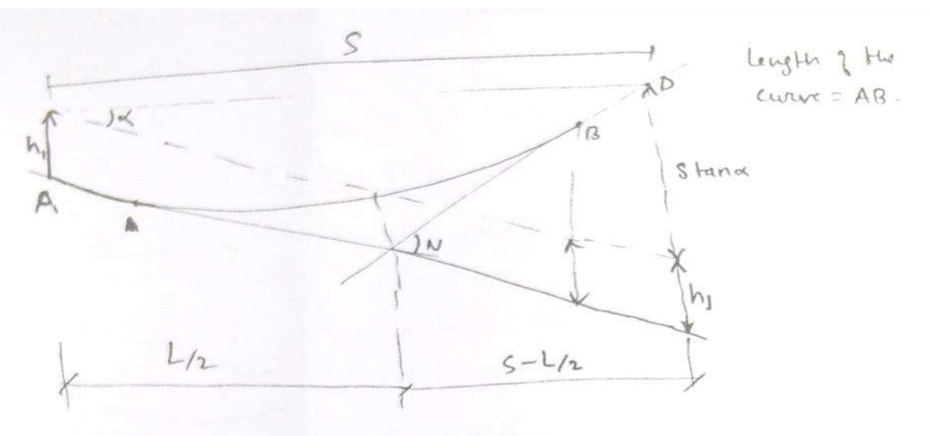
or, $h_1 + s\tan\alpha = \frac{N}{2L} \cdot s^2$

$$\boxed{\therefore L = \frac{N s^2}{2(h_1 + s\tan\alpha)}}$$

Usually, average height of headlight, $h_1 = 0.75\,m$; $\alpha = 1^\circ$

$$\boxed{\Rightarrow L = \frac{N s^2}{1.5 + 0.035 s}}$$

b) Total Length of the curve, L<SSD:



Here,

H_1+stand∝=$\left(\frac{s-L}{2}\right).N$

Or, $\frac{2s-L}{2} = \frac{H_1 + stan\propto}{N}$

$$2s - L = \frac{2Ch_1 + stan \propto}{N}$$

$$L = \frac{2Ch_1 + stan \propto}{N}$$

Recommendation for Design Considerations in Road Alignment.

Following recommendations are made for the design of horizontal & vertical curves:

A.) Horizontal Alignment:

A smooth and flowing alignment conforming to the natural contours is aesthetically preferred over long tangents slashing through the terrain. Following considerations are made:

I.) Avoid long tangents exceeding 3kms by introducing a curvilinear portion with long curves to avoid monotony.

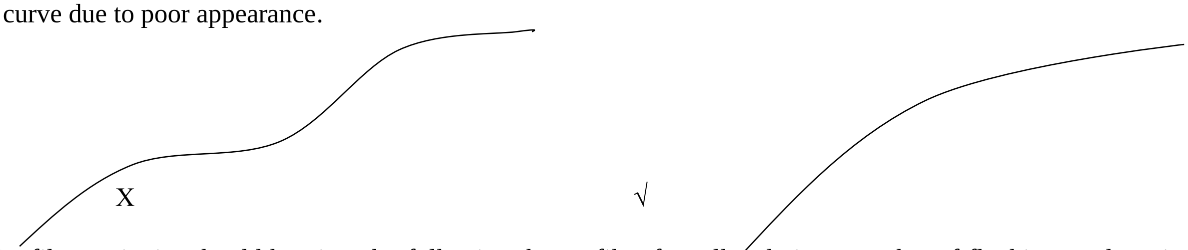
II.) Avoid sharp curves at the end of long tangents by introducing them only often series of varying radius curves. Curve length should be at least 150m for a deflection angle of 5^o and should be increased by 30m for every 1^o decrease in deflection angle

III.) Curve Proportioning such that reverse compound and broken back type of curves are avoid. Adjacent curves radius ratio of 15:1 is made as limiting value for compound curves.

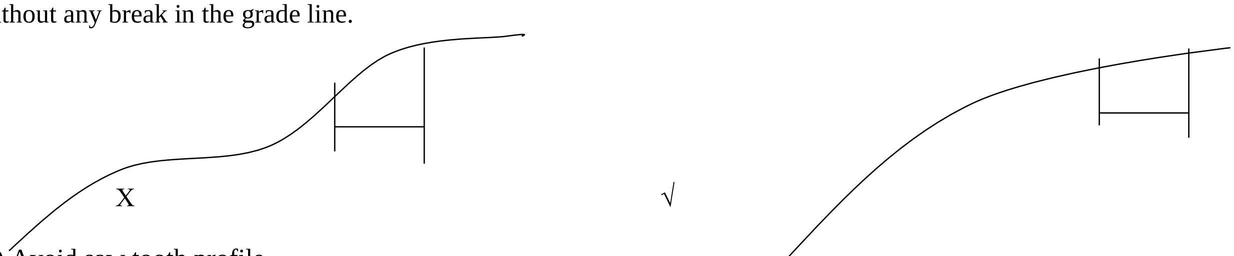
IV.) Co-ordination bet^n horizontal alignment with other road elements i.e. L & X- section, bridge, walls, culverts etc.

V.) Sitting of bridges only for small bridges with span length less than 60m. fluency of alignment should govern the choice of bridge location.

B.) Vertical Alignment:
i.) There should be no change in grade within 150m of length.
ii.) Avoid short valley curve due to being too hazardous and as it distorts perspective view of road.
iii.) Avoid broken back grade line (2 V-curve in same dir^{n} separated by a short tangent) preferably replaced by a single long curve due to poor appearance.



iv.) Profile continuity should be given by following the profile of small x-drainage to that of flanking road section without any break in the grade line.



v.) Avoid saw tooth profile.
Co-ordination between H&V curves.
→ V-curve either wholly within or outside of H-curve,
→ No sharp H-curve introduce at or near the:
- Top of pronounced summit of vertical curve,
- Bottom of sag curve.

→ Flatter H&V-curve at intersection.

DESIGN OF HILL ROADS

A will road is a one that passes through a terrain with cross-slop of 25% or more in overall terrain. A hilly or mountainous areas is characterized by highly broken relief with highly differing elevations, steep slopes, deep gorges and great number of water courses.

Design & Construction Problems:
- Considerable increase in road length sue to widely differing elevations and steep slopes,
- Varying sock formation within a short section causing difficulty and complexity in engineering assessment,
- Unstable slopes due to road construction,
- Varying hydro-geological conditions from place to place which cause difficulty in precise assessment of slopes,
- Road embankments crating extra overburden to weak layers resulting to formation of new slides,
- Costly special road structures to tackle highly broken relief eg: retaining /beast walls, culverts, props, chutes etc.
- Highly erosion central structures due to steep slope,
- Debris flow from upside of hill leading to movement of man resulting damage of road structures,
- Wide variation of meteorological states along the road structure affecting design & construction,
- Different construction technology as per place, need special precaution to be taken.

General Considerations in Road Geometrics:
- Link up with obligatory points fitting well in landscape and satisfying geometric requirements,
- Sum of ascends & descends bet^{n} extreme points being least,
- Advantages to start survey from higher obligatory points,
- Alignment with least resisting length preferred over various alternatives. Resisting length of a road is the effective length taken considering the total work done against the resistance.
- Adequate longitudinal & cross drainage structure are provided to avoid water accumulation to road surface,
- Trace cuts for pin bends prior to final cutting.

Geologically Considerations:
- Dip of the strata should be as small as possible or alternatively be inclined away from it,
- Roads are generally taken in cutting along hill face,

- For safety, the stability of the face is very important,
- The alignment should be so adjusted that the bedding planes of the rocks tend to dip away from the cut slopes rather than towards them,
- To present possible slides due to earthwork, care should be taken in following:
  - Restrict ground water flow by side fill,
  - Overloading of relatively weak layer under flying the fill,
  - Overtaking of bedding planes by heavy side fill,
  - Over steepening of cuts, unstable rock or fill.

HAIP PIN BENDS

While developing a route in hilly area, its often necessary to imert sharp turning angles wherein its very difficult or at tomes impossible to layout normal circular curves. Inscribing a curve inside the tangents will lead to substantial reduction in the length of the route resulting into steep gradients.
In such circumstance, its preferable to round off the route not by insoribing but by circumscribing the curve around the turning points by means of compound curves which are called as hair pin bends or reverse loops.

Important facts:

- Provided in hill sections having minimum cross-slope and max^{m} stability. The bend may be symmetrical or unsymmetrical having unequal reverse curve with unequal angles and radii.
- The convexities of both reserve curves are in opposite or same direction suitable for more or less straight contours,
- Route to be developed on the same side of a hill slope to change the direction of the route and gain elevation,
- Min^{m} gap between successive bends and 60m excluding reverse and transition curves. This gap further depends upon the hill slopes to avoid costly protective measures between the upper and lower arms of the bend.
- Describe to pave the road to the fill width in such bends,
- For good visibility, the island portion should be cleared off all the trees and other obstructions.

As such, hair pin bends should be avoided as far as possible due to:

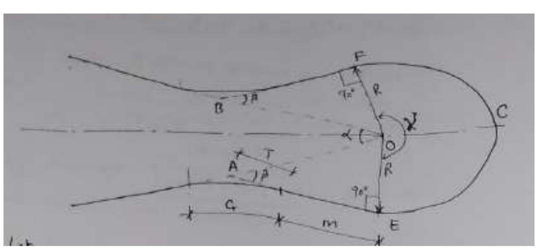
- Substantial speed reduction,
- Complexity in design and layout
- High construction cost.

Design criteria: As per NRS 2070
→ Maximum values for:
Design speed = 40kph,
Radius of curvature = 15m,
Length of transition curve = 15m,
Longitudinal gradient = 0.5%

→ Maximum values for:
Longitudinal gradient = 4%
Super elevation = 10%

→ Widening of carriageway = 4.0m

Geometry/Elements of Hair pin bends:



Let,

Radius of: main curve=r, reverse curve=r

Tangent lengthof: reverse curve=t

If B=angle of diviation at apex of reverse curve,

T=r $\tan{}^{b}/_{2}$

From $\triangle OAE$:

$$\tan\beta = \frac{OE}{AE} = \frac{R}{T+m}$$

or, $$\tan\beta = \frac{R}{r\tan\beta/2 + m}$$

or, $$\frac{2\tan\beta/2}{1-\tan^2\beta/2} = \frac{R}{r\tan\beta/2 + m}$$

or, $$2r\tan^2\beta/2 + 2m\tan\beta/2 = R - R\tan^2\beta/2$$

Contd.:

Or, $(2r+R)\tan^{2}{}^{b}/_{2}+2m\tan{}^{b}/_{2}-R=0$

This equation is quadratic in tan ${}^{b}/_{2}$, hence

$\mathrm{Tan}{}^{b}/_{2}= \frac{-2m=\sqrt{4m^2-4(2r+R)(-r)}}{(2r+R)}$

$$\frac{-2m = \sqrt{m^2 - R(2r+R)}}{(2r+R)}$$

Central angle of the circular curve.

χ=360-2(90-B)-$\propto$

=180+2b-$\propto$

Length of main curve,

$$C = \frac{\pi R\delta}{(2r+R)}$$

Total Length of the Bend=C=2(C_r+M)

CHAPTER-3

HIGHWAY DRAINAGE & DRAINAGE STRUCTURES

Highway drainage is the process of collecting, removing and controlling unwanted water from the surface and sub-surface regions of a highway within the right of way. This includes interception and diversion of water from the surface and subgrade of a road. Thus, highway design and construction is incomplete without suitable surface and sub-surface drainage system.

Importance of Highway Drainage

Highway drainage is important because of the following reasons:

i.) The stability of the soil subgrade is considerably lowered by excess moisture leading to subgrade failure.

ii.) The strength of pavement materials like stabilized soil and WBM is reduced due to increase in moisture content.

iii.) In clayey soil, the subgrade volume fluctuates considerably with variation in moisture content, which causes failure.

iv.) Formation of waves and corrugation in flexible pavement takes place due to poor drainage.

v.) Stripping of bitumen from aggregate due to prolonged contact with water causes loosening or detachment of pavement layers and formation of potholes,

vi.) Presence of water in fine subgrade soil causes mud-pumping in rigid pavements.

vii.) shoulders and pavement edges are considering damaged due to excess water,

viii.) Excess moisture causes increase in weight and thus stress in embankments and slopes thereby reducing the strength of soil mass and causes failure.

ix.) In pressure of water, Frost Action takes place in freezing temperatures which also causes damage,

x.) Erosion of top soil takes place in unsurfaced roads, slopes of cut & hill, embankment sue to surface water.

Requirement of Highway Drainage

i.) The surface water from the carriage way and shoulders should not be allowed to percolate to subgrade,

ii.) The surface water from adjoining land should not be allowed to enter the roadway,

iii.) The side drains should have enough capacity to collect and carry the collected water,

iv.) Flow of water across the road shouldn't cause formation of cross-ruts or erosion,

v.) Sub-surface drainage system should be used to drain off seepage and other underground water,

vi.) Highest level of GWT must be kept well below the subgrade level, preferably by at least 1.20m.

vii.) Special precautions to be taken in water-logged areas especially if detriment salts are present or if flooding is likely to occur.

The flowchart for planning/designing of a highway system is shown below:

Planning/Design of Highway drainage

Hydrological and
Metrological study

Hydraulic Design

Structural Design

Fig: Flowchart of Highway Drainage Study:

1.) Drainage Planning

2.) Hydrological/Meterological study

3) Hydrological/Meteorological study

- Surface run off calculation
- Fluctuation of WT,
- Flood level and flood discharge

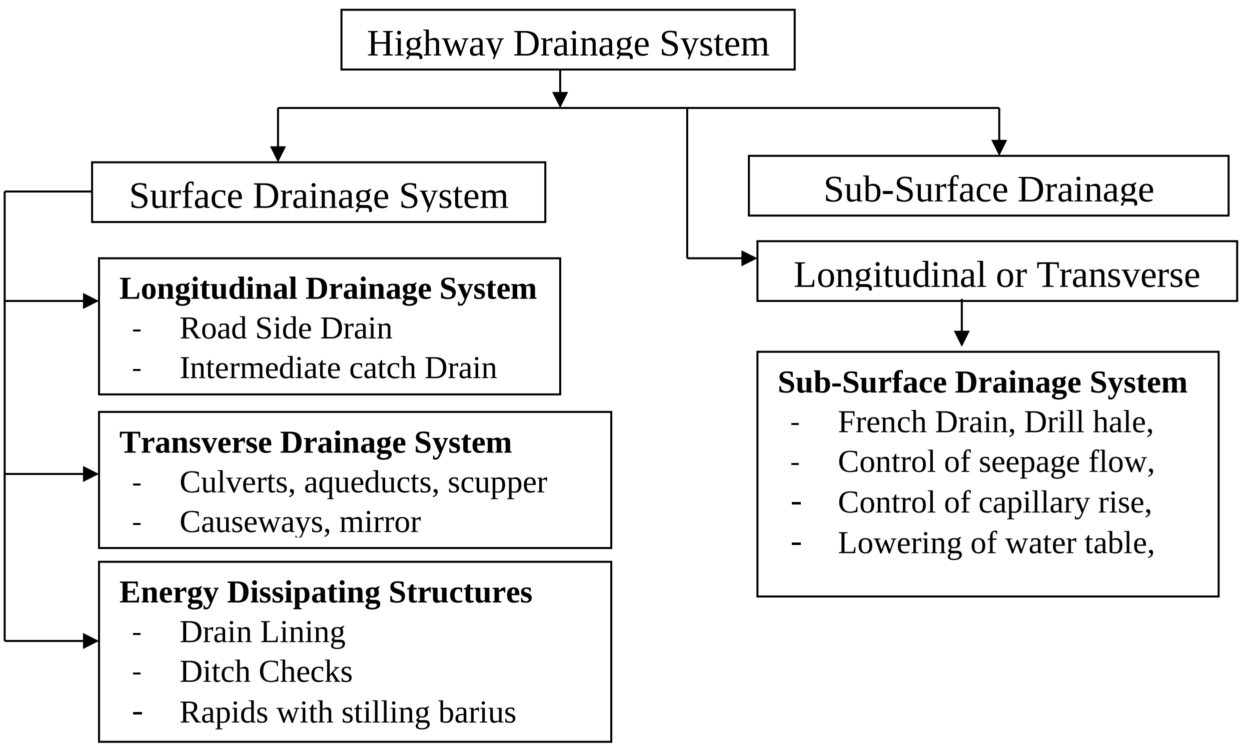
4) Hydraulic study,

- Selection of system measures
- Design of Hydraulic structures→Section & profile,
- Filter Design etc,

4) Structural Design
- Structural Stability Analysis
- Structural Element Design

Highway Drainage System
Highway drainage system solely concerns with the:
- Management of surface water (Surface Drainage),
- Control of moisture content in subgrade (Sub-Surface drainage),

As it is often said, "There are just 3 factors necessary for getting a good road; Drainage, Drainage & more Drainage". The frequency of pavement repair is directly related to the adequacy of the provisions of Drainage facilities and degree of timely attention on their O-M and repair works.



A) Surface Drainage:
The surface water is to be collected and then disposed off. Thus, surface drainage primarily serves by collecting the surface water coming through the roadway CV in camber) and footpaths which is then drained off to the nearest water course. For this purpose, longitudinal side drains are provided to receive water from hill slopes and road surface.

Fig.: Typical o/s of surface drainage in Urban Road

Design of surface Drainage System (Longitudinal Drains)
When natural channels for discharging the run-off are not available, it becomes necessary to design and construct artificial channels as:
- Side drains in cut slopes or longitudinal drain along the edge of embankment to dispose water to the nearby natural course.
- Catch drains or intercepting drains.

Analysis and Design:
Design of surface drainage system is divided into two phases:
a) Hydrological Analysis,
b) Hydraulic Analysis,

a) Hydrological Analysis:

It deals with the estimation of the maximum quantity of water expected to reach the elements of the drainage system under consideration. Such an excess water due to precipitation & other causes is called surface run-off which has to be very efficiently managed by an elegantly designed system. The amount of surface run-off depends upon type of soil, topography of area, type of ground cover vegetation, rainfall frequency and intensity. The hydrological study is done in following steps.

i) Calculation of peak run-off:

For small catchments, peak run-off is estimated by using rational formula:

$$Q\frac{c.i.A}{360}---(1)$$

Where,

Q= Peak-run-off (m3/s)

C=Coefficient of run-off

I= Rainfall intensity (mm/hr)

A= Catchment area in hectares.

ii) Run-off Coefficient (C)

it is the ratio of run-off to the rate of rainfall. Depending upon the nature of surface. Value of 'c' is taken as follows:

Nature of surface	**Value of 'C'**
Bituminous and concrete pavements	080-0.90
Gravel and WBM pavements	0.36-0.70
Impervious soils	0.40-0.65
Soil covered with turf	0.30-0.55
Pervious soils	0.05-0.30

For area having different nature of surface, 'c' is calculated by weighted coverage as:

$$Covg=\frac{\in ciAi}{\in Ai}=\frac{c_1+c_2A_2+\cdots+c_nA_n}{A_1+A_2+\cdots+A_n} \text{-------------(2)}$$

iii) Rainfall Intensity (i):

Value of 'i' of short period is observed to be more than the average for a while day. According to the British ministry of Health, 'i' is given by empirical formula as:

For rainfall duration:

$$i=\frac{760}{t+10}[\,5\sim 20\ minutes\ of\ rainfall]$$

$$i=\frac{1020}{t+10}[\,20\sim 100\ minutes\ of\ rainfall]$$

iv) Time of concentration (t):

Time of concentration is the time required by water to flow from the farthest point of the drainage are to the point/area under consideration for maximum run-off.

Time of concentration is given by:

$$t=t_1t_2----(4)where,$$

T_1= time of entry/inlet=$(0.885\ L^3/_H)^{0.385}$ ----------(a)

Where, L= Length from farthest point to sever entry.

H= Elevation difference (head) between two points.

T_2= Time of flow=$\frac{Length\ of\ sever}{Velocity\ of\ flow}$ ------------(b)

Depending upon soil type, velocity of flow is taken as allowable velocity ranging from 1~2.5 m/s.

Frequency of occurrence of the storm or the return period may be taken in the range of 5N50 yrs.

b) Hydraulic Analysis:

Once design-runoff (Q) is estimated, side drains are designed based on principles of flow through the open-channel.

- Assuming suitable flow velocity (v), based on surface, the c/s area is calculated by:

A= $^Q/_V$ ---------------(5)

Velocity of flow in unlined channel must be high enough to prevent silting but not too high to cause erosion.

Suitable channel section (Δ, rectangle, trapezoidal) is selected based on run-off and other site conditions & dimensions derived.

- Manning's formula is used to calculated longitudinal slope(s)

$$v=\frac{1}{\eta}R^{\frac{2}{3}}S^{\frac{1}{2}} \text{ ---------------(6)}$$

η= Mining roughness coefficient.

R= hydraulic mean radius=$^A/_\cap$

b) Sub-surface Drainage System:

No matter How we try to control surface water, it always finds its way into the sub grade and other pavement layers. Surface drainages are not adequate in the case of:

Water moving pervious sub-surface layer of soil,

High GWT causing soft sub grades and instability of slopes,

Percolation of rain water and capillary water through the sub grade which reduces its strength.

The various techniques used in order to remove the water located below the GL is called the sub-Surface Drainage system. It includes:

I) Lowering of GWT:

The Highest level of GWT should be fairly below the level of sub grade and must be preferably below by 1.20m. If that doesn't happen sub-surface drainage is needed to lower the GWT. Based upon the permeability of soil, the are two methods.

a) For relatively permeable soil, longitudinal drains are provided parallel to the road surface on either side as shown in fig. Below at a slope of (0.50-10.0)%. It catches the water at sub-surface level, carri3es and disposes to the nearest water source ensuring a lowered GWT.

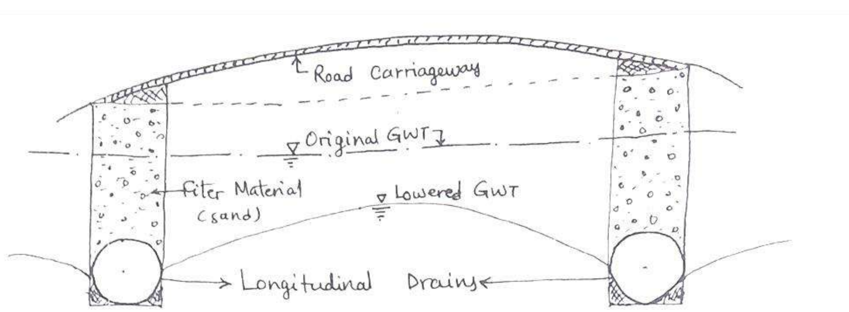


Fig: Longitudinal Drains to lower GWT

b) If the soil below the sub grade level is not permeable, transverse drains accompanying the longitudinal drains are provided at regular intervals as in fig. To drain the water from soil to the longitudinal drains.

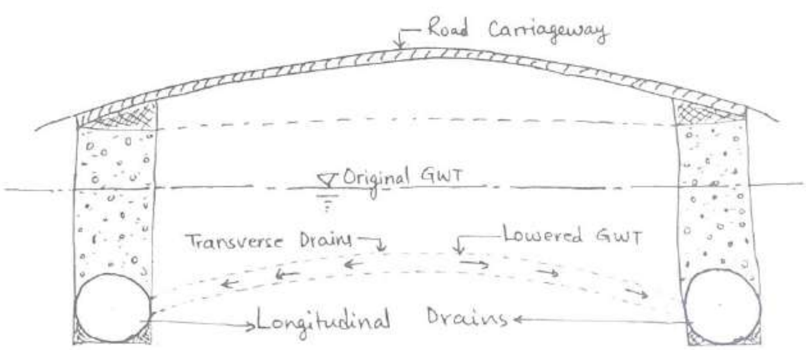


Fig: Longitudinal & Transverse Drains to lower GWT

ii) Control of seepage Flow:

When a permeable layer of soil overlies an impervious layer in a hilly region or in a cut area, seepage of moisture/water takes place from higher level to sub grade which softens the sub grade.

This softening of sub grade and lead to permanent failure if not treated in time. For this, seepage water is intercepted by means of a perforated drain pipe thus lowering the seepage line and GWT to desired level. The perforated longitudinal drain pipes are laid on the hill side of the road parallel to the road centre-line and is covered by granular filter material. This pipe intercepts the seepage water dropping the seepage line to a desired level well below the sub grade soil.

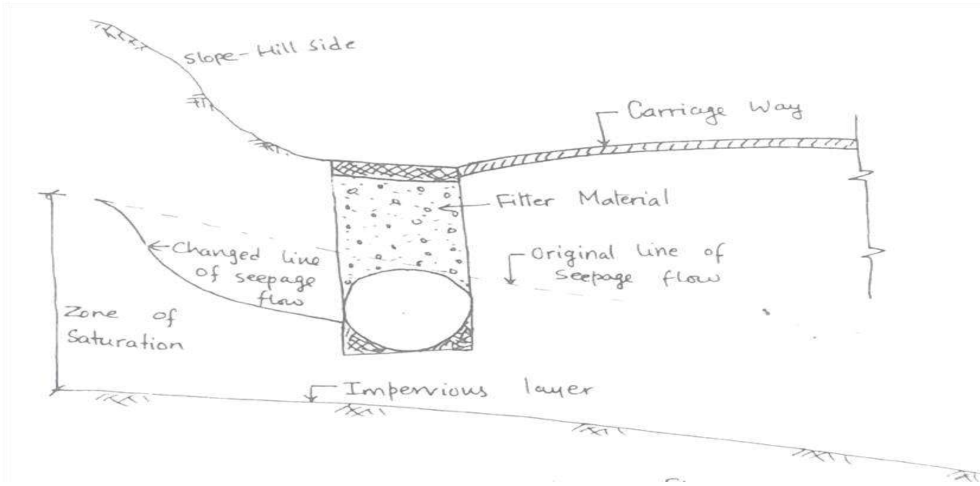


Fig: Control of Seepage Flow

iii) Control of Capillary Rise:

Capillary rise is a process by which water from below the sub grade level rises up to its level or above by capillary action depending upon soil permeability, characteristics of water and angle by which water contacts with soil capillary action is more severe with roads made from fine-grained soil and specially in embankments.

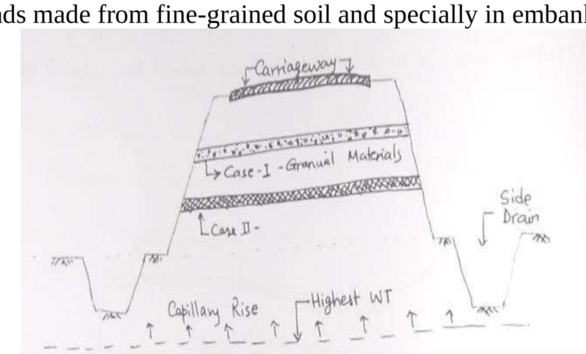


Fig: Control of Capillary Rise

Capillary rise is a process by which water from below rises up to the sub grade level or more causing problems. There are two solutions.

Case-1

A layer of granular material of suitable thickness is inserted between the subgrade and highest level of subsurface WT during the construction of embankment as in fig. This cuts-off the capillary action by breaking the pressure of upward seepage flow.

Case-2

A layer of impermeable or bituminous material or heavy duty polythene sheet is provided as a means of .....

Design of subsurface drain

The filter materials used in subsurface drains/trenches are so designed as to:

- Have sufficient permeability to flow without any resistance,
- Resist the flow of fine particles in foundation so as to avoid pumping failure.

For the design of subsurface drainage system,

i) Determine the depth of the trench,
ii) Select backfill filter materials,
iii) Determine the diameter of the pipe,
iv) Determine the number & size of per formation in pipe.

Hence the design of filter materials based on permeability and piping considerations is done as under:

1) Plot the grain size distribution cure/chart per the foundation soil with % passing on Y-axis & particle size on X-axis.

2) Find the value of D_{15} size of foundation material. Then, the upper limit of the filter material will be of size $5.D_{15}$ of the foundation material. Then the permeability is ensured if:

$$\frac{D_{15} of\ filter\ materials}{D_{15} of\ fondation\ materials} > 5$$

D_{15}=15% of the particles are only smaller than this size.

3) Lower limit of the filter material is taken as 5.D_{85} size of foundation material. Then piping is ensured if:

$$\frac{D_{15} of\ filter\ materials}{D_{85} of\ fondation\ materials} > 5$$

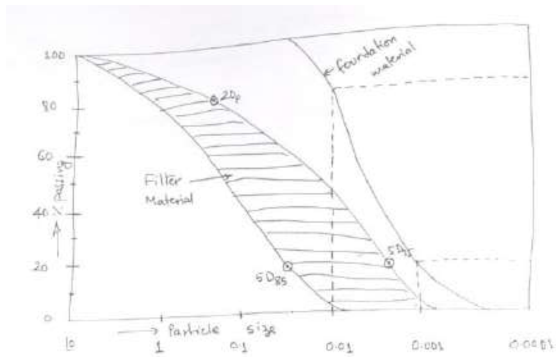


Fig: Design of filter Material

4) After the filter material is ensured, based on the rate of sub surface flow, size of longitudinal pipe is determined. The size of perforations in drain pipes or gaps in open-jointed pipes is then determined and let this be=D_p. Then a point is plotted to represent D_{85} size of filter given by the size equal to $2D_p$.

Drainage in Hill Roads:

It is often said that the three important factors to be considered while designing hill roads are:

1. Drainage,
2. Drainage and
3. More Drainage

As a result, hill road construction is often said to be a battle against water and as such the overall function. Life and performance of a hill road fully depends upon drainage structures. Following two factors make the drainage problems critical in hill roads.

- 80% of total annual rainfall is concentrated to the four monsoon months only. The rainfall is not steady but has high intensity at short intervals.
- Huge amount of water reaches the side drains and later to the water closing points. Hence management of this water and to control its flow velocity in and around the road is a challenge.

The various structures used in the drainage of hill roads are:

1) Catch Drain:

Surface water from the hill slopes can't be directly allowed into the side drains because such large discharge may require bigger sections. So in order to intercept & direct water from slope, catch drains are provided parallel to the roads and discharging into the nearest culvert. The protections like linings and energy dissipating measures like chutes, fall rapids etc. May have to be provided in side drains to prevent damage.

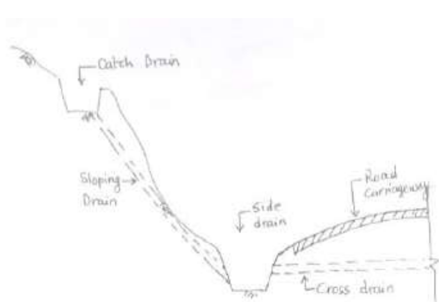
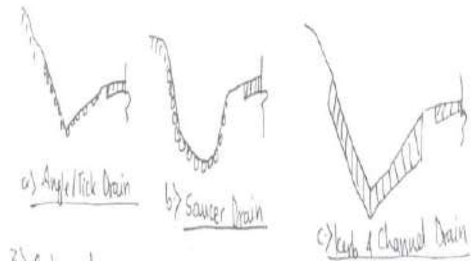


Fig.: Typical section of hill road with drains

2) Road side-surface drains:
Side drains are provided only in the hill side of the road due to limitations in formation width, in such a way that some vehicles can use them in emergency and for parking.



3) Sub-surface Drainage:
These are provided to check the ground water seeping across hill side above, at or below the road surface. It might cause problems in slope stability, weakens the road and caused permanent......

4) Cross Drainage:
Cross drainage works are provided to catch water from Catch drains and surface drains and also to provide ways of roadway over the stream courses etc. They are laid at right angles to the surface of the road and under the road. Catch pits are provided at the head of small drains to collect the scouring materials like stones, debris flow etc. - As far as possible, minor bridges shall be constructed, - for small & intermittent flow causeways are provided, - Where heavy rainfall occurs, culverts are provided and - for low-cost roads, scuppers are provided.

EROSION CONTROL
Erosion is the washing away of the soil particles. It is actually the disruption of soil mantle or underlying rock base by the action of natural or external factors like water, wind, Snow, weathered debris, plants, animals, construction activities et. Following are the causes of erosion:

- Water emerging from culverts and cross-drainage structures generally will have velocity greater than the non-scouring velocity of soil around it,
- Bed erosion of side drains & catch drains due to excess slope where velocity of flowing water is high,
- Road const^{n} activities disturb natural slope & remove vegetation cover,
- Artificial channel disturbs change natural flow pattern, etc.

Due to the above-mentioned reasons, erosion has to be controlled for the longer life of the road. Some of the various control measures are adequate while others may not depend upon the severity. Following are the effecting the severity of erosion:

1. Gravity,
2. Soil type and texture C porosity),
3. Precipitation and climate,
4. Storm intensity and duration,
5. Vegetation cover,
6. Surface area,
7. Slope length and gradient,
8. Inherently unstable geology,

The erosion have the following harmful effects:

- Formation of rain cuts which reduce the effective width of the roads and shoulders,
- Danger to the stability of slopes due to increased wt. of saturated soil and reduced shear strength,
- Recurring expenditure on maintenance.
- The water flowing over the cut slopes is due to direct precipitation which has following effects:
- Danger to stability of cut slopes due to increased wt. of the saturated soil and reduced shear strength, - See page of mater………….

Measures (Treatment for Erosion Control:
A variety of treatment is possible for embankments and cut slopes protection depending upon the severity of the erosion expected as shown under:

Erosion Treatment/Protection

- **Embankments**
  - Turfing
  - Stone pitching or revetment
  - Geo blanket, Jute netting, coir netting , bio-engineering
  - Berms
  - Raised karbs, gutters and flumes
- **Cut-slopes**
  - Bio-engineering & Small-scale civil structures
  - Longitudinal & cross-drains
  - Intercepting / Catch drains
  - Energy dissipating structures
  - Jute - netting, coir netting, Geo-blankets
  - Bituminous Treatment
  - Canal linings

These treatment measures are explained under:

1) Canal Lining:
Beds and sides of drains have to be lined to protect them from erosion where velocity of flow is high. For even higher cities, the lining may be combined with turf grass on sides. The stone masonry rip-rap lining or brick masonry lining at sides and bed concrete blocks may also be provided.

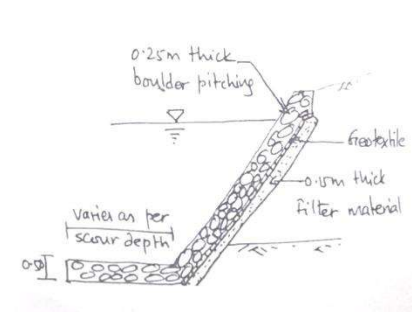
2) Turfing, Bioengineering + Small Scale Civil Structures:
Turfing is the plantation of grass, sods or seedlings on the embankment slopes. Sods are more preferred in steeper slopes while seedlings are preferred on flatter slopes. The Success of this measure depends upon the suitability of the soil to the development of turf culture.

- Purely sandy soils are unsuitable for turfing. In such cases, sand +0.25 +0.30 m thick layer of clay is provided over which turf can be placed.

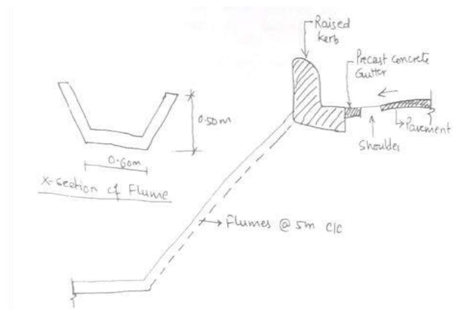
Turfing along with jute netting, coir netting and geo-grids helps the turf to grow by holding the soil firmly. Turfing along with bio-engineering & small scale civil engineering structures (which are explained later) can also be used.

3) Pitching:
It is done using rip-raps, concrete slabs bricks as per need,

- Suitable for high embankments in flood zones & heavy rainfall areas,
- Open jointed pitching is preferred because of the need to provide outlet for seepage water in the embankment,
- Pitching should be provided with a graded inverted filter bedding to prevent the soil particles from getting away.
- Use of gabions may be done as revetment.



4) Raised kerbs, Gutters and Flumes:



Flumes are open channels provided along the embankments to collect & dispose water through it so that it doesn't erode the slope. The dimensional spacing of flumes may vary depending upon the site conditions. At the outlet, Suitable energy dissipating structures shall be provided .

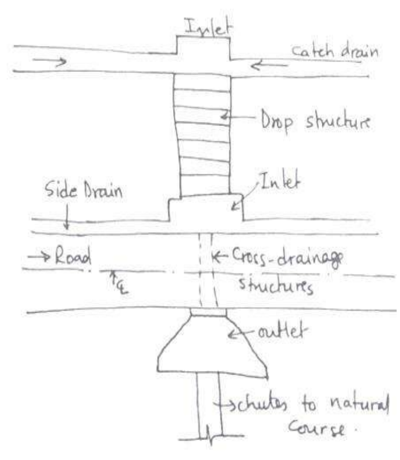
5) Geo textile and Netlon:
Geo textile, which are synthetic fabrics made out of polymers are very much effective in drainage management in highway. The fabrics serves the following purposes:

- Separation of two widely different natural soils to prevent their mixing under the influence of water,
- Filtering and
- Reinforcement
- Geo textile
- substitute of filter
- promotes turfing.

6) Bituminous Treatment:
Asphalt mulch treatment in slope helps to:
- promote vegetation growth,
- retain moisture content,
- raise the soil temperature by absorbing light rays. etc.

7) Catch Water Drain / Intercepting Drain:
- Discussed before.

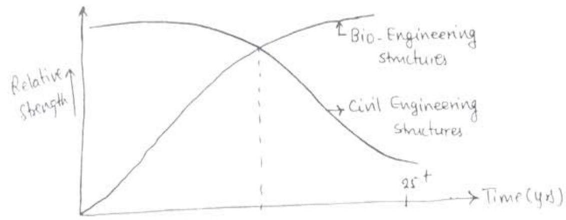
Hill Road Drainage System
1) Ditches I check
2) Drop structures
3) Catch water drains
4) Road side drains.
5) Rapids with stilling drain
6) Vegetation
7) Spur
8) Check dam.



Bio Engineering
Frequent losses of life and property are observed in Nepal due to natural and artificially caused landslides. Natural ones take place due to loose geographical structure, steep slopes and heavy rainfall etc. while due to ignorance of people, population density, deforestation etc. artificial landslides take place from time to time. Civil engineering alone has not been able to get rid of this problem. On this light, bio-engineering has been introduced as an effective, economical & sustainable solution -

About Bio- Engineering:
Bio- Engineering is that branch which deals with the use of vegetations alone or in combination with small scale civil engineering structures or non-living plant materials for the purpose of reducing the shallow seated instability and then on tolling erosion of slopes thereby reducing the chances of landslides from occurring and/or causing heavy damages.

Civil engineering structures are heavy, costly and need skilled technical manpower due to which sustainable solutions can't be achieved.



Also, civil structures have their load taking capacity regarding with time due to various reasons. As such, if vegetations are used jointly with civil structures, they share load imposed on the structures as time passes, thereby increasing efficiency of the system overall efficiency of the overall system.

Advantages of Bio - Engineering

1) Protects almost all slopes against erosion,
2) Reduces the instance of slow seated instability,
3) Locally available vegetations
4) Cost-effective & sustainable method,
5) Versatility in application i.e. high technology and skilled manpower not required,
6) Improves surface drainage I reduces slumping ?
7 Easy to prepare and maintain,
8) Physical flexibility,
9) Some vegetations yield fruits /products, enhance economy
10.) The only solution for some problems.
11) Environmentally and socially advantageous,
12) Diversity in vegetations is obtained,
13) Stability of landslides and slope can be checked from even the lower level of remote areas
14) Assist civil structures by sharing load on passage of time when their residual strength decreases.

Limitations of Bio-Engineering

1) Preferably used for shallow seated failures, mostly favorable for depths 1-1.5m depths. Shouldn't be used for deep seated failures i.e. failure depths more than 3m.
2) Not able to fully function at its initial stage,
3) Cheking of waterways with plant growth might cause damage to other structures,
4) Vegetation growth on structures cause adverse effect on the performance of structural material,
5) Needs after care, regular repair & maintenance.

Functions of Bio-Engineering System:

Bio-engineering alone or along with some small scale civil engineering structures are used for fulfilling of following engineering functions.

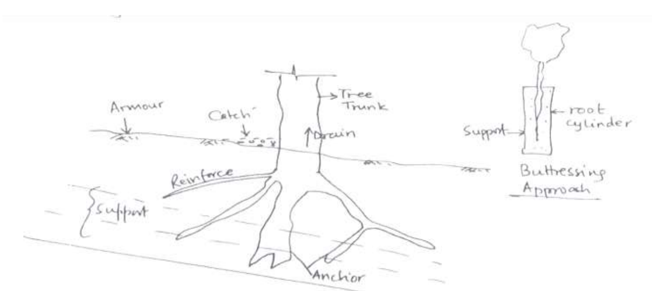


Fig: Bio- Engineering functions

The vegetations or plants used for bio-engineering can be woody on non-woody both a which carry out the following functions:

1) Engineering functions:

- Catch process of holding thin layer of soil part hereby restricting their movement. Bio-Eng. plants: Multi stemmed shrubs and bamboos, Civil Structures. Catch walls, catch wattle fences, netting,
- Armor: Providing protective cover to protect soil surface particles from movement. Bio-engs: - grass carpets Civil Structures: Pitching, revetment, breast walls,

- Reinforce: Mechanism of providing strength to bind the soil particles by densely rooted trees and grass. Bio-engineering: Dense rooted shrubs, grass and trees Civil Structures: Reinforced earth soil, nailing
- Anchor: firmly fixing of the soil particles and debris by the action anchoring action a deep long and throng roots. Bio-Engineering: Deep long and strong roots, civil structures: Rock Anchor
- Support: Support to soil mass debris from flowing by mechanical action of root system Bio- Eng, Shrubs, large trees Civil Str: Prop wall, toe wall
- Drain: Process & draining at the water quickly to remove excess load of water and soil system Bio-Engs: Diagonal plantation I drain cable drain sub-surface

2.) Hydrological functions:

The multiple stems and think of bio- engineering plants trap soils particles and debris from morning down the hill slope. The root systems bind and hold scale particles, rock and debris reducing the rate of erosion and hand slides. Vegetations play a major role in manipulating the hydrological regime by changing the quantities of water circulating from land and water bodies to atmosphere. The help in slope stability reducing the changes a erosion I landslides by:

- Interception of rain drops, protecting ground surface from the direct impact of raindrops,
- Leaf drip and stem flow reduces velocity,
- Evaporation of water from leaf & stem surface,
- Storage of water in canopy and stems,
- Transpiration through leaves,
- Vegetations decrease surface runoff and overland flow by increasing infiltration, soil water storage and sub-surface flow.

3.) Ecological functions:

- transforming harsh environment of degraded slope into a better ecological condition which in turn generates better micro-environment of the establishment and growth a plants, micro-organisms and small animals.
- Helps increase the biodiversity of the site.

Bio- Engineering Technique formulation.

The flowchart showing bio-engineering formula relation procedure:

[work plan]

Prioritization of work

Segmentation of site

Site Assessment

Structure selection

Civil Bio

Design

Resource budgeting &

Management

Implementation of civil structure

Implementation of Bio Structure

Work Monitoring /Quality Control

Maintenance of work

The summary of flowchart for bio-engineering technique formulation undergoes following stages:

A) Planning: (Bhadra- Ashwin)

- Make initial plan of the year's work,
- Prioritize the work based on its significance,
- Divide the site into segments for site assessment,
- Determine the appropriate civil engineering & bio- engg. works,

B) Design: (kartike- Mangsir)

- Design the civil and bio-engineering works,
- Select species to use which depends upon:
- Altitude of site,
  ~ slope, slope length and aspect of site,
  ~ Soil properties, as rainfall characteristics,
  ~ Biological and social considerations,
  ~ Availability & potential value of local users/ farmers.
- Calculate the required quantities and rates,
- Finalize priority against available budget,
- Arrange implementation and prepare document

C) Implementation (Poush - Shrawan)

- Prepare for plant propagation,
- Make necessary site arrangements,
- Prepare the rite for work,
- Implement the civil & Bio-engineering works,
- Monitor the work.

Bio Engineering Techniques:

1. Seeding:

Directly seeding on the slopes growth. For vegetation when Broadcasting on difficult slopes manual access is – Seed difficult & dangerous.

- Direct sawing in the prepared holes.
- Grass seeding
- Shrubs a Trees or Plants readings.

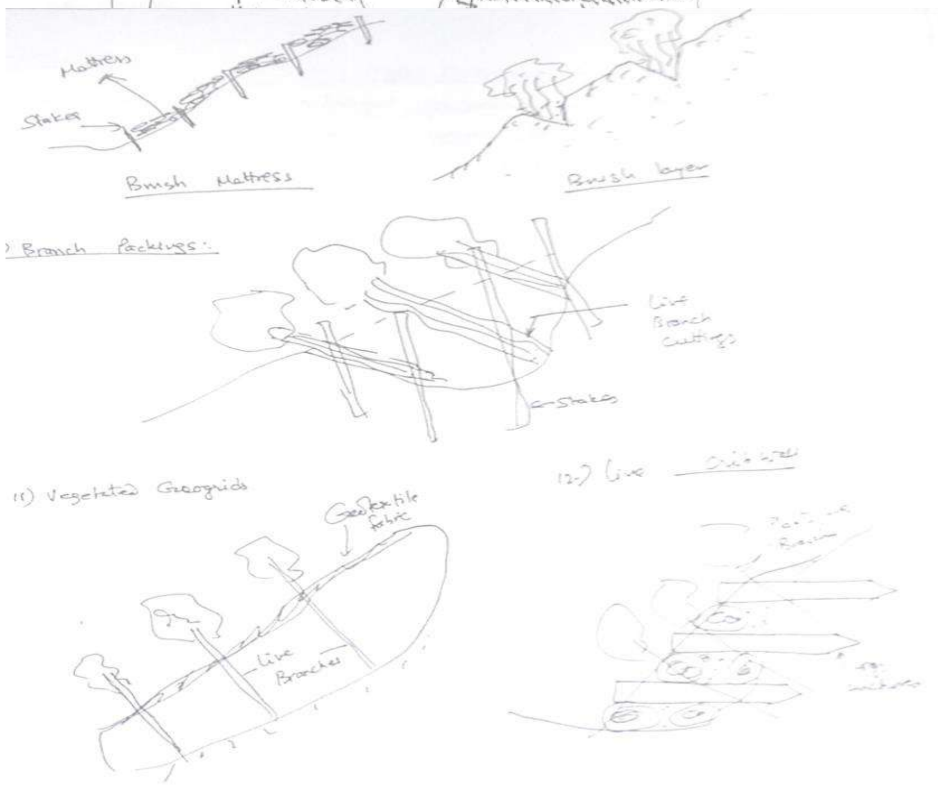
2. Planting:

Shrubs as tree seedlings raised in a poly pot.

- Grass lines (slip Plantation) in:
- Horizontal line: Armouring action in Coarse Grained soils,
- Vertical live: Used in fine grained soil, clay
  - Armour, Drain Controlled bullying,
  - Diagonal line – for mixed soil
  - Armour Drain, catch drain etc.
- Line to line spacing 250cm, plant to plant spacing = 10cm & Bamboo, utis, sit etc.

3.) Loose stones or Gabion chock dams
4.) Live check dams using big branches stems of dead trees,
    -Catch, armour & reinforce the gully flor
5.) Turfings on Embankments
6.) Jute netting, Geo grids, Geo blankets, it netting etc.
7.) Pallisades, - Grass covers on slopes, embankment.
8.) fascines or Wattles: bundle live cuttings that are staked Into treaches.

a) Brush Mattresses & layers



LANDSLIDES

Landslide, also known as landslip, is a geological phenomenon including a wide range of ground/soil movement in the downward and outward direction of slope along the surface by falling, sliding or flowing at a faster rate. All through the action of gravity is the primary driving force, there are other contributing factors affecting the original slope stability. Typically, fore-conditional factors build- up specific sub-surface conditions so as to make a the area / slope prone to failure but landslides actually occur after releasing some trigger before.

Causes and Mechanisms of landslides

- Landslides can be triggered by both natural and man-made changes in the environmental conditions,
- The geological history of an area as well as activities associated with human occupation contribute to slope failure,
- Rainfall, earthquake and human activities are important triggering factors of failure.

The broad causes of landslides are:

1) Natural Triggers:

- cloud bursts or high concentrated precipitation (200-1000 mm/day),
- Uncontrolled water flow on slopes from over flooded steep gullies,
- Toe cutting may activate failure,
- Earthquake, volcanic bursts 4 vibrations
- Flash flood due to GLOF failure of land slide

- Ground water (pore water pressure acting to destabilize slopes,
- Loss / Absence of vertical vegetative structure, soil nutrients, and soil structure (for eq: after a wild fire in forest etc.),
- Weakening of Hope through saturation by snow in glaciers melting, or heavy rains etc.

2) Anthropogenic / Man-made Causes:

- Deforestation, construction, agricultural or forestry activities,
- Large scale cultivation, quarrying, blasting
- Excessive hill/slope cutting, urbanisation which involves heavy earthworks altering the shape of the slope or imposing new load on existing slope,
- Vibrations from machinery of traffic,
- Submergence of lakes, dams, reservoirs and canals,
- Excessive soil disposal,
- Undermining caused by mining, tunnelling etc.

3) Surface / Subsurface water:

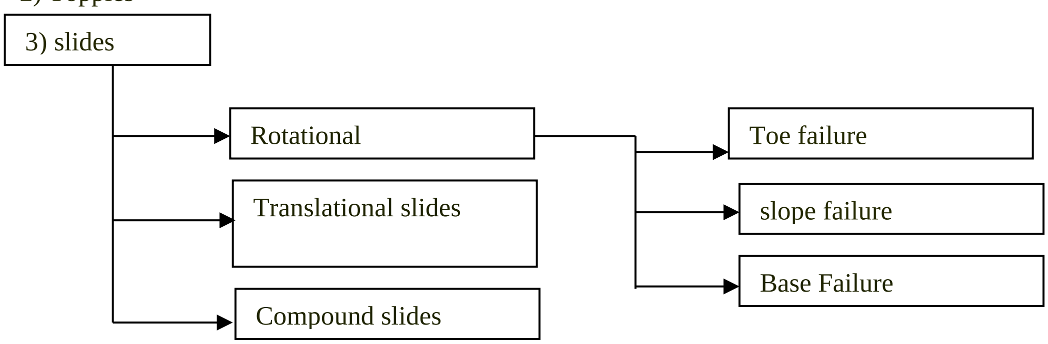
- Pore-water pressure due to adverse hydro-geological conditions and ground water,
- Surface water causes erosion and soaking of surface to cause shallow sliding
- saturated soil with underground water etc.

4) Adverse Geological conditions:

- Dips of bedding planes, clay seams or weak or in rock layers are nearly the same as those of slope causing planar sliding,
- Dip direction of joint set is nearly the same as that of the slope (120°),
- Great nos of unfavourably oriented joint-sets with many wedges.
- Weathering of rock mass
- Slope material is loose cohesionless eg. colluvium soil etc.
- Steeply dipping joints or bedding planes Crock) may lead to failure by overtopping of rock blocks.

Classification of slide

1) Falls
2) Topples



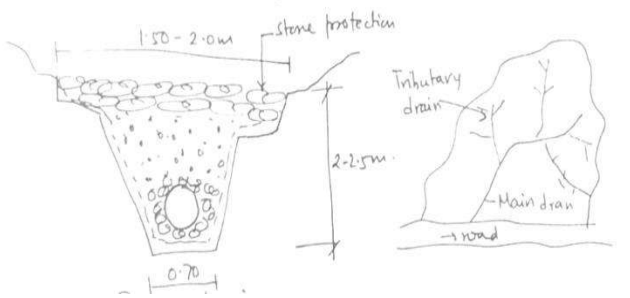
Types of slides

1) Deloris flow or mud flow
2) Earth flow,
3) Debris landslide,
4) Movement
5) Structure……….

Control / Rectification of Landslides

- Road side development
- Slope flattering / trimming,
- Provision of berms.
- Drainage of slopes, erosion control, provision of catch drains and sub-rusface drains
- Stabilisation of demis slide by providing sub-sun drainage with herring bore or french drains.

French drains.



- Densification by use of preloading, vibration, vibro floatation, grouting, sheet piles etc.
- Bio- engineering along with small scale civil engineering structures,
- Under severe conditions, slopes may be protected by:
  - stone pitching,
  - rip-rap

Application of Bio-engineering to the Road Network of Nepal.

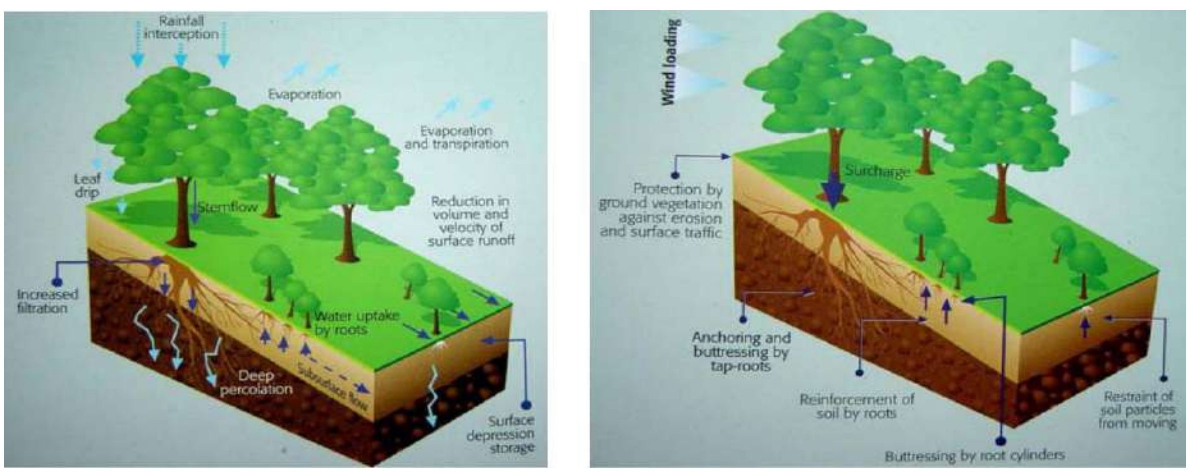
Definitions

Bio-engineering is the use of vegetation, either alone or in conjunction with civil engineering structures, to reduce instability and erosion on slopes. It should be a fundamental part of the design and construction of all roads in hill areas. This is mainly because it provides the best way to armour slopes against erosion, and can also provide a significant contribution to soil reinforcement and other anti-failure measures (Transport Research Laboratory, 1997). It is relatively low in cost, uses local materials and skills, and provides livelihoods benefits through economically useful products. It is often called “soil bio-engineering” to distinguish it from the bio-medical science that uses the same term.

Engineering effects of vegetation

Plants have a number of effects on soils and slopes, which can be categorised as hydrological and mechanical and these are shown schematically in Figure 1. They might be beneficial or detrimental, depending on the local environment and engineering needs of a particular slope. While the contribution made by individual plants to a slope is complex, plants used in combination can provide much greater effects than single plants, but with a similar increase in complexity. For example, a single grass plant can catch a small amount of debris and reinforce a small volume of soil with its roots. But if a line of grasses is planted across a slope, together they form a continuous chain to catch debris, and can provided a linear rather than a point of reinforcement. In the process of serving these functions, however, the contour line of grass will also increase the infiltration capacity of the soil. If the material characteristics are such that this may lead to a critical condition of saturation, then another function, that of drainage, will be required. This can be achieved using grass lines by planting the lines down at an angle rather than across the slope, and the more the line is angled, the less it will catch debris and the more it will help to drain the slope.

Figure 1. Effects of vegetation on Soils and Slopes: (a) Hydrological and (b) Mechanical. From Howell (1999).



Both bio-engineering and civil engineering systems perform *engineering functions*. Table 1 shows the main functions of common structures of each category. Obviously plants cannot emulate all of the functions of civil engineering systems, particularly those having effects deeper than about 0.5 metre, nor can they provide comparable physical strengths except in special circumstances. Also, plant types vary in their ability to serve the various engineering functions. For example, grasses are more suited to armouring the surface, while shrubs and trees fulfil functions such as reinforcing and supporting.

Table 1. Comparison of the main engineering functions performed by civil and bio-engineering structures.

Civil Engineering Techniques	Bio-engineering Techniques

Technique	**Function**	**Technique**	**Function**
Stone Pitching	Armour	Horizontal Grass	Armour, Catch, Reinforce
Revetment	Armour	Diagonal Grass	Armour, Drain, Reinforce
Dentition Work	Armour	Palisades	Catch, Reinforce, (Support)
Check Dam	Catch, Support	Brush Layering	Catch, Reinforce, (Support)
Retaining Wall	Support, Catch	Shrub Planting	Catch, Reinforce, Anchor, Support
Drainage Systems	Drain; Some Support	Tree Planting	Reinforce, Anchor, Support
Bolster	Support, Armour, Catch	Bamboo Planting	Catch, Armour, Reinforce, Support

Under most circumstances, bio- engineering can be effectively combined with appropriate and low-cost geotechnical applications to provide the most cost-effective, integrated solution to slope stability problems. This is important for places like Himachal Pradesh because, with the steep and dynamic slopes found in the Himalayas, most hill roads are engineered near to the margin of safety. Bio-engineering is the most affordable and effective way of enhancing civil engineering structures to increase stability as far as possible. The vegetative structures are also flexible, being capable of absorbing movement and recovering from damage. In this respect, bio-engineering is simply part of wise and sustainable asset management since it helps to ensure the life of physical structures, and reduces overall maintenance costs. On roadsides, plants reduce the supply of debris from degrading slopes, which is one of the greatest contributors to road maintenance costs through blocked drains and damaged pavements.

In this context, vegetation is very important in the control of erosion and shallow forms of instability (1 to 3 meters in depth at most). Some typical applications of bio-engineering are described in Table 2.

However, it must also be appreciated that the beneficial effects may be insignificant under extreme conditions, particularly in tropical and monsoonal climates, and that it plays no significant role in the stabilization of deeper failures of soils or rock.

Table 2. Description of the Main Systems of Bio-engineering.

System Type	**Design And Function**
Grass Planting	Grass seed is spread on to the slope, armouring the surface. Alternatively, grass is hand-planted in lines across the slope. The lines armour the slope and catch debris. Angled lines planted by hand may also help to drain the surface, but catch little debris.
Shrub and Tree Planting	Shrubs or trees are planted at regular intervals on the slope. As they grow, they create a dense network of roots in the soil. The main engineering functions are to reinforce and, later, to anchor. In the long term, large trees can also be used for slope support.
Brush Layering, Palisades and Fascines, *etc*	Woody cuttings are laid in lines across the slope, usually following the contour, in particular configurations. These form a strong barrier, preventing the development of rill, and trap material moving down the slope. In the long term, a small terrace will develop. The main engineering functions are to catch debris, and to armour and reinforce the slope. If they are angled, these structures can provide a drainage function.
Composite Systems	A range of composite systems are commonly used. Examples are: Live check dams, which armour and reinforce gully beds and catch debris; vegetated stone pitching, which provides strong armouring for ephemeral water courses; planted geotextiles, where the geotextile provides armouring, later supplemented by the vegetation, which also reinforces the soil.

Vegetation as a key component in off-road engineering is also environmentally sound and effectively forms a practical application of several environmental mitigation measures. In the hills, roads are an inseparable part of the slopes that they cross and they must be fully integrated into this landscape if they are to be sustainable. Bio-engineering techniques offer the best way of blending roads into the landscape and limiting damage to surrounding agricultural, horticultural and forest land. They allow the restoration of something of the original vegetation and ecosystems, and particularly of tipping sites and spoil disposal areas. Through both implementation and later productivity, they offer social and economic benefits for poor rural farmers. These benefits assume even greater significance due to the very small land holding size in the hills.

Slope stabilisation is a special branch of engineering in its own right. In India, it is given considerable treatment in standard texts such as Khanna (1999) and the IRC's Guidelines for Hill Roads (Indian Roads Congress, 1998). Yet despite this, and the widespread international understanding of the topic, there is still a tendency for cost considerations to lead to road construction or widening with a wholly inadequate amount of attention given to the stabilisation and protection of slopes.

In practice, *slope stabilisation* depends on the use of a retaining structure, which can be drawn from a menu of standard and specialist techniques such as those shown in Table 3. The vast majority of walls alongside roads are of the simpler and lower cost types, for the obvious reason of cost effectiveness. In order to achieve high levels of strength, physical structures are always required and bio-engineering measures can only complement the civil engineering solution adopted. In fact, vegetation can provide protection and reinforcement of backfill and surrounding slope areas, protection from scour and the undercutting of the foundations and sides of structures and a flexible extension to a wall through large bamboos, shrubs or trees close to it adding to the engineering functions of catching, supporting and buttressing.

Table 3. Comparison of Retaining Wall Types

Wall Type	Maximum Safe Height	Typical Width:Height Ratio	Advantages	Limitations
Dry masonry	4 metres	1:1 to 0.6:1	Well drained, flexible, relatively low in cost and blends well with the surroundings.	Low strength threshold (susceptible to lateral pressures and traffic vibrations); limited height of construction.
Composite masonry (crib construction)	8 metres	0.75:1 to 0.5:1	Better drained and cheaper than mortared masonry.	Strength not as good as for mortared masonry.
Mortared masonry	10 metres	0.75:1 to 0.5:1	Relatively easy to construct on steep terrain; most durable wall type.	Requires good foundations and cannot tolerate settlement; poor through drainage.
Gabion (wire crate)	10 metres	Width = ½ h + 0.5	Flexible without rupturing; tolerates poor foundations, and weak and saturated ground conditions; well drained; relatively low cost for strength.	Construction requires a relatively wide foundation footprint to achieve the same shear strength of mortared masonry.
Reinforced earth	8 metres	Depends on design; substantial horizontal clearance usually required to develop required tension resistance.	A high level of flexibility and the potential for a well-landscaped, "natural" finish.	Reinforcing is expensive and relatively difficult to obtain in remote areas; stability calculations are complex and it is difficult to achieve the correct compaction and tension.
Soil nailing	5 metres	Depends on design	A potential stabilisation option where space is limited for other types of retaining wall.	Costly; requires advanced technical skills and specialist equipment to build.
Mass concrete and reinforced concrete	10 metres	Depends on design	Strongest type of retaining wall.	Relatively costly; requires large quantities of cement and crushed aggregate, and advanced technical skills to build; poor through drainage.
Anchored reinforced concrete	10 metres	Depends on design	A strong wall type for certain situations where space is limited for other types of retaining wall.	Very costly; requires a sound bedrock foundation, advanced technical skills and specialist equipment to build.
Bored-pile wall built in situ	5 metres	Depends on design	Allows through drainage between piles, in sites with identifiable failure planes within reach of piling.	Very costly; requires advanced technical skills and specialist equipment to build.

Slope protection can be achieved using physical civil engineering measures, but is much better undertaken using bio-engineering systems. It is only in sites prone to particular attack that some form of revetment walling is advisable, such as at the toe of a weak soil slope where cattle are likely to be driven; or where running water is common, that stone pitching (small- scale rip-rap) is necessary. Surface coverings of cement-stabilised aggregate or other compounds can be very problematic due to the difficulties of drainage and consequent build up of pore water pressures. Beyond these specific locations, usually very limited in roadside positions, vegetation is generally cheaper, more effective and environmentally advantageous.

As Table 2 shows, most bio-engineering systems also strengthen slopes through providing reinforcement or support. Authors such as Ekanayake et al. (2004) point out that "soils with roots produce stress-displacement curves with higher peak strengths at larger shear displacements than soils without roots". This is unpredictable, however, on account of the infinite variability in the environmental factors that determine the growth characteristics of specific plants in particular situations. But what is predictability in geotechnics, when it is impossible to measure all of the relevant parameters affecting the stability of a slope? Theoretical models and calculations may only serve to simulate an accuracy that does not actually exist. The fact is that vegetation improves the coherence of slopes in almost every case and therefore contributes more than just surface protection; it provides a very valuable protection and strengthening of the top 500 mm or so of a slope, the zone in which all erosion and the great majority of mass failures occur.

There is a natural inclination to make direct correlations between the places that have been the focus of research and development projects over the years and the mountainous regions of northern India. However, such correlations can only be valid if the overall environment governing the performance of slopes in two regions are closely similar. It is crucial to be fully aware of the parameters that control stability on each slope under investigation and to take full account of the factors that will affect the short term and long-term slope management. It is advisable, therefore, to assess carefully all the factors that comprise the overall slope environment.

There is, in fact, no logical clear distinction between the use only of physical civil engineering structures and their combination with plants in some kind of bio-engineering system. Table 4 summarizes the various engineering functions that must be performed by structures in the stabilization, strengthening and protection of slopes and shows how both approaches (physical and biological) can be employed to optimum effect.

International experience

The options for the use of vegetation in engineering are numerous and have been covered well in the literature. Techniques are well established, with particular practical experience coming from the Alpine countries, particularly Austria (Schiechtl, 1980) and the United States (Gray and Lieser, 1982), which have formed the basis of recent thinking and practice. The current most comprehensive examples of text books are Coppin and Richards (1990), Gray and Sotir (1996), Morgan and Rickson (1995), and Schiechtl and Stern (1996). Conferences regularly either focus on bio-engineering (e.g. Barker et al., 2004), or contain a significant number of articles on the subject (e.g. HMG Nepal and PIARC, 2003). Country -specific examples of adaptation for particular application in the road sector may be found in many instances, such as the Caribbean (Clark and Hellin, 1996), Nepal (Howell, 1999) and Hong Kong (Geotechnical Engineering Office, 2000). More general texts on the use of vegetation for land stabilisation include the use of vetiver grass promoted over many years by the World Bank (National Research Council, 1993).

The biggest success with bio-engineering in association with low cost geotechnical engineering works is probably in Nepal, where extensive research in the 1980s was put into practice in the 1990s (Howell, 1999) . This experience is still being widely applied in the current programmes of the Government of Nepal itself, as well as those supported by the World Bank, the Asian Development Bank, the UK Department for International Development, the Swiss Development Co-operation and other donors (see, for example, the Nepali Times of August 2006). The results of innovative research in the late 1980s and early 1990s in Nepal that worked on a range of livelihoods opportunities in the management of roadside slopes in rural areas now forms the basis of pro-livelihoods rural road development on a significant scale.

Other examples of bio-engineering works are numerous and many can be found in the documents to which reference has already been made. The great breadth of international experience is nowhere fully documented, though the International Erosion Control Association, while somewhat Americo-centric, probably has the best reach to documented broad expertise through its publications, especially its large annual conferences (see http://www.ieca.org).

One of the key lessons from the practical experience gained in other countries is that geotechnical and bio-engineering disciplines need to be integrated in their approach to slope management. Neither is a total solution on its own and this is illustrated by failures that have occurred when either the wider slope conditions have been ignored or the engineering or planting materials used have proven inappropriate for the site.

Implications of plant ecology for bio-engineering

- Vegetation in Nepal grows in zones determined mainly by the temperature and moisture conditions for which each species is adapted.
- The zones are recognizable and definable within certain limits. They do not coincide with the terrain zones.
- Each of the species used for bio-engineering has a tolerance for site conditions that is reasonably well defined. As a result, species can be found to grow on almost any site, depending on its characteristics.
- Water is the main factor limiting plant growth in the warmer months.
- Soil nutrition seems rarely to be a limiting factor; in any case, the species used for bio- engineering are tolerant of very low fertility.
- The use of pioneer species for bio-engineering on bare roadside slopes helps to allow a vegetation community to establish, through the development of shade and better soil.
- A number of factors can cause regression if the plants are not well protected.
- Plants compete with each other for resources.
- In bio-engineering, the competition for light is the most critical aspect. If not managed, the canopy of higher plants can shade out the ground cover.
- As a result, regular maintenance is required to ensure that bio-engineering systems develop as required.

There is a range of natural plant communities. These do not hold all the engineering attributes required of bio-engineering vegetation systems. For this reason, as well, regular maintenance of the vegetation is needed to ensure that the optimum mixture of plants is both attained and sustained.

The use of vegetation in engineering involves manipulating nature for specific purposes. It is not simply a matter of establishing a vegetation cover to become part of a long-term natural plant community. Management of the plants to fulfil specific engineering functions can make vegetation play a much larger role in stabilizing and protecting a slope than it would do otherwise.

Because of the harsh nature of bare landslide or other disturbed roadside slopes, it is rarely possible to establish the final plants straight away. Instead, it is necessary to start with pioneers that are adapted to these conditions and then change the mixture of plants gradually to a community which is more-or-less stable. However, it is usually important to ensure that the slope is armoured against erosion. Grasses are by far the best plants to achieve this. But grasses mostly require full sunlight in which to grow; so, to sustain a good cover of grasses it is necessary to keep the shrub or tree canopy as thin as possible. On the other hand, without the shrubs and trees, the deeper reinforcing and armouring functions required on many sites would not be provided.

Table 4. Engineering Functions of Stabilisation Options.

Engineering function	Civil Engineering Solution	Potential drawbacks *	Bio-engineering alternative	Bio-engineering Solution	Potential drawbacks	Possible Optimal Combination of both
Support a weak soil mass by the provision of toe support. This can be achieved either by creating a heavy, immovable weight at the base of the slope, or by altering the slope to create an effect of buttressing and arching (where the soil between buttresses is supported from the sides by compression). The buttresses and arches of a building have similar engineering functions.	Retaining walls of masonry (bound or unbound) or gabion.	Drawbacks mainly relate to cost, foundation conditions and through drainage.	Large heavy vegetation, such as trees, at the base of a slope can provide support in the form of buttresses; or on a micro scale, clumps of grass can buttress small amounts of the soil above them. A lateral arching effect is created across the slope, between plants. Requirements are for extensive, deep and wide-spreading root systems, and many strong, fibrous roots.	Most trees, with the specific Selection dependent on Local Environmental factors..	Trees take a long time to establish, and do not offer a continuous line of support across the slope.	Retaining wall with trees above, beside and below, maximising the overall support of the slope.
Anchor a mass of weak surface material, through potential failure planes, into firmer strata below. This may be possible where a particularly incoherent mass overlies stronger materials, such as where colluvium rests above a relatively unweathered rock mass.	Soil anchors, soil nails and rock bolts.	Depends on there being a stronger underlying mass; difficulties of cost, design and construction.	Vegetation that will extend its roots below the potential failure planes. If the potential failure is deeper than about 0.5 metre, this is achieved only by large woody plants with big vertical roots (tap roots). Requirements are for plants with deep, strong, long, and vertically oriented roots.	Shrubs and trees that are deeply rooting.	Deep roots take a long time to develop and are unpredictable because of unknown subsurface conditions.	Combination of an artificial Anchoring system and trees.
Reinforcement of the soil to reduce deformation. This is particularly important to reduce shallow failures, especially when soils are saturated.	Reinforced earth systems.	Artificial soil reinforcement is complex to design and construct, and difficult to achieve on steep slopes.	Provide a network of roots that increases the soil's resistance to shear. The degree of effective reinforcement depends on the form of the roots and the nature of the soil. Requirements are plants with extensive roots with many bifurcations, and many strong, fibrous roots.	Densely rooting clumping grasses planted in lines; brush layers and palisades; some shrubs and trees.	None: plant roots always contribute to the shear strength of the soil.	Built-up slope with soil layers Interspersed with geotextile, and planted with grass etc.
Drain excess water from the slope, to reduce pore water pressure and increase slope strength and coherence. It is especially important to avoid the saturation of material, which leads to slumping due to a reduced loss of internal friction.	Surface or sub-surface drains, designed as per site conditions.	Surface drains require additional maintenance, often ignored in off-road situations.	Vegetation can be planted in a configuration that enhances drainage. Vegetation can also help to reduce pore-water pressure within the slope, by extracting water from the roots and transpiring it out through the leaves. Requirements are for plants to be planted in closely-packed lines; they must have an ability to resist scour and a high leaf area to enhance transpiration.	Downslope and diagonal vegetation lines, particularly those using clumping grasses. Most shrubs and trees.	Requires a good understanding of site conditions, and careful application of appropriate measures.	French drains and angled grass lines feeding surface water into the drains.
Armouring of the slope against surface erosion from both runoff and rain splash.	Revetments and surface coverings.	Too expensive to apply on a large scale; can only be used in select critical locations.	A continuous cover of low vegetation. Plants with high canopies alone do not armour the slope (the terminal velocity of a rain drop is reached after a fall of only 2 metres, and some canopies generate larger rain drops). The requirement is for a dense surface cover of vegetation, with a low canopy and small leaves.	Grass lines or a complete grass carpet of clumping or spreading grasses.	None: this is what grass does best.	Vegetated stone pitching, for gully floors and episodic water courses.
Catch eroding material moving down the slope, as a result of gravity alone or with the aid of water.	Catch walls and fences.	On steep slopes it may not be possible to construct a secure wall above the road.	Vegetation stems can perform this function. The requirement is for strong, numerous and flexible stems, and the ability to recover from damage.	Micro scale: clumping grasses. Larger scales: shrubs with many stems and bamboos.	It takes some years for plants to become sufficiently robust to perform this function reliably.	Catch wall with shrubs or large bamboos above.

PROBLEMS ON SLOPE

- Materials roll down the slope
- Water enters into the slope or liquefies the slope materials
- Loose state of materials
- Tendency of slope to move outward and downward or outward and downward movement of the slope
- Slip of overlying layer (sedimentary layer) or strata
- Accumulation of water on the slope

Bio-engineering can be used in the following condition

- All bare soil areas on embankment and cut face slopes
- All sites where there is a risk of scour erosion (gulling)
- All slopes where there is risk of shallow debris flow and translational slide (Up to 2 m)
- Any Slope components where civil engineering structures are used
- Any area such as tipping and quarry sites, camp compounds, where any rehabilitation is required
- Wind erosion control
- Small run off control in catchment area
- Water course and shoreline control
- Vegetative Barriers (Shelter and Noise reduction)

BENEFIT OF BIOENGINEERING

In Nepal, roadside bioengineering has been practiced since last 21 years. For watershed management still it is not implemented in effective way. Bioengineering is an excellent tool for stabilizing areas of soil instability. On areas of potential or existing mass wasting, it may be best to use a civil engineering system (such as check dam, toe wall, catch wall, stone pavement etc.) alone or in combination with bioengineering.

Benefits of bioengineering in a watershed includes

- Projects usually require locally available excavation equipment. As a result, there is less cost and less impact on slope. In addition, limiting hand crews to one entrance and exit route will cause less soil disturbance to the site and adjoining areas.
- Erosion areas often begin small and eventually expand to a size requiring costly traditional engineering solutions. Installation of bioengineered systems while the site problem is small will provide economic savings and minimize potential impacts to the slope and adjoining resources.
- Use of native plant materials and seed may provide additional savings. Costs are limited to labour for harvesting, handling and transport to the project site. Indigenous plant species are usually readily available and well adapted to local climate and soil conditions.
- Bioengineering projects may be installed during the dormant season of late fall, winter, and early spring.
- Bioengineering work is often useful on sensitive or steep sites where easy accessibility is not feasible.
- Years of monitoring have demonstrated that bioengineering systems are strong initially and grow stronger with time as vegetation becomes established. Even if plants die, roots and surface organic litter continues playing an important role during reestablishment of other plants.
- Once plants are established, root systems reinforce the soil mantle and remove excess moisture from the soil profile. This often is the key to long-term soil stability.
- Bioengineering provides improved landscape and habitat values in the watershed.

SCOPE OF BIOENGINEERING

- Mining and reclamation and land drainages
- Highways and railways, reservoirs and dams
- Construction sites, building and recreation
- Waste disposal and public health
- Airfields and helipads
- Waterway

Mass Movement and Landslide

Landslide: It is the outward movement of mass of rock or debris down slope. In addition to this definition, mass movement occurs when shear stress exceeds shear strength of the material.

Mass wasting/movement: down slope movement of soil or rock material under the influence of gravity without the direct aid of other media such as air, water or ice. Mass wasting is more inclusive than landslide because the latter does not include falls, topples, creeps as they do not have distinct planes or zones of sliding.

Factors contributing to increase in shear stress

- Removal of lateral or underlying support
- Increase of load
- Increase of lateral pressure
- Transitory stresses

Factors related to the decrease in material strength

- Change in intra granular force
- Change in material structure

CLASSIFICATION OF MASS MOVEMENTS

There are many classification schemes for mass movement (landslides) proposed by different authors like Campbell (1951), Hutchison (1968, 1969, 1977), Crozier (1973) and Varnes (1958, 1978).
Hutchinson's classification considers movement criteria including depth, direction and sequence of movement with respect to the initial failure. (Varnes 1978) Classification is based on nature of source material and the type of movement involved

Types of Landslide/mass movement according to Varnes

The types of landslide proposed by Varnes (1978) is the most commonly used in the world. It was also adopted by Landslide Committee, Highway Research Board, Washington, D.C. It divides landslides into falls, topples, slides, lateral spreads and flows. Wherever two or more types of movements are involved, the slides are termed as complex. Varnes (1978) has divided the material prone to landslides into classes, e.g. rock and soil. The soil is again divided into debris and earth.

Falls

Falls are abrupt movements of the slope material that becomes detached from steep slopes or cliffs. Movement occurs by free-fall, bouncing, and rolling. Depending on the type of materials involved, the result is a rock fall, soil fall, debris fall, earth fall, boulder fall, and so on. Typical slope angle of occurrence of falls is from 45-90 degrees and all types of falls are promoted by undercutting, differential weathering, excavation, or stream erosion.

Topples

A topple is a block or serial of block that tilts or rotates forward on a pivot or hinge point and then separates from the main mass, falling to the slope below, and subsequently bouncing or rolling down the slope.

Table 3.1, Types of Landslide (Varnes, 1978) Slides

Type of movement			Type of material		
			Engineering soils		**Bedrock**
			Predominantly fine	*Predominantly coarse*	
Falls			Earth fall	Debris fall	Rock fall
Topples			Earth topple	Debris topple	Rock topple
Slides	Rotational	Few Units	Earth slump	Debris slump	Rock slump
	Translational	Few units Many units	Earth block slide Earth slide	Debris block slide Debris slide	Rock block slide Rock slide
Lateral spreads			Earth spread	Debris spread	Rock spread
Flows			Earth flow	Debris flow	Rock flow
			(Soil creep)		(Deep creep)
Complex			Combination of two or more principal types of movement		

Although many types of slope movement are included in the general term "landslide", the more restrictive use of the term refers to movements of soil or rock along a distinct surface of rupture, which separates the slide material from more stable underlying material. The two major types of landslides are rotational slides and translational slides.

Rotational slides

These slides refer to a failure, which involves sliding movement on a circular or near circular surface of failure. They generally occur on slopes of homogeneous clay, deep weathered and fractured rocks and soil. The movement is more or less rotational about an axis that is parallel to the contour of the slope. Such slides are characterized by a scarp at the head, which may be nearly vertical. These slides may be single rotational, multiple rotational or successive rotational types; accordingly, they may have a single surface of rupture, multiple surfaces of rupture. A "slump" is an example of a small rotational slide.

Translational slides

These are non-rotational block slides involving mass movements on more or less planar surfaces. The translational slides are controlled by weak surface such as beddings, joints, foliations, faults and shear zones. The slides material involved may range from unconsolidated soils to extensive slabs of the rock and debris. Block slides are transitional slides in which the sliding mass consists of a single unit or a few closely related units of rock block that moves down slope. Translational slide may progress over great distance if conditions are right.

Lateral spreads

Lateral spreads are a result of the nearly horizontal movement of unconsolidated materials and are distinctive because they usually occur on very gentle slopes. The failure is caused by liquefaction, the process whereby saturated, loose, cohesionless sediments (usually sands and silts) are transformed from a solid into a liquefied state, or plastic flow of subjacent material. Failure is usually triggered by rapid ground motion such as that experienced during an earthquake, or by slow chemical changes in the pore water and mineral constituents.

Flows

There are several types of flows and a short description of them is given below.

a. Creep

Creep is the imperceptibly slow, steady downward movement of slope-forming soil or rock. Creep is indicated by curved tree trunks, bent fences or retaining walls, tilted poles or fences, and small ripples or terracettes.

b. Debris flow

A debris flow is a form of rapid mass movement in which loose soils, rocks, and organic matter combine with entrained air and water to form a slurry that then flows downslope. Debris flow areas are usually associated with steep ravines where there are some active landslides. Individual debris flow areas can usually be identified by the presence of debris fans at the termini of the drainage basins. In general, the following conditions are important for formation of a debris flow:

- Slopes with 20-45 degrees
- Saturated loose rock and soil materials with high content of clay minerals
- High intensity and duration of rainfall

c. Debris avalanche

A debris avalanche is a variety of very rapid to extremely rapid slide-debris flow process.

d. Earth flow

Earth flow has a characteristic "hourglass" shape. A bowl or depression forms at the head where the unstable material collects and flows out. The central area is narrow and usually becomes wider as it reaches the valley floor. Earth flows generally occur in fine-grained materials or clay-bearing rock on moderate slopes and with saturated conditions. However, dry flows of granular material are also possible

e. Mudflow

A mudflow is an earth flow that consists of material that is wet enough to flow rapidly and that contains at least 50 per cent sand-, silt- and clay-sized particles.

Complex movements

A complex movement is a combination of two or more types of movements mentioned above. Generally huge-scale movements are complex, such as rock fall, rock/debris avalanches.

LANDSLIDE CAUSES

1. **Geological causes**

- Weak or sensitive materials
- Weathered materials
- Sheared, jointed, or fissured materials
- Adversely oriented discontinuity (bedding, schistosity, fault, unconformity, contact, and so forth)
- Contrast in permeability and/or stiffness of materials

Morphological causes

- Tectonic or volcanic uplift
- Glacial rebound
- Fluvial, wave, or glacial erosion of slope toe or lateral margins
- Subterranean erosion (solution, piping)
- Deposition loading slope or its crest
- Vegetation removal (by fire, drought)
- Thawing
- Freeze-and-thaw weathering
- Shrink-and-swell weathering

Human causes

- Excavation of slope or its toe
- Loading of slope or its crest
- Drawdown (of reservoirs)
- Deforestation

- Irrigation
- Mining
- Artificial vibration
- Water leakage from utilities

Causes and Mechanisms of Slope Failure

What is the cause of failure?

Any condition that generates, starts and triggers the failure is the cause

Cause of Failure

- Rainfall - it can cause devastating failure as debris flow can be channeled in steep flow gully
- Earthquake- seismicity is major landslide trigger
- Groundwater - causes increased pore water pressure at depth and failure plane is deeper than surface water failure plane
- Surface Water- erosion or soaking of surface to cause shallow sliding and effect of water infiltrating from surface can cause shallow failure
- Weathering- rock strength is reduced as constituent mineral are broken down into weathering products; physical bonds between constituent minerals are weakened or broken. So rock can fail long weakened fractured plane through its body. Hence progressive and cyclic failure is possible.
- Under cutting/ Toe cutting — slope is undercut by flowing water or stream or by the opening up of a road cutting
- Addition of weight (surcharge)
- Differential weathering in rock — cause is a combination of weathering of the rock layers and plane failure of hard rock layers

Erosion

Erosion is the removal of particles from the surface by flowing water. An arbitrary depth limit of 25 mm can be adopted for erosion: this depth refers only to the initial removal of particles and is used to distinguish erosion from mass movements; if particles are continually washed away, the surface will be progressively lowered, giving rise to the forms of erosion described below. For example, a gully 2 metres deep can be developed by the steady removal of particles from its sides to a depth of no more than 25 mm at a time. The process which causes this is still erosion. There are numerous terms to describe erosion, and the most common ones are explained below. When it comes to the protection of critical roadside slopes, many of the distinctions are largely academic.

Natural or geological erosion: the wearing away of the Earth ‘s surface by water, wind or ice under natural environmental conditions of climate and vegetation, undisturbed by man. Normal erosion: the gradual erosion of land used by man which does not greatly exceed natural erosion.

Accelerated erosion: erosion which is much more rapid than normal, or natural or geological erosion, primarily as a result of the actions of man or animals.

Splash (or rain splash) erosion: the spattering of small soil particles caused by the impact of rain drops on wet or weak soils; the loosened particles may or may not be subsequently removed by surface runoff.

Sheet erosion: the removal of a fairly uniform layer of soil from the land surface by runoff water (or overland flow). this type of erosion is due to non-homogeneous soil mass

Rill erosion: erosion whereby numerous small channels of the order of tens of millimeters in depth are formed and this type of erosion is due to homogeneous soil mass.

Gully erosion: the process whereby water accumulates in narrow channels and, over short periods, removes the soil from this narrow area, often to considerable depths. The exact conditions under which each of these occur varies greatly. Sheet erosion is uncommon on roadside slopes, but can be found on extensive bare soils with compacted surfaces. More common is the development of rill or gully erosion through the channelization of surface runoff (when it occurs) at the micro level. Once drainage lines start to form rills on weak materials, they can enlarge rapidly into gullies.

Gullies. Gullies begin as very shallow, narrow incisions in the slope (rills). If a gully is deeper than 2 m, its sides fail in ways similar to a normal hill slope. Hill slope protection measures are then appropriate on the gully sides, as well as the gully floor requiring its own protection.

Erosion by piping. This is the removal of fines along an underground channel. Percolating ground water in permeable fine soils of low plasticity can remove fines along a fissure to a point where an underground stream is formed. The roof of this stream cavern can enlarge upwards towards the surface and eventually collapse to create an open, elongated chasm or pit. n

water management and gully protection work

Water is the main cause of slope instability and therefore its management is a major consideration in slope stabilization, whether it is by civil or vegetative methods. The process we have worked through in this session should help them plan more effective schemes for managing sub-surface drainage.

SURFACE DRAINAGE SYSTEM

Surface drains are installed in the surface of a slope to remove surface water quickly and efficiently. Surface-water drains often use a combination of bio-engineering and civil engineering structures. Cascades are surface drains designed to bring water down steep sections of slope. Any site less than 35º. Certain drain types can be used on slopes up to 45º (e.g. drains constructed using gabion wire or concrete-bound masonry). Cascades are normally used on slopes steeper than 45º.

Practical features

- Always design drainage systems to run along natural drainage lines. Choose locations for the drains so that the maximum effect can be achieved using the minimum possible volume of construction.
- Always ensure that drain outfalls are protected against erosion.
- Only use a rigid geometrical pattern of drains on newly formed fill slopes where there are no clear natural drainage lines.
- Excavate a foundation until a sound layer to build on is located. Drains must be well founded like all other civil structures.
- Run main drains straight down the slope. Feed side drains in on a herringbone pattern.
- Never use contour drains: these block very easily and are also highly susceptible to subsidence. A blocked or cracked drain can create terrible damage as a result of concentrated water flow.
- Design and construct the drains in such a way that water can enter them easily on the higher side but not seep out on the lower side. Use weep holes and thick (≥ 20 gauge), black polythene membranes carefully to achieve this.
- A flexible design is usually an advantage. Concrete masonry can be easily cracked by the slightest movement in the slope, and then leakage problems result.
- If there is a risk of people or animals damaging the drain, make sure that the construction is strong enough (*e.g.* use gabion rather than dry stone construction).
- Once the drain is completed, backfill around it and compact the fill thoroughly.
- Apply appropriate bio-engineering measures to enhance the effectiveness of the drain.
- Where the site requires deeper drainage and the machinery is available, drains can be drilled into the slope.

Table 1 gives comparison details of the main drain and cascade types.

Drain type				
Structure	**Bio-engineering**	**Main sites**	**Advantages**	**Limitations**
Surface drains				
Unlined natural drainage system (rills and gullies already developed on bare surfaces).	Grasses in the rills and gullies, and grasses and other plants on the sides.	Existing landslide scars and debris masses.	By far the cheapest form of surface drain. Rapid drainage is assured.	There is a risk of renewed erosion in exceptionally heavy rain in weak materials.

Unlined earth ditch system.	Grasses and other plants on sides and between feeder arms.	Slumping debris masses on slopes up to 50º, where the continued loss of material is not a problem (*e.g.* in debris masses well below a road, draining straight into large rivers)	By far the cheapest form of surface drain.	There is a serious erosion hazard, especially on steep main drains, so this type should be used only where further erosion is not a problem. Leakage into the ground may also occur.
Unbound dry stone system of ditches.	Grasses between stones (as vegetated stone pitching), and grasses and other plants on sides and between feeder arms.	Almost any site, however unstable, where the ground is firm enough to hold stone pitching and the flow of water is not too excessive for this construction technique.	A low-cost drain type. Strong and very flexible. These two features make it good on unstable slopes.	A membrane of thick, black polythene may be required to stop leakage back into the ground.
Bound cement masonry ditch system.	Grasses and other plants on sides and between feeder arms.	Only on stable slopes with suitable material for good foundations.	A strong structure for heavy discharges.	Relatively high cost. Very inflexible, so there is a high risk of cracking and failure due to subsidence and undermining.
Wire bolster cylinders (herringbone pattern).	Grasses and other plants on sides and between feeder arms.	Almost any site, however unstable, without excessive amounts of stone, but where the ground is firm enough to hold the structure. The drainage discharge should not be excessive.	A medium-cost shallow type of drain. Very strong and flexible, which makes it good for unstable slopes.	A membrane of thick, black polythene may be required to stop leakage back into the ground.
Open gabion ditch system.	Grasses and other plants on sides and between feeder arms.	Almost any site, however unstable, where the ground is firm enough to hold a relatively big structure, and where a large volume of discharge is possible.	A large and high-cost type of drain. Very strong and flexible, which makes it good for unstable slopes.	A membrane of thick, black polythene may be required to stop leakage back into the ground.
Dry stone cascade.	Grasses and other plants along the sides.	Any slope section steeper than 50º, where foundations are adequate and discharge is relatively low.	A low-cost form of cascade with a degree of flexibility.	A membrane of thick, black polythene may be required to stop leakage back into the ground.

Mortared masonry cascade.	Grasses and other plants along the sides.	Very stable slope sections steeper than 50º, where foundations are very good.	A strong structure for heavy discharges.	Relatively high-cost and inflexible cascade type, so there is a high risk of cracking and failure due to subsidence and undermining.
Gabion cascade.	Grasses and other plants along the sides.	Any slope section steeper than 50º, where foundations are adequate and discharge is likely to be high.	Very strong and flexible, which makes it good for unstable slopes.	A relatively large and high cost cascade type. A membrane of thick, black polythene is required to stop leakage back into the ground.
Concrete cascade.	Grasses and other plants along the sides.	Very stable slope sections steeper than 50º, where foundations are very good.	A very strong structure for the heaviest discharges.	Very high cost and inflexible cascade type. The risk of cracking and failure due to subsidence and undermining is partly offset by the innate strength of the construction.

Sub surface Drainage System

Drain Type

Drain type

Structure	**Bio-engineering**	**Main sites**	**Advantages**	**Limitations**
Sub-surface drains				
French drain system (perforated pipe (of durable, high grade black polythene, 150 mm diameter with approximately 40 holes of 5 mm per metre) in a drainage medium of aggregates). Drain can be made more resistant to disruption by building it in a casing of gabion	Grasses and other plants along the sides and between feeder arms.	Almost any site, however unstable, where the ground is firm enough to hold the structure and the flow of water is not too excessive for this construction technique.	A relatively low-cost and common sub-surface type of drain. Very flexible, which makes it good for unstable slopes.	A membrane of permeable geotextile should be used. If the flow is too great, piping may occur underground. The outfall must be monitored to check that the drain is functioning, but the hidden nature of the drain means that this cannot always be fully ascertained.

Site-specific design of drain to pick up seepage water. An open ditch or a drain with a flexible gabion lining is preferred.	Plant grasses and other species along the sides.	Any slope with obvious seepage lines.	Specific drains can be designed for any site, leading to the optimum collection of water.	Great care is needed to ensure all seepage water is trapped by the drain. Movement in the slope may affect this.
Deep surface drain types (deeper versions of the surface drains described above, designed to catch shallow ground water seepage).	As for each surface drain type described above.	As for each surface drain type described above.	Open drains allow easy cleaning and repair, as well as monitoring of effectiveness.	The usual practical maximum depth is about 1.5 metres. Special care must be used to allow water to seep into the drains.

Construction Steps for Sub-Surface Drains

- The site to be treated should first be trimmed to an even slope: there should be no protrusions or depressions that will interfere with the bolsters; loose rocks should be removed if possible.
- Starting from the bottom of the slope, mark out the lines for the drains. The main drains should run straight down the slope; the branch drains should be at 45º to the line of the slope and each slanting piece should normally be 5 meters long (although the design must be flexible to take individual site conditions into account).
- Dig trenches along the lines, normally about 500 mm wide and 1000 mm deep.
- Lay a sheet of black polythene along the bottom and lower side, but not the higher side, of the branch trenches (but not the main drain trenches).
- Lay 1.3 m wide gabion bolster panels lengthways along the trenches.
- Inside the wire mesh, lay sheets of geotextile terram paper, cut to the same dimensions.
- Fill the main drain bolster with angular 40-70 mm chippings (aggregate). Stones must be poured in from above and packed firmly but at random within the mesh.
- Fold the terram paper carefully over the stones so that there are no gaps; then fold the upper edge of the wire bolster panel over the top and join it together.
- Repeat steps 7 and 8 for each of the branch drains.
- Tie the wire of the branches (or herringbones or ribs) to the wire of main drain (or spine).
- Backfill by soling (placing on end) around and above the bolsters with boulders of 100-200 mm size.
- Compact the material around the drains and clean away surplus debris as necessary.
- Implement bio-engineering works throughout the site.

CH-4: TRAFFIC ENGINEERING
TRAFFIC CHARACTERISTICS & TRAFFIC CONTROLS

Traffic Engineering is that branch of engineering that deals with the application of scientific principles, tools, findings techniques for a safe, rapid, convenient and economic movement of people and goods thereby ensuring the enough improvements in traffic performance of road networks and has through systematic traffic studies, scientific analysis a engineering applications. As Per Prof. Ress Blunder of California University:

"Traffic Engineering is the science of measuring traffic and travel the study of the basic laws relating to traffic flow & generation and then application of this knowledge to the professional practice of planning, designing and operating traffic systems to achieve safe and efficient movement of people and goods. Traffic engineering is closely associated with pavement engineering, urban planning, highway planning, human factor engineering etc.

Scope

The basic objectives of traffic engineering are to achieve efficient, free and rapid flow of traffic with least number of traffic accidents. The T.E. aspects /scope are mainly

1. Traffic characteristics such as vehicular and traveller
2. Traffic study such as volume, speed, accident, parking, O and D etc.
3. Traffic operation such as control, sign, signal, marking etc.
4. Design such as intersection, parking, terminal, lighting
5. Traffic planning such as mass transit, traffic management etc.
6. Traffic administration such as engineering, enforcement, education and environment etc.
7. Research and development etc.

Traffic Threshold for Road Up gradation: There is some provision of traffic threshold for road upgrading in the policy document of DOR, i.e. "Design Standards for feeder Roads (3rd Revision), 1997. Further the Capital investment in the road in the form of upgrading shouldn't be made until additional benefits are assured.

This can be generally achieved when:

Combined cost of maintenance roads + cost of upgrading, same cost on upgraded (Recurrent & Periodic) + voc

Maintenance and voc will increase with higher traffic levels, the determining factors for upgrading a road from le stage to the next is the level of traffic that actually wing the road.

Analysis of total transportation costs (construction/ upgrading lance, voc) for a range of traffic levels on the earthen, gravelled and bituminous roads has been done by Would-Bank Computer-based "Highway Design and Maintenance" standard model (HDM III/IV). A standard graph of total transportation cost" vs "Traffic level" is maintenance, plotted for each construction standard from which threshold value for traffic required for upgrading the road been determined. For simplicity, Dor working group has slightly modified the threshold values given by the graph as follows:

Threshold for upgrading from:	Traffic level Hill	VPD Flat
Stage II (FWET) to stage III (FWGT) (Earthen to Gravel)	50	100
Stage III (FWGT) to stage IV (AWBR) (Gravel to Bituminous)	150	250

Capital Cost:

ER: E/w + side drain (earthern) + culvert stream crossing excluded.
GR: Cost of earthen roads & cost of gravelling.
BT: Cast of Gravelled Road & Bituminous Road with shoulders.

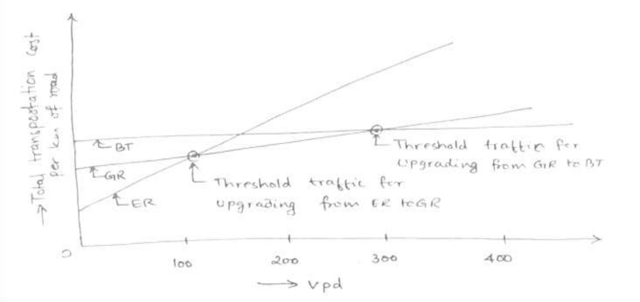


Fig.: Threshold traffic for Upgrading

Traffic Control and Road Safety:
Road safety is the most important aspect of highway and traffic engineering Road safety ensures the reduction on the traffic / road accidents. Usually in all road designs, road safety is taken as an important parameter and level of serviceability of roads have always to be accompanied with road safety.

Status of Road Accidents in Nepal:
Recorded Casualities per year by accidents=1200

Vehicle Type	% of total accidents
Motorcycle	43%
light vehicles	28%
others	29%

Accident scenario:

Area	Urban
Urban	48%
Highway	29%
Rural	23%

- 30 ~ 40% are found to occur after Sunset.
- 40% of recorded casualities are young (15-40 yos) people.
- Pedestrians are mostly effected
- Highly accident cluster area are bridge approach, road intersections, built-up area. Three major causes of accidents are:
  - ~ Driver's negligence,
  - ~ Overtaking (unsafe),
  - ~ Alcohol consumption
- other causes are due to road conditions.
- As a result of this, wood safety issue has been very strongly addressed by Dor.

The safety status of roads is not satisfactory in Nepal to due the following factors:
- Poor road condition, lack of proper maintenance,
- Road under LRN are not constructed as per design standards in geometrical and other aspects.
- Safety fund is inadequate. Existing fund is not effectively utilized to improve accident prone clusters, Inconsistent road width, bridges not matching road width
- Insufficient road safety measures such as signals, signs, other road safety appurtenances etc.
- Lack of attention to safety of pedestrians, etc.

About 1.3 million people are killed and so million injured un road accidents worldwide and the fatality rate is high in Asia or developing countries w.r.t. developed European countries.

Country	Nepal	India	Bhutan	B'desh	Thailand	Austria	Spain
Fatality/ 10000 veh.	15	13	15	13	25	3	4

- In Asia, 1% of GDP Accident Cost
- Road accidents cause heavy losses to economy due to loss of output, charges incurred in hospitalization/treatment, damage to vehicles and property etc.
- UK Transport Research Laboratory (TRL) indicates Fatality rate per licensed vehicle is very high in developing countries than in industrialized countries.

Road safety in various stages of Highway System:
I safety is a very essential parameter in almost all the stages of highways. Right from planning stage up to the operation/maintenance phase it can't be ignored Road safety is an essence for the following stages: "

a) Planning stage:
- Careful planning of the land use and zoning should be one accordingly so that travel is minimized. Residential areas should be separated from industrial and Commercial areas.
- Road and streets shall be classified into a systematic hierarchy.
- Towns and villages along the route should be bypassed or served through 'spur' roads.

b) Highway Design for Road Safety: or Highway Design Consideration for Road Safety (Exam)
- Design speed (preferably 85th percentile speed) shall be very carefully selected as per terrain and road class,
- Roads must have minimum SSD, OSD wherever possible or else suitable precautionary sign shall be installed,
- Provision of large radii, adequate super elevation, transition curves and avoid of sharp curves as for as possible, good shoulders in level of carriageway shall be provided in single and intermediate lanes narrow roads.

- Vertical curves shall be fully contained within the horizontal curves to avoid shocks.
- Broken-back horizontal curves is curves in the same direction separated by a short tangent shall be replaced by a single curve. If unavoidable, minimum tangent length of 10 sec travel time should be ensured.
- Climbing lanes are desirable for small vehicles to safely take heavily loaded trucks on long sections of a Road with steep gradients.
- Embankment ride slope should be as that as possible to avoid causality in case of accidents.
- Texture of pavement surface should be sufficiently lough to avoid skidding.
- Proper and adequate provision for road signs and markings,
- Reflectorised road markings, road delineators for road safety at nights enhancing risibility,
- Provision of proper and adequate safety appurtenances like safety barriers, delineators, road/ street lightings etc.
- No short valley curves
- No sharp horizontal curve at top of summit curve, bottom of valley curve
- Flatter H and V curve at intersection
- Adequate provision of setback and super elevation
- No long tangent section more than 3km to avoid driver’s monotony
- Pedestrian sidewalks (with slopes such that wheel chairs can also travel) should preferably be raised above the head level by providing kerbs of suitable height and pedestrian quard rails.
- Elegant junction design with channelization, acceleration & deacceleration lanes, separate right turn pockets, signals & markings

"Road safety during to achieve safety is the control of recognized hazards to achieve an acceptable level of risk".

3) Road safety during construction stage & Maintenance stage:
- Before some distance of work undergoing install the informatory boards at both ends as "Work under progress"
- Proper management of construction and non-construction works at all times,
- Suitable bypass/ diversion provided as for as possible
- Equipment needs to transport materials, workers to the site,
- Manhole covers and other accesses to utility services shall be opened for a limited time whenever needed and then closed immediately after the work is finished.
- well trained and experienced persons involved in the supervision of works related to signing, lighting, guiding construction works,

4) During operation:

- Adequate signs and signal Systems
- Good low enforcement,
- have disciplines etc

Road Safety Audit CR S.A.):

A Road Safety Audit (RSA) is defined as the formal safety performance examination of an existing or future road of intersection by an independent, multi-disciplinary team. It qualitatively estimates and reports on potential road safety issues hazards and identifies probable opportunities for improvements in safety for all road users.
"Prevention is better than cure" (principle) The main objective of RSA is to answer the following questions:

- What elements of the road may present a safety concern to what extent, to which load users and under what circumstances?
- What opportunities exist to eliminate or mitigate the identified safety concerns?

Road safety audits are often pro-active investigations, rather than reactive investigations of site with histories of complaints and poor safety performance. The RSA differs from the traditional / conventional traffic safety studies in following ways:

(i) RSA is performed by a team independent of project while in conventional system it may not be completely independent of the design team.

2) RSA is done by multi-disciplinary team conventional team is with only design and/or safety expert.
3) Considers all potential road users us considers motor vehicles,
4) Accounts for road users' capabilities and limitations.
5) Often generates a formal RSA report,
6) Often generates a formal response report.

Benefits of RSA:

The RSA has the following advantages:
1) Arrive at a design to result into safer roads to reduce:

- societal costs of collisions,
- the number and severity of crashes,

2) Identifying safety issues and correcting them before the projects are built thereby reducing the throwaway and reconstruction costs to correct identified roads with safety deficient safety issues,
3) Life cycle costs are reduced since safer designs often carry lower maintenance costs,
4) Promote awareness of safe design practices.
5) Integrate multimodal safety concerns,
6) Consider human factors besides motorized vehicles in all phases of design,
7) Liability claims that comprise of both agency and Societal costs, are reduced.

Stages of RSA:

There are three basic forms/ stages of RSA:

1) Audit of existing network:

To check a road or network for consistency to make sure that a road user (human, vehicles) does not encounter unexpected road safety issues.

2) Audit during various stages:

- Feasibility stage or project scoping when the general nature of project is determined,
- Preliminary Design Stage, when alternate course of action for the project are analysed, selected or discarded,
- Detailed design stage, Construction stage, to make sure work zone traffic controls are protecting load users and workers,
- Preopening stage, to make sure the completed project is performing as intended.

3.) Thematic Audit:

Thematic audits focus on a particular aspect of a road. They may be used to investigate road safety issues brought up by road user groups, or audits conducted to support a land development application.

The RSA should cover various aspects of highway facility which include:

- Horizontal and vertical alignment,
- Visibility at bends and intersections,
- Cross-sectional elements i.e. kerbs, medians, shoulders etc.
- Intersection elements,
- Roadside furniture's and ancillaries,
- Profiles for earthworks in embankment & cutting,
- Drainage considerations,
- Road markings, load signs/signals, safety appurtenances.

Legal Provisions for Road Safety in Nepal

- Transport Management act, 2049,
- Public Road act, 2031
- Local Governance act, 2055
- Road Board Act , 2059

DOR: For Road Safety:

DoR is a responsible organization in the aspect of Nepal to maintain road safety standards through its branch Traffic Engineering and Safety Unit CTESU). It has Conducted following actions till now in the field of road safety.

1) Road safety Audit Manual, 1997 has been developed to perform RSA for various stages,

2) DOR has made RSA mandatory for :

- all new construction and maintenance/rehab of NH&FR,
- all major new construction or rehab/ all works, for busy junctions, all signing schems of Urban Roads.

3 Input of Road Safety engineer is taken for all type of detailed a feasibility study in Consultancy works,

4) DOR designing roads based on following & key principles:

- Designing for all road users,
- Providing a clear and consistent message to drivers,
- Encouraging appropriate speed and behaviour by design parameters,
- Reducing conflict areas,
- Making allowances for the impaired driver,
- creating forgiving Roads (roads that ensure that when a mistake is made fatal and serious injury crash outcome doesn't result).

DoR for Road safety: – contd" CROAD Safety Manual - Grist) To make Road Safety issues institutionalized DoR has in issued a Road Safety Audit manual back in 1997 which envisages that for has always been issue on this issue. A separate Traffic Engineering and Safety Unit (Tesu)" was formed inside of Dot to look into this expect (which is now renamed as Road 4 Traffic Unit CR Unit (RTU)). With the various advancements in the technology DoR may be looking forward to update he provision but the theme this manual still is efficient way a traffic". till date.

With a basic principle of "Prevention is better than cure, the manual has defined Road Safety Audit as "A systematic method a chocking the safety aspects of load schemes in order to detect potential Safety Hazards before the road is open to traffic". It aims at performing the safety Audits on all the National Highway and important feeder & Urban Roads as well. The Safety Audit shell be done at:

Stage 1 feasibility Audit

Stage 2: Draft Design

Stage 3: Main Audit during Detailed Design

stage 4: Pre-opening, find Audit

The TESU has been assigned as the focal unit of DoR for these works Projects for Safety Audit are supposed to be referred to TESU either by DDG, Foreign Cooperation Branch or by the project Manager himself "The Earlier a road is Audited for design and development, the better"

Various Stages of RSA

S.N.	Stages	Responsibility of:
1	Refer Project of TESU	DDG as Project Manager with Consultations from DG

2	Receive DPR, Survey Reports Design by TESU	PM
3	Study DPR, Plans A site Inspecting	TESU
4	Meet & discuss with the Consultants & designers	TESU
5	Conduct the Safety Audit	TESU
6	Prepare reports to PM & DG	TESU
7	Discuss and agree on the changed to be made with PM 4 DG	TESU & PM together with DG
8	Completion meeting with Designers 4 PM report corrections to designs team, 4 to DG fox final approval	PM
9	Follow-up	TESUE.PM with Project implementation Team

The key Principles set by DoR through this manual are:

1. Design for All Road Users,
2. Provide a clear and Consistent message to the driver,
3. Encouraging appropriate speeds and behaviour by design
4. Reducing conflicts,
5. Making Allowance for the bad or impaired Driver
6. Creating a forgiving Road.

Common Problems Identified by RSA Manual:

1. Inappropriate use of design standards,
2. Schemes ignore Roadside Communities
3. Signings are Inadequate
4. To little attention given to creating a forgiving Road,

RA Checklists:

RSA checklists are prepared for roads as follows:

- National Highways & feeder Roads with AADT >1000, upd
- National Highways & feeder Roads with AADT >150 rpd
- National Highways & feeder Roads with <4000 vpd
- Feeder Roads and other Rural Roads with AADT <150 upd The details on Checklists are described as follows:

Checklist No.	Checklist Description	key Details
1	Planning	- Development plan or Strategy? - Design Adequacy? - Route fitness & service? - Junctions Appropriateness & frequency? - Harmful routes avoided? etc
2	Cross-Section	- lanes, medians, shoulders as per standard? - Narrow sections - side drains - Transition between existing road 4 project road?
3	Alignment	- Design speed? - Sigh Distance? - Major inconsistencies in the alignment? - fitness of horizontal & vertical Alignment? - Grades as per design - Transition between existing road & project road?

4	Road Site communities & facilities	- Traffic signs near approach of big towns or villages - Pedestrian Safety Provisions - Parking provisions - Improvements
5a 5b	Junctions General	- Safely located? - Suitable Type? - Adequacy & Junction/ - Proper Signals at entry & exits? - Adequacy & standardisation? - Adequate provisions for pedestrians and non-motorized vehicles? - Adequate night Lighting?
5c 5d	Additional checks for Roundabouts	- Simplicity Geometry? - Too many entries for safe, efficient operation 1 Roundabouts Enough separation? - Entry path, entry speed within 50 kph? - Adequate visibility at entry, & roundabout? - forgiving Island design for errant vehicles - Needs of pedestrians, cyclists & non-motorize vehicles considered? - Adequacy of signs & Signals? Paints & locations etc.
6	Special road uses	- Surrey a pedestrians & non-motorized vehicles, - Conflicts between road users? - Crossing for pedestrians? - Guardrails at footpath to reduce accident - I risk for children's - Needs of cyclists & non-motorised vehicles? - Bus stops? - Separate lanes if volume of motorcycle traffic is justified (for towns)
7	Signs, markings and lights	- Various aspects & Road Signs placements lightings etc.
8	Road Side Hazards	- Roadside Hazards parapets, designs & placements! - poles or columns to disturb traffic flow - Safety banner?

Nepal Road Safety Action Plan (2013-2020):
As per UN estimates, nearly 1.3 mil people die from Road Traffic Accidents CRTAs) per annum ire more than 3000 people die every day in average. Also, about 30-50 mil people get injured annually leading to disabilities annually due to RTAs and 90% of such fatalities often occur in how and middle-income countries having even less than half of the world's registered fleet. They also result in a huge economic loss to countries worldwide and especially developing countries can ill offered such massive losses. Recognizing this fact, UN Road Safety Collaboration (UNRSC) was established in 2004 to better address global road safety issues It has issued a call for a decade of action for its member countries to be dedicated in road-safety issues.

It has issued on the mandate of UN Global Action, Nepal developed has developed Road Safety Action Plan (ASAP) (2013-2020) in live with the Global action plan.

About 1.20 million of motorized vehicles (approx.) have been registered to in Nepal by f.4. 2010/11 as per DOTM records. Survey has been done in various regions of the country and reports are Issued.

Based on past research and monitoring the findings on TAs in Nepal are summarized as under:

- About half of all the RTAs nation wise occur in Kathmandu valley alone where almost half of total fleet fly.

- Severity of RTA injuries and fatalities among the vehicle sheet are higher in the region outside than Kathmandu valley. Pedestrians are the most vulnerable groups in accidents because the pedestrian - safety is often under-rated.
- People between 15-40 years of age are often affected followed by those above so years of age.
- In are dominant while urban areas RTAs due to motorcycles than in rural areas comprise mostly of bucks and bus accidents.
- About 13% of total fatalities 4 31% of total serious injuries are found in long distance routes & hence are of serious concern.
- About 30-40% of total accidents occur after sunset when traffic is low wherein driver negligence, drunk driving, random parking reckless pedestrian crossing, poor conditions of roads are major causes,
- Accidents are mostly clustered at intersections in urban roads while at bridge approaches, intersection & wad side built-up areas in Highways.
- The economic loss due to RTAs in Nepal is found to be at least Rs. 27 bill ($41.2 mill) as per conservative estimates.

Road Safety strategy:

The detailed formulation of the road-safety strategy is proposed as one of the main activities of this action plan. The brief outline of the strategy is as follows:

Vision:

Safe road infrastructures and services backed with effective post-crash response and conducive environment resulting in little or no causalities from RTAS. **Mission:**

i) Mitigate loss of life, properties & economy from RTAS.
ii) Complement broader mission of National Strategy on the prevention and control of violence, injuries and disabilities.
iii) To meet the targets of the UN Decade of Action.
iv) To provide a common framework for stakeholder agencies to implement the various interventions, required to mitigate the outcomes of RTAS.

Nepal RSAP:

In line with un global action plan, Nepal RS AP (2013-2020) was produced in February 2013 to address for the road safety issues & minimize RT As. It has five pillars as follows:

Pillar No:	Description
1	Road safety and Management
2	safer loads and mobility
3	safer vehicles
4	safer Road – Users
5	Post - crash Response

The five pillars of SAP (20 13-2020) are discussed below:

No: 1- Road safety and Management:

Main objective

i) i)Adopt UN legal instruments,
ii) Encourage creation of regional road safety instruments,
iii) Improve horizontal coordination
iv) among stakeholders,
v) iv)Develop sustainable rood –safety strategies of reduce accidents,
vi) improve accident data collection and research.

Proposed key Activities:

i) i)Establish the National Road Safety Council(NRSC)
ii) ii)Train stakeholders
iii) iii)Amend the vehicle &Transport Management Act 1993,local self Governance Act,1999 & develop various guidelines,
iv) iv)Develop a national road- safety strategy and implementation modality,
v) Reliably, scientifically compile, analyze the RTA statistics and research on effective countermeasures.

Pillar No: 2 - Safer Roads and Mobility:

Main objectives:

The objective of this pillar is to improve Inherent safety of all road users especially most vulnerable groups (i.e. pedestrian, bicyclists and motorcyclists etc.). It is due by:

- Adopting UN & international standards to design safe roads,
- Road safety Audits and arresements.
- Incorporating safe design practice during design, construction

Proposed key Activities:

i) Develop load safety audit manual for non-strategic roads and gradually enforce safety audits in all roads both SRN and Non-SRN.

ii) Introduce compliance in policy for safety audit compliance recommendation for both SRN and non-SRN,

iii) Develop design guidelines for safer roads and then construct required infrastructures to ensure road safety.

iv) Investigate accident black spots for all road types and instruct appropriate counter measures.

v) Enforce work-zone safety from construction to DLP in all road projects 4 contracts,

vi) Establish road-safety units in DOLIDAR and municipalities in valley along with DOR,

vii) Train stakeholders on safe loads and safety audits,

Pillar No-3: - Safer vehicles:

The main objectives of this pillar are to:

- Adopt both active and passive technologies available for safer vehicles,
- Create harmonization with the global standard, publicity and incentives for the consumers in their adoption.

Proposed key Activities:

i. develop and introduce standards for safer vehicles, spares.
ii. Amend VT MA 1993, VT MR 1997.and develop national transport policy to reinforce safes vehicles.
iii. Review route-permit procedure,
iv. DOTM institutional development,
v. Financial incentives to promote in-vehicle safety devices
vi. Improve vehicle inspection problem.
vii. Research major public vehicle accidents, school bus safety and intitiate mitigation countermeasures.
viii. Basic repair and maintenance training for public vehicles

Pillar No-4: - Safer Road Users

Main objectives:

Develop comprehensive programs to improve road-users behaviours through

i. sustained, stronger reinforcement of traffic rules,
ii. sustained road safety awareness campaign.,
iii. Increased effort to improve use of seat belts &helmets,
iv. Reduce drunk drinking and other risky behaviours,
v. Introduce better speed control,
vi. Heavy penalty to undisciplined road users including pedestrians.

Proposed key Activities:

i. Amend VT MA 1993, UT MR 1997. to invigorate safe road-users,
ii. Strictly enforce use of seatbelts & helmets, safety of public transport and develop comprehensive code-of-conduct for all road- users,
iii. Public awareness campaign and research for all road-users,

iv. Include road-safety education in school curriculum and update with regular revisions,
v. Train drivers & other road users,
vi. Improve driving license produce scientifically,
vii. Establish road safety units in DoTM and develop the institutional capacity of traffic police,
viii. Construct modern driving training centers & enhance capacity.

Pillar No-5:- Post-Crash Response

Main objectives:

i. Improve post-crash response,
ii. improve capacity of health care systems to provide emergency treatments after serious crash/ accidents,
iii. long-term rehabilitation of crash victims.

Proposed key activities:

i. Introduce toll-free telephone number for RTA emergencies,
ii. Develop ambulance policy for post-accident treatments and training for emergency treatments.
iii. Develop strategy and introduce revolving fund for RTA victims and disabled. iv.) Open Trauma case centers and train for RTA injured
iv. Research and prioritize treatments for serious injuries from RTAs
v. Develop, introduce comprehensive injury surveillance system in hospitals, health centers,
vi. Establish road safety units in the Ministry of Health and population and institutionally enhance it,
vii. Develop ambulance network along the major highways, urban and rural loads.

ROAD ACCIDENTS.

Road accidents occur when a vehicle collides with another vehicle, pedestrian, animal, road debris or other stationery obstruction such as tree or utility poles etc. such collisions may result into vehicle / property damage, fatal injuries and even deaths. One of the main objectives of traffic engineering is to ensure safe traffic movements. Road accidents can't totally be prevented but by suitable traffic engineering and management, the accident rates can be considerably decreased.

Accident studies:

A traffic engineer needs to carry out systematic accident studies to investigate the causes of accidents and to take preventive measures in terms of design and control. It is essential to analysis every individual accident and to maintain Zone-wise accident records. The various objectives of accident studies are to:

- study the causes of accidents and to suggest corrective treatments at potential locations,
- Evaluate existing designs & support proposed designs,
- Carry out before and after studies to see improvements,
- Compute financial losses,
- economically justify for improvements suggested by engineer.

Causes of Accidents:

The main causes of accidents are:

1) The road and its condition:

- Road design and geometry being defective, inadequate width, inadequate SSD/OSD, improper lighting, lack of traffic control devices, inadequate provision for provision and non-motorized traffic.
- slippery or skidding road surface, pot holes, ruts and other damaged road conditions.

2) The Vehicles:

- Condition and extent of maintainable condition,
- Condition of brakes, steering, lighting systems tyre bursts
- And other defect in the vehicles,

3) The Drivers:

- Excessive speed, rash driving, carelessness, violation of rules,
- Age, sex, training, drunken driven, psychological effects,
- driver judgement, failure to see or understand the
- situations, signs or signals
- Fatigue caused by long drives, sleep or alcohol etc.

4) The Road Users:

- Pedestrians violating rules and regulations, lack of knowledge
- Carelessness in using carriageway meant for road traffic.
- Passengers getting in/out from moving vehicles

5) Environment and other factors:

- foggy, poor visibility, heavy rainfall, snowfall etc. - Cattles and stray animals on the road,
- Incorrect signs and signals,
- Ribbon settlement development,
- Risk encroachment,
- Overloaded vehicles,
- badly located advertisement boards and service stations.

Traffic Safety: Theoretical Aspects with respect to the Haddon Matrix

Road Accident is Due to

		Factors		
Phase		Human	Vehicles and equipment	Environment
Pre-crash	Crash prevention	Information Attitudes Impairment Police enforcement	Roadworthiness Lighting Braking Handling Speed management	Road design and road layout Speed limits Pedestrian facilities
Crash	Injury prevention during the crash	Use of restraints Impairment	Occupant restraints Other safety devices Crash protective design	Crash-protective roadside objects
Post-crash	Life sustaining	First-aid skill Access to medics	Ease of access Fire risk	Rescue facilities Congestion

Period	Human Factors	Vehicle Factors	Roadway/Environment Factors
Before Crash Factors contributing to increased risk of crash	distraction, fatigue, inattention, poor judgment, age, cell phone use, deficient driving habits	worn tires, worn brakes	wet pavement, polished aggregate, steep downgrade, poorly coordinated signal system
During Crash Factors contributing to crash severity	vulnerability to injury, age, failure to wear a seat belt, driving speed, sobriety	bumper heights and energy adsorption, headrest design, airbag operations	pavement friction, grade, roadside environment
After Crash Factors contributing to crash outcome	age, gender	ease of removal of injured passengers	the time and quality of the emergency response, subsequent medical treatment

Pre-crash phase

necessary to select all countermeasures that prevent the crash from occurring.

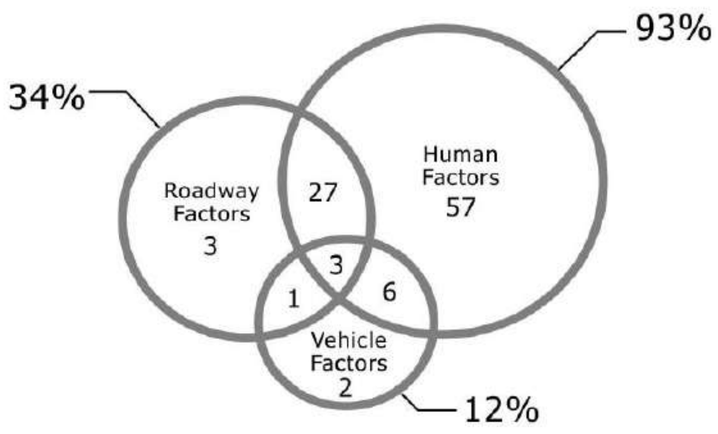
Crash phase

associated with countermeasures that prevent injury from occurring or reduce its severity if it does occur.

Post-crash phase

involves all activities that reduce the adverse outcome of the crash after it has occurred.

Approximate Distribution of causes



Source: Treat 1979

Safer Road Design Approach

Road design

- Safety cantered road design
- Road classification and setting speed limits according their function
- Safer intersections, roundabouts, separate lanes, road dividers on highways
- Timely road maintenance and rehabilitation
- Improving visibility of road users
- Bollards and fences between pedestrian paths and road
- Geometric elements as per standards.
- No sudden changes in standard along highway
- Better coordination of horizontal and vertical alignment as road alignment is 3D object
- Pavement surface characteristics (skid resistance)
- Construction of by-passes and service lanes
- Design and construction of grade separated intersections
- Road lighting
- provisions bus/truck lay-byes

- service roads
- junction improvements
- overhead signs, cautionary /regulatory/ informatory retro-reflective sign boards at suitable distance.
- crash barriers, median railings
- road markings, traffic lights and delineators, etc
- Provision of on street parking facilities and zoning
- Shallow drains
- Flat embankment slopes
- Adequate setback distance (poles, bridge parapets etc.)
- Flexible safety barriers
- Correcting erroneous traffic signs

Safer Vehicle

Four organs of safer vehicles

Modern and appropriate vehicles
Appropriate policy and law
Strong organizational capacity
Modern Licencing system

Consideration

- Vehicle construction has to confirm to the requirements of both active and passive safety
- Safety components such as, safety belts, laminated safety glass for windshield, instrument panel and lighting system, rear view mirrors, power steering in case of buses and heavy commercial vehicles etc should be mandated.
- Promote use of crash avoidance technologies
- Making engines not very powerful
- Speed limiters on existing vehicles
- Vehicles with better braking system
- Vehicles with appropriate crashworthiness criteria thus transferring less energy to occupants
- Padded interiors and absence of sharp objects
- Softer car and bus fronts
- Child restraint
- The regulations for an annual fitness check for both commercial and private vehicles.
- Yearly Pollution Under Control checks.
- Introduction of modern Inspection and Maintenance system.

Road user discipline

- use of helmets by two-wheeler riders, wearing of seat belts
- red light violation/lane discipline
- detection /prosecution of drunken driving
- prevention of plying of over loaded vehicles

Pedestrians' Safety

- be self-disciplined and strictly follow traffic rules and regulations
- utilize sidewalks/footpaths and overhead bridges wherever provided
- always cross at marked cross walks or traffic lights.
- If the footpaths do not exist, walk on the sides of the road and not on the middle of road
- ensure that they are clearly visible to drivers before crossing roads, and cross roads only when traffic completely stops.
- At traffic lights, only cross on green signals. Never cross the road on red lights, and be patient and wait for the green signal
- be extra careful at turning points and intersections, because at such points the visibility for drivers is worse

Road safety management

- encouraging alternative travel modes
- route permitting of public vehicles, vehicles road worthiness, disposal of old vehicles
- speed limits on roads
- area wide traffic calming measures
- daytime curfews for trucks in cities reduce the number of crashes involving pedestrians
- traffic control at roadwork sites
- demerit point system and license suspension
- fixed penalties
- DUI legislation, enforcement
- Environmental streets

- Access control
- Intersection control (yield sign, stop sign, road markings, intersection channelization, traffic signal)
- One-way streets
- Reversible lanes
- Signalized pedestrian crossings
- Stopping and parking control
- Bus lanes and bus stop design
- Variable message signs
- Dynamic route guidance
- Increased enforcement
- Public awareness
- Observance of laws and regulations
- Establish graduated driver licensing programmers for novice drivers

Other policy level issues related to road traffic safety

- Organizational structuring
- Data management and sharing
- Quantified road safety targets
- Motor vehicle taxation
- Road pricing, congestion pricing
- Land use plans, road plans and construction
- Changes in modal share of travel

Identifying and Treating Accidents:

1) Identify Accident clusters - taking causality data for clusters.
2) Accident data collection - Data from police records,
3) Preliminary accident analysis -Checking the site against norms,
to identify factors - Checking accident natures, (Identification and analysis I - Stick diagram/collision diagrams of various accident factors) - Analysis of accident factors.
4) Site visit to access road - for access of road condition and other engineering with inspecting road cross-section, road geometry & road surface.
5) Further studies (Traffic - Traffic counts, speed surveys, road Characteristics, conflict study, user behaviour, conflict studies, safety parameters) Physical safety parameters studies,
6). Develop radial measures
- cost-effective long-term user friendly
– B/C analysis - First year rate of return (FYRR)
7). Detail design and implementation,
- details design, site trial, fund arrangement implementation.
8). Monitoring & Evaluation (Rectification if needed)
- Initial observation in first few days & weeks, before/after studies,
- Record keeping - Rectifications (If any).

Accident studies and records:

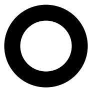
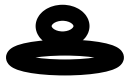
The various 7 Collection steps involved in Traffic Accident studies are:
Collection of accident data:
-General Date, time, persons involved with their particulars, seriousness of injury i.e., minor, fatal, serious etc
-Location: Description and details of the location,
- Vehicles: vehicle details like registration number, vehicle
model, loading details, vehicular defects etc.
–Nature of: Condition of involved vehicles, collision details, Accident damages, injuries, causalities, pedestrians or objects involved etc.
-Road and traffic condition: geometry, surface characteristics (wet or traffic and dry) traffic types, traffic density etc.
-Causes: various possible & primary causes of accident,
- Costs: Total cost of damage, injuries & causalities etc.

II) Accident Report:

- Legal authorities should be reported ASAP like police more especially in serious case of injuries, causalities or severe damage to property.
- Separate report of individuals involved.
- Based on data collected, accident report with all facts is prepared which is useful for subsequent analysis in future, claims for compensation etc.

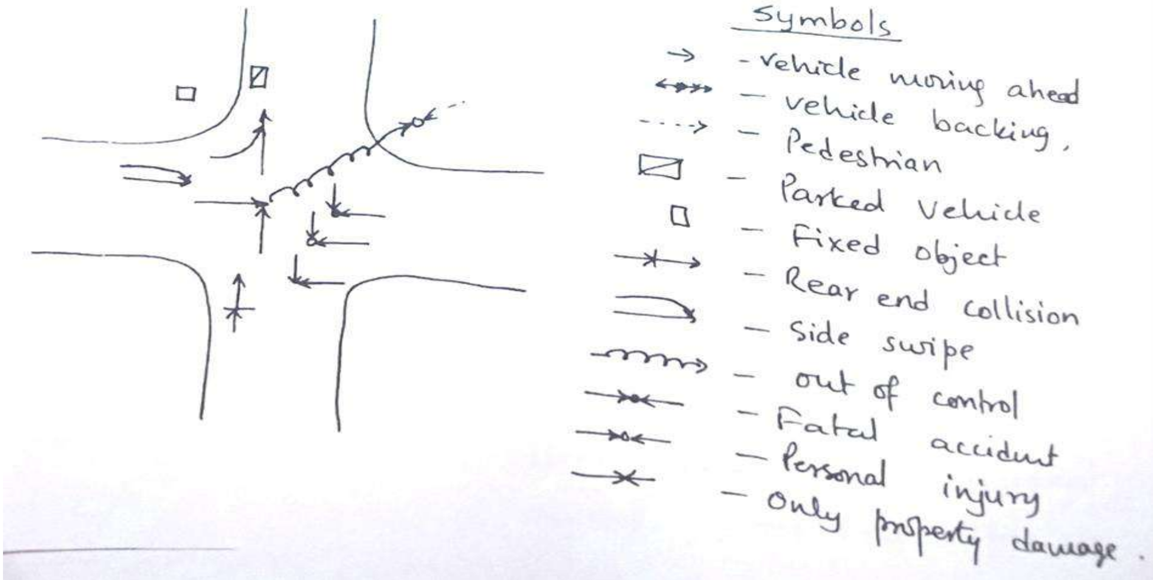
II. Accident Records:
The accident records are maintained giving all particulars of the accident, location and other details. Following records are kept:
a) Location files:
- to keep location of accident and identify accident prove zones,
- Location files maintained by each nearby police station,

b). Spot Maps:
- Spot maps show accidents by spots, pins or symbols
- on the map. A suitable scale of say 1 cm= 40~60 m may be used for spotting urban accidents.
- Common legends used in spot maps are:

Type of Accident	Fatal	Non-Fatal
- Motor vehicle- pedestrian - Other vehicular traffic		

c) Condition Diagrams:
- All-important physical conditions of an to be studied are shown in scale.
- Important features to be shown include roadway limits, trees, details of the curves, verbs, bridges, culverts, Sad way conditions, obstruction to vision, property lines, signs, signals etc. which are shown by standard symbols.
- If required, condition and collision diagrams may be combined together in a single sketch, if necessary.

d). Collision Diagram:
- These diagrams approximately show the path of vehicles and pedestrians involved in the accidents.
- collision diagrams are most useful to compare the accident pattern before and after the remedial actions have been taken.



Accident Investigations:
Following investigations may be carried out to scientifically Analysis accidents on a systematic basis:
A) Recording General Observations:
- Lengths of skid marks due to full / partial skidding,
- relative position of vehicles/ object involved and collision diagrams supplemented with photographs.
- Details of accident injuries and damages.
- Roadway /pavement conditions and environmental conditions,
- Condition diagrams with relevant measurement and dimension.

b) Driver Tests:
- Alcohol consumption test using Breathalyzer or by spinal fluid for a dead driver.
- Test on driver characteristics like reaction time, judgment of distance, angle of clear vision etc. for night incidents, tests on glare vision, glare recovery etc.

c) Skid Resistance:
- Skid resistance of pavement surface measured by portable pendulum type skid resistance tester or another suitable device.

d) Vehicle Tests:
- General vehicle condition, test on essential accessories,
- Condition of brakes and steering,
- details of dents, other objects involved and cross-sectional details of the collapsed members.

e) Probable Causes of the accident:

It involves on the investigations of causes (primary probable Secondary and contributing causes) of the accident, its type, site conditions, position of vehicles, other objects involved and other existing conditions.

f) Cost Analysis:

Estimation of the cost of accident is worked out by the cost involved for the following items:
- injuries and fatalities of persons involved,
- Damage to vehicles
- Damage to property,
- Other consequences including traffic delay,
- Investigations and legal proceedings.

Analysis of speed from skid Resistance:

Let S = Braking distance or skid resistance,

W= weight of the vehicle, v, v2 = initial & slowed down final speed

$KE = \frac{1}{2} mv^2 = \frac{1}{2} w/g\ v^2 = wv^2/2g$

Reduction in K.E. = Work done against friction

$W/2g\ (V1^2 - V2^2)$ = Force {W. f} * Distance (s)

$= W/2g(\ v1^2 - V2^2) = W.\ f.\ s$

$= v1^2 + 2gfs$

Measures for reduction of accidents:

the rate measures, often called as "3-Es" to decrease of accidents and minimize damages if they occur are

1. Engineering,
2. Education and
3. Enforcement

1) Engineering Measures:

a) Road design:

Optimized geometric features like sight instance, pavement width, horizontal and Vertical profile, intersection elements, surface Characteristics etc.

b) Preventive maintenance for vehicles:

Braking system, steering and lighting Maintenance for arrangements, checked frequently theory Vehicles penalties to defected found. More needed public carries.

c) Before & after studies:

After accident investigations, implications Studies of corrections. Before and After studies test the efficiency of preventive measures.

d) Road lighting:

Proper road lighting specially at intersections, bridge sites and where there's restriction to traffic movement.

2.) Enforcement Measures:

a) speed control:
- Develop disciplined speed habits.
- Surprise checks on spot speed at selected locations at frequent intervals & timings & legal actions to violators.

b) Traffic Control:
- signs, signals, markings etc. maintained Devices
- and corrected time to time.

c) Training and supervision:
- Training before licensing & supervision after licensing Renewal of license only after certain checks.

d) Medical checks:
- vision and reacting time at suitable frequencies preferably three years

e) Special Precautions:
- For commercial vehicles provision of conductor / attendant to give direction.

f) Observation law:
- by legal authority / traffic police

3) Educational Measures

a) Education of Road Users:

for all road users, pedestrians and passengers. It should preferably be started from school level. Posters, pamphlets can be provided at places.

b) Safety Drive:

Imposing traffic Safety weeks where drivers are refreshed about safe driving Training courses, films, documentaries may be provided.

- Traffic Control Devices and safety traffic Appurtenances: the various aids and devices used to control /regulate the traffic control devices. They are:

a) Road signs:

- They are backed by law to enforce the regulation purposes, give timely warning of hazardous situations when they not self-evident lack of SD etc.
- Regulate traffic by imparting messages to the driver for stopping, give away, limit speeds etc.
- supply information on highway routes, directions etc.

The road signs are of following 3 types:

i. Cautionary / warning signs: to warn wad users of the hazardous situations on or adjacent to roadway. Eg: Humps, steep grade, cycle/ pedestrian crossing narrow bridge, falling rocks etc.
ii. Mandatory / Regulatory signs: mandate users about the certain laws, regulations, restrictions etc., the violation of which is a legal offence. Eg: Speed .89 limit (40), no parking P, one-way, stops & give way etc.
iii. Informatory signs: To provide guidance to the new or regular road users in direction, place identification, roadside facilities, petrol pumps, chainages, parking and non-parking areas etc.

b) Traffic Signals:

These are needed for the control and orderly movement of conflicting streams of vehicular and pedestrian traffic more specially at intersections. Green (G), Red (R) and Amber (A) lights are used for Go, stop, stop-see-Go If properly designed and set, they can assist to assign right of way impartially to traffic unlike manual control which can stop, interrupt traffic streams at personal whim of a traffic controller. They are of:

i) Traffic control signs:

- Fixed timed
- Manually operated
- Traffic Actuated

ii) Pedestrian signals:

- red & green

iii) Special signals:

- flashing amber signs to stop -see - go.

c) Road Markings:

These are lines patterns, words or other devices except signs set into, attached or applied to road elements for controlling, warning, guiding & informing road users.

Role of markings:

- Guide, control, psychological barrier for traffic,
- delineator for traffic path & clearance from hazards.
- Help cyclists / pedestrians to channelize to safe Locations

Eg: Center-lives, traffic lanes, no parking/ overtaking zones.

d.) Safety Appurtenances:

These are becoming increasingly necessary with the increasingly speeds and higher volumes of traffic plying on a highway. They include:

- Road delineators: indicates, hazard & object markers etc.
- Traffic impact attenuators.
- Roadside reset areas.
- safety barriers, edge barriers, median barriers etc.
- Traffic Aid posts.

Traffic Regulations

Traffic regulations cover all aspects of control of vehicles, drivers and all other road users. The laws & regulations give legal coverage for strict enforcement of following 4 phases:

1. Driver Control: through driving license, driver test, financial responsibility, civil liability.
2. vehicle control: registration, requirements, equipment's,
3. Dimensions &weight limit of vehicles.
4. Flow Regulation through direction, turning overtaking,
5. Speed limit, prohibiting signs etc.
6. General Control: To report accidents, recording and disposing traffic violation cases.

Maintenance of Traffic Control Devices & Safety works: There are 3 types of major maintenance works

1) Preventive Maintenance:

- Activity to prevent deterioration failure,
- Need of inventory database,

2) Routine Maintenance:

- Minor maintenance, repairs,
- Vegetation clearance
- cleaning
- Replacement of aged signs and signals.

3) Emergency Maintenance:

- Replacing missing signs or other devices due vandalism, storm, accident or floods etc.
- Development of priority system for response of emergencies.

4) Pavement Marking Maintenance:

Maintenance of:

- center lines,
- Edge lines,
- Transverse lines
- Symbols & miscellaneous markings

TRAFFIC ENGINEERING

As discussed earlier, "Traffic Engineering" is that branch of engineering which deals with the improvement of traffic performance of road networks and terminals by:

- scientific traffic studies.
- scientific analysis and engineering application.
- planning and geometric design.
- Regulation and control

Traffic engineering therefore deals with the application of scientific principles, tools, techniques and findings for safe, rapid, convenient and economic movement of people & goods. The basic objective of traffic engineering is to achieve efficient, free and rapid flow of traffic with least number of traffic accidents. The study of traffic of traffic engineering is divided into following categories:

1) The human elements is involved in all action of the road user either as a pedestrians, cycle car driver or a car driver or a motorist. Study of characteristics and limitations of the road users is important as the physical, mental and emotional characteristics of human beings affect their ability to safely operate their vehicles or act as a pedestrian.

The various factor which effects the characteristics of the road user may be broadly classified as follow:

- **physical characteristics are of:**
  - permanent characteristics like vision, hearing, strength and the general reaction to traffic situation.

- ➢ Temporary characteristics due to fatigue, alcohol drugs, sickness etc.
- ➢ Both these characteristics reduce alertness and increase the reaction time and increase the reaction time effecting judgment in some situations.

- **Mental characteristics:**
  - ➢ Knowledge, skill, intelligence, expensive, literacy, attitude etc. can affects the road user characteristics:
- psychological characteristics:

These include emotional factor like attentiveness, fear, anger, superstitions, impatience, maturity, attitude etc.

- environmental factors:

These comprise of traffic stream characteristics, facilities of the traffic, atmospheric conditions and the locality. They also include weather visibility and other atmospheric condition.

2) vehicular characteristics:

A road can be designed for any vehicles but not for an indefinite vehicle as such various vehicular characteristics that effect the design and traffic performance such that the road car can cater existing and anticipated traffic.

Vehicular characteristics are of following types:

- Static characteristics: that affect road design are the Dimensions, weight, maximum turning angle etc. for eg:
- the height of driver's seat effects visibility distance and height of headlight effect headlight SD at curves.
- Length of vehicle affects the capacity, OSD and the manoeuvrability of vehicles.
- Gross weight, axle and wheel loads of vehicle governs the structural design of pavements and cross drainage.
- Dynamic Characteristics: of vehicles affecting road design are speed, acceleration, breaking characteristics vehicle body design.

Vehicle Dimensions:

- width effects width of traffic lanes, shoulders and parking facilities. Capacity decreases.
- Height effects clearance (vertical) in various places.
- length effects safe OSD, road capacity and parking

Facilities

- Weight of loaded Vehicles: Maximum weight of loaded vehicles, affects the design of pavement thickness and design gradients. Limiting gradients are governed by both the weight and power of the heavy vehicles.
- Power & speed of vehicle: Power of a vehicle generates speed of vehicle which is the main governing factor in design of almost all the geometric features.

Some useful relations' If u= Initial/Average speed,

t = duration of brakes applied,

Braking length,

Laag

retardation,as y

-skid

resistance,

f =

Also, 0100

Average skid resistance=42

(for given braking)

distance

= off tracking - 1 2 3

(la kaue tengt width of wheel bare, Ra Radius of werve

TRAFFIC STUDIES

Traffic Studies are carried out to analyses the traffic characteristics which help in designing / deciding the geometric features and traffic control for safe and efficient traffic movement. These include:

1) Traffic volume study,

2) Speed studies

- spot speed study
- speed and delay study

3) Origin & Destination (O&D study),

4) Traffic flow characteristics,

5) Traffic capacity study,

6) Parking study

7) accident study.

1) Traffic Volume Study:

Traffic Volume is the number of vehicles crossing a section of road per unit time at any selected periods common units include veh/day, veh/hr. counting:

- Mechanical Counters,
- Manual Counters

Presenting of traffic volume data:

- Annual Average Daily Traffic (AADT)/(ADT),
- Trend charts showing volume trends over period of yrs,
- Variation charts showing hourly, daily and seasonal variation,
- Traffic flow maps along the routes,
- Volume flow diagrams at intersections,
- 30th in highest hourly volume or Design hourly volume.

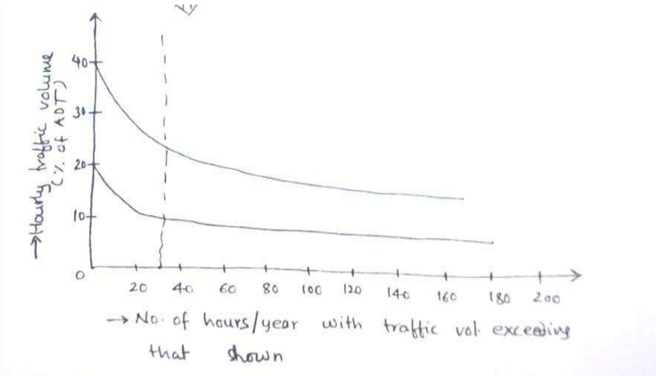


Fig: 30th Highest/Design Hourly Volume.

The 30th highest hourly volume is derived from the plot between hourly volume and the number of hours in an year traffic volume is This exceeded. On context, "The 30th highest hourly volume is the one that be exceeded only 29 times in a year and all other hourly volumes of the year are less than this value. Also called as design hourly volume, this value has a good significance due to following reasons:

- The highest or peak hourly volume of the year will be too high that it will not be economical to design facilities according to this volume,
- The Annual Average Hourly Volume (AAHV) found from AADT will not be sufficient during considerable period of a year.
- There will be congestion only during 29 hours in a year.

2) Speed on roads fluctuate w.r.t various factors like geometric features, traffic conditions, time, place, environment and the driver. The speed studies are of following two types:

a) Spot speed study

b). Speed & delay study

a) Spot speed Study:

Spot speed studies are useful in:

- -Planning traffic control and in traffic regulation,
- Geometric Design,
- Accident studies,
- Study of traffic capacity,
- Decide speed trends,
- Compare diversity of drivers and vehicles under specified conditions.

Means:

- Enoscope, graphic recorder, electronic meter, photo electric meter, radar speed meter, photographic methods etc.
- of all of them, radar speed meter is most efficient as it can measure spot speeds instantaneously and also record them automatically. However, it is very expensive.
- Enoscope, a mirror box, supported simply by a stand is used due to its ease of use.

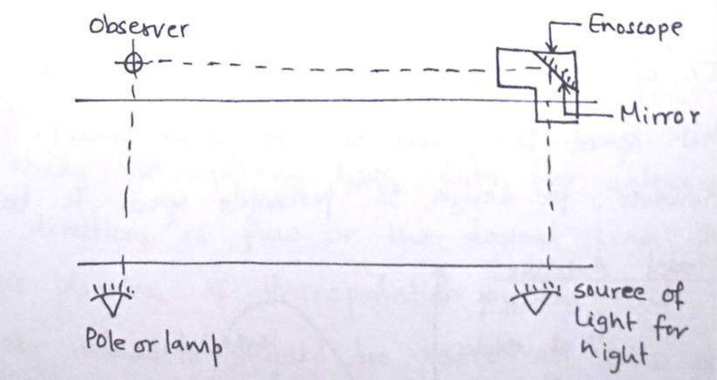


Fig: Spot speed Study by an Enoscope.

Presentation of speed Spot Data:

i). If Average speed of vehicles:

- from spot speed data, frequency distribution from various speed ranges vehicles in such range.
- The arithmetic mean is taken as "Average speed".

II) Cumulative speed of Vehicles:

A graph is plotted as below:

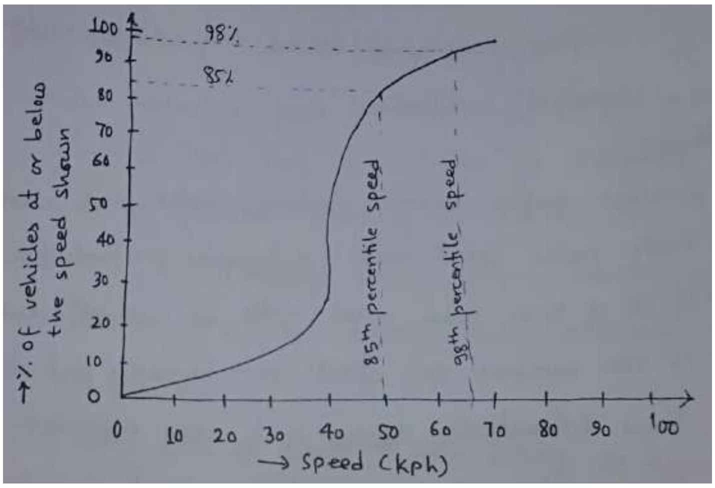
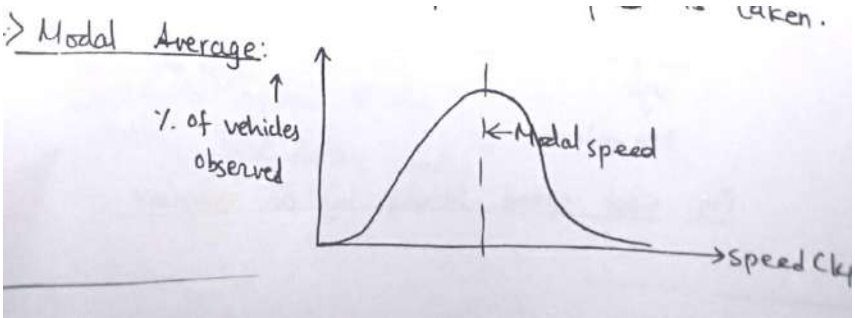


Fig: Cumulative Speed Distribution

- 85th percentile speed is the speed at or below too which 85% of vehicles are passing or only 15% vehicles than above that speed. It's taken as safe speed limit.
- However, for design 98th percentile speed is taken.

III) Modal Average:



- Elevated Observations,
- Photographic methods.
- License

3) Origin and Destination (O&D) Studies:

O&D studies are carried out mainly to:

- Plan the road network and other facilities for vehicular traffic.
- Plan the schedule of different modes of transportation for the trip demand,

O&D study provides the basic data for determining the desired directions of flow or the desired lines. This the scientific planning of transportation system and mass facilities in cities should be based on of data of passenger trips. This as well helps to estimate future traffic needs with socio economic study.

b) speed and delay studies:

It gives running speeds, overall speed, fluctuations in speed and the delay between two stations. It also studies the delays due to congestion at different spots, causes and their measures. They are also used to find the travel me and to carry out Benefit -to-cost (B/C) analysis.

Techniques:

- Floating Car or Riding Check Method,
- License plate or Vehicle Number Method,
- Interview technique,

The various applications of O&D studies are:

- Judge adequacy of existing routes and new networks,

- Plan transportation system and mass transit facilities in cities including routes and schedule of operation,
- locate expressway and major routes,
- Establish preferential routes,
- Locate terminals and plan terminal facilities,
- Locate new bridges,
- Locate intermediate stops
- Establish design standards for roads, bridges, culverts etc.

Techniques:

- Road Side interview method,
- License Plate method,
- ~ Return Post Card method,
- ~ Tag on car method,
- ~ Home Interview method,
- ~ Work spot Interview method.

4). Traffic flow characteristics and Studies:

Study of traffic flow characteristics includes both transverse and longitudinal distribution of vehicles in the traffic stream which is useful in design features like traffic capacity, volume number of lanes and width of Carriage way. It's especially essential for large intersections to decide regulatory measures like one-way movement and

5). Traffic capacity studies:

Relevant Terminologies:

- traffic volume: number of vehicles passing through a given point or section along a given direction during a specified unit (veh/hr, veh/hr)
- traffic density: number of vehicles occupying a unit length of a lane of a roadway at any instant.
- Traffic volume= traffic density *speed (veh/hr)
- traffic capacity: ability of a roadway to accommodate traffic volume. It is expressed as the maximum no. of the vehicles in a given point in a unit time (i.e hour).unit –(veh/hr)/lane.
- Basic/theoretical: the maximum number of passenger cars that can pass a given point on a lane or roadway per prevailing conditions.
- Possible capacity: The maximum number of vehicles that can pass a given point on a lane or roadway per hour under the prevailing conditions.
- Practical capacity: also called as "design capacity", it is the maximum number of vehicles that can pass a given point on a lane or roadway ignoring delays and restrictions.

The Theoretical Maximum Capacity or Basic Capacity for single lane is given by

c=1000.v/s

c = Theoretical max. capacity, [= speed (kph),

s = Avg. c/c spacing of vehicles.

Following factors affect practical capacity:

~ lane width,

~ Lateral clearance,

~ Width of shoulders,

~ Commercial Vehicles

~ Alignment of roads,

~ Intersections etc.

- Design Capacity and Level of Service (LOS):

The capacity flow or the maximum possible flow on a roadway or on a traffic lane is attained at a particular optimism speed. Speed, when is higher or lower than this, results all decrease flow in a streamline with no chances of overtaking.

At such a condition in a roadway, when the "volume to capacity ratio" approaches a maxi mum possible value 1. e. 1.0 (i.e. volume contained by the road reaches its capacity), the Los is considered to be fairly low.

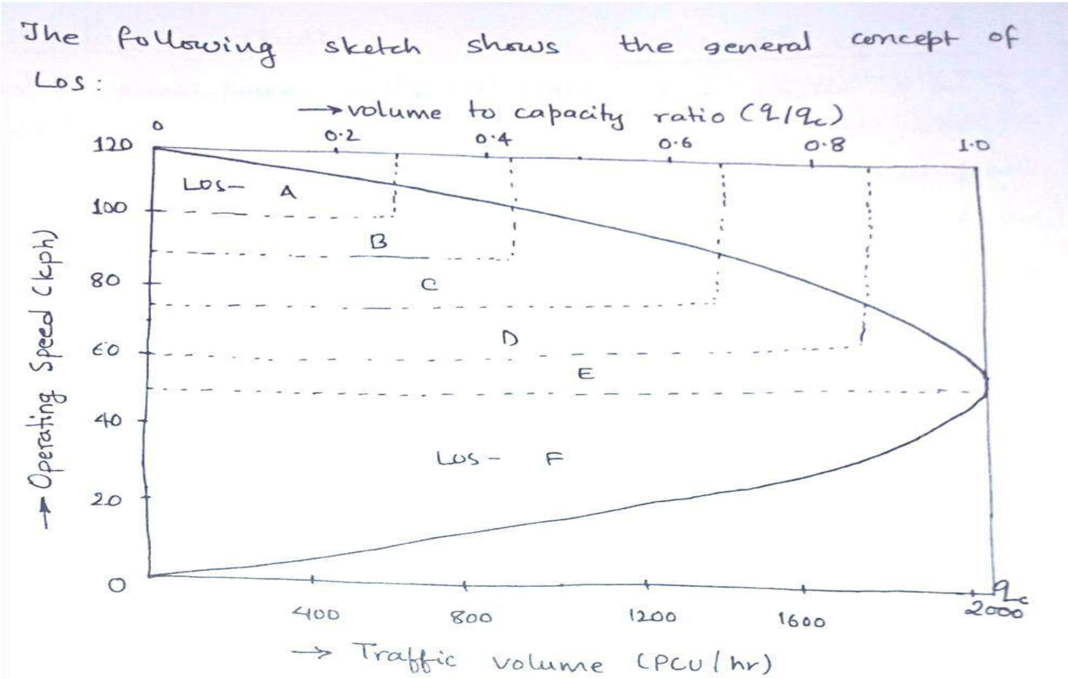


Fig: General Concept of Los

LOS-A: Volume to capacity ratio low free flow with design speed. Overtaking possible, comfort riding.

LOS-B: Zone of stable flow with speed at or near free flow with some restrictions.

LOS-C: Still in zone of stable flow, speed now more closely controlled by higher volumes.

LOS-D-E: Unstable flow, volume rising towards capacity. Speed & manoeuvrability goes on limiting.

LOS-F:Vol/Capacity ~1.0, forced flow at low speed. There's a time".

Passenger Car Unit:

In a mixed traffic flow condition, comprising of cars, vans, buses, trucks, auto, bicycles, motorbikes, bullock carts etc. it's very much difficult and complex is estimating the traffic volume and capacity unless one Common standard unit is assigned to different categories of vehicles. In such a case, Passenger Car Unit (PCU) is taken as a standard vehicle w.r.t which other classes of vehicles are converted.

PCU way be considered as a measure of the relative space requirement for a vehicle w.r.t to a passenger car Under a specified set of roadways, traffic & other conditions.

factors affecting PCU

- Physical and dynamic characteristics of a vehicle
- Longitudinal and transverse gaps between vehicles,
- Traffic stream characteristics,
- Geometry of a roadway,
- Regulation and control of traffic,

- Environment and climatic conditions.

6) Parking Studies:

In urban areas and metropolitan cities, availability of parking space for automobile users is of a major importance. parking demand is especially high in commercial, residential and industrial areas having multi-stored buildings. As such, parking studies are important to evaluate the available facilities as well as to reach for new options if required.

Various Aspects:

1) Parking Demand:

Demand calculated by:

~ Making cordon counts of selected area,

Demand= Accumulated vehicles

= (Outgoing - Incoming) vehicles

Counting of vehicles parked in an area during the various working hours especially during peak hours.

Interviewing with people, users of selected area.

2). Parking characteristics:

Study of the prevailing parking practices in the selected area and the general practices found therein. Also the various parking patterns, interference to moving vehicles due to parking, accident cases due to parking are also studied.

3) Parking Space Inventory:

- proper place to meet parking demand surveyed and maps are prepared. Proper design for facilities is done.

Parking Patterns:

Generally, there are two types of parking patterns:

1). On-street - Parking:

The vehicles are parked on the edges / shoulders of a roadway separated from the main carriageway by some load markings. These are done in such a way that they cause minimum obstructions and hazards to the traffic flow on a

roadway. They Are of:

~ Parallel Parking - 90° parking (w.r.t alignment)

~ (Acute) Angle Parking

~ In-line parking

Angle

lasting line

I parallal (90°)

In-line - Road center line

2) Off - Street Parking:

Separate / Special provisions are made for parking in high demand areas free- of or with cost beyond the roadway or streets. They are of:

~ Surface Car - parking (open areas beyond roads / streets).

~ Multi-storey parking,

~ Roof Parking

~ Mechanical (Car) parking

~ Underground / Basement Parking.

Factors affecting Parking Demand:

Following factors have full impact on parking demands:

1). Parking Accumulation: No .g parked vehicles at a specified time,

2). Parking duration: Length of time over which the vehicles we the parking facility,

3). Parking Volume: Number of vehicles involved in parking

activity,

Occupancy: Ratio of facility available number of vehicles using the parking to the number of parking facilities at a specified time.

Traffic Signals.

Conventionally, at intersections having a large number of Crossings and light-turn traffic (For left hand drive system), traffic police were used to control traffic to provide orderly movements and to reduce accidents. Now, this has been replaced by the use of Traffic signals which are control devices used to direct the traffic to stop and proceed at intersections using red and green traffic signals automatically. The main requirements of traffic signals are to draw attention, provide meaning, and time to respond and to have minimum time waste.

Types:

1). Traffic Control signals:

- Fixed time signals,
- Manually operated signals,
- Automatic signals.

2) Pedestrian signals

3) Special traffic signals

Type of signal Systems:

1). Simultaneous system: all signals show same indication on a routes

2). Alternate systems all signals show opposite indications on a route.

3) Simple progressive system

4) flexible progressive system.

Design of Isolated fixed Time signal:

General principles:

1). Stop time or Red phase (R1) of route-1 is the sum

of 'Go' and clearance interval (i.e. Green + Amber) phase for the cross flow.

R1= G2 + A2

In this time, if there are no turning movements, the Pedestrian crossing time may also be incorporated.

2). At the end of Red Phase, amber- red lights are put on together for a short duration to indicate get-set-go. It's called 'Red- Amber' or 'Initial Amber at which the vehicles are not supposed to cross the stop line.

3). clearance time or clearance Amber Phase is provided just after the green phase before the red phase which should fulfill the following two requirements:

a) Stopping time for approaching vehicles before the stop lines as light signal changes from Green Amber Red.

b) Clearance time for vehicles within the intersection at

time from Green to Amber

4) Go /Green time is decided based on the approach volume during peak hours and to enable the queued Vehicles to clear off in most of the cycles.

Methods :

following given are some methods for signal design:

1) Trial Cycle Method:

- make traffic counts for the roads (say 1, &2) n1 & n2 for 15 min during peak flow conditions.
- if,c1= suitable trial cycle for say Road 1, then,

No. of cycles = 15*60/c1 = 900/c1, in 15 mins.

- Assuming time headway of 2.5 secs, the Green Periods

(G1 &G2) for roads 1 & 2 are given by:

G1 = 2.5n1.c1/900, G2= 2.5 n2. C2/900

Example:

Q.) n1 = 178, n2 = 142 15 min traffic count. A1=3 see, A2=2 sec, Avg. time-headway = 2.5 sec.

Design traffic signal timings.

Trial-1. Assume cycle length C;=C1=C2 = 35 secs, say

Then,

G1= 2.5n1c1 = 2.5*178*35/900

= 17.30 sees.

G2 = 2.5n2 C2 = 2.5*142*35/900

= 13.80 secs.

Total cycle length= 17:30+ 13.8 +3+2 = 36.10 >C1 ~ Trial -2 Assume Cii = 45 sees, then,

G1= 25 * 178*45/900 = 22:25

G2 = 2.5* 142 445/950 = 17.75

→ Total cyde length= 22.25 +17.75 + 3+2 = 45 secs =Assumed

2). Webster's Method:

This is a rational approach where the optimum cycle is determined based on:

- the saturation flow' per unit time, (s),

- the normal flow (q)' during design hour,

Design Steps:

Consider, qi= normal flow at road (i=1,2,...)

Si = Saturated flow on road (i=1,2,...)

2)find ratio, yi= qi/si

3)The optimum signal cycle (Co) is given by:

Co=1.5 L +5/1-y

where, 1-Y Y = Y,+ X2 + ...

L= Total lost time=2n+R

N= no.of phase

R= All-Red Time

4.) Then the green times are given by:

Gi= Yi/Y (Co-L)

example: q1= 400, q2= 250, s1= 1250, S2= 1000, n=2, R= 12 sec

y1=q1/s1=400/1250=0.32, y2=q2/s2=250/1000=0.95

= Y, +Y2 = 0.32+0.25 =0.57

L = 2n + R = 2*2 + 12 = 16 sec.

Co = 1.5XL+S = (1.5*16 +5/-0.57 67.5 » G, = 033(67.5-16) - 29 sec, 922 0:25 (67.5-16) >22.5 sec.

Assume, A.=A = 2sec

Total cycle length=29 +22 5+2 +2 +16=71.5sec.

Traffic Islands:

Traffic Islands are raised areas constructed within the roadway to establish physical channels through which the vehicular traffic may be guided. They often serve more than one function as:

- Reduce area of possible conflicts between traffic stream,

- Establish the desired lines of crossing & merging of traffic stream,

- Change the direction of flow of traffic stream,

- Convenient locations for placing other traffic control devices,

- Serve as Refugee islands for pedestrians.

Types:

1.) Divisional Islands:

- Separate opposing flow of traffic on a highway with four or

More lanes

- Head-on collisions and other accidents are reduces

- large width of island required if the head light glare is to be reduced during night driving

- Kerb should be unmountable, high enough to prevent vehicles from entering into the islands.

2) Channelizing Islands:

-Guide the traffic into proper channel through intersection area,

- Size and shape depends upon the layout and dimensions of the intersections,

- Considerable profession experience and still required for design because improperly designed and placed islands may lead to violation

3). Pedestrian Loading Islands

- Provided at regular bus stops and similar places for the protection of pedestrians,

- At places where crossings exist, they act as refugee islands

4) Rotary Islands

~ Control of Access on Highways:

-full or partial control of access on highways/ expressways is necessary to prevent ribbon developments and encroachments in increase in the number of accidents and a Considerable reduction in Los for vehicle operation.

- full control a access means the preference is given to through traffic by providing access connections with selected public loads only which prohibits crossings at grade or direct private drive way connection.

- Partial control of access may have some a private drive way connection and some crossings at grade.

- Express ways are divided arterial highways for motor traffic with full or partial control of access and generally provided with grade Reparation at intersections.

- Arterial highways are primarily meant for through traffic, usually on a continuous route and have partial control of access.

Design of Intersections:

- Intersections consist of through turning and crossing traffic, - Unavoidable except in the case of expressways or freeway systems where grade separation is provided for conflicting steams and access is controlled fully or partially,

- The efficiency, safety, speed, cost of operation and capacity of road systems very much depends upon intersection design,

Intersections

At Grade:

Grade Separated channelized Intersection

Overpass

A Underpass Unchannelized Intersection

Interchanges

- Diamond Rotary Intersection

- Rotary - Pastial Clover Leaf

[Full Clover leaf I)

Intersections at Grade:

There intersections meet at about the same level allowing traffic manoeuvers like merging, diverging, crossing, wearing etc.

Basic Requirements:

1.) As minimum area of conflict as possible,

2.) Relative speed and angle of approach of vehicle should be small,

3.) Adequate visibility,

4) No sudden change of path,

5). Geometric features like turning radius and width of Pavement should be adequately provided

6) Proper signs should be provided on the road approaching the intersections to warn the driven,

7). Good lighting at night is desirable,

8). In intersections with high volume of fast-moving traffic,

separate provisions shall be made for safe passage of non-Vehicular traffic like pedestrians, cyclists etc.

These types of intersections are of following:

a) Unchanneled Intersections:

- Whole of the intersection area is paved with no restriction to vehicles to use any part of intersection area,

- Lowest class of intersections and easiest in design but most

complex in traffic operations with maximum conflict area and a greater number of accidents unless controlled by signals / traffic police,

- plane Intersection: - No additional pavement width for turning movements,

flared Intersections: - Pavement widened by a lane or more in the intersection area

b) Channelized Intersections".

- Island are introduced into the intersectional area thereby reducing the total conflict area,

- The area, radius of entrance and exit curves are designed suitably to accommodate the channelizing island of proper

- These islands help to channelize turning traffic control their speed and angle of approach and to decrease conflict area at the intersection.
- Better control on the traffic entering and learning.

The various advantages of channelization are:
- vehicles confined to definite paths,
- Merging angles can be flattened to cause minimum dissention,
- Conflict areas considerably decreased,
- Angle between intersecting streams may be kept as desired in a favourable way.
- Speed control
- Refugee Islands for pedestrians,
- Points of conflicts can be separated
- signs and other traffic control devices can be kept over the channelizing islands.

c) Rotary Intersections:
This is an enlarged road intersection where all the converging vehicles are forced to move round a large central island in one (clock wise) direction before they can weave out of the traffic flow in their respective desired

directions radiating from the central island. Rotary eliminates the necessity of stop pine even for crossing stream of vehicles reducing the conflict area.

Factors affecting design of rotary:

1) Design speed,

2) Shape of central Island,

3) Radius and width of rotary roadway,

4) Wearing angle and wearing distance,

5) Width of carriage way at entry and exist,

6) Entrance and exit curves,

7) Capacity of rotary

8) Channelizing Islands,

9) Camber and Super elevation,

10) Sight distance, grade,

11) Lighting, Traffic Signs / signals.

12) Provisions for cyclists and pedestrians.

Condition when Traffic Rotary is justified:

- Lowest (number) limit of traffic volume on 500 vehicles all intersecting roads put together per hour
- Maximum limit of traffic volume when = 5000 veh/hr. totally may not function efficiently (AASHTO) = 3000 veh/hr (IRC)

IRC Recommendation for mixed traffic:

→ Intersecting motor traffic =50% (or more) of total traffic Fast traffic turning right = 30% (or more) of total traffic.

Advantages of Rotary:

1) No need to stop vehicles; consistent & comfortable journey,

2) All vehicles have equal opportunity as of those turning right,

3) less vehicle operating costs than in signalized intersections,

4) No need of traffic police or control devices,

5) Less risk of accidents,

6) Most advantageous when number of intersecting roads is between four and seven,

7) Highest Capacity of all the intersections at grade,

Limitations of Rotary:

1)Requires comparatively a large area of land and hence costly in built up areas

2) Not justified when pedestrian traffic is large as in urban areas

3) In case of mixed traffic conditions consisting of large number of pedestrians and cyclists, the design of rotary becomes to elaborate, operation / control of traffic gets complex,

4) Not suitable when angle of intersecting roads is acute of when there are more than seven intersecting roads,

5) Troublesome when distance between intersections is less,

6) Troublesome in case of large number of cycle and animal drawn vehicles,

7) Not justified in case of low traffic volumes.

II). Grade Separated Intersections:

Various types a bridge structures like T-beam, arch, prestressed and rigid portal frame type are used to separate the grades of the intersecting loads with clearance from 4.30m minimum to a as 5.20m if double one decked vehicle is anticipated the type of bridge structure is selected depending upon the design, construction other considerations like site conditions and aesthetics. They are of:

A) overpass:

The major highway is taken above by raising its profile above the general ground level by means of embankment and an over-bridge across another highway.

Advantages:

- -Reduction of troublesome drainage problems,
- wider road taken above smaller means span of bridge becomes less i.e., the cast of bridge structure will be less,
- Aesthetic preference to the main through traffic and less feeling of restriction or confinement.
- Future / Lateral expansion or construction of separate bridge structure for divide highway possible.

Disadvantages:

- It the major road in lolling terrain is to be taken above, the vertical profile will also have rolled grade line.
- If high embankments need to be provided by steep glades, the increased grade resistance results spread reduction in heavy vehicles,
- -Restriction in right distance if long vertical curves aren't provided.

b). Under-Pass:

if a highway is taken by depressing it below the ground to cross another by means of an under-bridge, it is called as an under-pass.

Advantages:

- Adequate sight distance, timely warning to traffic,
- Advantageous to turning traffic when major road is depressed because the traffic from cross road can accelerate while descending to the major highway and the traffic from major highway can decelerate while ascending to the cross road.
- Advantageous in economy when major highway is taken on its grade and cross road is depressed.

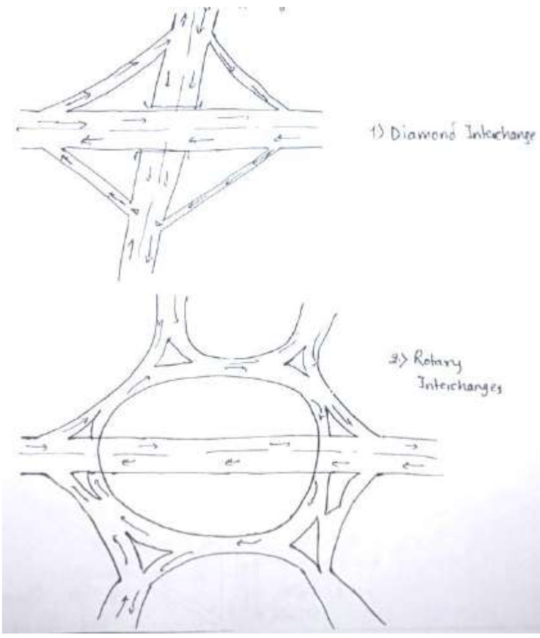
Disadvantages:

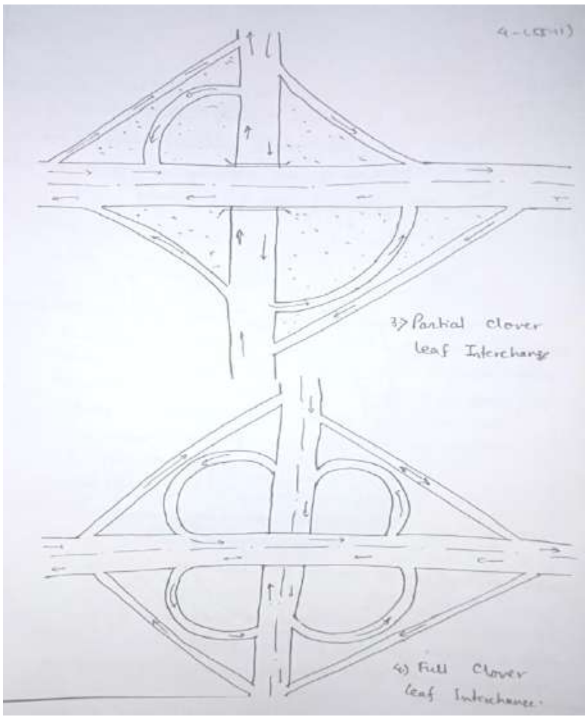
- Excess drainage and water logging problems specially during rainy seasons.
- The overhead structure may restrict the vertical sight distance even at the valley curve near the under-pass.
- feeling of restriction to the traffic at the sides and unless the
- clearance is sufficiently large, the capacity of intersection is affected
- No possibility for stage construction of bridge at under pass.

c.) Interchanges:

- -Grade separated intersection with complete interchange facilities as essential to develop a highway with full control of access.
- Perfectly fits when there is intolerable congestion and accidents at the intersection of two highways carrying very heavy traffic.

There are following types of interchanges


1) Diamond Interchange
2> Rotary Interchanges


3> Partial clover leaf Interchange
4) Full Clover leaf Interchange.

Highway Lighting:

The rate of highway accidents and fatalities during night driving is several times higher than that during day driving. Poor night visibility attributes to this cause among many other causes. Highway lighting is particularly more important at intersections, bridge site, level crossings and in is where there is restriction of traffic to movements.

factors affecting night visibility:

- Amount and distribution of light flux from lamps,
- Size of object
- Brightness
- Reflecting characteristics of pavement surface,
- Glare on the eyes of the driver,
- Time available to see an object,
- Brightness of the background

Design factors:

- Lamps (types, illumination power etc.),
- Luminaire distribution of light,
- Spacing of lighting units (s)

s= lamp lumen *coeff. of utilization & Maintenance factor/ Average lux *width of Road

- Height and overhang of mounting units,

Lateral Placement

Lighting

Layouts

-Single sided

- Double sided

- Central

Traffic congestion in Kathmandu Valley:

The population of Kathmandu valley including 3 districts is about 4 million. Due to accessibility to opportunities of jobs, education, health facilities etc. there's unexpected migration of on from rural areas of Nepal to Kathmandu Valley.

Facts:

- Registered Vehicles - 0.5 million (60% of entire - vehicle types: (In valley),

2 wheelers = 75% (0.5PCU), Cass- taxis = 10% (1.0 PCU),

Micros = 47. (1.5 PCU),

Trucks = 2%. (3:0 PCU),

Buses/others = 3% (3.0 PCU).

from these data’s, it is clear that the increase in cars and motorcycles in last 5 years is significant. The average Increase in vehicles in Kathmandu Valley is about 13% annually. The total of about 1500 km of road network in present in Kathmandu Valley among which the interior network is narrow and single lane. The average speed of vehicles in ring roads is <15kph and that on inside of ring roads is <8 kph. The condition of the pavement is also poor as a result of which congestion has become a major problem in Kathmandu valley,

Also, the transportation types are:

Public - 7%

Private - 85%

others - 8%

The road density in the valley is 14m per hectare lie. 5.6% of total developed land) which is very less in comparison with the growing traffic. Due to these reasons, traffic congestion has come out as a major problem and is remedy has been as essence for good service to the people in the valley

Impacts :

- High voc - loss in economy
- a Lengthy journey time, - loss of time,
- Health hazard, considerable gas emission,
- Aesthetically not good, bad appearance of city,
- Growing number of vehicles, need to meet demand.

Critical Problems:

Statement "Bottleneck junctions within core areas such as; kalimati. Tripureshwor Thapathali, chabahil, singh durbar, etc.

2.) Behaviour of Road Users:

- violation of laws and regulations,

- Random stopping and parking of vehicles,

- Overtaking behaviour of public vehicles.

- Pedestrian discipline being very rough,

3) Poor road conditions,
4) Considerable to relative number of able of private transportation relative to public transportation; rapid increment in motorization,
5) High concentration of two-wheeler vehicles,
6) Increment of footpath and roadway,
7) Surface water management, roadway flooding during rainy season specially in Jamal, Tripureshwor area,
8) Manually operated traffic signals
9) Poor/lack of provision for pedestrians,
10) Haphazard and unmanaged parking areas,

Existing Gon Rules:
- Pubic Road Act 2031: Row encroachment,
- Vehicle and Transport Management Act, 2049 (UTMA)
- VTMR
- Route Permission,
- Emission Tests etc.

Action Plan:

1) Improvements of junctions and road surface condition
2) Correction of road user's behaviours,
3) Discourage private transportation by introduction of very reliable public mass transportation,
4) Upgrade traffic operation mechanism,
5) Strengthening of linking roads and constructing new transport infrastructure,

6) Increase Los by decreasing service volume,

7) keep the road in serviceable condition, by backlog maintenance and effective planned maintenance,

8) Public awareness

Vision:

Obtain a Sustainable Transport for Kathmandu, Smooth and efficient traffic movement with a reasonable travel time.

Short term solutions:

1) Correction of road users behaviours by :

- Entry restrictions for pedestrians, Strict enforcement of traffic rules & monitoring,
- lane separation,
- Revision of Traffic Acts / Regulations

2) Development of river corridors

- Ongoing,

3) Maintenance of good road condition,

4) Clear road and footpath encroachment

5.) Re-evaluate the demand & supply of each route,

6) Install automatic traffic signal at Junctions after implementing junction improvement programs,

7) Building enough parking places for public/private vehicles,

8) Review drainage capacity and re-install proper drainage Structures for major roads,

9) One way traffic management of single lane loads connecting to ring road.

10) Stopping route permit issuance to new vehicles for a certain period of time,

11) overhead bridges / Underpass in busy road with 500-600 uph,

12) Campaigning frequently for public awareness,

13) Increase belief in public transportation system:

- -Change pattern of journeys,
- discourage two wheelers,

14) Pedestrian priority in old towns, i.e. Basantapur, Thamel etc. where restriction of vehicle entry is a must,

15) Widening of Ring Road, from Kalanki to Koteshwor is ongoing.

Long Term Solutions:

1. Separate master plan for town / cities,
2. Fly over / Cut cover tunnel at major junctions,
3. Mass transport: Monorail, Metro-rail
4. Reoperation and extension of trolly bus for ring road,
5. Giving shape to concept of outer-ring road,
6. Decentralization of services and facilities, " Traffic management cell DTM + DOR +Tp.

CH-5. CONSTRUCTION OF HIGHWAYS

Normally two types of pavements exist:

- Flexible Pavements and
- Rigid Pavements

Regardless of the type of pavements, they need to have the following desirable properties:

- "Structurally sound enough to withstand the stresses imposed on it,
- Should be sufficiently thick to distribute the loads and stresses a safe value on the sub grade soil,
- Should provide a reasonably hand wearing surface to reduce the abrading action of wheels,
- Should be dust-proof so that traffic is not impaired,
- should be smooth enough to provide comfort to road uses at the high speeds and to develop low friction,
- should have a texture and adequate toughness to avoid skidding of vehicles,
- Should be impervious to water,
- should be durable against weathering actions,
- Should have the least possible, maintenance and the Vehicle operating costs,
- should have sufficient visibility at nights

Highway Materials:

The various materials that make up the various pavement, layers are as discussed under:

1). Subgrade Soil:

Sub grade soil is an integral part of a pavement structure that provides support to the foundation from beneath. Due to these reasons, its properties are very important in the design of pavement structures so that it possesses enough stability under adverse climate and loading conditions. If the sub grade condition is poor, it may result in the formation of waves, corrugations, rutting and shoring in flexible pavement. In case of rigid pavements, pumping, blowing and consequent cracking of comment concrete takes place which demand the strength of sub grade soil.

Desirable Properties:

- Stability,
- Incompressibility,
- Permanency of strength,
- Minimum volumetric changes and stability
- Good drainage
- Ease of compaction,

It is a regular practice to see and check whether sub grade has these properties. California Bearing Ratio (CBR) test is a widely accepted one:

CBR TEST

California Bearing Ratio (CBR) test is a very well known procedure to evaluate the stability of the soil subgrade and other pavement materials.

Apparatus

- A cylindrical plunger of 50mm dia. to penetrate at the rate of 1.25 mm/min,
- A proving ring to record load values for penetration levels
- Mould to keep soil specimen with surcharge.

Procedure:

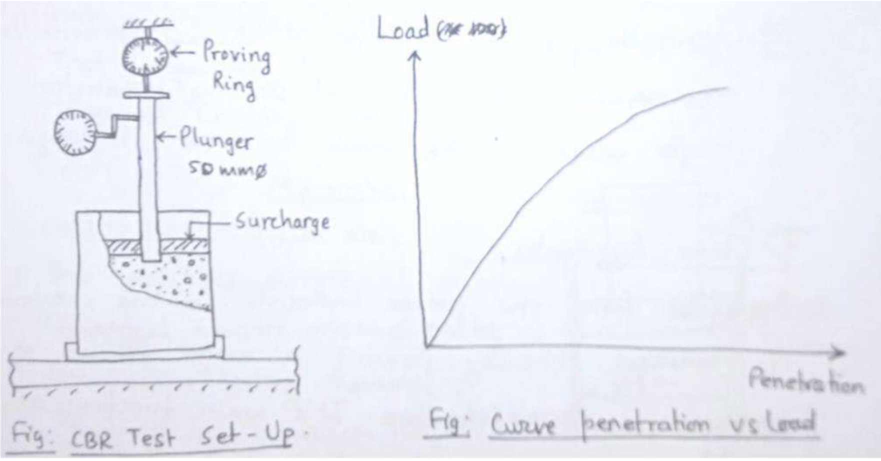


Fig: CBR Test Set-Up.

Fig: Curve penetration vs Load

- Specimen is taken in mould, soaked for four days, the swelling for soil & Water Absorption values are noted
- Surcharge weight is placed on the top of the specimen,
- Assembly kept under the plunger of loading frame

- Load values are noted corresponding to penetration values for 0.0, 0.50 1.00 1.50, 200, 250, 3.0,4 0,5 0,75 10.0 and 12.50 um
- A curve is plotted load values plotted with penetration us as shown in the fig. above.
- The CBR of the specimen is given by :

$$CBR = \left[\frac{\text{Load Sustained by Specimen @ 2.5 mm and 5.0mm value of penetration}}{\text{Load sustained by standard aggregates at same level of penetration}}\right]$$

Generally, CBR is higher at 2.5 mm penetration In case CBR is higher at 5.0 higher value of CBR should be taken penetration level, larger value of CPR should be taken in design.

2) Stone Aggregates:

Aggregates from the prime materials in the construction of pavement thereby forming a major portion of the pavement materials/structure. It's main functions are to:

- bear stresses due to wheel load,
- resist abrasion due to moving traffic.
- Cement Concrete pavements,
- Bituminous concrete
    - ~Premix
    - ~Asphalt Concrete
- Granular base course.

Desirable properties of stone aggregates:

Good load aggregates need to have the following desirable properties:

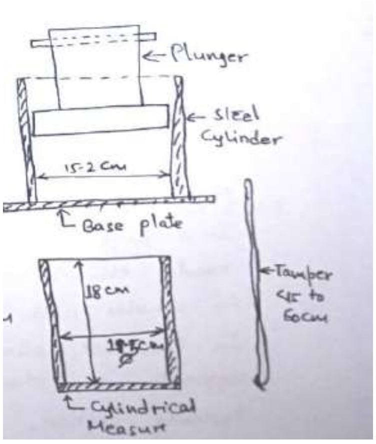
- Strength: - to resist stresses due to wheel load,
- Hardness: -Against abrasion due to moving traffic,
- Toughness: - Against impacts coming on the road surface,
- Durability: - Against adverse weathering actions (Soundness)
- Shape : - Proper shape reckons maximum strength,

- ❖ Adhesion: - with bitumen against affinity with water,
- ❖ Soundness: Impact

Tests on Aggregates:

1) Crushing Strength Test:

- -Test conducted to find the strength of aggregates.
- Aggregate Crushing Value (Acv) is determined



Apparatus:

- steel cylinder 15.2cm dia,
- Base plate and plunger,
- Cylindrical measure -11.5cm 8, 18cm ht,
- Compression testing machine,
- Tamping rod 45~60 cm height.

PROCEDURE:

Dry aggregate sample passing through 12.5mm and retaining through 10 mm sieve filled in cylindrical measure in three equal layers.

- Each layer tamped for a5 times by of test specimen is taken, W_1 say,
- Weighed sample place layers and again
- The plunger is placed load of 40 tones is applied @ 4 tons/min by a compression testing machine.
- The crushed aggregate is removed and served through a 2.36 mm seive. Let the weight of aggregates passing through 2.36 um seive is W2. This measures the agg. Crushed due to the applied load. Then,

ACV = w2/w1* 100%

The recommended values :

~For Surface Course. Acv *30%

~For Base Course, ACV *45%

2) Abrasion Test:

Abrasion test is done to measure the hardness of road aggregates against the abrasion (due to vehicle loadings). It is done by Los Angeles Abrasion Test (LAA test). In the roads there's a continuous rubbing action between the tyres of vehicles with aggregates.

In this test, abrasive charges are made to call with sample aggregates to determine the % wear due to the relative rubbing action.

Apparatus:

- Hollow cylinder with both ends closed internal diameter 10cm and length 50cm, it rotates about its horizontal axis when powered.

- C.I abrasive charges spheres with 4.8cm with weight 390~ 445 gms. The number of charges to be used depends upon the gradation of aggregates.

Procedure :

-5~10 kg of sample aggregates (based on gradation) is taken, (say W1) and placed on the abrasion testing machine

The machine is rotated @ 30~33 RPM for about soon 1000 revolutions based on gradation,

- Abraded aggregates are sieved through 1.70mm IS sieve and weight passing through it is taken and weighed (W2).

LAA (%) = W2/W1 *100Y.

Recommended values:

- For High Quality concrete works & surfacing, LAA <30%,

- For base courses, LAA up to soy is acceptable

1) **Soundness Test:**

Soundness test is conducted to measure the resistance of the aggregates against weathering action,

PROCEDURE:

- Aggregate sample immersed in saturated solution of Sodium sulphate or magnesium sulphate for 16-18 hrs,
- It's then taken out and dried @ 105~110% in even
- which completes a cycle of immersion and drying.
- Test cycles done for a predetermined numbers.

Result:

Loss in weight :
→ <12% when immersed in Sodium Sulphate,
→ <18% when immersed in Magnesium sulphate

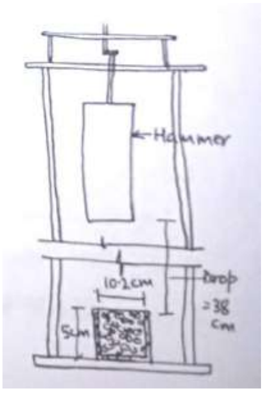
4) Impact Test:

- for testing toughness against impact

Apparatus:

- A cup of 10.2cm x 45cm ht. with specimen,
- Metal hammer of weight 13.5 ~ 14 kg with free fall of height 38cm.

Procedure:



- Aggregate specimen passing through 12.5mm and retained on 10mm sieves, filled in a cylindrical measure in 3 layers. Each layer is tamped for as times. Say W1 = weight of the specimen

- The specimen is placed on the test cup in three layers, each layer being tamped for 25 times.
- The specimen is blown by the hammer with a free fall of 38cm.
- the crushed aggregate sieved through 2.36 mm sieve after 2 15 blows. Let w2 weight of passing.
- Then, Impact Value = W2/W2 * 100 %

Impact value
*30% for wearing Course
$35% for BBM ,
$40%. for WBM.

5) Specific Gravity and Water Absorption:

~ Specific Gravity is the measure of quality or strength of the material.

~ Stones with high values of water absorption are porous and thus weak and vice-versa.

Procedure:

- 2kg of dry aggregates placed in wire basket & immersed in water for 24 hours
- Sample weighed in water and buoyant weight is found,
- Sample taken out, dried in oven @ 100N 110°C, dry weight is then determined:

Sp. Gr. = Dry wt. of aggregates / wt. of equal vol of water

Absorption Water Absorbed= Water AbsorbedX100%
Total weight

6) Shape Tests:

The shape of the aggregates plays vital they react role in how they react to loads and other external forces and impart strength Tests are done for:

- Flakiness Index,
- Elongation Index,
- Angularity number.

7) Bitumen Adhesion Test:

This test is done to check how well can aggregate adhere to bitumen so that problems like stripping don't occur. This test is done by following six methods:

1) Static Immersion Test,

2) Dynamic Immersion test,

3) Chemical Immersion test,

4) Mechanical Immersion test,

5) Immersion trafficking test,

6) Coating test.

Out of this static immersion test is mostly used, where

- Aggregates fully coated with binder is immersed in water at a specified temperature.
- Degree of stripping determined as % of stone surface stripped off after a specified period of time
- -stripping value >25% for various surfacing works when aggregates coated with bitumen is immersed in water for 24 hrs maintained at a temperature of 40°c.

3) Bituminous materials

Bituminous Materials

Asphalt/ Bitumen | Tar

Native Asphalt | Petroleum Asphalt (Bitumen)

- The term "Bituminous Materials" is generally used denote the substances in which bitumen is present or from which it can be derived. Bitumen is defined as an amorphous, black/dark coloured, cementitious (Solid, Semi-solid/viscous) substance composed principally of high molecular weight hydrocarbons and which are soluble in Carbon Disulphide.
- - Native Asphalts are those which occur in the nearest to pure state in nature. Native asphalts associated with a large proportion of mineral matter are called Rock Asphalts.
- → Bitumen or Petroleum Asphalt are obtained from fractional or destructive distillation of crude petroleum where in the portion of bituminous material present in the source widely differs with respect to the source from which it is derived.
- Tar doesn't naturally exist and is obtained as the condensates, in the processing of coal, petroleum, oil-shale, wood or any other organic materials.
- **Bitumen / Asphalt**
- The bituminous materials i.e., bitumen /asphalt Have the following characteristics:
- **→ High sensitivity to Temperature:**
- Highly fluid consistencies at high temperature whereas they become very stiff and brittle at low temperature. This change of consistency with temperature is often called as "Temperature Sensitivity" or "Temperature Susceptibility":

- → They Age or Oxidise: Bituminous materials undergo oxidation w.r.t time/age. With time oxidation process increases making them brittle. Oxidation also increases with temperature. Colour as well changes from 'black' to grey' as they age.
- key Asphalt products obtained from Refinement:
- **1: Asphalt Cement:**
- This form of asphalt is solid at normal atmospheric temp. To be used in pavement, it has to be heated to a temp. of 135°C/275°F at which it becomes fluid so that it can be readily mixed with aggregate. It can be used to make: Hot mix, Hot mix Asphalt, Asphalt concrete, Asphalt Cement Concrete (ACC). The hot mix so produced is then out spread on roadways and compacted.

II) Cutback Asphalts:

Asphalt has to be in of liquid form to be mixed with aggregates for this, the viscosity of asphalt is reduced by more volatile diluent that have higher fluidity even at low temperatures. Such asphalt dissolved in petroleum solvents are typically called 'Cutbacks'. After application, the solvent phase evaporates/volatise leaving behind the asphalt binder leading to hardening of cutback and the process is called 'Curing: Cutbacks are of:

a) Rapid Curing (RC): They use highly volatile petroleum products like gasoline or naphtha as 'solvent' which evaporates in a rapid rate i.e. curing is rapid. Used in tacks coats or surface treatment.

b) Medium Curing (MC) Use relatively fewer volatile products like kerosene. Used in patch mixes, prime coats or for ready-mixing operations.

c) Slow Curing (SC): Formed by either:

- using least volatile solvents like diesel and gas oils, or
- by controlling the rate of flow and temperature of the crude during the first cycle of refining.

Uses: Prime coats, patching mixes, dust palliatives on low volume gravel roads.

II) Emulsified Asphalt:

Emulsifying is the process by which the blending of asphalt cement is done with water under carefully controlled conditions using highly specialized equipment’s and suitable chemical additives / emulsifying agents. Thus it takes a form of a two-phase system consisting of two immiscible liquids, one being dispersed as fine globules into the other. In asphalt emulsions, lightly heated asphalt is run through a colloidal mill together with an emulsifying agent to produce globules of size 5~10 um. These asphalt globules are mixed with water to form a liquid mix of roughly 75% asphalt and 25% water by mass. The emulsifiers coat the asphalt globules and impart a surface charge that make globules repel each other. They are typically classified by four factors:

a) Charge: - Cationic (tve) or Anionic C-ve)

- Cationic emulsions to be used with anionic aggregates lie. gravel, quartz etc.

- Anionic emulsions to be used with cationic aggregates like limestone

b) Viscocity: - High or low viscocity - Nuwbered 1&2 as per viscocity.

c) Setting Rate:

Setting rate refers to how quickly can asphat coalesce to its original condition. Classified as :

- Rapid Setting CRs): It has little or no ability to mix with the aggregate. Uses: Surface dress, penet" mac,
- Medium Setting (MS): mix with coarse aggregate,
- Slow setting (ss): mix with fine aggregate.

d) float: - High float.

TAR Tar is a viscous liquid obtained when natural organic materials like wood, oil-shale etc. are carbonized and destructively distilled in the absence of air. Based on the materials from which it is derived, it is classified as wood tar or coal tar. Due to being superior coal-tar finds more use in road werks than wood tar.

stages of Production:

- Carbonization of coal to produce crude tar,
- Refining or distillation of crude tar,

- Blending of distillation residue with distillate oil fraction to give the desired road tar.

Grades of Tar

RT-1 to RT-5 based on viscocity or other properties.

Tests:

- Specific Gravity test,
- Viscocity test,
- Equiviscous Temperature CEUT),
- Softening Point,
- Softening Point of Residue,
- Float test,
- Water Content,
- Distillation fraction (Upto 2000, 200 1270 C 270-300c),
- Phends, % by volume,
- Nephtalene , % by weight,
- Insoluble material in Toulene (% by weight),

Comparison between Bitumen and Tar:

Bitumen	**Tar**
- Petroleum product, - Naturally available, - Soluble in GS 4 ccl_4, - Good weather resistance - Less suceptible to temperature, - Less free carbon	- Produced by fractional distillation of wood or coal (organic matters) - Not available in nature, - Soluble only in Toulene - Poor weather resistance - More susceptible to temperature, - More free carbon

Tests ON BITUMEN

To find its applicability in the road works, bitumen has to be tested under following grounds:

1) Consistency Tests:

The consistency of bitumen is checked by conducting the following tests:

I) Penetration Test:

Penetration test is done to check the hardness or softness of bitumen. It is conducted as follows:

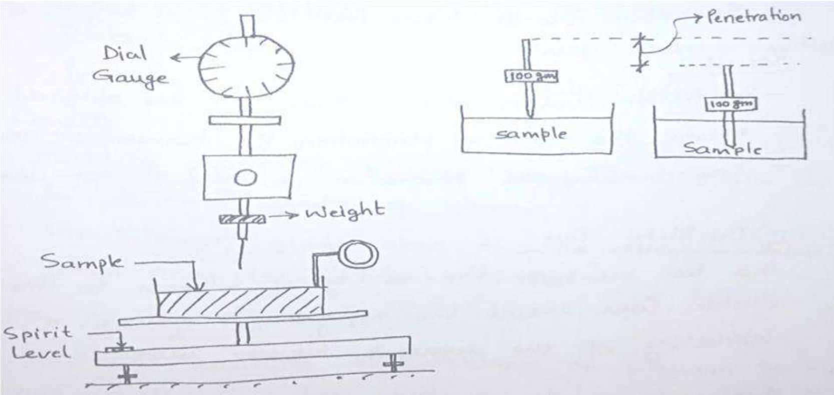


fig: Penetrometer

Apparatus:

Penetrometer consists of an assembly of a total weight of 100 gm with device for releasing & locking at any position.

→ Graduated dial gauge is present to measure the value of penetration.

Procedure:

- Bitumen softened to a pouring consistency is stirred and poured in a container to a sufficient depth,

- Sample is kept in a temperature-controlled bath of 25°c for one hour,

- Dial gauge is set to zero, needle is kept in position the sample and released for 5 seconds,

Penetration value measured at 3 different spots at least 10 mm apart,

- Penetration records Results: taken from dial gauge @ $^1/_{10}$%th of a mm.

Results:

- Penetration values 80/100, 100/120etc. are obtained that means the value of penetration lies between 'a' and 'b'
- Lower value of penetration is used in hot climates,

I) Ductility Test:

This test measures the ability of bitumen to form thin ductile film around the aggregates to achieve a good interlocking of the aggregate - bitumen mixes.

Apparatus: -

- A pulling machine to pull the specimen at a pre-calibrated rate @ speed of 50mm/min
- Has a constant temperature water bath.

Procedure: -

- Bitumen sample is heated, poured into assembly mould excess bitumen is cut by a hot knife and the resulting surface kept levelled.
- It is then cooled in the air and kept in a water bath maintained at a temperature of 27C for 2-3 - sides of the mould are removed, clips hooked on the machine and pointer set to zero.
- The pull is applied gradually @ 50 mm/min,
- Distance upto which the bitumen stretches without breaking is called as "Ductility value.

Results:

- Ductility values of bitumen vary from sN100 cm for different grades of bitumen,
- For bitumen grade above as the minimum ductility value is required to be 75cm.

III) Viscocity Test :

This test measures the resistance of bitumen to flow and is thus a true measure of consistency.

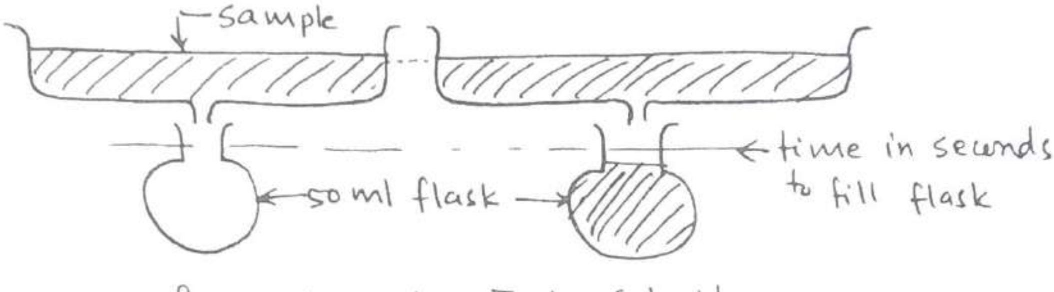


fig: Viscocity Test Set-Up.

Apparatus:

- Orifice type Viscometer,
- soil receiving flask .

Procedure:

- sample kept in a container of the Viscometer at standard test condition and specified temperature,

Time required in seconds, for bitumen to flow from Orifice to fill the some receiving flask is noted,

- Higher the Viscocity higher will be the time needed.

I) Float Test:

For a range of bitumen for which consistency can't be measured by a penetrometer or a viscometer, float test is used.

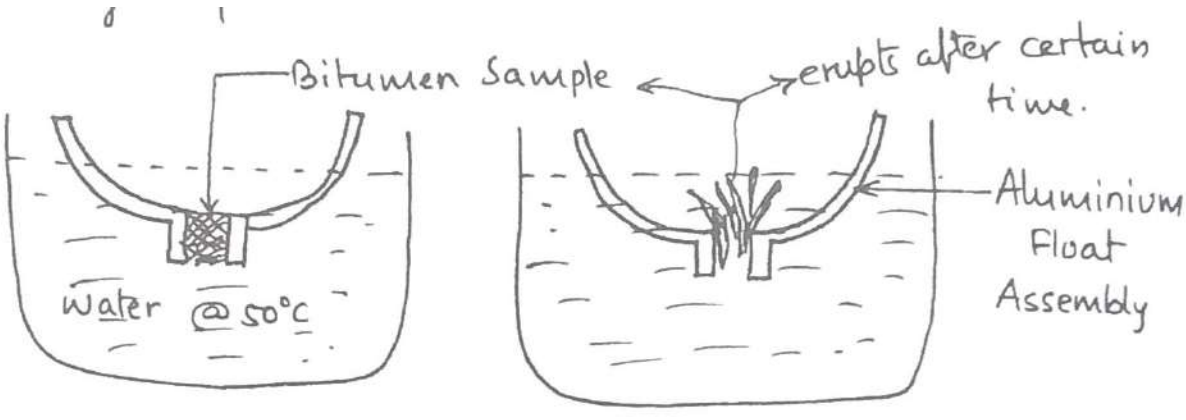


fig: Float Test Set-Up.

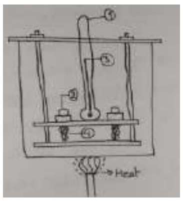
Apparatus:

- Hot water bath at controlled temperature of 50^0c,
- Float assembly of aluminium with brass collar.

Procedure:

- Speciment filled in brass collar cooled to a temperature of 5°c, screwed in float and kept in water bath @50^0c.
- Time required by water to force its way through the bitumen plug is noted as a "Float Test Value"
- "Higher the float test value, stiffer is the bitumen sample"

v) Softening Point Test:



Legends:

1) Thermometer

2) Ring & ball

3) Value of softening point at which,

4) bitumen falls down by melting,

This test is carried out to identify a temperature at which the bitumen softens at a specified Conditions of test.

Apparatus:

- Ring and Ball Apparatus with steel balls,
- Heating Source.

Procedure: -

A brass ring containing sample of bitumen is suspended in water/ glycerine at a given temperature,

- Steel ball placed upon the sample and heat is applied @ 5°c per minute until the bitumen softens.
- The temperature at which the softened bitumen touches the metal at a specified depth below the ring is recorded as the "softening point".

Results:

-Higher the bitumen grade higher will be the value of "Softening Point".

- Range of softening Point values 35°C~70°C.

2) Composition Tests:

Following tests are carried out for the composition of sample bitumen:

i) Distillation Test:

- This test is conducted to identify the quality, quantity of the volatile and non-volatile materials.

ii) Ash Content Test:

- To check the volume of inorganic materials, present in the bitumen.

I) water content Test:

- to check the percentage of water contained by the bitumen in a dissolved state.
- Max water content $0.20% by weight,

IV) Loss on Heating:

on heating, bitumen loses the volatiles and gets hard.

- 50 gm of sample is taken, weighed and heated up to a temperature of 163°C for 5 hours in a special oven built for this test specially,
- loss in weight on heating t% by weight of sample.

Solubility Test:

Pure bitumen completely dissolves in C_2S and CCl_4.

- Sample of about 10 gm of bitumen is dissolved in about 100 ml of solvent solution is filtered, residue in dried and weighed Percentage of insoluble residue

Spot Test:

Spot test is conducted to detect the overheated or cracked bitumen.

- 2 gm of bitumen is dissolved in lo ml of Naphtha.
- from the solution, a drop is placed on a filter paper after an hour and another drop after 24 hours of preparation of the solution.
- If the bitumen is not cracked or overheated, stain left on the paper has a uniform colour.

3) Specific Gravity Test:

The specific gravity of bitumen is determined either by using a pycnometer or by preparing a cube-shape specimen in semi-solid and solid state and weighing in air & water.

$$\text{Sp. Gr.} = \frac{\text{Mass of given volume of substance @27°c.}}{\text{Mass of equal water displaced @ 27°c.}}$$

- Generally, sp. gr. of bitumen is between 0.97~1.02. The Sp. gr. of cutback cut back bitumen may be less based on the type and properties of diluents used.

4) Flash & fire point Test :

Bituminous materials leave out volatiles at different temp. as per their grades which catch fire and are this hazardous.

- Flash point is a temperature at which the volatile takes fire momentarily as "flash" under specified test conditions.
- Fire point is a temp. at which the material ignites for at least about 5lecs under specified test conditions.
- **Design of Bituminous Mines:**
- The mix design should aim at an economical blend with proper gradation of Aggregates and adequate proportion of bitumen so as to fulfill the derived properties of the mix.
- The min design than aims at demining the properties of aggregates and bituminous materials which would result into a mix having the following properties: SPV FEW
- 1) sufficient stability to satisfy the service requirements of the pavement and the traffic conditions without undue displacements
- 2.) Sufficient proportion / content of bitumen to ensure a deniable pavement by coating the aggregates and bonding them together and also by water - proofing the mix. P
- 3.) Sufficient voids in the compacted mix as to enable slight amount of additional compaction due to traffic and to avoid flushing, bleeding and loss of stability, v
- 4.) sufficient flexibility even in the coldest season to prevent cracking due to repeated of plication of loads, F
- 5.) Sufficient workability during placing and confecting the wine, w
- 6) cost economical mix that would result into a stable, doable and skid resistant pavement.

Design Steps:

1.) Selection of Aggregates:

Based on availability and economic considerations, aggregates with sufficient strength, hardness, toughness and soundness are chosen keeping in view the availability and economic considerations.

2.) Selection of Aggregate Grading:

Properties of bitumen mixes i.e., stability density etc. density open the aggregates and their grain size distribution.

3.) Determination 9 Specific Gravity:

specific Gravity a bituminous material is already known.

If W., W2, Ws, WA = % by weight of aggregates

and G1, G2, G3, GG = Sp. Gr. a respective aggregate, then.

Average specific gravity of blended wire (Ga) is given by:

$$Ga = \frac{100}{\frac{W1}{G1}+\frac{w2}{G2}+\frac{w3}{G3}+\frac{w4}{G4}}$$

4) Proportioning of Aggregates:

- Design grading decided based on type of construction work, thickness of the layer and the availability of aggregates.
- Proportioning & available aggregates done by analytical (graphical method on by trial and enoz method.

5) Preparation of specimen:

- The specimen is moulded depending upon the specifications & the test method to be adopted

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5) Preparation of specimen:

- The specimen is moulded depending upon the specifications & the test method to be adopted
- 6) Sp. Gr. of Compacted specimen:
- Theoretical Maximum Sp. Gr. of the mix Gt:
- $$Gt = \frac{100}{\frac{(100-Wb)}{Ga} \times \frac{Wb}{Gb}}$$
-
- Wb=% bitumen content
- Ga = Avg. Sp. gr. g aggregates,
- Gb = Sp. Gr. of bitumen
- If G = Actual Sp. Gr. 9 Specimen, the theoretical density of is given by :
- Vt = 100G Gt
- → % Air Voids in the specimen
- Vo = 100 - 8t =100 (Gt - G) / Gt
- Voids in mineral Aggregates,
- Volume UMA = V + Vo = (100 - G)/ Wa
-
- where, Vb=% of bitumen by not
- Wa=% Agg. Content by not.
- % Voids filled with Bitumen (V FB)
- $$VFB = \frac{100.\ Vb}{VMA}$$

- 7) Stability test on the compacted specimen based on the, selected design method 8.) Selection of Optimum Bitumen content: Based on the adopted test method and considered design requirements.

Marshall's Method:

The resistance to plastic deformations of cylindrical specimen of bituminous mixture when loaded by @ 5cm / min.

Optimum binder content for the particular aggregate mix type and traffic intensity expected is calculated

Apparatus:

A cylindrical mould. 10.16 cm dia and 6.35cm height with a base plate and a collar A compaction pedestal and hammer with weight 4.54 kg and height of free fall of 45.7 cm to compact the specimen .

A sample extractor to extrude the compacted specimen from the mould.

A breaking head to test the specimen by applying a load on its periphery perpendicular to the axis in a loading frame of 5 tonne capacity @ 5 cm/min.

A dial gauge to measure deformations of specimen during loading.

Materials:

Coarse aggregates, fine aggregates and fillers proportioned and blended to arrive at a gradation as specified,

Bitumen of specified grade.

Procedure:

Approximately 1200 gm of mixed aggregates and the filler are taken and heated to a temperature of 175 ~ 190°c ,

Bitumen is heated to a temperature of 121 v 145c.

- Required Qty.of the first trial percentage of bitumen, hay 3.5 ~4 % is added to the heated aggregates and thoroughly mixed at a temperature of 154 ~ 160 c.
- 'The mix is placed on the fore-heated mould and compacted by the hammer with so blows on either side at temperature of 138-149 °C.
- Three to four specimens with different trial contents of bitumen may be prepared
- compacted specimen cooled to room temperature in the mould and then removed from the mould using bitumen extractor.
- War diameter & height of compacted specimen measured. Weight In air and when suspended in water is taken.
- specimen immersed in thermostatically temperature controlled water bath @ 60 +1°C for 30-40 mines.
- specimen taken out one by one placed in the Marshall test head and tested to determine Marshall Stability

Value:

Test is done for :

- Marshall stability value = Max. load in kg before failure.
- flow Value = Deformations observed in the specimen in 0.25 mm units upto max load.

Corrections applied to stability value for average height of specimen not having 6.35am as per available correction table.

Above procedure repeated for varying bitumen contents. The following relations are used for the calculation of

percent Air Voids (Vv) - 100 (Gu - Gm) /Gm

$$G = \cfrac{100}{\cfrac{W1+W2+W3+W4}{G1\ \ G2\ \ G3\ \ G4}}$$

symbols having

usual meanings

Percent Air Voids in Mineral Aggregates (VMA):

VMA = Vv + Vb

Percent Voids filled with Bitumen (VFB):

VFB = loo Vb

VMA

Graphs are plotted with % bitumen contents along y-axis following values on y-axis

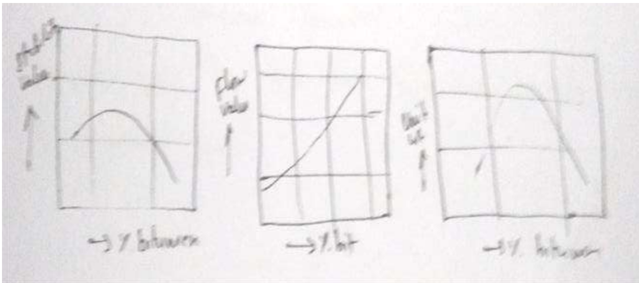
1) flow value

2.) Stability value

3.) Unit weight

4.) % Voids in Hotel mix (Vv)

5.) VFB



Bitumen contents are found from the graphs of the test values for the following:

i) Bitumen content for maximum stability (say, B1)

ii) Bitumen content for maximum unit weight (lay B1)

iii) Bitumen Content for the median of designed limits of percent air voids in total mix (4%.),

The Marshall Stability value flow value and VFB value are checks with Marshall mix design Criteria /specifications shown in table below:

Test Property	**Specified value**
1. Marchall stability . kg	340 min.
2. Flow value, 0.25mm units	8~16
3. Vv %.	3~5
4. VFB %	7.5 ~85%

Design of Highway Pavements:

A pavement layer is considered to be more effective and superior if it is able to distribute the wheel load stresses through a larger area per unit depth of the layer. This the stresses received on the sulogade are considerably lower than those received on the surface under the wheel loads and this reduction in stresses depends upon the pavement thickness and the characteristics of pavement layers.

The main objective of a well designed and constructed pavement is therefore to keep the wheel deformations on a pavement within permissible limits by transferring to a larger area underneath safely, much that it can sustain a large number of repeated loads in design life.

Types of Pavements:

Based on their structural behaviour, and the way they can transfer wheel loads, pavements can be classified as:

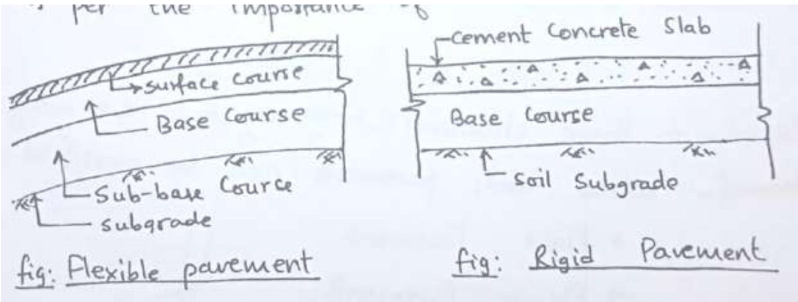
- Rigid Pavements,
- Flexible Pavements,
- Semi- Rigid Pavements
- Composite Pavements.

However, only the first two types are specially treated as pavement types.

I.) Flexible Pavements:

Flexible pavements have negligible flexural strength but possess flexibility in structural action under the application of wheel loads. This, the top surface will have the deformations reflected from the lower layers.

Vertical Compressive stresses are transferred to the lower layers by "grain-to-grain" transfers through the point of Contact which is maximum at the contact point while decreases as it goes to the lower layers. Accordingly, the quality of the materials decreases from top layer to the bottom layer for economizing the overall road cost. It's made of local soil, gravel, WBM or bituminous materials as per the importance of road



I) Rigid Pavements:

These types of pavements can take the flexural strength up to 40 kg/cm2 However, they are not flexible in nature. After preparing a well- compacted soil sugared, cement concrete slab of PCC, RCC or PSC is laid over a layer of sub-base / Bare course. They are normally analysed & designed based on elastic theory assuming the pavement as an elastic Sheena ajar al Olin l has foundation.

The common differences between feasible and sigil Pavements are as follows:

Parameter	flexible	Rigid
1. Design Accuracy	Less	More
2. Design Life	10-20 yrs.	>40year
3. Maintenance	Frequent	70%less
4. Initial Cost	less	50% more
5. Stage Construction	Allowed	Partly allowed
6. Surface Characteristics	Good	Better
7.Imperiousness	Partly	Fully
8. Glare & nigh visibility	Poor	Excellent
9. Traffic Distribution/ diversion during construction	Few hours	Few days
10. Overall Economy	less	More.
1 1. Technology	Moderate	High

Design Factors:

Pavement design consists of two parts:

- Mix design of materials to be used in pavement layers for optimized designed and economy,
- Structural design for the design of thickness of various layers constituting the pavement.
- The various factors that affect the design of pavement are broadly discussed as under:

1) Traffic factors / Design Wheel Load:

following factors affect the design

a) Maximum wheel Loads:

Loads imposed on the pavement sections are different depending upon the configurations of wheel loads. Typical wheel load configurations of a tractor-trailer unit of a heavy duty vehicle is as shown below:

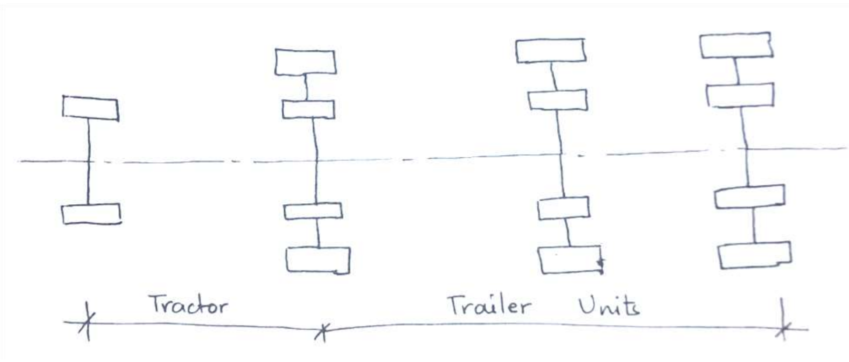


Fig: Wheel load configuration of a Tractor Trailer Units

The thickness and quality requirement of a pavement is mainly affected by the axle load configuration of a vehicle. According to IRC Recommendations:

- Maximum Axle Load = 8170 kg.
- Equivalent Single wheel Load = 4085 kg.

Bossiness's thory:

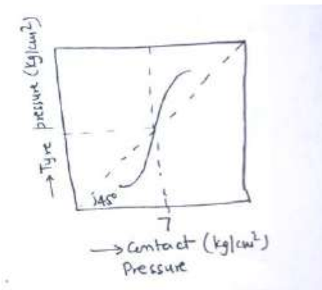
Vertical 8hen (D2) = Pz [1-Z3]

(a²+Z²)¾

b) Contact Pressure:

The tyro pressure decreases w.r.t. depth of the pavement and finally get diminished after a certain point. This is a reason why upper layer should be consisting of better

quality materials than the lower ones. The pressure intensity at wheels is greater than at 'in-between wheels. This, the pavement thickness is designed for maximum tyro pressure. Contact pressure and tyro pressure are two similar terms but the value of contact pressure is found to be more when the tyro pressure is<7kg/cm². The ratio of contact pressure to tyro pressure is called as Rigidity factor (RF <,= or >1)



c)Equivalent Single Wheel Load (ESWL):

often, heavy vehicles have the dual wheel assembly such that rear wheels carry the maximum load. However, the damaging effect on pavement in such a case might not always be twice as that of due to a single wheel.

As shown in fig. (next page), take a dual wheel assembly where:

P = load acting on each wheel,

a= radius of circular contact area of a wheel,

d=clear spacing between the wheels

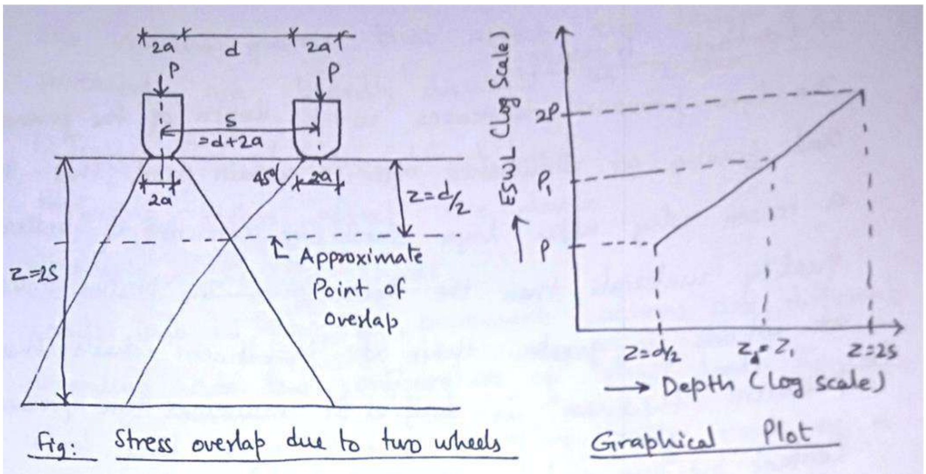


Fig: Stress overlap due to two wheels   Graphical Plot

Here, the elc spacing of two wheel loads s' is:

S= d+2a

The load is assumed to have been dispersed at an angle of 45°. So, up to a depth d/z, each wheel load acts independently after which stresses due to wheels begin to overlap. After a depth 25 or more, the area of overlap is considerably high. So, the stress is considered to be due to the sum of two wheel loads i.e. 2p. This value representing two wheel acting as a equivalent single wheel is ESWL.

A plot is prepared for the depth below the surface against ESWL in log scale for the coordinates:

(d/2, P) and (25, 2P)

The ESWL for in-between depths are interpolated.

d) Repetition of wheel loads and equivalence factor:

The deformation of pavement sugared due to single wheel load may be small but the repetition of such loads will lead to increased magnitude of elastic & plastic deformations. Accumulation of such unrecovered or permanent deformations results in pavement failures. Thus the pavement should be designed for such an equivalent load that has the same effect on pavement as a particular toad with patellar no of repetitions.

McLeod assumes that pavement thickness is only enough for one million (10%) repetitions of single wheel Load during the average life of the pavement.

In mixed traffic conditions with vehicles having wheel loads of varying magnitudes, the traffic is expressed of in terms of an equivalent number of standard axles (80len or 81 70kg).

The structural damage caused by an angle load is assumed to vary as the fourth power of its ratio to the standard able load. This is called as the equivalence factor (F) or Venire damage factor (VDF). Then,

F(VDF)=(L/ Ls)4

L = Axle load Imposed,

Ls = Standard axle load.

2.) Pavement Materials:

The pavement materials have to satisfy the characteristics of strength corresponding to a designed angle load. The materials in the base and sub-base layers should be evaluated for Suitability as per design requirements.

CBR test for stability of sugared 4 other pavement materials,

Elastic Module test is done by Plate Bearing Test to find out the elastic module for different materials based upon the different design methods.

Sugared methods.

∇ max=1.5[p.q] –for flexible plate

Es

∇max=1.18[p.q] – For rigid plate

Es

Elastic Modulus:

$\nabla=1.5\,[p.q]\,\#F^2$ - for flexible plate

Es

$\nabla=1.18[p.q]\,\#F^2$ -- For rigid plate

F^2= Dimensionless displacement factor.

3) Climatic factors:

variations in → Moisture content, → Temperature → frost action.

4) other factors:

Various other factors that affect design of roads are

Road geometry:

- Horizontal and vertical rescue
- Pavements at junctions
- overstressing

Environmental factors:

- Aesthetic
- Landscape,
- Pollution etc.

special factors like government special policies i.e., otter seal, SOST, OBST etc.

Failure Criteria for different pavements

For flexible pavements:

- Fatigue cracking,
- Rutting
- Thermal cracking etc.

for Rigid Pavements:

- Fatigue Cracking,
- Pumping,
- Spelling etc.

Commutative Number of Standard Axles (Ns)

$$Ns=\frac{365*A*VDF[(1+r)n-1]}{r}$$

Where,

A=Initial traffic (lomm.vehl day)

n=Design Life

r=Annual Growth rate

VDF=Vehicle Damage Factor

Design of Pavements

I)Flexible Pavements:

In flexible pavements the top layer receives the wheel load and transfers it by 'grain-to-grain' transfer to the series of layers below where in the subhead finally transfers that load to the soil below. As such, maximum stresses are in top layer and gradually decreases with depth with no layer being overstressed at any time and superiority of the materials to be used is chosen accordingly.

Design Method:

a) Empirical methods:	b) Analytical methods:
- Group Index (G.I.) method,	- Birnuster's Method
- CBR method,	- Triaxial test method,
- Road Note 31 method,	- Boussinerg's theory method
- AASHTO road test method,	- Shell pavement design manual
- Mcleod method	
- IRC method	

a) Empirical Methods:

Empirical methods of pavement design are discussed in as details as under.

i) Group Index (G.I.) Method:

Group Index (G. I.) value is an arbitrary index assigned to soll types given by the following equation:

$$G.I. = 0.2a + 0.005ac + 0.01\ bd \text{ where,}$$

a= portion of material passing 0.074 um sieve, greater than 35 & not exceeding 75%

b= portion of material passing 0.07 mm sieve (Greater than 1s, not exceeding 35%) c= Liquid limit in excess of 40,>60 [0~20]

d= Plasticity Index in excess of 10 >30 (0~ 20)

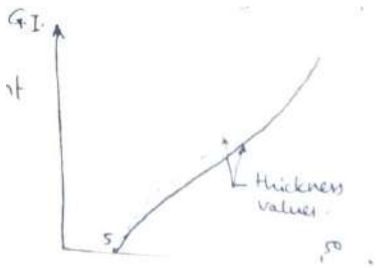
The value 9 G.I. ranges from 0.20 with weaker soil- sub grade having the higher G.1 value & vice-versa.

Design Method:

i) The anticipated traffic is estimated (in commercial vehicles per day) and assigned as :

Light = <50/day, Medium = 50~300/day, Heavy =>300/day.

ii) The appropriate design curve is chosen and the total pavement thickness is found out from the G.I. design chart corresponding to the GI values.



2) CBR method:

In 1928, California California Division of Highways (USA), developed design curves / Charts correlating the CBR values and the required pavement thickness as a cover to protect the subgrade support to cater for wheel roads of 3175kg. 4082 kg, and 5443 kg respectively representing light, medium and heavy traffic.

Also, U.S. Corps of Engineers researched that there exists a relationship between wheel load, pavement thickness, type pressure and the CBR values (within a range of (10-12) %] Thus the CBR design curves can be extended for various loading conditions using the expression:

where,
P= wheel Load (kgs),
p= type pressure ckg/cm2),
A= contact area (cm2)
t= Pavement thickness.

$$t = \sqrt{p\left[\frac{1.75}{CBR} - \frac{1}{p\pi}\right]} \quad \frac{1}{4}$$

$$t = \left[\frac{1.75}{CBR} - \frac{A}{\pi}\right] \quad \frac{1}{2}$$

IRC Recommendations:

IRC recommends a design Chart from A-F traffic classification as vol. of conm. vehicles (day & coresponding thickness where.

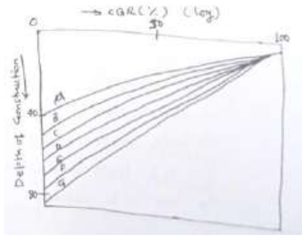
A → (0-15) Comm veh/day

B → (15-45) Comm veh/day

C → (45-150) Comm veh/day

D → (150 - 450) Comm veh/day

E → (450-1500) Comm veh/day



3) Overseas Road Note CORN)/ TRL UK methods:

ORN 29, ORN 31 are the two methods.

i) ORN - 29 method:

- The features in this method are: at covers are load repetitions (cumulative number of standard and load),
- It uses materials such as rolled asphalt, bituminous macadam, lean concrete, soil-cement & wet mix, dry bound macadam etc for road base & surfacing causes.

Estimation of Traffic :

- Traffic data is obtained from actual surveys and a suitable growth rate is assumed.
- able pavements are designed for 20yr life and rigid pavements are designed for a life of 40 years.

Different curves are used for obtaining:

- Sub base thickness based on CBR value,
- Road Asphalt dense macadam road base and surfacing thickness based on Cumulative Standard Axles (Ns),

Eg.

- For standard axles > $11*10^0$
- Min wearing course > 4cm thick,
- Min bare course >6cm thick.
- when <$0.5*10^c$
- wc > 2cm, & suitable base.

II.) ORN-31, TRL-UK:

There are three main steps to be followed to design of a new road pavement by ORN-31 method.

1) Estimate the amount of traffic and the number of equivalent standard axles that will use the road over a selected design life.

Ns = 365*4* VOF * [*1+73"-1]

r

2.) DCP test is done over the soil subgrade over which the road is to be to build. DCP test gives the value of Penetration Index (P.I.) and the strength of the subgrade soil is given by:

$$\log CBR = 2{:}48 - 1.057 \log (P.\ I.)$$

3) There are 8 types of design catalogues which give the most economical combination of thickness of pavement layers that can provide satisfactory service over the design life of the pavement. The various thickness values of the different layers are given with respect to the values 9 Traffic (in mesa-million standard axles) vs CBR.

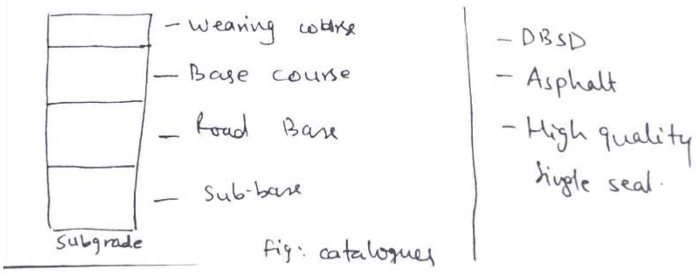


fig: catalogues

Flowchart of design by ORN-31

S.N.	Activity	Sub-Activity
1	Survey of possible routes	- Asess geotechnical problems - Search material source - Choose routes
2	Assessment of traffic (Assign Traffic class)	- Measure traffic volume by clay, - Measure axle load, - Choose design life (20 yrs), - Calculate total traffic,
3	Measure subgrade strength (Assign Subgrade Class)	- Assign climate regime, - Test soils, - Define uniform sections, - Design earthwork.
4	Select pavement materials	- Locate sources, - Test properties, - Accept, reject or modify - Asess severe sites.
5	Select structures	- Cost (Risk Analysis, - Design of Drainage, -Review of local expertise.

4) AASHTO Road Test Method:

AASHTO Road test was a series of exp by the American Association of state Highway an Transportation Officials. It was done to:

- Study the performance of pavement structures of known thickness under moving loads of known magnitude and frequency.
- To determine how traffic contributed to the deterioration of highway pavements.

Design Steps:

1) Performance Measurements:

- Performance based user assessment is done by a panel of experts who drove around in a standard vehicles and give rating of the pavement as:

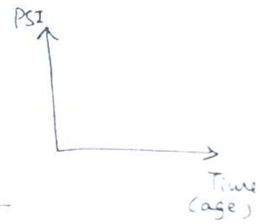
0-1	- V. Poor
1-2	- Poor
2-3	- Fair
3-4	- Good
4-5	-V. Good

- Performance indicatess given by measurable characteristics
  - Visible
  - Surface friction
  - Roughness
- True performance (user) is correlated with the measured performance and Present Serviceability Indere (PSI) is calculated as:

$PSI = A_0 + A_1 F_1 + A_2 F_2 + A_3 F_3$ where

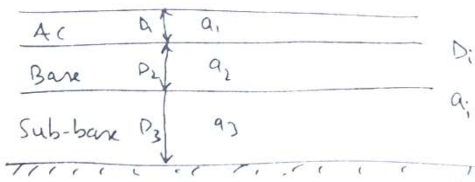
$A_0 \ldots A_3$ = Regression Coefficients,
F_1 = Measure of roughnes,
F_2 = Measure of rutting
F_3 = Measure of Cracking

PSI Vs Time curve is plotted.



- Definition of Structural Number (SN) is done

$SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_2 + \ldots$



D_i = layer depth
a_i = structural Coefficient
m_i = Drainage coefficient

2) Design Inputs / Calculation & Outputs :

→ Design Variables:

- Design Life,
- Material properties
- Traffic
- Reliability

- AASHTO reliability factor F_R is used to adjust for traffic for reliability

  $W_{18} = W_{18} * F_R$ Select suitable material properties:

- Select suitable material properties:
    - μ_3 Values
    - Resilient Modules (M_R),
    - $\mu_3 = 1.18*10^8 * M_R^{-2:32}$
- Selection of pavement layer types.
- Computation of Required thickness by:

  ~ Baric approach
- Delemine require structural Number CSN) for design Traffic
- Identify trial designs to meet required SN.
- Nomograms used to solve for SN

- Equation:

$$\log (W_{18}) = (Z_R{:}S_o) + 9.36 \log (SNH) - 0.2 + \frac{log\left[\frac{PSI}{4.2-1.5}\right]}{0.4+\left[\frac{1094}{(SN+1)^{5.19}}\right]}$$

$$+2.32 \text{ Log } (MR) - 8.07$$

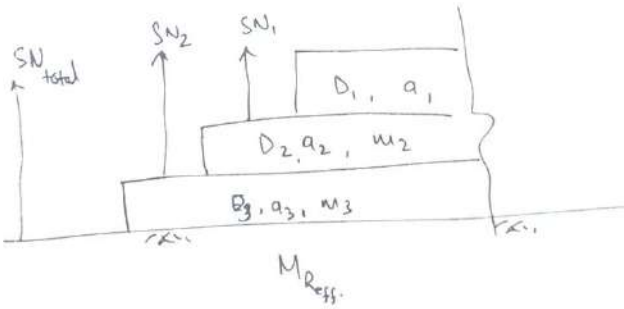
Solving the equation:

- Declare known variables – W_{18}, Z_{R1}, S_o, PSI, M_e

- Give initial estimate for SN,

- Solve equation by solvers like Excel, Matlab etc..

Nomogram determines SN required to protect the subgrade with each structural layer protected against overstressing.



5) Stabiliometer Method (California Resisting ER) value Method):

Francis N. Havem Materials and Research Engineer for the California Division of Highways, developed Hareem method of bituminous mix design using Stabiliometer which was then named Hareem Stabilometer.

From this test for a test specimen used the values of Cohesiometer (C) and stabiliometer Resistance (R) was found i.e.,

$$\Rightarrow \quad C = \frac{L}{W(0.2H + 0.0176H^2)}$$

L = weight of shots in gm,
W = width/diameter of specimen (cm),
H = Height of specimen (cm).
C = Cohesiometer value.

$$\Rightarrow \quad R = 100 - \frac{100}{\frac{2.5}{D_2}\left[\frac{P_v}{P_h} - 1\right] + 1}$$

P_v : Vertical pressure (@ 11.2 kg/cm²) applied,
P_h : Horizontal pressure (@ 11.2 kg/cm²) transmitted by specimen
D_2 = Displacement of stabilometer fluid

Theory and Procedure:

Hence in this method the pavement thickness is found out using the stabilimeter- R value and Cohesion meter C-value It is established that the pavement thickness varies:

- directly with R value and logarithm of load repetitions
- inversely with fifth root of C-value.

$$T = \frac{K(t_1)(90 - R)}{C^{\frac{1}{5}}}$$

Where,
T= Total pavement thickness in cm,
K= Constant= 0.166
T_i= Traffic index =1.35 $(EWL)^{0.11}$
EWL= Equiv. Wheel load (annual)
R= stabiliometer R-value
C= cohesiometer C=value

Here,
The equivalent wheel load (EWL) is found for annual AADT as:
EWL constants are =∑[no. Of axle*AADT $_{\text{corr. Axle}}$*EWL constant]
Where, EWL constants are given for different axles as:

No. Of axles	EWL constants (Yearly)
2	330
3	1070
4	2460
5	4620
6	3040

For a projection of N years with traffic increase rate of I %,

$$(EWL)_n = \frac{(1+1.i)*N*EWL}{2}$$

Equivalent C-value:

The cohesiometer value, C is obtained for each layer of pavement material separately separately from tests. A composite test C-value for total pavement section from tests is not possible. As such, Composite or equivalent c-value of the pavement in multi layers with known values of thickness of each layer and e-value of material in that layer is given by:

$$\frac{tg}{T} = \left(\frac{C}{cg}\right)^{\frac{1}{5}} \quad \text{----------(1)}$$

$$C = cg\left(\frac{tgC}{T}\right)^{5} \text{-----------------(2)}$$

Here, the pavement is assumed to consist of any one material like gravel base course with known C-value .

CG= C-value for gravel
tg = Thickness of gravel course.

Now,
tg value for any other layer can be found out using eq^n (1),. For layers with i=1,2,3,

tg = ∑(tg);

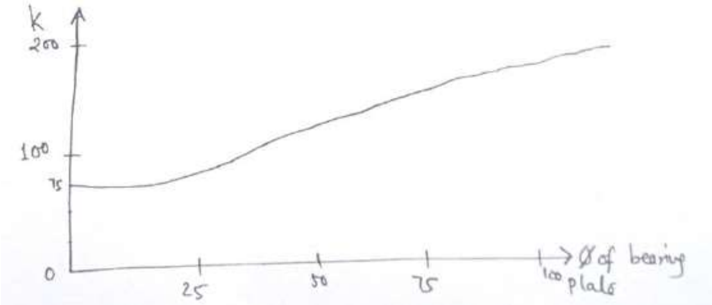
Overall c is found using eq^n (2)

e) Mcleod Method:
N. W. Mcleod through Canadian Department of Transport Conducted repetitive plate bearing tests on airfields and highway pavements using various sizes of plates to arrive on a design method for pavement from the plate recommended Test an empirical design equation was recomented:

$$T = k\left\{log_{10}\left[\frac{p}{5}\right]\right\}$$

where
T= Required thickness of Gravel base, cm
P= Gross wheel load, kg
K= base course constant
S= Sub grade Support, kg

Here,
k depends upon loaded area i.e. on the plate diameter and a curve between plate dia. vs k is given
S is calculated from the support measured for 30cm ø plate at 0.5cm deflection and ten repetitions.



7) Asphalt Institute Method (USA):
The pavement design by this method is achieved in following steps:
i) The pavement structure recommended by this method is in the form of full-depth Asphalt "which is an asphalt pavement where asphalt aggregate mixtures are employed for all courses above sub grade and then this is converted to equivalent thickness of asphalt concrete to materials in the field.
ii) Cumulative no. of standard axle load of 8170 kg, (m)

$$N_s = p\left[\frac{(1+r)^{x+y}-1}{r}\right]$$

where,
P = Common traffic volume at least count,
LDF=Lateral displacement factor depending on lane of roadway.
N=Design period
Y=constant period
iii) Elastic modules of subgrade (E_{sg})

$\{$

Esg= 10*$CBR_{subgrade}$ - CBR<5
176*$CBR^{0.64}$ - CBR> 5

iv.) Full depth asphalt (T) is obtained from charts of N_s V_s esg.
v.) Assume,
wearing course = 50 mm.
Then, equivalent thickness of base + Sub-base
= T-50 } in terms of asphalt concrete.
With $t_{stan} = 1.4\ t_{base}$
&
$\frac{E_{base}}{E_{sbase}} = E_{sg} * 0.30 * h^{0.45}$ | h= thickness of granular materials, mm.

vi) $(t_{base})_{act} = t_{base} * [\frac{eac}{e_{base}}]^{\frac{1}{3}}$

$(t_{base})_{act} = t_{base} * [\frac{eac}{e_{base}}]^{\frac{1}{3}}$

Then,
Tactual =50+ $(t_{base})_{act} + (t_{base})_{act}$

b) Analytical Methods:
Following given are some analytical methods:
i) Triaxial Method:
L.A. Palmer and E. S. Barber (1910) proposed a design method based on Boussinesq's displacement equation for homogeneous elastic single layer:

$$\Delta = \frac{3\,p \cdot a^2}{2E\,(a^2+z^2)^{1/2}}$$

p = tyre pressure
= $P/\pi a^2$
P = wheel load, kg
a = radius of contact area, cm
Δ = Design deflection
(0.25cm)

$$\text{or, } \Delta = \frac{3 \cdot \frac{P}{\pi \cancel{a^2}} \cdot \cancel{a^2}}{2E\,(a^2+z^2)^{1/2}}$$

$$\Rightarrow \Delta = \frac{3P}{2\pi E (a^2+z^2)^{1/2}}$$

Here,

$$a^2 + z^2 = \left(\frac{3P}{2\pi E \Delta}\right)^2$$

$$\text{or, } z^2 = \left(\frac{3P}{2\pi E\Delta}\right)^2 - a^2$$

$$\Rightarrow z = \left[\left(\frac{3P}{2\pi E\Delta}\right)^2 - a^2\right]^{1/2}$$

Assuming, the pavement is incompressible, z becomes T, the thickness of pavement

$$\Rightarrow T = \sqrt{\left(\frac{3P}{2\pi E_s \Delta}\right)^2 - a^2}$$

E_s = Mod. of Elasticity of Subgrade (kg/cm²).

2) Burmister's (layered system) Method:
The total man of pavement and subgrade doesn't poses a constant E value as assumed by Boussinesg in his analysis. However, Boussinesg's analysis can be taken as special case of Burmister's Layered System Analysis. If, E_s, E_{sb}, E_b are the elastic module of Subgrade, subbase and base respectively, then,
$E_s = E_{sb} = E_b$ Boussinesa's Analysis
$Es < E_{sb} < E_b$ Layered Analysis.

Assumptions:

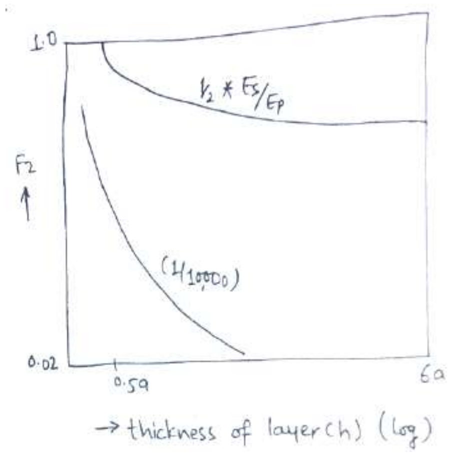
- The materials in the pavement layers are homogeneous, isotropic and elastic with $Eb > E_{sb} > E_s$.
- Surface layer is infinite in horizontal directions and finite in vertical directions, the underlying layer in two layered system is considered infinite in both dirts.
- The layers are in continuous contact, the top layer is free of shearing and normal stresses outside the loaded area.

The Burmister's approach utilised the reinforcing of the actions pavement layers. In 2-layered system, a factor for displacement (F2) which depends on, Es/Ep & h/a, where, Es, Ep = Elastic Moduli of pavement & subgrade resp. h= pavement layer th, as radius of loaded area.

The relationship between two layer deflection factor fy and pavement thickness in terms of radius of loaded area (a) and ratio (Es/Ep) is given graph as follows:

$$a = \sqrt{\frac{p}{\pi p}}$$

$$p = \pi a^2 . p$$



Thus, the displacement equations given by Burmister for a flexible loaded plate of radius 'a' under a Uniform pressure of p as:

$$\Delta = 1.5 \left[\frac{p.a}{e_s}\right].F_2 \quad - flexible\ plate$$

$$\Delta = 1.18 \left[\frac{p.a}{e_s}\right].F_2 \quad - Right\ plate$$

For a single layer,
$H=0, {}^{Es}/_{Ep}=1, \therefore F_2=1$

Design of Rigid Pavements:
The rigid pavements are made of PCC/RCC/PSC as per the importance of highway. The load carrying capacity of such pavement is mainly due to the rigidity and high modulus of elasticity of the slab itself i.e. slab action. The rigid pavements are analyzed by plate theory wherein the concrete slab is assumed to be a medium thick plate Where the sections before bending remain plane after bending.

Westergaard's Analysis:
Westergaard's analysis considers the rigid pavement as a thin elastic plate resting on an aqueous foundation. The upward reaction at any point is assumed to be proportional to the deflection at that point i.e.

$p = k. \Delta$
$k = \frac{p}{\Delta}$ where,

K= Modulus of subgrade reaction (kg/cm^3),

þ= Sustained pressure (kg/cm^2),
Δ= Displacement level (Maxn = 0.125 am)

k= $^1/_{0.125}$.p =8p kg/cm^3

Relative Stiffness of slab to subgrade:
Subgrade offers certain resistance to slab against its deflection depending upon the stiffness properties of the subgrade soil. The resistance to deflection again depends upon its flexural strength.

The resultant deflection of the slab which is also the deformation of the subgrade is a direct measure of the magnitude of the subgrade pressure. The pressure-deformation characteristic of a rigid pavement is this a function of relative stiffness of the slab to that of soil subgrade".

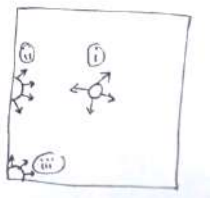
- Wester guard defined the term as "Radius of relative Stiffness (1)" which is given by:

$$l = [\frac{eh^3}{12k(1-\mu^2)}]^{\frac{1}{4}}$$

E = Modulus of Elasticity of cement concrete (kg/cm^2)
μ= Poisson's ratio for concrete =0.15,
h= Slab thickness (cm),
K: Hercules of subgrade reaction / subgrade modules (kg/cm^2)

Stresses acting on a Rigid Pavement:
Before we jump to acting stresses, it is essential to know about the positions of load critical to the pavement slab. They are of:

i) Interior loading: Load at any place remote from all the edges.
ii) Edge loading: Load at any place/edge remote from a corner.
iii) Comer loading Load touching two edges at comer with load centre bisecting the corner angle.



According to Westergaard, the equivalent radius of resisting section approximated in terms of load alistribution and slab thickness (h) is given by:

$$b = \sqrt{1.6a^2 + h^2} - 0.675h$$

where,
b= equivalent radius of resisting section (For a <1.724h)
a= radius of wheel load distribution, cm
h= Slab thickness, cm
For a=1.724 h b=a

The load stresses acting on a rigid pavement are:
1) Wheel load stresses:
2) Temperature stress,
→ a. Warping Stress
→ b. Frictional stress

1) Wheel Load Stress:
- Goldbeck's Formula:
  A.T. Goldbeck researched that majority of concrete slabs fail at corners. He derived a formula for stress due to a point load at the corner of slabs as:

$$s_c = \frac{3p}{h_2}$$

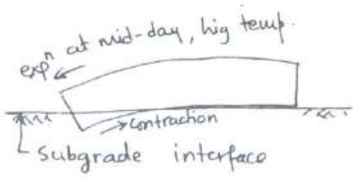
P= Concentrated point load at corner, kg.
H= Slab thickness

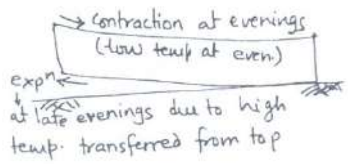
S_c= Stress due to corner load, kg/cm^2

Temperature stresses are of two types:

2) Warping stresses:

Warping stresses are induced in the rigid slabs due to daily variation of temperature. The maximum temperature difference between top and bottom of slabs at mid-noon and late evenings cause warping stresses development.





a) warping Down b) Warping Up

For temperature difference of = $\Delta t = t_2 - t_1$, if the slab has no restraints; then

Unit elongation of top fiber $\} = \frac{E.e.\Delta t}{2} =$

Unit contraction of bottom fiber J 2

Where,

E= thermal coeff. of concrete

E = Modules of elasticity of concrete.

Bradbury proposed that:

For interior region,

$$S_{t(i)} = \frac{E.e.\Delta t}{2}\left[\frac{c_x + \mu c_y}{1-1^2}\right]$$

C_x= Coeff. based on $^{Lx}/_{l}$ in desired direction

cy= Coeff. band on $^{Ly}/_{L}$ in direction normal to L_x

μ= Poisson's ratio.

For edge regions,

$$S_{t(e)} = cx\frac{E.e.\Delta t}{2}$$

$$c_y = \frac{E.e.\Delta t}{2}$$

Where is higher

For corner regions;

$$S_{t(c)} = \frac{E.e.\Delta t}{3(1-\pi)}\left[\sqrt{\frac{a}{2}}\right]$$

where,

a= radius of contact relative area,

l= radius of relative stiffness

b) Frictional stresses: Frictional stresses are developed due to seasonal uniform rise/fall in temperature in the slab fibres which lead to overall expansion and contraction of slab. Since the slab movement is restrained, friction develops between bottom fibres of the slab and the soil subgrade, due to the change in length of the slab inducing frictional stresses. Stresses induced due to this phenomenon vary with slab length. In short slabs frictional stresses are negligibly small. In long slabs, which undergo movement of more than 0.15cm equating.

Total force developed in cls = frictional resistance due to movement subgrade restraint in half length of slab.

$$sf*(kB*100)=\beta\frac{1}{2}*\frac{k}{100}*w*f$$

$$s_f=\frac{WLF}{\ldots\ldots.}$$

W=unit wt. of lomc.
F=coeff. Of friction
L_1B=Slab length &….

2) During winter:
At edge, stress is higher where,
Critical combination = load stress + warping stress + frictional stress

since the diff. in diff in temperature Δt, is of lower magnitude in winter than in summer. The combination given by (1) may be worst for most of the regions.

3.) At Corner Regions:
The critical combination occurs at the top fibre of the slab, when the slab warps upwards during the mid nights. There's no friction at corner region. So, Critical combination = load stress + warping stress at corners.

IRC Recommendations for design of Rigid pavements:
IRC has made following recommendations for the design of rigid pavements:
a) Design Parameters:
Design when load = 5100kg with eq. circular area = $15cm^2$
Tyre pressure = 6.3~7.3 kg/cm^2
Traffic volume projection for 20 years design life,
$\Delta_d = P^1 (1+r)^{n+20}$ where,

Combination of stresses:
1) During summer:
- Load stress at edge is higher than the interior,
- Critical combination of a load stress + warping stress + frictional Stress at edge stress region

A_d = No. of commercial vehicles/day (laden wt >3tonnes),
P^1 = No. of commercial vehicles/day at last count,
r= annual rate of increase in traffic intensity (taken as 75%. if not available),
n=no. of years between last traffic count and the Commissioning of new cement Concrete pavement,

Make necessary adjustments in the pavement thickness based on the traffic intensity obtained. For eg:
for A_d > 4500 Adjustment = +2cm.
- Collect temperature records to calculate warping stress,
- Determine modulus of subgrade reaction using plate load test (standard plate size = 75cmg, deflection @0-12504)
- Flexural strength of pavement < 40 kg/cm^2

  for M_{25} -M_{30} concrete grade, $e=5000\sqrt{f_{ck}\frac{n}{m^2}}$

b) Calculation of Stresses:
- Wheel load stresses at edge and corner regions are calculated using Westergaard's analysis using diff. charts,
- Temperature stresses at edge region calculated as per the Westergaard's analysis using Bradbury's coefficients .

c) Design Steps for Slab thickness:
→ Width of slab is decided based on the lane width and spacing of joints.
→ Length of slab= Spacing of contraction joints

Design steps for slab thickness (contd)...
A trial thickness is assumed for the slab to calculate the stresses, warping stress is calculated for the edge region & subtracted from the allowable flexure strength to find residual strength to soffit edge loads,
Then load stress at edge is found. Available F.o.s. in edge load stress w r.t. residual strength is found.
F.os.is analyzed of Fos ~1 or slightly higher trial thickness is taken , else the above procedures are repeated

po until fos ≥1

- The total stress (F_T) is calculated due to wheel load and warping and then checked for slab thickness (h).

If F_t < Allowable flexural strength,

- the slab thickness is adequate

Else Increase the thickness suitably.

- The design thickness' h' is adjusted for the intensity of traffic or classification at the end of design life and using the adjustment value as per IRC table. This gives the final thickness suiting all requirements.

d) Spacing of Joints:

for expansion joints: - Max^{m} spacing for 25 mm thick joints is kept between 60 ~140 m w.r.t. different slab thickness, foundation types (smooth or rough), construction period (winter or summer) etc.

At summer & writer for smooth foundation:

Maym spacing	for	Slab thickness
Summer	Winter	50
90m	50m	20m
120m	60m	25m

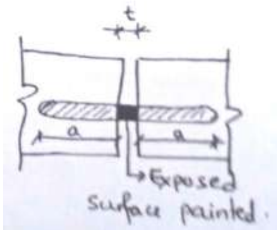
For contraction joints:

Spacing of contraction Joints	Reinforcement Status
4.5m	unreinforced
13 m	reinf. @2.7 kg/am², slab= 15cm
14m|	reinf. @3.8 kg/cur², slab = 20 cm.

e) Design of Dowel Bars:

Dowel bars of m.s. are provided for load over 5100kg and slab thickness above 15 cm (since they don't function satisfactorily for lower /thin slabs) in order to allow the opening and l or closing of a joint, maintaining slab edges at the same level. length of the dowel bar equal to joint thickness is exposed and shall be painted by corrosion resistant materials

Dia (mm)	Slab th(cm)	length	Spacing
25	15	5ocm	20cm
25	20	50cm	30cm
2/8	2/5	soma	30cm
25			



f.) Tie Bars:

Deformed m.s. bars are used as tie bars across the longitudinal joint to keep together the adjacent slabs firmly. These bars are designed to withstand tensile stresses due to maximum tensile forces in the bar as a result of friction developed between pavement layer & subgrade. To calculate area of steel per m. length

Total Subgrade friction = Total tension in tie bars

wt .of half slab × f $= A_s \times S_c$

or $R_c * b * \frac{h}{100} * \frac{Lc}{2} \times f = A_s \times S_c$

$$As = \frac{8c \cdot b \cdot h \cdot Lc \cdot f}{200Sc}$$

Recommendations:

slab th. (cm)	dia (mm)	Spacing (cm)
15	10	35
20	12	40
25	12	40

g.) Design of Reinforcement:

Area of longitudinal and transverse steel required per m width and length of slab is given by:

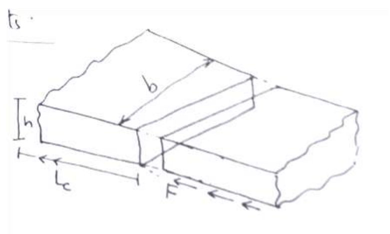
$$As = \frac{L.F.W}{25}$$

L=distance between free joints
W = wt .of unit pavement area (kg/cm²)
S= Allowable working stress in street
(50-60% of Yield stress
f= Coeff. of friction (usually f=1.5)

Joints in Rigid Pavements:
Cement Concrete pavements undergo volumetric changes due to variations in temperature, shrinkage due to variations in temperature , shrinkage due to setting and changes in water content. As such, small slabs are provided with joints instead of long ones to make them free of cracks and to ensure that stresses induced due to expansion, contraction and warping are within limits. Following joints are usually provided.

- Expansion joints to minimize effects of stresses produced due to variation in temp (especially due to increment),
- Contraction joints to minimize effects due to drop in the ambient temperature, Warping joints to minimize effects due to variation in daily temperature, Construction joints to haul works at the day's end or mechanical problems & then continue the next day:
- longitudinal joints whenever pavement width >5m.

Spacing of contraction joints:
Here, let.
L_c = Length of concrete panel,
b = width of slab (m)
h= height of slab (in cm)
f= Coeff. of friction,



Frictional stress developed,

$$f = W.F = y_c.b.\frac{h}{2}.\frac{l_c}{2}.f = r_c.\left(\frac{l_c bh}{200}\right) kg$$

Provision of joint Ken spacing (L_c)
a.) when, F = Allowable tension in concrete i.e.
no provision of reinforcement.
F = T_c. (b. 100 * h) = 100 T_c bh
or, $\frac{L_c \text{ bh}}{200} . r_c f$= 100 Tc. bh
$L_c = \frac{2x10t_c}{r\ c\ f}$
b.) when reinforcement Ast. is provided,

$$\frac{l_c bh}{200}.rcf = 1st\ ast.$$
$$L_c = \frac{200\ 1st + Ast}{r_c bh.f}$$

Spacing of Expansion Joints:
IRC recommends the minimum width of expansion joints to be 25mm to be filled with joint sealants. The width of the joint actually depends upon the length of the concrete lab. If, & is the mash displacement,
d= $\propto_c$. Lc. ΔT
$L_c = \frac{\delta}{\propto_c.\Delta T} cm$
$L_c \frac{\delta}{100\propto_c.\Delta T} m$
$\propto_c$= Coeff. of linear exp^n cm I of concrete ,
ΔT = change in temp.
L_c = length of slab.

5.4 Contract Management :

Contract Management and administration is a process of systematically and efficiently managing contract [creation, I and analysis] for the purpose of maximising financial and operational performance and minimising risk.

Contract Management:

- to know how to manage,
- to execute project according to milestones.
- To ensure the work to be accomplished in time,
- to integrate work schedule, time schedule, fund and resources.

The following aspects popularly called as 4 M's are an evence of construction management i.e.
- Materials – Money - Manpower - - Machine
In detail they are referred as:
Resource Mobilization,
- Progress and Quality Monitoring
- Dispute Resolution,
- Target achievement,
- Resource Demobilization,

Construction Management:
The management of works starts much before the actual commencement of works. It includes activities such as invitation of tenders, selection of contractors, mobilization and actual execution.
The following aspects deserve careful consideration Construction management:
i) Management of materials,
ii) Management of labour,
iii) Management of equipments
Efficient management of the materials includes:

- Assessment of requirements,
- Location of sources of supply,
- Purchase transport, storage and issue on works.

The procurement should be so phased that works don't suffer at any stage due to lack of materials and at the same time, the stock of materials is not high. It should be ensured that there's adequate supply of labor, amenities to labor such as temporary housing, medical facilities and creches for children provides an a part of the condition of contract.

Equipment management is of prime importance because of high cost. The efficient equipment management includes:

- Selection of proper size, number and specifications equipments to do the work in hand,
- Preparation of an utilization program,
- Experienced operators and adequate maintenance,
- Safety aspects.

5.5) Environment and Social Impact Assessment in Road sector and its mitigation:
The highways and traffic will have the following effects on the environment

- Noise pollution,
- Air pollution,
- Biological effects,
- Visual Intrusion and degradation of aesthetics,

According to EPA 2053, and EPR, 2054, these effects will be studied under the following basis:

- Socio and economic impact,
- Cultural and physical impact,
- Chemical Impact and
- Biological Impact

It has been clearly indicated about the provisions for projects related to highways requiring IEE and EIA.
Proposals requiring BES, IEE and EIA

For BES
Up to 250 m bridge and local roads
For IEE

i) Construction of bridge more than 250 m
ii) All New Road construction up to 25 km except local road.
iii) Construction of 5~50 km long ropeways,
iv) Construction of 1~5 km long cable car routes,
v) Construction of tunnel up to 3 km
vi) Fly over and monorail route
vii) 10 to 50 km National Highway for upgrading/width increasing /reconstruction etc.
viii) National/internal water way route

Proposal requiring ELA: All which are more than the limit of IEE stated above.

Environment Assessment:
For the environmental assessment of a road various datas regarding physical, biological and cultural elements in the planned road area needs to be collected within the zone of impact.
For BES
For IEE study:
For IEE study following data are collected,

i) Base line information on biophysical, social, socio-economic are collected to provide description of the status & trends of environmental factors against which predicted changes can be compared and evaluated based upon the importance.
ii) Identification and analysis of potential impacts,
iii) Outline of major I relevant measures like:
- project alternatives to minimize impacts,
- Preventive and corrective measures,
- Compensatory measures to restore, rehab or replace damages

iv.) Preparation of Monitoring Plan:
- To identify whether the proposed mitigation measures are sufficient to alleviate or set off the anticipated negative impacts and to enhance beneficial impacts

v) IEE Report preparation and Approval
- as per format given by EPR, 1997,
- Approval by ministry, MOPIT.

For EIA study
Following stages are conducted for EI A study:
1) Screening and scoping,
2) Baseline information regarding physical environment, biological, socio-economic and cultural environment,
3) Project description,
4) Identification and analysis of project alternatives,
5) Identification and analysis of potential direct and indirect impacts.
6) Conduct public consultation, disclose notice and conduct public hearings.
7) Identify suitable management and mitigation measures,
8) Prepare Environmental Social Management Action Plan [EMAP]
9) Monitoring of EMAP and others.
10) Environmental Auditing.

Social Assessment:
Social assessment includes:
- Loss of land due to construction,
- Loss of standing agricultural crops due to construction,
- Health hazard to local people due to construction worker,
- Occupation, health and safety issue during the construction of projects.

The positive impacts which these type of social assessments bring about are:
- Increase the valuation of land in the vicinity of the Row
- Increase in settlements and growth of economic activities around row,
- Impact in existing economic standards of local people.

Capturing Environmental, Social & OHS situation:
For Bridges Environmental Issues:
1. Collection of Construction materials from legal limit of bridges.

2. Discourage private parties & Collect as per rule 500m u/s & 1 km d/s of bridge location.
3. Confined equipment yard & material source,
4. Construction Methodology approved particularly for diversion in river bed, formation of embankment for staging of formos etc.
5. Unattained Heavy Equipments to avoided
6. Illegal folder (firewood collection near forest)

Others

- Tree Cutting
- slope Protection etc.

Social & OHS Issues:

1. Accident Records
2. Any code of Conduct proposed by the Contractor,
3. Any local community Grievances noticed I recorded,
4. Approved traffic safety measures in place including Signboard flagman, barricade, night vision signs, notice to local and Concerned authorities
5. Child labours to be discouraged
6. Contract information Signboards,
7. Drinking water availability at Site
8. first Aid box and emergency measures made available
9. Location of labour camp logistics as per specification
10. Grievances regarding land acquisition
11. Nearest police station 1 Hospital I medical store Identify"
12 OHS officer
13. Post Construction site clearance
14. Row encroachment is.
15. Insufficient Safety Gadgets at Site, quality of gadget as specific
16. Record a labour
17. Enough Sanitation facilities, toilets at Site
18. Appropriate Tools available at Sites for working,

5.6. Quality Control and Assurances:

Quality is:

- Degree of Goodness,
- Fitness for purpose,
- Conformance to specification.

Dimensions of Quality:

⇨ Performance (will the product do the intended job),
⇨ Reliability (How often does it fail),
⇨ Durability (How long does the product last),
⇨ Serviceability (How easy to repair),
⇨ Aesthetics (How does it look like),
⇨ Features (what additional character it has),
⇨ Goodwill (Reputation of Company | Product),
⇨ Conformance to Standards.

Quality control (Qc):

The process performed to ensure conformance of any good / service work with valid requirements i.e. the operational techniques and activities used to check that the requirements for quality have been met.

Quality Assurance:

All those planned and systematic activities necessary to provide confidence that a particular product will satisfy given end product requirements for quality.

Also, Quality Assurance is a system or program used to monitor and evaluate the aspects of a project, service or facility to determine if quality standards are being met.

Total Quality Management:

Iso Definition: TOM is a management approach of an organization, centred on quality based on participation of all its members and aiming at long-term success through customer satisfaction as well as benefits to all the members of the organization and the society.

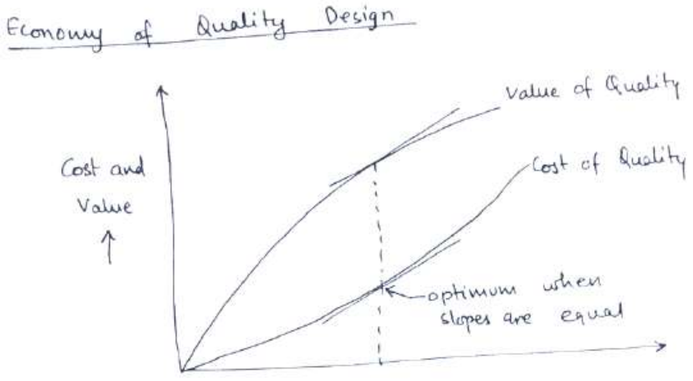
Quality Management Plan:
QMP defines the acceptable level of quality which is typically defined by the client and describes how the project will ensure this level of quality in its derivable and work progress.

Quality can be obtained through:
-duality design
- QAP approved and implemented,
- Following quality policy
- Strong implementation of Qc system.

Quality Management System (QMS) intends that the excellence expected can be obtained. It has 3 elements:
- Quality Assurance Plan (QAP),
- Quality Control Process (8C),
- QA (Quality Audit) system of tracking and documentation of QA & QC programs

Quality Control System:
Quality Control System comprises methods, procedures and organization for dc of works in following sequence:
i) Complaint testing for materials including laboratory trials,
ii) Complaint testing for methods and equipment prior to commencement of work including site trials
iii) Controlled testing during construction (Process Control),
iv) Acceptance testing on part / completed works.

Elements of QA system for road project:
1) Assessment of requirements of road project,
2) Choice of quality materials and design,
3) Development of technical specification & acceptance criteria,
4) Choice of construction method/ equipment / plant
5) Field supervision and quality control, construction technique, surface finish to desired profiles,
6) Assessment of quality inspection and of finished roads.
7.) Periodic inspection and maintenance measures.



Increasing quality of design

The optimum level of quality occurs at the level the marginal cost of one additional unit equals the marginal value. Below this optimum level, additional cost buys more than worth of quality.

Findings regarding QA in DOR:
Findings in PRO offices:
-The laboratory and testing facilities within the DROS are inadequate and poorly maintained and managed,
- Insufficient staffs are deputed to work in the labs and few are appropriately trained and experienced,
Much of DRO work is against its objective of the maintenance concept and is off SRN (i.e.on LRN).

Other problems Regarding QA &QC:

Supervision and quality control are very weak in DROs and projects. The reasons behind this are:

- No clear-cut responsibility accountability between the staffs for supervision of works,
- No proper and close monitoring system for supervision,
- No strict adherence for submission or compliance with DAP,
- No proper lab setup,
- Low priority for Lab management and material testing,
- Tests reports are required only for payment,
- Samples taken by the supervising team without the knowledge of sampling and testing,
- No monitoring system for quality control,
- Lack of trained lab technician and lab assistants.

Problems regarding QA

The quality assurance objectives of various parties that are involved in a project differ & often bring conflict.

Client: Maximise quality without undue cost overrun

Designers: A level of quality assuring satisfactory performance of structure, rise of professional reputation without undue costs,

Contractors: Satisfy the specification at minimum direct cast.

Suggestions to Improve QA/Requirements for Sustainable QA

1) Supervision through DROs and Projects:

- Staffing on vacant position with clear job description,
- One-Engineer mandatorily deputed as lab in charge
- Submission and follow-up for conformance to QAP,
- DRO labs need to be upgraded with time,
- Detailed Records to be maintained and filed,

2) Strengthening of DRO labs by providing adequate staff, equipment and other resources,

3) Institutional Recommendation including:

- one engineer designated as lab-in-charge in each DRO and responsible for QA activities,
- Permanent ac unit to be established in Dor with appropriate power to intervene,
- Provision of a "Regional Lab in each regional zone equivalent to CRL. RD to conduct visits frequently to supervise monitor and evaluate the quality control aspects of works.
- Senior material Engineer to be appointed in each RD to monitor lab tests in DROS

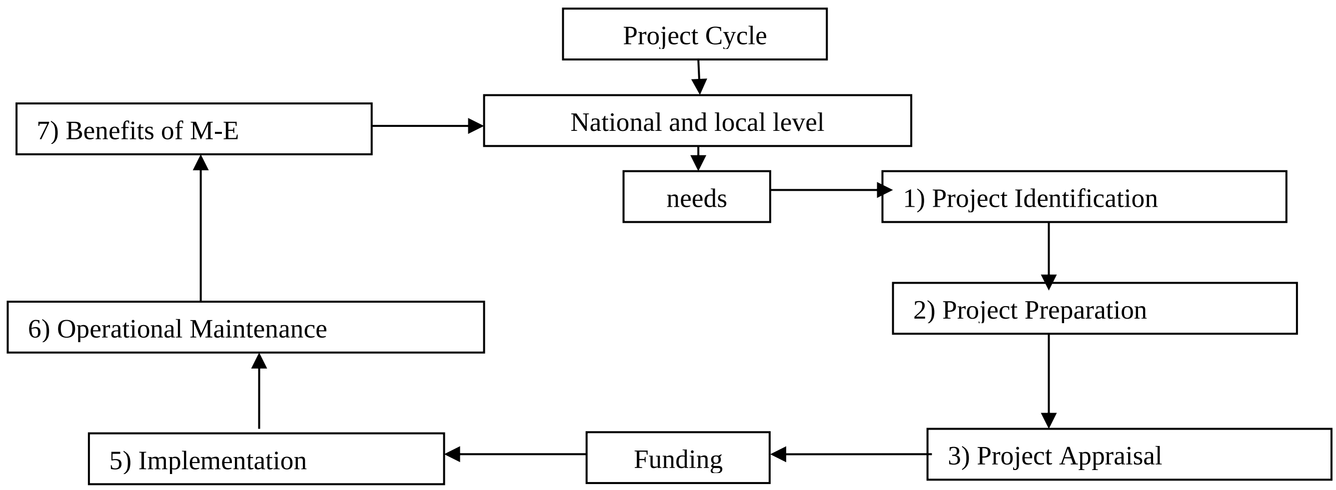
4) Provide necessary and adequate training to related staffs regarding Qc and lab testing,

5) Reward and punishment systems to be established by DoR after making and its of DROs, and projects.

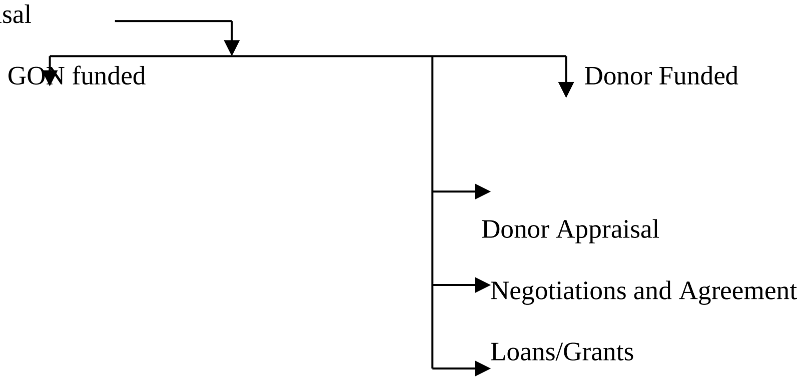
6) Necessary to amend legislation so that existing directives and rules are followed and to ensure that payment are conditional on QA process,

7) Completion of all QA measures to be made a mandatory

5.7) Monitoring and Evaluation



A project cycle goes through following Phases:
1) Project Identification
2) Project preparation
3.) Project appraisal



4.) Funding,
5) Project Implementation
6) Operational

Monitoring:
Monitoring is a continuous or periodic review and overseeing by management at every level of the hierarchy of implementation of a project to ensure that input deliveries, work schedule, targeted outputs and other required actions are proceeding as per plans and Monitoring can be classified as:

a) Process Monitoring:
It observes development processes taking place within an organization aiming at the improvements in efficiency and effectiveness of the organizations. It has the following characteristics:
- It measures the capacity building at the organization,
- Processes have dynamic objectives where priorities may change or new objectives are formulated to update with time,
- There are multiple routes open to be followed according to the availability policy options for the organization,

b) Project Monitoring:
It monitors the performance of a project with regard to its physical output in terms of quality, quantity, time and cost.
- It shows input/output relationship,
- The project objectives are predetermined
- Usually there's only one route to achieve the goals,
- Delivery of tangible assets is essential

Monitoring Systems in DOR:
There are two types of monitoring systems:

1) NPC - Progress Monitoring System:
NPC has progress monitoring system which works on it set us progress achieved based on approved programs. It has two systems:

a) General System:
It is Input-output monitoring insists of progress reports of physical works completed us financial expenditures along with problems & suggestions.

b) Core Project System:
Npc classifies some important projects as core projects which demand monthly , trimesterly & yearly progress reports in NPC format. Usually account contoller office of that region (intrat in cht.), stops the financial activity of such projects is 80% progress is not met as per target set in the approved programs.

2) Donors' - Project Monitoring System:

Donors like ADB, WB assisted projects have their own project level monitoring system based on log frame approach of planning programming and monitoring. It involves quarter yearly progress reporting from projects involving tools like Ms-Projects etc. validated by regular field visits.

Levels of Monitoring:
Monitoring is done at following levels:
a) Project level:
Project Level monitoring is responsible for day to day and periodic monitoring of project involving time, cost, quality and quantity control.

b) Central / Sectoral / Ministry level:
At ministry and departmental level, a monitoring and evaluation Unit is established which is involved in:
Recording of progress and M-E reports,
Reporting to internal CMOPIT) and external (Department of Auditor's General and NPC) organisations,

- Advising and development of feedback system with Computer networking,
- Uniformity and standardization of formats & procedures,
- follow-up, communication, dissemination and facilitation,
- Capacity building,
- Preparing departmental monitoring policy and globalization of monitoring procedures,

C) NPC level:
It can be considered as external monitoring of projects which lays down guidelines an procedures from national point of view and make occasional visit of projects & organize progress review meeting.

Evaluation:
Evaluation is a process of determine the relevance, efficiency and effectiveness of a project in a objective, especially its long term and broader objectives. It gives:
- Information for target adjustment,
- Information for re-planning
~ With M&E →ongoing Evaluation,
E alone at end →ex-post evaluation

Benefits of M and E: one impacts and benefits of M-E are to determine the extent to which the project has achieved its original objectives. Me process has following advantages:

- Provides information and guidelines to future planning process,
- The performance evaluation of implementing agencies,
- Contractor and consultant involved in the project are also involved in the stage,
- Monitoring of input-output- benefit-sustainability by the selection of indicators like -time-quantity -quality-cost.
- Evaluation of process and impact on ongoing midterm and completed projects.
    - Efficiency, impact
    - Effectiveness, effect
    - Ration ability,
    - Sustainability.

Stages of evaluation:
1) Evaluation of logical framework, preparation, development,
2) Evaluation framework and action plan,
3.) Data Collection and analysis,
4) Conclusion on evaluation and reporting at the end.

Evaluation Tools:

- Direct observation,
- Targeted Group techniques,
- Semi structural interview,
- Sampling,
- Questionnaire surveys,
- SWOT analysis,
- Kirk Patrick model for education
- Goal

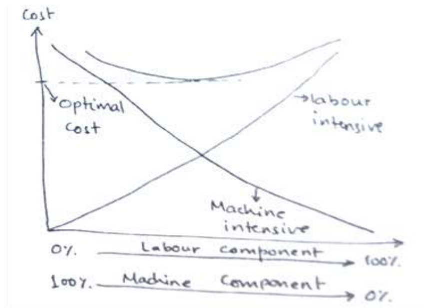
M&E Tools & Formats:	Institutional Framework
Annual programme, Annual progress reports, Project basis statistics/status, Monthly / Timester progress report, New project information, Project inspection, Log- frame basics	NDC NDAC, MDAC, DSMC M & E DIV-NPC, MO F etc M & E div in line ministry/Departments CBS census/surveys. NDC=National Dev. Committee NDAC=Nat. Dev. Action Committee MDAC=Ministry Dev. Action Committee

Research done by ILO shows that for the same lever of local infrastructure investment using labor in method, there are following advantages:

- 2~4 times employment opportunities (unskilled),
- Drop foreign exchange requirement by 50-60%,
- Decrease overall road cost by 10-30 %,
- Reduce environment impacts,
- Increased use of associated local resources,
- Rise in overall economy of that area,

In Nepal RAP, Gtz (RCIW) are practicing labour intensive method of road construction by making RBG and SBG user groups. Road track opening activities are often performed. The groups are supplemented with shovel, pick-axes & other tools.

- DOR has employed length workers and supervisors to promote routine base labour-intensive road maintenance operations.
- Also, PPA, PPR have promoted the Labour-intensive projects by awarding project costs up to Rs. 16 mill. directly to user Groups.
- Apply team balancing approach, intelligent mix of non-appropriate technologies with optimal labour component is an essence
- Also, our long-term 20-year plan and DOR policy INTP-2058 has promoted the labour-intensive works.



Basic Pillars of Labour-Intensive Methods:

Labour Intensive approach of load construction is supposed to have followed basic pillars:

Participation of the benefiting community in the project execution,

- Help to make land available along the alignment of road for its proper construction,
- Use of locally available materials in road construction,
- Labour comes from local community creating the employment specially in non-farming seasons,
- Trains people in maintaining roads independent of external assistance,
- Training, learning and earning is done collectively thereby increasing organizational capacity of community.

Avoiding Excessive Machinery use:

- For all work that can be done manually,
- Community Independent of companies that sell or hire equipment's,

Environmental Sustainability:

- Land moving is minimum | minimum slides, less disturbance damage to stable slope.

Project Sustainability:

- Local communities gain "sense of Ownership" along with capacity to construct and subsequently maintain roads.

Design of Overlays

Before designing for overlays, following evaluations are done

i) Evaluation of pavement surface condition,

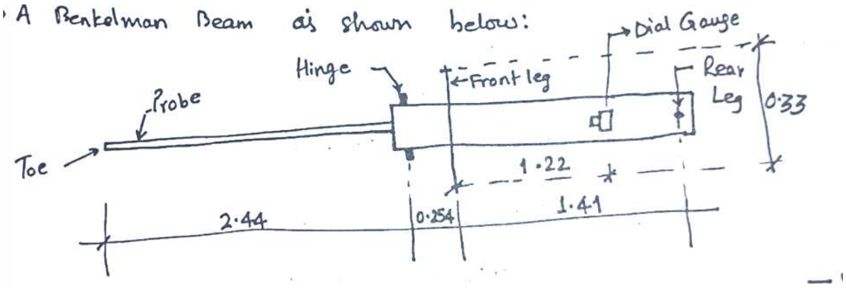
ii) Structural Evaluation of pavements,

The thickness of overlay required over a basement may be determined by:

- Conventional Pavement Design Methods
- NOT methods like Benkelman Bean Deflection method

Benkelman Beam Deflection Method:
Scope: This test is done to determine the rebound deflection of a pavement under a standard wheel load and tyre pressure.

Equipments used:
→ A Benkelman Beam as shown below:



Design Wheel load with dual wheel assembly of gross weight 4085kg. with inflation pressure of 5-6 kgt/cm^2
A trick with rear axle load g 8170 kg

Procedure:
1. Pavement condition assessed and classified as Good I fair/poor w.r.t the cracks, ruts, irregularities observed. The test points are then located within range of 500m
2. Observations to be taken from edges:
N 0. 90m for pavement width ≥3.5m
N 0.60m for pavement width <3.5 (narrow roads)

Observations:
At least to or most preferably 20 observations should be made as follows:
i) Truck driver slowly takes truck parallel to the edge of steps with assembly placed centrally over wheel the point. Benkelman beam proved placed under the rear wheel assembly at the centre and initial dial gauge reading (D;)is noted,
ii) Similarly, the truck is further moved ahead up to a distance of 2.70m, the intermediate dial gauge reading (D;) is noted.
iii) Again the truck is further moved ahead to a distance of 9.0m and final dial gauge reading (D;) is noted.
Here, D_0, D_i and D_f make one set of deflection readings. As required, 'n' number of readings are taken over distressed stretch of road.

4.) Rebound Deflection CD) :
for D. there are two conditions, @
Also a division of dial gauge 20.01 mm (units) .
1.) If D_i-D_f ≤2.5 divisions, no corrections.
D= 2 (D_0-D_f) = 0.02 (D_0.- D_f) mm.
ii) If D_i -D_f > 2.5 divisions, correction is required
A factor k= 2.91 is introduced such that
- D= 2 (D_0.- D_f) +2K (Di-Df) = 0.02 (D_0-D_f) +0.0582 (D_i-D_f) mm.

This gives rebound deflection for first set of observations.

5.) characteristic Deflection (Dc):
say 'rt' no. of readings at several points are taken, then
mean deflection
Standard deviation

$$(\bar{D}) = \frac{\sum_{i=1}^{n} D_i}{n}$$

$$(\sigma) = \sqrt{\frac{(\bar{D} - D_i)^2}{n-1}}$$

Then, characteristic Deflection

Deflection, $D_c = \bar{D} + \sigma$ (As per IRC)

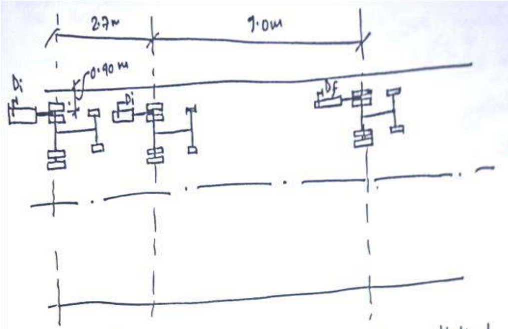


fig: Observation set of Benkelman Beam Method

6.) Overlay Thickness (h_o): or strengthening of existing pavement

For successful maintenance of pavement, it is essential that they have adequate stability to withstand the design traffic under prevailing climatic and sub grade conditions. If pavement have to support, increased wheel loads repetitions, it can be achieved either by diverting the traffic to other route or strength the existing pavement. For the overlay

As given by the IRC equation, the thickness (Ho in mm) equivalent to granular material of WBM layer of overlay required is given as:

Ho= 550 $\text{Log}_{10}\left(\frac{D_s}{D_n}\right)$

When D_n = A factor given by IRC based on project Design Traffic value of Da ranges from 1~1.50

Type of overlays:

As per conventional methods overlay are of following types:

1) Flexible overlay over flexible pavement,

$H_0=h_d=h_e$

H_d=thickness presently designed

H_e=thickness of existing pavement

2) Rigid overlay Rigid pavement.

$$h_0 = [h_d^a - x h_e^b]^n$$

Where,

Value of a, b,n, x to be taken from tables

H_0= required overlay thickness

h_d=design thickness

h_e= existing pavement thickness

In the rigid-to-rigid overlay, the interface between the old and new concrete cannot perfect bond such that the two slabs could act as monolithic. Two typical interfaces are possibly a) providing maximum possible interface bond by making the old surface rough and b) separating the two slabs at interface by thin layer of bituminous material or without interface bond.

3) Flexible overlay over rigid pavement

H_0=2.5 (F.h_d-h_e)

Where,

F=factor depending on modules of existing pavement.

For calculating the thickness of bituminous, $H_b=H_o/1.5$

4) Rigid overlay over flexible pavement: thickness of rigid overlay is calculated by design criteria of rigid pavement such as the plate bearing test for finding. the design is made for K value and design wheel load.

Road Construction Technology

Road Construction Technology

Road construction technology is that branch of highway engineering which deals with all kinds of activities and technology or operations for changing existing ground in the designed shape, slope, and to provide all necessary facilities for smooth and efficient traffic operation and also include the reconstruction of existing roads. As per the nature and type of works and elements of road to be constructed various activities can broadly divided into several works.

1. Site clearance and Earthwork
   - Site clearance
   - Earthwork for cutting and filling
   - Excavation for borrow pit
   - Excavation for structural foundation
   - Disposal of surplus earth
2. Drainage works
   - Side drains
   - Causeway
   - Vented or Flood bridge
   - Culverts
   - Minor bridge
   - Major bridge
3. Protection works
   - Earth retaining structures
   - River training works
   - Gully control works
   - Land slide stabilization
   - Bridge protection works
4. Pavement works
   - Sub grade works
   - Sub base works
   - Base works
   - Surface works
5. Miscellaneous works
   - Road ancillaries
   - Traffic sign/markings etc
   - Road furniture
   - Bio engineering works
   - Public awareness about road and traffic

Road Construction Tools, Equipment, and Plants

Although the road construction may be done manually but it takes lot of time to complete the road project. The quality of the works may not be achieved to the desired degree and which cannot maintained strictly by using intensive labour force within time in comparison to construction equipment. In developing countries like Nepal the trend of using construction equipment increases rapidly. Construction equipment used in road construction project is:

1. Tools
- Hand shovel
- Chisel
- Peak
- Spade
- Hand rammer
- Brushes
- Trowel
- Wheel barrows etc

2. Equipment
   a. Earth moving equipment
- Dozer

- Scraper
- Loader
- Excavator
- Dragline
- Clamshell
- Trench digger

b. Compaction equipment

- Smooth wheel rollers
- Vibrating rollers
- Pneumatic rollers
- Sheep foot rollers
- Rammers

c. Leveling equipment

- Grader

d. Paving equipment

- Binder sprayer
- Heating kettle for binder
- Aggregate spreader
- Cement concrete mixer
- Bituminous paver
- Cement concrete paver etc
- Air blowers
- Cleaning devices

e. Lifting Equipment

- Backhoe
- Crane

f. Transporting equipment

- Dumping trucks
- Tippers
- Trucks flat body
- Mini dumper
- Tractors

3. Plant

- Cement concrete plant
- Asphalt concrete plant
- Cold premix plant
- Aggregate crusher plant
- Screening plant
- Washing plant
- Sand blowing plant
- Fully maintained laboratory and testing equipment.

ROAD CONSTRUCTION TECHNOLOGY:

Based on priority, there are various types and standards of roads. The selection of base/subbase course and the surface course depends upon the following factors:

- Type and intensity of traffic,
- funds available for construction and maintenance,
- Subgrade soil and drainage conditions,
- Availability of construction materials at site,
- Climatic Conditions,
- Availability of plants and equipment's,
- Time available for completing the con project,
- Altitude at which construction has to be made,

Some fundamental Procedures:

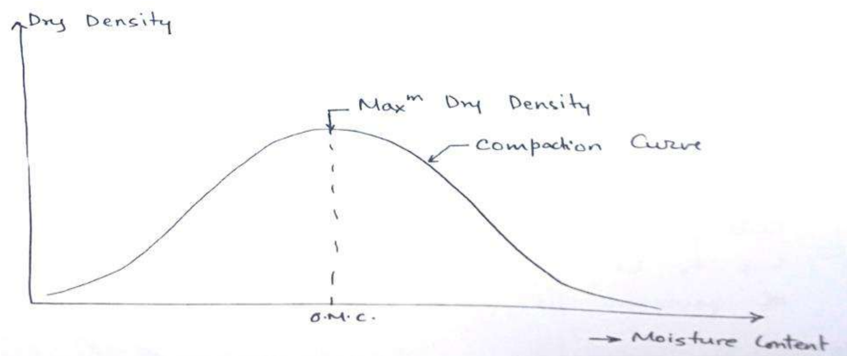
- Preparation of Soil Subgrade:

Subgrade is the lowermost part of highway under excavation or at embankment or at natural ground level. By grading, it is brought to the desired grade and camber after the completion of site clearance works like cleaning, Cutting off of grass, roots, rubbish or other organic matters. It has to be essentially compacted well before any layer of pavement is placed over it.

Compaction:

Compaction is the process of expelling the air from soil mass mechanically to reduce the voids increasing the density of soil. This increases the stability of soil as well as reduces any chances of settlement 4 adverse effects of water content. Compaction is achieved by rolling, ramming, vibration etc. Facters effecting compaction are:

- Water Content
- Amount and means of compaction,
- Type and method of compaction,
- Types of soil,
- Addition of Admixtures,



Thus, compaction control is done by the measurement of- Moisture content and Dry Density.

Soil stabilization:

If the stability of local soil is inadequate for supporting Wheel loads, soil stabilization to techniques are implied improve the quality of such inferior soil, strength, density, bearing capacity etc. Stability of soil is often achieved by:

- Proportioning techniques involving mixing of various types of soil together with aggregates etc. and compacting,
- Use of cementing materials ie omc, lime, bitumen etc. with soil mixed, blended and well compacted,
- Use of modifying agents like stabilizers etc.,
- Use of water proofing agents to stop ingress of water into weak soil
- Use of water repellent agents,
- Heat treatment,
- chemical Stabilization techniques

Following are some methods of soil stabilization:

1) Mechanical Methods:

It involves mixing and blending of various types of construction materials together like coarse aggregate, fine aggregate, soil etc. in required proportions to obtain designed stability after compaction. It is affected by the following factors.

- Property of soil,
- Gradation of aggregates,
- Mechanical strength of aggregates,
- Compaction,
- Presence of salts, mica organic matters etc.

2) Soil-Cement Stabilization:

soil, cement and water are blended well and compacted to form a strong sub-base and base course. The cement hereby acts as strengthening and bonding agent. Such materials are however, weak in abrasion and thus can't be used in surface works / wearing course. It is often effected by:

- Type of soil,
- Type and amount of cement,
- Mixing and pulverisation,
- Amount of compaction and curing,

- Addition of admixtures etc.

3) Soil- lime Stabilisation:
Clayey soils have high plasticity index for which lime is used as modifier / binder which considerably reduces the P. I. of such soils making them friable and easy to be pulverised with very less affinity with water.

Soil-time stabilisation is affected by:
- Type of soil,
- Type and amount of time content,
- Compaction and curing,
- Addition of additives.

4) Soil- bitumen Stabilisation:
This is done by the use of cutback and emulsions for waterproofing and binding such that the inherent strength and other properties are retained. It's affected by following factors:
- Type of soil,
- Type and amount of bitumen,
- Mixing and compaction,
- Curing,
- Additives.

5) Stabilisation of Black - Cotton Soils:
Due to high volumetric variations in black cotton soils and their high plasticity nature, cement or lime are used. for cost effectiveness, line is more frequently used. This process modifies the following properties:
- P.I. is decreased to as much as zero,
- Affinity with water and thus volumetric variations are decreased by large extent,

-Less shrinkage after compaction,
- Less cement requirement.
- following measures are adopted for stabilising the black cotton soils:
- Subgrade soil is treated with little lime upto desired depth,
- Well compacted soil-lime for sub-base course,
- Soil- lime with admixtures for base course &
- Preferably superior type of materials in surface course.

Preparation of Bituminous Surfaces Interface Treatments:
Before laying any types of bituminous course over a surface, it should be free from dust, dirt or other organic materials. Over the prepared surface, a thin layer of bituminous binder has to be provided before laying of surface treatment by spraying which is called interface treatment. Interface treatment can either be a prime coat, tack coat or seal coat.

a) Prime Coat:
Similar to primer in painting, a thin layer of low viscosity liquid material is applied over an existing porous surface using a mechanical sprayer @ 75 ~ 24.6 kg (m? It's mainly applied to plug in the capillary voids of the porous surface and to bind together all the loose materials.

b) Tack Coat:
It's the application of the bituminous material over an existing impervious pavement surface to bind it with the surface / course to be overlaid. It is applied by a sprayer mechanically @ 4.9.9.8 kg/m2 based upon surface applied.

c) Seal Coat:
It's a very thin layer of surface treatment, a top layer provided over a relatively pervious or existing worn-out bituminous pavement for the following purposes:
- To seal the surface against ingress of water, - To develop skid resistant surface,
- To give a new life to existing worn out surface by means of patching

Construction of Some Major Pavement Types:

Earthen Road

It is cheapest type of road pavement, suitable for dry season and its construction depends on the type of soil available at site but preferable to have a soil liquid limit below 35% for base and wearing course and plastic limit less than 6% for base course and 4 to 10% for wearing course having camber 5 to 4%.

Construction procedure

a. Soil survey – Beyond right of way borrow pits, materials should be free from organic matter. The trees, shrubs grass roots and top soil are removed before excavating earth for construction.
b. Location – Center line with wooden pegs and reference page are fix.
c. Preparation of sub grade – clearing site, grading cut or fill to the desired grade, shaping of sub grade and compaction before placing the pavement materials
d. Pavement construction – The borrowed soil (more than one soil type mixed to the desired proportion if necessary) are dumped on prepared sub grade and pulverized. The filed moisture content is checked and additional water mixed if necessary to bring it up to OMC. Soil mixed spread, rolled in layers compacted thickness not more than 10cm.
e. Open to traffic after setting of compacted earth. Choice of compaction equipment is based on type of soil. At least 95% of dry density should be achieved. Camber and grade are checked and corrected if necessary.

Gravel Road

It is considered superior to earthen roads as they can carry heavier traffic. It may be feather edge type (varying thickness to attain the camber) and trench type (better confinement gravel) having camber 4 to 3.3%. Hard durable and strong varieties of crushed stone or gravel of specified gradation for maximum density is used but in practice, softer varieties are also used. Rounded stone or river gravel are not preferable as they have poor interlocking. For construction generally manually with hand tools or excavation, hauling compacting equipment can be used.

Construction Procedure

a. Materials – Gravel to be used for construction is stacked along the sides of the proposed road.
b. Location – wooden pegs for centreline and reference pegs for carriage way are driven.
c. Preparation of sub grade - clearing site, grading cut or fill to the desired grade, shaping of sub grade and compaction before placing the pavement materials
d. Pavement construction
    - Gravel is placed carefully in the trench so as to avoid segregation.
    - Gravel spread with greater thickness at center and less towards the edges so as to obtain the desired camber.
    - Rolling with smooth wheel roller or vibrator. It starts from edges and proceeding towards center with ½ width of roller overlapping.
    - Control of field moisture and density (depend on specification generally 95%). Camber and grade checked properly.
    - Open to traffic – after few days of completion, traffic is opened.

Construction of WBM Roads: These are a bit superior over gravel roads wherein the Crushed Road aggregates along with screenings and binding materials are bound together by rolling along with water to fill up the pores. Use of perfect gradation of materials, rolling combined with spray of water gives perfect bonding and as such can be used for any works course.

Materials:

- Coarse (crushed) aggregates, screenings and binding materials as per specification,

Equipments:

- Water tanker to spray water during compaction,
- Grading equipments, - Compacting equipments, rolless etc.
- Other required minor equipments,
- Construction and Opening to Traffic
- Subgrade preparation, grading and compaction to required Camber,

- Lateral confinement is done, aggregates spreaded,
- Rolling done over the spread aggregates mixed with screenings to fill voids. Water frequently sprinkled,
- Binding materials applied in required quantity and allowed to dry for a few days. Unevenness is checked and rectified (if found),
- Final Compaction is done.

Bituminous Roads:
These are flexible pavements made by laying a course of bituminous materials over an existing / prepared surface. Stage wise construction of different layers is done for enhanced strength laying one after the other for a certain period of time. Some popular types are:

- **Seal coat and other interface treatments** like prime coat and tack coat. Prime coat is applied on pervious layer for example on WBM with low viscosity cut back. Main function of prime coat is to seal the pores and water proof the underlying layer and to develop interface condition for bonding and tack coat is applied on relatively impervious layer for example existing bituminous pavement. Main function of tack coat is to seal the pores and water proof the underlying layer and to develop interface condition for bonding.
  - Prime Coat,
  - Tack coat and
  - seal coat.
- **Surface Dressing,**
  - ➢ Surface Dressing is a simple, highly effective and inexpensive road surface treatment comprises of a thin film of binder and then covered with a layer of stone chippings.
  - ➢ Basic surface dressing consists of spraying a film of binder onto the existing road surface followed by the application of a layer of aggregate chippings and then rolled to promote contact between the chippings and the binder and to initiate the formation of an interlocking mosaic.
  - ➢ It is a very effective maintenance technique capable of greatly extending the life of structurally sound road surface.
  - ➢ It can provide an effective and economical running surface for newly constructed road pavements.
  - ➢ It is widely used in Nepal as a part of planned maintenance.
  - ➢ It is done in dry and clear weather condition having ambient temperature above 16 degree Celsius.

Application

1. Maintenance Resealing: Existing Road as a repair treatment or as periodic maintenance.
2. Reconstruction and New construction: Usually low cost to provide a running surface and seal.

Functions

- ➢ To seal the road against water penetration.
- ➢ To stop the disintegration and loss of aggregate from the road surface.
- ➢ To provide anti-skidding road surface.
- ➢ It provides a distinctive colour to the road surface and more uniform appearance to a patched road.

Limitations

- ➢ It does not contribute to structural strength of the road structure.
- ➢ It cannot improve shape and riding quality of a road.
- ➢ It is only appropriate for roads which are structurally sound.
- ➢ Only suitable for dry and clear weather having ambient temperature above 16 degrees Celsius.

Types

- ➢ Single surface dressing which is used in normal case for resealing purpose.
- ➢ Double surface dressing which is used on badly deteriorated surface and on new road construction.
- ➢ Racked in surface dressing which is used where traffic is heavy or fast.
- ➢ Pad coat which is used on very hard road surface like concrete pavements.
- ➢ Sandwich dressing which is used on existing binder rich surface and sometimes on gradients.

Principle

- ➢ Bitumen must adhere to the road surface and chippings.
- ➢ Bitumen must be capable of being sprayed safely and evenly.
- ➢ Bitumen thickness must be sufficient to retain chippings.
- ➢ Chippings must adhere to the bitumen and be retained under the action of traffic.
- ➢ Size of chippings must be appropriate for the site characteristics.

- Completed surface dressing must be durable and effective.
- Must be acceptable to and safe for the road user.
- Several factors affect the application rate of bitumen and chippings like existing surface, traffic, climate, type of binder, characteristics of chippings.

Construction procedure for surface dressing

Material required

- Bitumen of grade 80/100 to 180/200 is used.
- Quantity of bitumen required as per specification.

Type of surface	First coat kg/sq m	Second coat kg/sq m	Third coat kg/sq m
WBM or existing bituminous pavement	1.2 to 1.45	1 to 1.2	1 to 1.2
Black top surfacing	1 to 1.2	1 to 1.2	1 to 1.2

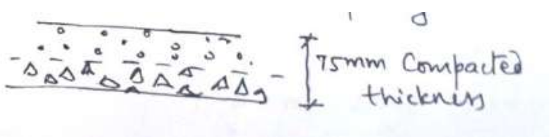
- Coarse aggregate should be of crushed stone, clean, strong, durable etc. with the Los angles abrasion value is 35% maximum, aggregate impact value is 30% maximum, flakiness index 25% maximum, water absorption 1% maximum and stripping value 25% maximum.
- Quantity of aggregate required for first coat passing through 18mm and retained 9mm is 14 to 15 kg per sq m and for second coat passing through 12mm and retained on 6mm is 9 to 11 kg per sq m.
- Plant and equipment are bitumen heating device, bitumen sprayer, mechanical sweeper or hard brush, aggregate spreader and pneumatic roller etc.

Construction steps

- Preparation and intensive cleaning of existing surface
- Application of binder
- Application of stone chipping
- Rolling of first (or final coat for SBST) at least four passes
- Opening to traffic with controlled lower speed less than 10kmph for 7 to 14 days
- Brooming and cleaning of loose aggregate
- Application of binder and stone chipping for second coat
- Rolling of second coat (or final coat for DBST) at least four passes
- Opening to traffic with controlled lower speed less than 10kmph for 7 to 14 days
- Brooming and cleaning of loose aggreagate
- Application of binder and stone chipping for third coat
- Rolling of third coat at least four passes for TBST
- Finishing and opening to traffic

Built-Up Spray Grout:

- Consists of two layers of composite construction of compacted crushed aggregate,
- Bituminous binder is spread over each layer and finished with key aggregates at the top to provide a total compacted thickness of 75 mm.
- A suitable wearing course has to be invariably provided over this layer before opening to traffic



Penetration or Grouted Macadam

It is one of the popular bituminous pavements having thickness 5 to 7.5 cm

Construction procedure

Material required

- Bitumen of grade 80/100 is used and quantity depends upon desired degree of compaction such as 50 to 67 kg for 5 and 7.5cm thick per 10sqm respectively.
- Aggregate should be of crushed stone, clean, strong, durable etc. with the Los angles abrasion value is 40% maximum, aggregate impact value is 30% maximum, flakiness index 25% maximum, water absorption 1% maximum and stripping value 25% maximum.

- Plant and equipment are bitumen heating device, bitumen sprayer, mechanical sweeper or hard brush, aggregate spreader, air compressor and pneumatic roller etc.
- Gradation of aggregate is

	Thickness of layer	Coarse aggregate	Key aggregate
Maximum size of coarse aggregate for	7.5 cm	63 mm down	25mm down
	5 cm	50 mm down	19mm down
Approximately quantity required for	5 cm	$0.60m^3/10m^2$	$0.15m^3/10m^2$
	7.5 cm	$0.90m^3/10m^2$	$0.18m^3/10m^2$

Construction steps

- Preparation and intensive cleaning of existing surface
- Application and spreading of coarse aggregate
- Rolling from 10 tonnes roller
- Application of bitumen
- Spreading of key aggregate
- Rolling from 10 tones
- Application of seal coat
- Finishing and opening to traffic after 24 hours

Premix (Based on the technique of mixing and construction it can be hot or cold mix and based on gradation of aggregate it can be open or dense graded)

a. **Sheet asphalt**
    - it is a carpet of sand bitumen mix without coarse aggregate.
    - Materials used are sand, filler, and bitumen.
    - This mix is durable, stable, dense and impervious.
    - In Great Britain, it is called as Rolled Asphalt.

b. **Mastic asphalt**
    - Mixture of bitumen, fine aggregate, and filler in suitable proportion, it is void less and impervious mass.
    - Ingredients similar to bituminous concrete but the properties different.
    - The mastic asphalt when cooled, results in hard, stable, and durable layer which is suitable to withstand heavy traffic.
    - Mostly used on surfaces on bridge deck slab.
    - It is prepared by heating aggregate, filler and bitumen to 200 to 225 degree Celsius for 5 hrs.
    - At 200 degree Celsius mastic asphalt has a consistency of flow. But on cooling to atmospheric temperature it hardness to semi solid or solid state.
    - Can be laid and spread without compaction 2.5 to 5 cm thick.

Bituminous Bound Macadam

This type of premix of pavement is open graded and mostly used as base course in developed countries, if laid as surface course at least seal coat is required. Usual thickness of the layer is 5 to 7.5 cm and aggregate sizes used are 37mm down. Material required

- Bitumen of grade 80/100 is used and quantity depends upon road surface such as 4 to 7.5 kg for black top and 7.5 to 10kg for WBM per 10sqm respectively and binder content maximum 3 to 4.5 % by weight.
- Aggregate should be of crushed stone, clean, strong, durable etc. with the Los angles abrasion value is 50% maximum, aggregate impact value is 35% maximum, flakiness index 15% maximum, water absorption 1% maximum and stripping value 25% maximum.
- Plant and equipment are bitumen heating device, bitumen sprayer, mechanical sweeper or hard brush, aggregate spreader, air compressor, mechanical paver grader or manual method and pneumatic roller etc.

Construction steps

- Preparation and intensive cleaning of existing surface
- Tack coat or prime coat application
- Premix production
- Placement of the mix at site with paver or grader or manually
- Rolling (8 to 10 tones) and finishing the paving mix
- Application of seal coat
- opening to traffic after 24 hours

Bituminous Carpet

Premix of bituminous carpet is prepared from stone chipping 10 to 12mm size, coarse sand above 6mm and bitumen usually 2 to 2.5 cm thick layer is used as surface coarse.

Material required

- Bitumen of grade 80/100 is used and 7.32 to 9.76kg per 10sq m for prime coat and 14.92 kg /10sq m for the mix.
- Aggregate should be of crushed stone, clean, strong, durable etc. with the Los angles abrasion value is 40% maximum, aggregate impact value is 30% maximum, flakiness index 25% maximum, water absorption 1% maximum and stripping value 25% maximum.
- Quantity of aggregate is 0.18cubic meter/sq m and passing from 20mm and retained on 10mm and quantity of aggregate is 0.091cubic meter/sq m and passing from 12mm and retained on 6mm are required.
- Sand should be clean, hard, and durable.
- Plant and equipment are bitumen heating device, bitumen sprayer, mechanical sweeper or hard brush, aggregate spreader, hot mix plant and pneumatic roller etc.

Construction steps

- Preparation and intensive cleaning of existing surface
- Tack coat or prime coat application
- Premix production
- Placement of the mix at site with paver or grader or manually
- Rolling (8 to 10 tonnes) and finishing the paving mix
- opening to traffic after 24 hours

A) Bituminous Concrete premix

- It is highest quality construction in the group of black top surface.
- Gradation of aggregate strictly controlled to provide dense mass.
- Mineral filler is used to fill up the voids of fine aggregate.
- Thickness of the layer depends upon traffic intensity and quality of base course for light, medium, heavy and very heavy traffic 5cm, 8cm, 8cm, and 10cm total thickness is required respectively.
- It is a mixture of coarse aggregate, fine aggregate, mineral filler and bitumen for the use as a layer of binder coarse and wearing course. It is costlier compared to any other types of black top pavements.
- Bituminous concrete layer is more durable, have better riding quality and more load carrying capacity. Material required
- Bitumen of grade 30/40, 60/70, 80/100 is used and quantity shall be 5 to 7.5% by weight of aggregate.
- Suitable proportion of aggregate should be as per gradation requirement. Maximum size 20mm down or 12.5mm down. Binder content required depends up on Marshall Stability test.
- Aggregate should be of crushed stone, clean, strong, durable etc. with the Los angles abrasion value is 30% maximum, aggregate impact value is 30% maximum, flakiness index 25% maximum, water absorption 1% maximum and stripping value 25% maximum.
- Mix should have following properties

	Heavy	Medium	Light
Stability kg	800	550	380
Flow value	2 to 4 mm	2 to 4.5 mm	2 to 5 mm
Voids in mix %	3 to 5	3 to 5	3 to 5

- Plant and equipment are bitumen heating device, bitumen sprayer, mechanical sweeper or hard brush, aggregate spreader, hot mix plant and pneumatic roller etc.

Construction steps

- Preparation and intensive cleaning of existing surface
- Premix production hot mix plant
- Placement of the mix at site with paver or grader or manually as per required shape and depth
- Rolling (8 to 10 tonnes) first two passes and finishing the paving mix
- Quality control of bitumen concrete construction such as intensive cleaning of underlying layer, cutting vertically the edges of previously laid bituminous concrete longitudinal or transverse joints. Tack coats along the joints and wherever as per condition.
- Opening to traffic after 24 hours

Periodical checks

- Aggregate grading, bitumen grade, temperature of mix during production compaction, and Marshall Stability test should be done. For every 100 tons of mix above tests are conducted in laboratory and for every 100 sq m field density is conducted by core cutting method.

Otta Seal Road
Construction of otta seal:
origin-from otta valley, Norway - 1960. Otta seal is a bituminous surfacing consisting of graded aggregates ranging from natural geared to crushed rock in combination with relatively soft (low viscocity) binders with or without sand cover seal.
After rolling and trafficing, the binder works it way through the aggregates' interstices which results into a dense. durable matrix that relies on both mechanical interlock and binding for its strength similar to a bituminous premix.

Construction Procedure:
Materials:
- Bitumen of MC 800 or MC 3000 - cutback,
- Well geaded aggregates with all desirable properties as per specification.

Equipments:
- Storage tank with bitumen heating device,
- Mechanical broom or hand brushes, Air Compressor, - Bitumen distributor,
- Aggregate spreader, - Pneumatic roller Construction steps:
- Preparation and intensive cleaning of the external surface by air compressor or broom.
- Application of prime coat @ specified rate,
- Application of binder @ specified rate
- Application of well graded aggregates @ specified rate,
- Rolling with two pneumatic rollers (12 tons or more) with a minimum of is passes
- After completion of initial rolling, one pass by 10-12 ton roller is beneficial to embed larger aggregates After 2 days of sealing, excessive rolling done by a pneumatic roller with minimum of 15 passes by 10-12 tons.
- Aggregates dislogded by traffic during the immediate post construction plane shall be brough back in wheel tracly in the first a . ...

- Spreading of binder @ specified rate of application,
- spreading of sand @ specified rate, and curing pneumatic roller for 4 weeks,
- Rolling by a is executed
- After 8~12 weeks, a second layer/coat in the similar process

Comparison of Otta seal & chip seal

S.N.	Details	otta seal	Chip Seal
1	Aggregate Quality	- Relaxed Requirement -Stronger requirement - strength, shape - strength, shape - Grading, dust content - Grading, dust content - Binder Adhesion – Binder Adhesion - Emphasize locally available natural gravel of crushed agg.	- Stronger requirement - Strenth, shape - Grading, dust contect - binder adhesion - Use of natural chips
2	Binder	- Relatively soft binder	- Relatively hard binder
3	Design	- Empirical, experience based	- Rational approach
4	Construction	Relatively less sensitive	- Sensitive to standard to workmanship standards of workmanship
5	Durability	- Enhanced durability due	- Reduced durability to soft binder & closed texture cvice-versa)
6	Aestheticity	- Not initially good	- Good

7	Skid Resistance in wet weather	- Initially low	– Initially high wet weather
8	Life - Single otta seal	-SBSD : 4-6 y 8 ~ 10 years	Life - Single otta seal
9	Binder - High bitumen content – Relatively		

Advantages of Otta Seal:
- Lower initial Construction cost more than 20%),
- Longer service life (4-5 yrs more),
- lower maintenance cost

Otta seal, Not successful in Nepal, why ?

- Lack of information regarding the Otta seal in terms of its design and construction,
- Resistance to change from conventional construction to Otta seal by clients, contractors,
- Design problems, the thickness of CRM-subbase should be based on design and not by ad-hoc basis,
- Lesser consideration of weather/ Climate and binder viscocity plus its spray temperature,
- Second cover and sandcover has to be constructed as per specification. However, Contractors are always in a hurry & hance not meeting up to requirements.
- Insufficient rolling
- Inferior binder /cutter

Construction of Cement Concrete Pavement

- It consists of construction of pavement slabs and design and placement of joints. Construction of cement concrete pavement have
  a. Cement grouted layer – on open graded compacted aggregated 18 to 25mm laid mixture of cement, sand and aggregate (1:1.5:2.5) is spread.
  b. Rolled concrete layer – aggregate, sand, cement and water with less plasticity is used and compacted.
  c. Cement concrete slab – usually executed either by alternative bay method or continuous bay method.
  Materials Required

- Portland cement
- Coarse aggregate should be of crushed stone, clean, strong, durable etc. with the Los angles abrasion value is 35% maximum, aggregate impact value is 30% maximum, flakiness index 25% maximum, water absorption 1% maximum, stripping value 25% maximum, crushing value is 30% maximum, and soundness value of sodium sulphate 12%, magnesium sulphate 16%.
- Fine aggregate should be free from deleterious materials and organic matter. Ratio of ingredient should be designed at least to achieve the strength of 250kg/sq cm.
- Plant and equipment are mechanical sweeper or hard brush, concrete mixture , batching device, wheel barrow, needle vibrator, float, straight edge belt, brush, concrete paver, water browser etc.

Construction steps

- Preparation of sub grade or sub base
- Placing of forms
- Batching of ingredient materials and mixing properly
- Transporting and placing of concrete
- Compaction of concrete
- Finishing of laid concrete
- Curing of cement concrete
- Field controls such as making cubes of concrete for strength test

What are the differences in applications between pipe culverts and box culverts?

- Basically, a culvert means a covered hydraulic structure which conveys fluid. Therefore in a broad sense, pipe culverts in a small scale represent normal pipes like precast concrete pipes.
- In terms of hydraulic performance, circular section is the best geometrical sections among all. Therefore, for relative small discharge, precast concrete pipes and ductile iron pipes are normally used which are circular in shape. But for applications of very large flow, precast concrete pipes and ductile iron pipes may not be available in current market. In this connection, cast-in-situ construction has to be employed. It is beyond doubt that the fabrication of formwork for circular shape is difficult when compared with normal box culvert structures. However, circular shape is the most hydraulic efficient structure which

means for a given discharge, the area of flow is minimum. Therefore, it helps to save the cost of extra linings required for the choice of box culverts.

- However, box culverts do possess some advantages. For example, they can cope with large flow situation where headroom is limited because the height of box culverts can be reduced while the size of pipe culverts is fixed. Secondly, for some difficult site conditions, e.g. excavation of structure in rock, for the same equivalent cross-sectional area, the width of box culverts can be designed to be smaller than that of pipe culverts and this enhances smaller amount of excavation and backfilling.

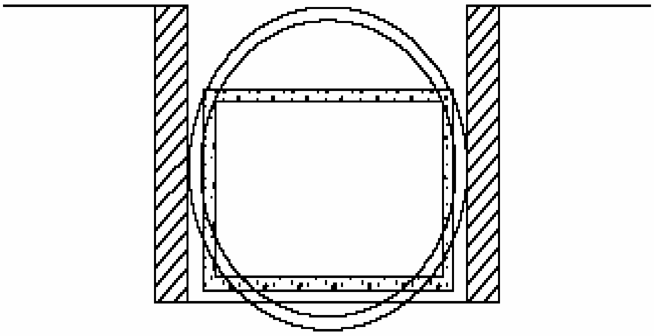


Fig. Small spatial requirement of box culvert than pipes

What is the importance of air void content in bituminous pavements?

- The air void content of bituminous materials is an important control parameter for the quality of bitumen being laid and compacted. If the air void content is too high, it allows for intrusion of air and water. Moreover, it also increases the rate of hardening of binders which produce premature embrittlement of pavements. In addition, too high a void content will also lead to differential compaction subject to traffic loads and result in formation of ruts and grooves along the wheel track.
- However, a minimum amount of air void should be maintained to avoid instability during compaction process and to provide space for bitumen flow in long-term consolidation under traffic loads. A sufficient amount of air voids should be designed to make room for expansion of binder in summer and compaction by road traffic as suggested by National Association of Australian State Road Authorities (1968), otherwise bleeding and loss of stability may occur and the pavement will deform readily under severe loads.

What is the function of longitudinal joints in concrete road pavements?

- A longitudinal joint consists of a tie bar placed at the mid-depth of a concrete pavement and it is not intended for joint lateral movement. Then one may doubt the reasons of placing longitudinal joints in concrete pavements. In fact, longitudinal joints are normally designed at a regular spacing e.g. 4.5m to accommodate the effect of differential settlement of pavement foundation. When uneven settlement occurs, the tie bars in longitudinal joints perform as hinges (Ministry of Transport (1955)) which allow for the settlement of concrete carriageway. Moreover, it also serves to cater for the effect of warping of concrete due to moisture and temperature gradients by permission of a small amount of angular movement to occur so that stresses induced by restrained warping can be avoided.
- Dowel bars are provided in longitudinal joints for the following reasons:
- (i) In case of the occurrence of uneven settlement between adjacent panels, it helps to maintain a level surface by transfer of loads through dowel bars.
- (ii) Keep the longitudinal joints close

For rigid pavement, what are the advantages of using lean concrete sub-base instead of traditional granular sub-base?

- There are several shortcomings of using granular sub-base in concrete carriageway:
- (i) Since sub-base is permeable, water can seep through sub-base and soil particles will be pumped out through contraction/expansion joints when subject to traffic load. Consequently, voids are formed underneath the pavement structure and the concrete pavement may crack under severe traffic loading.
- (ii) Lean concrete increases the strength and renders the roads capable of carrying heavy traffic loads (David Croney and Paul Croney (1992)).
- (iii) Due to workmanship problem, it may have uneven distribution of sub-base and these results in cracking of concrete carriageway when subject to severe traffic loading.

CH-6 HIGHWAY MAINTENANCE & REHABILITATION

Need for Highway Maintenance:
Highway maintenance is defined as preserving & keeping the serviceable conditions of highway as normal as possible and as best as practicable. Maintenance operations involve the assessment of road condition, diagnosis of the problems and adopting the most appropriate maintenance are of the maintenance works not done at all or done faulty or the pavement structure is inadequate for present day traffic / loading its useful life is reduced drastically which demands huge investment of funds and sincere effort of engineers for maintenance. Even the well designed and constructed highways may require maintenance and the extent depends on several factors including the pavement type. Failures ranging from minor/localised to major take place due to one or a combination of several causes.

General Causes of Pavement Failures:
General causes of pavement failures that need the maintenance measures can be given as:
1) Defects in the quality of materials used,
2) Defects in construction methods of quality control,
3) Inadequate surface and sub-surface drainage that may cause water stagnancy in different pavement layers.
4) Increase in magnitude of wheel loads /axle loads and the number of load repetitions due to increase in traffic,
5) Settlements due to inadequate compaction of foundation, of fill materials itself, 6) Environmental factors including heavy rainfall, soil erosion, high water table, snowfall, frost action etc. " Poor drainage facility, blockage, clogging, insufficient sizes and dimensions of the drainage components.

Types of Maintenance:
Depending upon the type of failure and corresponding remedial measures, maintenance of roads /highways can be classified as follows:

a) Routine Maintenance:
These are of localised nature required continually on any loads of any conditions regardness of its engineering Characteristics. It includes:
~ Cutting off and clearing grasses, shrubs and bushes on side drains and shoulders, ~ Grading and reshaping of unpaired shoulders,
~ clearing and cleaning of ditches that are found in the road way or at its sides,
~ Maintenance, cleaning of road signs / posts,
~ Removing temporary obstructions on a roadway, etc.

b) Recurrent Maintenance:
They are also of localised nature carried out at certain recurrence intervals of six months or a year (and hence name) depending upon the traffic volume, pavement type and condition. Minor equipments are used to carry out such works. Such works comprise of:
- Localised patchworks or pot hole repairs,
- Repair of holes, ruts and depressions,
- Repair of edges, - Local reconstruction etc.

c) Periodic Maintenance:
Any quality of road due to continuous catering of traffic volume of various load types and repitition gets weared out after certain periods resulting into formation of cracks, loss in friction etc. In such cases, these are the major and costly maintenance of works required after several intervals / periods for reconditioning the pavements. It includes:
~ Sealing of thin hair cracks by slurry sealing
~ Resealing works,
~ Renewal of wearing surface, overlay works,
~ Resurfacing works.

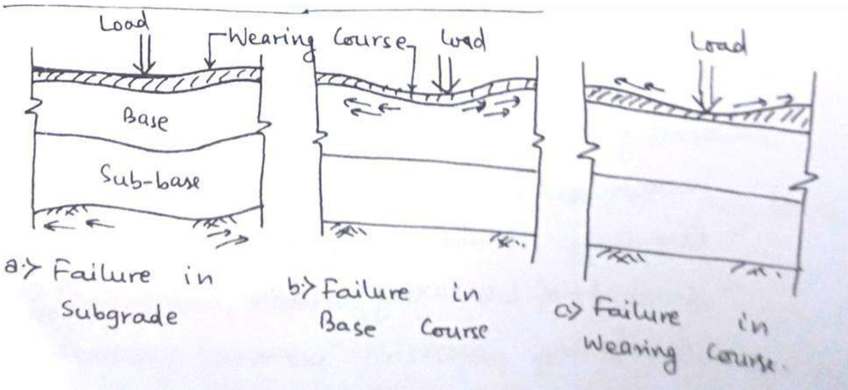
Emergency Maintenance:
Nobody can predict when and where natural disasters and God's Acts hit the highway portion(s). As such emergency maintenance are done on a road destructed by any unforeseen and unpredictible causes. These are also carried out after a period of 10 years. They include:

- Reinstatement of road after design period by reconstruction of the pavement, the structures and the drainage,

- Urgent and emergency maintenance works to reopen the loads due to temporary obstructions due to slides, quakes, wash out of roads etc.

Pavement Failures
Different types of pavements have different types of failures. Flexible pavement has its own failure patterns While rigid pavements has its own types.

A) Failure in Flexible pavements:



The localised settlement of any one component layer of the flexible pavement structure results in failure. Each pavement layer should be stable within itself hereby contributing to the overall stability of pavement. Ultimately surface deformations are seen when failure takes place in subgrade or base or sub-base or surface.

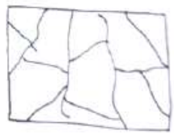
I) Failure in Subgrade:
can be noticed by the excessive undulations or waves and corrugations in the pavement surface as well as depressions followed by hearing followed by hearing of surface. It can of pavement be attributed by two basic reasons:

- Inadequate stability due to:
  - Inherent weakness of soil,
  - Excessive moisture,
  - Improper compaction
- Excessive stress Application due to:
  - Inadequate pavement thickness,
  - Loads in excess of design value lead to consolidation & plastic deformations.

ii.) Failure in sub base or Base Course:
Due to: - Inadequate stability or strength,
- Loss of Binding action,
- Loss of base course materials,
- Inadequate wearing course materials,
- Use of inferior materials, crushing of base course,

iii) Failure of Wearing Course:
Failures in wearing course are observed due to:
- Lack of proper mix design,
- Improper gradation of aggregates,
- Inadequate binder content and inferior binder quality,
- Lack of strong supervision and quality control,
- Volatization and oxidation of binder making the bituminous surfacing brittle,

Typical failures in flexible Pavements:
The various types of failure in flexible pavements are:
1) Cracking
Cracks are often found in flexible pavements which often be narrow and interconnected (<3mm) or they can even wide than a mm and are called cracks. These are of:
Alligator/Map Cracking:



- These cracks occur due to relative movement of materials in pavement layers caused by:
- repeated application of heavy wheel loads,
- moisture variations resulting in swelling and shrinkage of subgrade and other pavement materials.
- Localised weakness in the underlying base course

Longitudinal Cracks: These occur due to:
- Differential volume changes in subgrade due to frost actions.
- Settlement of fill and sliding of side slopes.

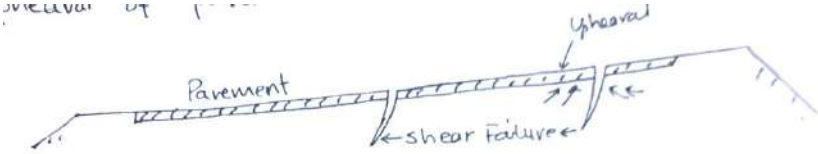
Cross Ruts:
They are formed along the C/s of a road due to heavy camber or other reasons owing to large flow velocity of water along the cross slope stripping the wearing course and forming the nuts.

Reflection cracks:
These are observed overlays provided over concrete pavements having or over defected surface of flexible pavements with a pre-treatment works. These cracks don't affect in structural actions in Case of rigid pavements but the cracks allow water to pass through them which later on causes pond pumping.

2) Longitudinal Ruts:
Consolidation of one or more pavement layers takes place due to inadequate constriction compaction during construction and also due to repeated application of wheel loads on the same direction. This attributes to formation of ruts along the wheel path in longitudinal direction which are often accompanied by wearing along the wheel path.

fig: longitudinal ruts.

3) Shear failure and Cracking:
Shear failures are associated with excessive loading on weak pavement mixes owing to low shearing resistance due to inadequate stability or excessive heavy loading. This results in the formation of shear cracks by the Upheaval of pavement materials.



4) Frost Hearing:
Localised upheaval of pavement portion takes place due to alternate freezing and thawing action in cold regions depending upon the ground water and climatic conditions.

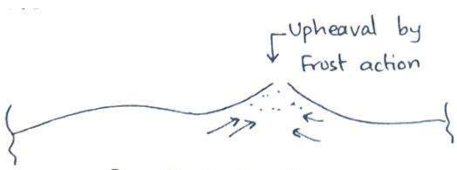


Fig: Frost Heaving:

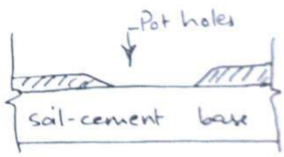


Fig: Pot/Pach Holes

5) Pot Holes / Patch Holes:

when the surface course is not keyed / bonded with the underlying base course loss of materials takes place by slipping forming potholes / patch holes. It often occurs when bituminous surfacing is provided over the existing cement concrete base course or soil-cement base with inadequate or no application of primal tack coats.

Failures in Rigid pavements:

1. Cracks
    - Alligator cracks,
    - Longitudinal Cracks,
    - Reflection cracks,
2. Ruts
    - longitudinal ruts,
    - cross ruts,
3. Sheer failure and cracking
4. Frost, upheaval,
5. Edge cracking,
6. potholes and patch holes,
7. Depressions & minor settlements,
8. Lack of Binding to the lower course,
9. Bleeding of bitumen,
10. Mud pumping in larger thickness like asphalt concrete etc.
11. Corrugations
    - in the form of ridges & valleys
12. Shoving- Plastic movement in the form of wave
13. Bumping & sags\
14. Ravelling- Dislodgement of the aggregate from the binder
15. Cold joints Hot mix asphalt paved adjacent to an existing pavement.

B) Failures in rigid pavements:

Failure in rigid pavements is mainly recognised by the of formation structural cracking. failures are seen to be attributed by following a factor:

i) Deficiency in Pavement materials and workmanship:
Deficiency in pavement materials may be due to:
- Use of soft aggregates with low ACU, LAA values,
- Toor workmanship during construction of joints,
- Pour fillers/ sealants at joints,
- Poor surface finish
- Inadequate wring after concreting.

due to the above-mentioned reasons, following defects are usually observed:
- Disintegration of cement concrete,
- Formation of cracks,
- Spelling at joints,
- Poor riding surface / slippery surface,
- Ingress of surface water,
- shrinkage cracks etc.

ii) Structural Inadequacy of Pavement System:
This may be due to:
- Inadequate thickness,
- Inadequate subgrade support due to poor subgrade soil.
- Inadequate mix design,
- Incorrect spacing of joints

Structural inadequacy of pavement has following defects:
- Crushing scaling of cement concrete,
- Cracks at slab corners and along longitudinal joints,
- Settlement of slabs,
- Widening of joints,
- Mud-Pumping

Typical Failure in Rigid Pavement:
Some frequency seen typical failures in rigid pavements are:
1) Scaling of cement Concrete:
- Due to deficiency in the mix or presence of some chemical impurities which damages the mix.
- Due to excessive vibration given to mix which causes se-aggregation of aggregates owing to rough and shabby surface finish.

2) Shrinkage Cracks:
Shrinkage cracks are developed during the curing operation of cement concrete pavements immediately after construction.
They are widely affected by the properties of cement as well.

3) Spalling of joints:
The spalling in joints takes place as a result of poor material fillers / sealants used therein, poor alignment of fills along the joints, poor workmanship etc. As a result, the cement concrete gets spalled damaging the pavement.

4) Warping Cracks:
If the joints are not well designed to accommodate the warping of slabs at edges, this results in development of excessive stresses due to warping and the slab develops cracking at the edges in an irregular pattern. Provision of reinforcements as per requirement can overcome it.

5) Mud-pumping:
Application of heavy loads causes the pavement to deflect at critical locations due to downward movement which forced out/ejects a part of muddy slurry each time through the spaces in pavement joints, cracks or edges. Mud-pumping is caused mainly by:
- Extent of slab deflection,
- Type of subgrade soil,
- Amount of free water,

6) Structural Cracking:
Structural cracking takes place when the thickness of slab is not designed efficiently for the amount and type of vehicles likely to roll on the pavement. Improper assumption of axle loads and load repetitions doesn't result in required thickness of concrete slabs, amount of required reinforcement etc.

Pavement condition assessment/Pavement Evaluation:
Pavement evaluation is a technique of assessing the condition of a pavement both structurally and from the point of view of surface characteristics. The condition of flexible pavements may be evaluated by unevenness, ruts, patches and cracks while that of rigid pavements may be assessed by the cracks developed and by faulty joints effecting the riding quality of the pavement.

The chief purposes of pavement evaluation area:
i) To research on the performance of pavements of different specifications over a period of time,
ii) To assess maintenance needs such as patch repairs, renewals, resealing etc.
iii) To assess the need for structural overlays on the distressed pavements.

These are Usually done by:
- Roughness measurement (IRI), vehicle mounted bump integrator,
- Visual rating, surface distress indicator (SDI),
- Non destructive (Benkelman beam method) and other destructive testing methods.
- Pavement texture: concerned with safety.

Pavement Distress refers to flaws such as cracks, potholes, ravelling (material loss etc.) can be observed by simple tools / methods like, visual indication of deterioration, walkover surveys etc.

Pavement Roughness refers to longitudinal & transverse distortion of the road surface.

Methods to Assess Pavement Condition:
Some methods to assess condition of pavements are:
1) Visual Condition Survey (SOI):

The visually assessed characteristics of pavement are used to develop a visual indicator called a Surface Index Distress (SDI) rating. Sol is a very important pavement condition indicator for the assessment of condition of pavement surface. It includes all types of surface defects affecting the surface integrity left untreated which may:
- seriously reduce serviceability,
- reduce pavement life,
- increase Vehicle Operating cost

objectives:
- to determine the overall pavement condition,
- to determine the distress level to carry out the planned maintenance activities,
- to monitor pavement performance & effectiveness of maintenance
- to develop and implement effective maintenance strategies.

Method of SBI / Visual condition Survey:
- Driving and walk surveys,
- Visual assessment using 20% sampling procedure,
- 6 level rating index from o to s as given below:

Rating (score)	Incidence of Defects	Incidence of Minor Defects
0	None	None
1	1~20m^2 / 100m	1 occurrence
2	<50% of the area	2-4 occurrence
3	≥50% of the area	<30%of the area
4	-	≥30% of the area or Patholes/base exposed <20% of the area
5	-	Potholes and base exposed ≥20% of the area.

SDI Value	**Pavement Status**	**Deterioration**	**Remedial Measures**
0.00 - 1.70	Good	Low	- Resealing only
1.80 ~ 3.00	Fair Medium	- Resealing + local patch (pretreatment)	1.80 ~ 3.00
3.10 ~ 5.0	Poor	High	- Rehabilitation, if severe - reconstruction

Defects are divided into two groups.
Major defects (with crack width >3mm),
Minor defects (with crack width <3 mm.)

Types of Defects

Minor	**Major**
-Narrow Interconnected cracks (<3mm) -Line Cracks -Sealed cracks	- wide interconnected cracks (33mm) ~ Sealed
- Shallow patches,	Potholes >>30mm deep >150 mm dia
- Shallow ravelling or scabbing (20mm)	- scabbing >15mm
- Slickness,	-Rutting >15mm
-Bleeding,	- Exposed base/sub-base
-Short edge Break (b<10cm, l<5m)	-Long edge breaks -Corrugation, shoving

2.) Roughness Measurement (IRI):
International Roughness Index (IRI) taken as standard unit to measure roughness

Objectives:

- to determine riding quality (Good, Fair, Poor) of the pavement surface,
- to determine structural strength of the pavement The impacts of roughness are:
- Increase in wear and tear of vehicle parts,
- Increase in voc.
- Reduction in safety, comfort and speed.

Uses of IRI:
- to measure road condition
- to plan maintenance activities,
- to determine voc.

Instruments used to measure IRI:
i) The MERLIN roughness machine,
ii) The vehicle mounted bump integrator.

IRI Value	Road Status
<3.5	Good
< 3.5 ~ 8.5	Fair
>8.5	Poor

Maintenance Management System (MMS) or Pavement Management System:
The type and extent of maintenance requirement of a load depends upon the serviceability standards of that road, need for maintenance, prioritization of the maintenance operations and available funding resources. As such there's a need of systematic approach that is appropriate for the road maintenance management. The various factors that need to be included in the MMS are:

i) Minimum acceptable serviceability standards for the maintenance of different road categories,

2) Field surveys to evaluate maintenance requirements
3) Assessment of various factors influencing the maintenance needs such as subgrade, soil, drainage, climate of traffic, environmental conditions etc.,
4) Estimation of rate in of the pavement under of deterioration of the pavement! the prevailing set of conditions,
5) Type and extent of maintenance requirements with various alternatives possible and their economic evaluation
6) Availability of funds for maintenance operations.
7) Maintenance cost, availability of materials, manpower and an equipments to necessary to undertake maintenance operations,
8) Need based allocation for optimum utilization of the inputs and fixing maintenance priorities.

Hence to achieve all these factors, computer models are developed to facilitate maintenance planning and optimal allocation of resources. The main elements of MMS are:

i) A basic road data bank (road register)
ii) A pavement performance model,
iii) Selection of intervention levels and
iv) Listing out priorities for maintenance.

As such, MMS is an orderly and systematic approach for planning, organising, monitoring & evaluation of maintenance activities and their cast using computers.

A typical flow chart of MMS is shown below

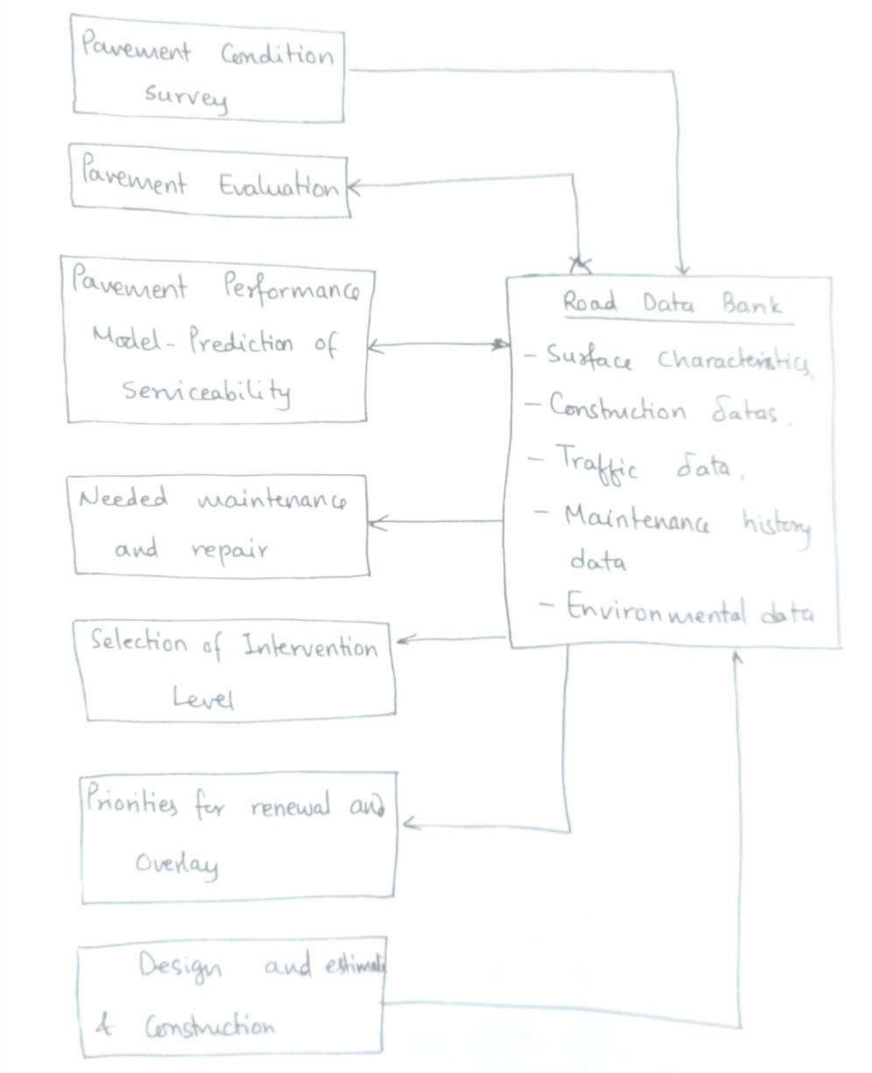


Fig. Flowchart for MMS

Pavement Management System in DOR:
Pavement management involves:
i) Response management to deal emergencies,
ii) Management for central to make best use of the resources,

The aim of pavement management is to ensure that timely and appropriate action is undertaken on the roads and care must therefore be taken to ensure that the system doesn't become an end in itself.
Pavement management principles are examined under 3 sub-headings:

1) strategy and Approach:
There are three basic strategies for pavement management:
a) Application of planned maintenance deferring the need for rehabilitation and reconstruction and keeping voc a minimum (Good/fair, SDI = 0-3.0),
b) Rehabilitation with minimal routine and recurrent maintenance when pavement condition reaches poor (Rehab cost is 3~4 times the cost of planned maintenance)
c) Reconstruction with minimal routine and recurrent maintenance when pavement condition becomes totally Unserviceable and gets failed. [Reconstruction cost is 3-4 times the cost of rehabilitation)
There are two basic approaches to apply pavement Management strategy comprising planned Maintenance:
a) Cyclic Approach:
- Pre-ferriable for planned maintenance,

- Pavement actions are undertaken at fixed intervals (Principally actions are to be undertaken few months early rather than later),

organizing the procedure:

- Establish control section,
- Define activities,
- Allocate resources,
- Optimize resources,
- Prioritize central section.

b) Intervention Approach:

- Direct response to present level of pavement deteriator",

-This approach is complex difficult since variables like resources, workload and funding need to be managed,

- Needs comprehensive database and trends. But optimal result is obtained in terms of serviceability.

2.) Management Levels:

Basically, there are 3 independent management levels in DOR:

a) Network Level:

- Effective pavement management starts at network level (DOR, HQ),
- First job is to allocate the priorities based on the strategic importance and traffic level,
- Establish rolling plan for reseating, rehabilitation and reconstruction,
- Monitor overall condition of SRN

b) Operation Lend:

- Responsibility of Maintenance branch concerned in overall detail planning and implementation,
- Region and divisions are responsible for day-to-day planning, organisation and development of implementation,
- Prepare Annual Road Maintenance Plan (ARMP).

Project level:

Upgrading of SRN in large scale is carried out by the projects. These projects require donor support and are often under foreign Cooperation Branch (FCB).

3) Management of Information:

Planned maintenance requires reliable data on which Objective decision can be made and implemented. They are:

- Inventories,
- Pavement deterioration process, means to define & measure,
- Traffic level and composition,
- Relative cost of reconstruction, rehabilitation and that of planned maintenance.
- Voc to wad users.

Planned Maintenance:

Planned Road Maintenance is the series of interdependent activities carried out on and off the road to preserve the road assets and maintain its serviceability.

Planned Maintenance is also sometimes called as Management for control and is necessary to:

- make the best use of available resources,
- Defer most costly activities i.e. Rehab & Reconstructions,
- provide high level of management control over maintenance operations,
- provide agreed level of serviceability on each road such that total transport costs are kept to a minimum.

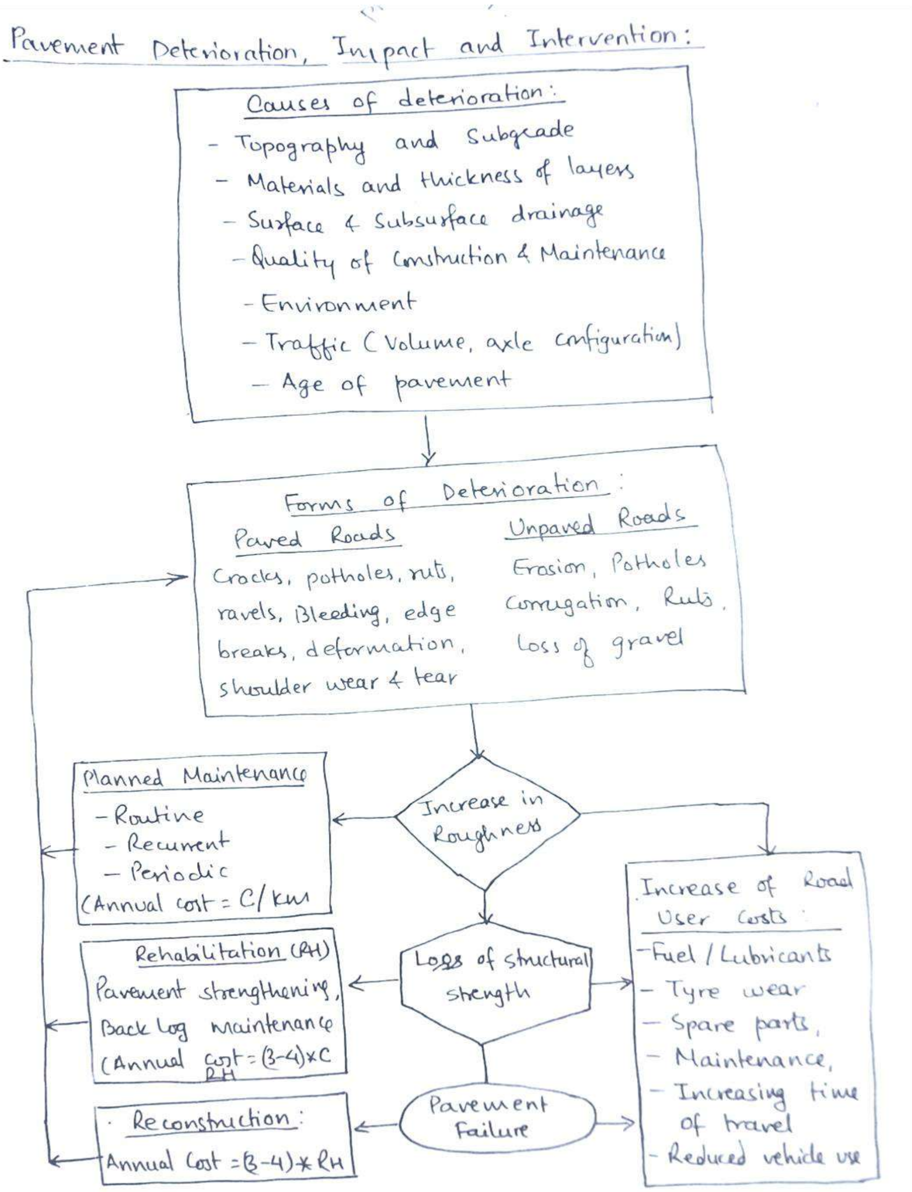
Purposes:

- Reducing deterioration,
- Lowering Vehicle Operation Cost (VOC),
- keeping the road open,
- Safety,
- Environmental Issues,
- Preserve the assets,

Procedure in DOR:

- Prepare annual program, ARMP in each division which sets out the organization and management of labour for planned maintenance,

- Prepare multi year programs for periodic maintenance programs at central and regional level,



Maintenance challenges, Sources solutions:
Challenges:
The various challenges in the maintenance are:
A) Adherence to Maintenance Culture:
- Attitude, behaviour of staffs, workers and contractor
- Inadequate level of awareness of all stakeholders,
-Commitment, will and drive of all stakeholders

B) Managing the Environment:
1) Technical management to strengthen capacity and Capability of road agency, RBN and contractors,
2.) Financial management:
- role of road (audit) agencies & RBN,
- GON support,
- Balance focus on construction and maintenance by ministries, NPC and Road Agencies.

c) Organizational Management:
- Revision of maintenance policy, rules, procedures etc.
- Motivation of bureaucrats / contractors / Length workers etc.

Describe the role of RBN and analysis of Existing Road maintenance Practice in DoR.

Roads Board Nepal CRBN) was established under the Road Board Act, 2058 with the aim of providing sustainable funds for planned maintenance of roads. RBN is a self-governing self-sustaining and organized entity based on ppp model.

The major function of RBN is to collect manage and allocate funds for road maintenance to the road agencies like Dor, Municipalities, DOLIDAR, DDCs etc.

The prime objectives of RBN are
-To create a stable (self-sustaining fund by involving road users, channel it to the road sector to implement the Integrated Annual Plan (IAP) and other road development and road research activities.
- To carry out various maintenance activities of the road and make arrangements for imposition and collection of tolls from the vehicles plying on the road,
Allow limited percentage of funding to other higher Category of maintenance works such as rehab, reconstruction, upgrading etc. only when resources remain surplus after addressing to the priority maintenance activities such as routine, recurrent, periodic and emergency maintenance.

Current Government Policy for SRN maintenance:
1) Road maintenance is addressed in various policies in Nepal which include.
- Nepal Transport policy 2058:
  * CH-7
- sector wise transport policy – Transport Fund and Maintenance management,
  * CH-6
  Working policy - Transport Infrastructure
- The DoR strategy, 1995
- Master plan for SRN, SWRP & PIP (I), 2007

2) The Dor strategy, 1995 cleary aims to maintain the road network and provide a reasonable Los to road users at all times thereby saving a considerable Capital investment made in roads,
3) The Dor strategy with its 6 objectives, 9 policy options and 51 key measures envisages to meet the set of goals in reduction of total road transportation costs. All the policy option and key measures have their strong focus on maintenance.
4) At present : 'SRN Maintenance Policy document is being prepared for which the consultant already has submitted the draft report.
5) Core road Network principle for NH/SRN maintenance also applied from f.y.2077/078.

Source of Fund:
RBN has currently been relying on the following resources to collect funds:
i) fuel levy on diesel and petrol for vehicles,
ii) Road user tox (toll),
iii) Vehicle registration fee,

other possible resources that are yet to be tapped are:
- Vehicles registered abroad but used in Nepal,
- Penalties for non-complies to the rules under this act,
- Subsidies and other national and international institutions etc.

It collects road user fee from three road sections, from SRN of Nepal's road network:
→ Hetauda - Narayanghat } East-West Highway
Narayanghat - Butwal
" Naubise-Mugling → Prithvi Highway

RBN allocated 70% of its resources to SRN through DoR and 30% to LRN through DOLIDAR. Road agencies have to provide a minimum counterpart fund of 30% to municipalities and 20% to DDCs.

Issues of RBN/Problems of RBN Fund and maintenance practice
The various issues of RBN are:
RBN has covered almost all amount required for routine and recurrent maintenance but provided only partial coverage for periodic, rehabilitation & reconstruction Works. According to WB study, about 40%. gap exists i.e. RBN funding needs to be increased by 2.5 times to achieve full coverage.
fund disbursement is in following pattern:
25%. fund after signing MoU with RA,
30% fund after 25% of work completion
30% fund - after 75% of work completion,
15% fund after submission of WCR.

2) Milestone Schedule:
It's difficult to achieve since Fy of GoN ends on Ashad while that of RBN ends by kastik.
3) fuel levy is not fully disbursed to the road maintenance fund,
4) Government or political intervention in the structure of GON,
5) RBN has also to suffer LRN,
6) Due to funding problem, SRN is getting backlog maintenance specially in periodic, rehabilitation works since RBN allocates only 30%. of required
7) RBN fund only covers about 60%. SRN roads, mainly paved roads while other gravel/earthen roads are left.

Probable solutions:
1) Institutional solutions for existing revenue mechanism:

- All concerned stakeholders have to work to transform RBN into a functional second generation of road fund. RBN shall be given full authority & responsibility to regulate the users' charge mechanism of meeting the maintenance cost of all SRNS.
- Fuel levy direct to RBN fund to get underlying benefits from a stable, predictable and timely provision of funds,
- Electric tolling system to reduce administrative expenses,
- Establishment of pavement maintenance system (PMS) for reasonable estimation of required fund.
- Establishment of new toll plaza by proper assessment according to the latest upgraded road according to traffic volume.
- Establishing weighing bridge and control the overload.
- Additional fund collection by Value captured principal.
- DPs (Development partner like ADB, WB) also provide the space for the maintenance beside the new construction.
- PBMC, ROT also used in the maintenance.

2) Revenue Generation and financing for Maintenance:

- Establish new collection centres at Eastern, western, mid-western and far-western regions which is a current essence to collect more funds,
- Sustainable financing through user-pay principle against economic benefits received in the form of me, money, comfort, safety by road users. (PPP model),

If this is implemented, RBN will move to the next of maintenance through full commercialization and 'fee for service" basis.

3) others:

- To implement various solutions some amendments may be needed to RBN act GoN & DOR policy,
- Establish a strong Monitoring & Evaluation mechanism
- Other income generation through lease of Row, auction of tree plant, land development tax etc.
- Provide incentives including medical treatment costs for person aged over 58 years and has served more than 5 years and subject them to force leave'. On the vacant positions employ new young workers.
- During the leave or retirement from work (by age or other legal reasons), the person shall be either benefitted by
- incentives or
- job for family person in same post.
- The length workers who are working in contract basis are not suitable for permanent recruitment in DoR.
- For new recruitment of supervisor, minimum education level of SLC shall be imposed.

PBMC in Nepal Concept:

- Performance Based Maintenance Contract (PBMC) for the maintenance and management of road network is a new concept designed to increase the efficiency
- and effectiveness of road maintenance operations.
- It should be ensured that the physical condition of the road under contract is adequate for the need of road users, over the entire period of contract,
- This is more advanced form of maintenance mgmt system, widely used in developed countries.
- These contracts include initial works paid on an output basis and subsequent maintenance paid on performance basis for a period of 3-5 years. During the bidding process, contractors compete among each other by proposing a fixed monthly lump-sump fee per km. of a road to be paid to them and the Contractors are paid for the output.
- The work usually comprises of pavement surface improvements with or without an overlay and routine maintenance backlog. PBMC contracts include the 'Performance and Operational' indicators
- The Performance Indicators include SDI, IRI & axle load control. The operational indicators include specific items related to pavements, Row, structures, drainage, road signs and markings.
- One fundamental feature of PBMC is that the contractor is responsible for designing and carrying out the actions he believes are necessary to comply with the service quality levels stated in the contract.
- The service quality levels are defined from road users' perspective and may include factors such as average travel speeds, riding comfort, safety features etc.
- If the service quality level is not achieved in any month, the payment for that month may be reduced or even suspended.

Performance Based Maintenance Contracts (PBMC)

- Performance based maintenance Contracting is an approach for maintenance where a private Contractor assumes responsibility for managing the conditions of transportation assets to predefined conditions.
- The Hall mark 9 PBMC is to pay a contractor based on the results achieved and not on the methods for performing the task. this approach of contracting provides incentives, disincentives or o the contractor to achieve the targets or performance standards for measurable outcomes and sometimes outputs
- The disincentives or incentives can consist of reductions or increases in payments for respectively falling short or exceeding desired targets.
- They may also include Liquidated Damages for failing to satisfy the coc/ contract provisions, an award fee for satisfying qualitative Criteria and a contract extension for performing well etc.

Various Names:

- Performance-Based Maintenance Contract (USA)
- Performance Contract (Western Australia),
- Total Maintenance Contract (Texas),
- Performance - Specified Maintenance Contract (Australia, N2)
- Managing Agent Contract (UK).
- Contract for Rehabilitation and Maintenance (Argentina),
- Area Maintenance Contract (Finland Ontario Canada).

Why PBMC??

Commonly cited motivations for using PBMC:

1) Potential to increase Los and reduce agency costs,
2) Performance criteria focused on customer-oriented outcomes,
3) Pressures on operating expenditures budgets,
4) Need to do more with fixed work force,
5) Achieve expenditure stability & long-term, lump-sump contracts with fairly predictable payments to contractors,
6) Shifting risks from employers/agencies to the contractors
7) Significant benefits from effective partnering between the agency and contractor,
8) Encourage the contractor to minimize life-cycle costs by assuming the long-term contract,
9) fostering on innovations - Contractor is free to use any method to meet performance targets & specifications rather than adhering to some specific requirements
10.) Reductions in contract Administration requirements.

Impediments/obstructions to PBMC:

1) Lack of government support,
2) Lack a culture from agency and contractors being familiar with system, resistant to charges.
3) Inadequate experience with PBMC or negation first try
4) Adjustments / Adaptations required to go from methods/process to performance specifications.

5) lack of training
6) lack of legalizing authority, rules, acts etc.
7) challenges in estimating in-house Vs contractor costs
8) Loss of quality sometimes the first years long-term contract,
9) Insufficient Contractor capacity,
10) Inability to achieve sufficient competitive environment,
11.) Incomplete or inaccurate asset inventory and condition data,
12) Loss a control over methods, equipments and materials used,
13.) Concerns that life - cycle contacts will increase
14) Concerns that privatization will lead to loss in employment of various in-house staffs.
15) Concern & Union Members that PBMC will undermine wages, benefits, work conditions, job - security that government offers,
16) Need to secure substantial funds to undertake budgetary process for large, multiyear contracts
17) contractor's inability to effectively handle reactive maintenance such as erosions, repair a traffic control devices, incident and emergency response.
18) Challenges a reassuming the responsibility for maintenance is the contractor fails to perform especially if the contracting agency sells off its equipments and lays off all its maintenance staffs excluding only those required to administer the contracts.

Advantages of PBMC:

- Potential reductions in cost,
- Improved level of service,
- Transfer a risk to the contractor
- More innovation
- More integrated services,
- Enhanced Asset Management,
- Ability to reap the benefits of partnering,
- Building a new industry,
- Achieving economies of scale,

Disadvantages of PBMC

More costly procurement process.
- longer procurement process,
- Reduction in competition,
- Uncertainty associated with long-term contracting relationships,
- Challenges in mobilizing,
- Poor people out of jobs,
- loss of agency control and flexibility,

Risks in PBMC:

- Pour quality in construction,
- Unexpectedly severe weather, environmental problems
- Emergencies,
- Unanticipated legislative changes,
- Unexpected traffic growth,
- Scarce / In adequate resources,
- Rectification of errors by contractor troublesome

Basic steps of PBMC:

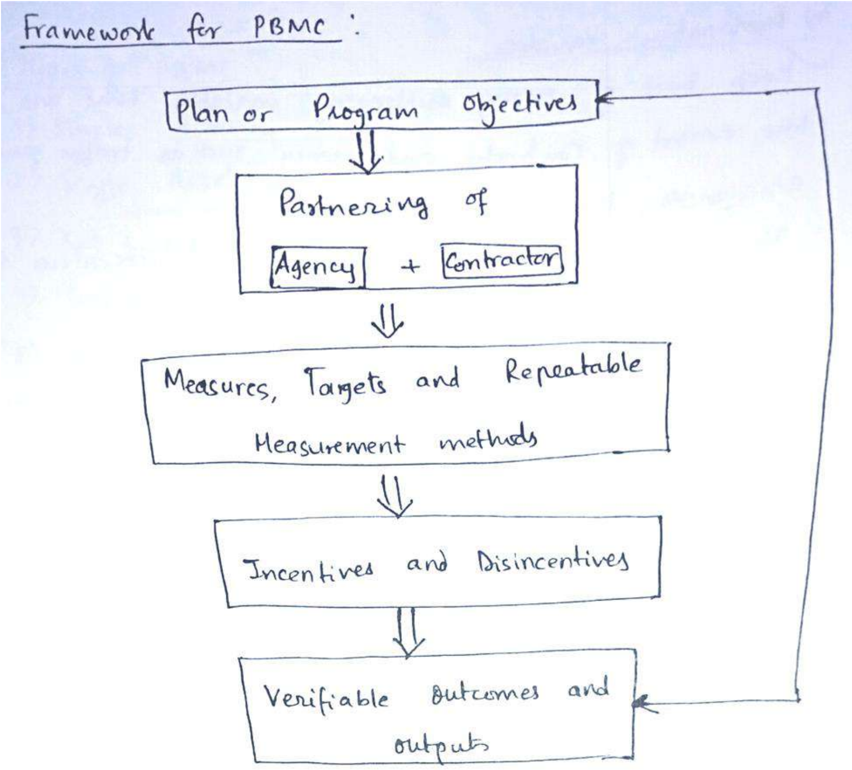
1) Discuss / Decide maintenance and areal roads that will be the faces of from PBMC, or would benefit or would
2) Complete an inventory of assets and assess their condition,
3.) Determine scope of services,
4.) Determine and Los and define define achieved, Los to be
5.) Define subcontractors, qualifications f contractor
6) Set term of Contract
7) Address record-keeping,
8) Define comer's responsibilities,
9) Define Contractor Insurance requirements,
10.) Determine bonding requirements,

11) Establish payment criteria with incentives/disincentives,
12) Define approach for performing inspections,
13) Draft Request for proposals CREP),
14) Hold pre-bid meeting, finalize and issue final RFP,
15.) Award contract conduct meeting before start of work,
16) Authorize work to begin, allow contract to perform work,
17) Conduct periodic and random inspections of performance,
18) Make monthly payments to the contractor according with the performance,
19.) End contract, unless it is renewed for a subsequent term ousting to exceptional performance by the contractor.

Types of PBMC:
1) Single Activity
2) Single Asset,
3) set of related activities,
4) Corridor
5) Area wide
6.) Hybrid
7.) Agency. to - Agency
8.) Warranty, bared,
9.) Multi-phone.

Basic Categories & Measures:
1) Inputs: are resources applied to maintenance ie. labour, at materials, equipments associated financial expenditures and times facilities of land used
2) outputs: are accomplishments or how much wore gets done. Es lane / miles of bituminous resurfacing or linear feet of gurad rails replaced -It reflects officiency and effectiveness of the organization carrying out the maintenance works,
3) outcomes: Results or changes occurring as a result of maintenance, focus is made on customer-oriented outcomes. i.e.
- Smoothness a pavement.
- Visibility of signs and markings at night,
- Cleanliness of rest areas, .. Amount & litter on road

4) Explanatory Variables:
Keep track of many explanatory variables that are outside control of Contractor and agency such as traffic growth weather, emergencies, terrain etc.
- It gives a basis for adjusting incentives / disincentives and more fairly helping in allocating risks.
In summary areas in which maintenance performance measures are needed for PBMC includes:
1) Road side Furniture's (fences, Guard rails, Crash barriers etc.)
2) Shoulder (surface, striping edge drop-off),
3) Pavement roughness, rutting, skid, appear etc
4) Signs, Signals, markers, striping,
5) Signs, Brush trimming brush removal, tree cutting, control of invasive plant,
6) Planting care of wild flowers, native vegetations,
7) walls and retaining structures,
8) Drainage c catch basins, culverts, detention ponds etc
9) Bridges maintenance,
10.) Erosion, snow & ice control,
11) Signals and other electronic equipments
12) Incident management and emergency response,
13) Removal of obstructions,
14.) Litter pick up
15) Graffiti removal.



Trainings Required:

- The acquisition process,
- Understanding and use of performance measures & standards,
- Roles/Responsibilities to be assigned to contractors/Subcontractors
- Implementation examples of effective practices from agency and Contractor, lessons learnt.
- How to get the most from partnering
- QA & Qc procedures
- Evaluation of contractor performance
- Payment model methods, assessment of incentive/disincentives,

PBMC Experience in Nepal:

PBMC in Nepal appears to have been originated from suggestions made by World Bank in 2002. It was felt Useful for Nepal to experiment with approach used maintenance approach used in other countries.

Without adequate discussions and plans within Dor, RMDP selected a pilot trial of Butwal - Narayanghat section (113 km) of East West Highway. PBMC for this road was contracted for 2 years (Ma4, 2003 ~ May 2005] Later ADB supported RNDP started PBMC in the following SRN from 2005 to 2010:
Pathalaiya - Chaurahawa section (248 km) of East - West Highway,
kohalpur - Gaddachauki Section (201 of East-West Highway,
kohalpur Amiliya section (14 km)

However, PBMC was not found successful in Nepal for various reasons and ADB also carrying out the evaluation of PBMC in Nepal. Main experiences and issues are:
1) PBMC was started without enough preparatory works, especially the required training to both the Dor staff and the contractors,
2) Contractors took PROMC as an extended DLP, carrying out maintenance only when defects are encountered,

3) Lack of self-monitoring by contractors and proper inspections by Dor led to poor performance Contractors In Nepal are in general not considered to be matured enough for Work arrangement on self-controlling mechanism.
4) In PBMC, improper and complex performance indicates and penalty systems are being used but also, even due to lack of contractors' perception and incompetency towards output-based maintenance systems, effectiveness Can't be observed

Suggestions:

(1) Monitoring of PBMC requires high degree of trust in the honesty of the Contractor, something that can be rarely found in Nepalese context. On the other hand, constant monitoring from the client side is expected, for the unrepaired defects which are subjected to the penalties from the contractor. The rate of success relies upon both the honesty of the contractor and commitment of the client in the constant monitor
2) Provide institutional support to create the compatible environment to implement PBMC,
3) Bidding documents being used in PBMC should be improved by reducing too many indicators but in required numbers to smoothen out payments.
3) Lack of self-monitoring by contractors and proper inspections by Dor led to poor performance Contractors In Nepal are in general not considered to be matured enough for Work arrangement on self-controlling mechanism.
4) In PBMC, improper and complex performance indicates and penalty systems are being used but also, even due to lack of contractors' perception and incompetency towards output-based maintenance systems, effectiveness Can't be observed

Performance Based Maintenance Contracts:
That are a lot of models that are available for administering and implementing road maintenance works throughout the wood. The availability, affordability, and suitability. of such models that best blends into our system is necessary. To evaluate /analysis PBMC in Nepal we should highlight some broad aspects of there several models
1) Direct labour:
  - Employ staff & own equipment's used for maintenance
  - No Local Contracting capacity for which the gout has to develop its own capability to road maintenance Construction & maintenance.
  - Flexibility and quick response to need specially In case of special or emergency works.
  - It has expenditures under following heads
  - which requires regular funding:
- Establishment costs - Salaries, pensions, housings and other employee benefits
- Capital Cost of equipment
- Running of equipment
- Purchase of materials

Major problem is in funding gap proportionately under all the heads leading to materials unavailability equipment's a manpower idle etc.

2) Input Based Contracts:
- Schedule of rates taken from the contractor for a selected list a activity to be done
- Contractor paid for the quantity a as her the rates of respective items maintenance
- cover periodic maintenance rehab or routine & recurrent Sometimes both.
- Benefit Encourage efficiency on Budget at optimization by giving the works to
- the lowest bidder with which more 1 works could be done
- Dements a May lead to poor workmanship Tendency to concentrate efforts an
- items with profitable rates.

3.) Output (Performance) Based Contracts:
The recent innovation in maintenance system wherein the contractor is paid a fix sum to maintain all or past. the road infrastructure to a predetermined or specified level thereby focusing on output (Performance) of contractor. It comprised of every maintenance operation on a certain route or section rising from routine/recruitment to specific or periodic or rehabilitation.

Three types of PBMC can be mentioned:
a) Contract comprises of initial rehabilitation of a road in poor conditions followed by routine/ maintenance for a period of 3-5 years. In affects this is a more extension of DLP.
b) Contract covers only routine maintenance works, such as patching, drain cleaning or vegetation control. Might be of a year or less.
c) The contract is for an extended period say for 10 years and the contractor is free to choose his options & timing for periodic cycle. Client is only convened with the serviceability level of the road as per contract with a specified level of the road as per contract with a specified service level with certain indicators like create ruts or patches.

PBMC For Nepal

Department of Roads has carried out to contracts an PBMC each on heavily trafficked. 75 km sections of the E-w highway to the east of Pathalaiya. It's of type @ mentioned above wherein initial works comprise an overlay and routine maintenance follows after. The PBMC then starts & runs for a period. It has following features:

Specifications:
It includes performance and operation 2 Performance Indicators
- Surface Distress Index (SDI)
- Intonation Roughen Index (IRD).
- Axle load Control
Operational Indicators
- Specific Items a pavement right of way structures, drainage i road signs & markings Performance Indicators:
a) Unnecessary are & soil: - If the Contractor is in full compliance with all the operational indicators (patches, crack seals ate:) then. SDI will always remain close to zero.
b) Unjustifiable IR: Roughen indicator required for it to not increase by more than 10% each year. With operational indicators fully complied the only cape this exceed 10% is only when the pavement structured layers below the overlay...
fail over which the contractor has no control
c) In practicable Axle Load Control: - No vehicle shall exceed the axle load more than 10.2 tone for this Contractor has to establish weighing Stations at silent needed points. But he has no legal authority to stop vehicle from road using the so deemed unpracticable or the performance Indicators deemed Indicators deemed unnecessary or unworkable.

3.) Operational Indicators: - Are comprehensive through may be idealistic given to general levels of road maintenance in Nepal - less impact than other indications
4.) Performance Monitoring - Established contractor as the "Self-Control Unit" which puts responsibility weight age of Performance Monitor to Contractor. The self-Control Unit is responsible for day-to-day monitoring with only random checks by the client for his ... Consultant)
- Requires high degree a trust in honesty of the Contractor which is rare in Nepal
Joint monitoring is kept Monthly but I may need daily or at times hourly.

Conclusion:

- Before mentioning PBMC has failed in Nepal we should reconsider following points:
- Specifications made simple, consider and practicable
- Deterring the model of PBMC to be used after properly evaluating Pavement District land
- Controlling Axle Load of Punishing Vehicles not as per kept on responsibility or client wherein Weigh Unite supplied by the contractors.
- Daily Monitoring facility required

Water Management in Road Maintenance Works:
Highway Departments / Road agencies spend more than 25% of their budget on drainage. Problems caused by poor drainage include rutting, pavement distress, flooding. Together or alone, these defects will lead to premature failure of roadways.

Water Management:
Water needs to be collected and drained off from the road surface as soon as possible. Drainage includes handling of existing water source as well as removing water from the pavement surface and shoulder of underground water in the pavement structure.
1) The drain should have adequate shape, size, slope and stability,
2) Inlets / Outlets of drains and cross-drains should be properly designed and maintained.

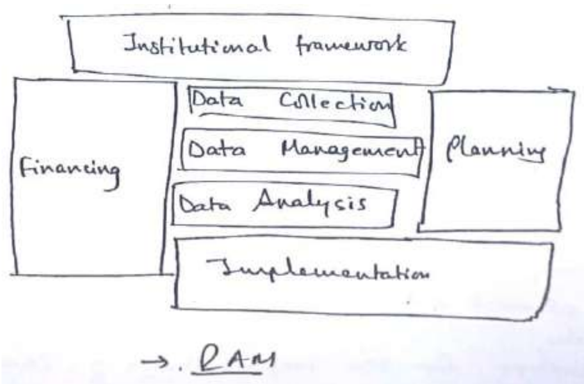
Road Assets Management:
Road Transportation system ensure mobility access to social life enabling Integration because their performance is essential Bens to have quality life competitively along with economic and sustainable development.

Road Assets Management is thus a process of keeping not only the loads but all the subordinating, supporting & ancillary structures intact ensuring safe, easy, economical & conformable serviceability of road infrastructures at all times. As such it is said that "load Asset Management is a permanent process". It goes through the following steps:
~ Establish a complete inventory of all road networks with all its elements

~ Provide a clear picture of the current condition / performance of a road network, ~ Conduct regular surveys to predict future demand of traffic and service needs.
~ Estimate the current valuation of all Road Assets.
~ Estimate maintenance needs and costs
~ Prioritize objectives related to desired quality and performance road network
~ Set up funding resources for regularly and timely maintenance and for upgrading of Road Assets
~ Develop a sustainable road's policy and invest in research and innovation.
~ Implement coherent and balanced policies for preservation of road asset at all levels.
~ Define a strategy for the implementation of RAM plan.

Road Asset Management System (RAMS): RAMS is considered to include any system that is used to select, store, analyse & process the road and bridge inventory Condition, traffic related data for road planning and programming purposes. RAMS includes:
~ Data collection of unchangeable data like road surface, alignment possibly etc. and variables like road condition, traffic et.
~ Data Management: Avails all the collected data together for
- planning & monitoring.
~ Data Analysis: Optimization a collection to result required allocation.

following are the entities required:
- Institutional frame wash,
- financing
- Planning
- Supplementation
- Institutional



Following wing are considered as best are practices in introducing and disclosing roads assets management:
1. limit the date to be collected
- collect only what is required at of only what is required at an appropriate level of accuracy,
- Ensure data is in a correct format & reliable.
- Introduce proper quality control procedures,

2. Make the database easy to Use: - Easy to use & understand the well-structured data.
3. Start with a simple software,
4. Institutionalize from start
5 Publish Annual Performance Statistics,
6. Integrate into decision making process,
7. provide Sufficient and predictable funding,
8. Separate management from implementation,
9. Ensure high level support,
10. Continue development Support Capacity,
11. Develop the works, implementation

CH-7 HIGHWAY IN TUNNELS BRIDGES AND TUNNELS

Any Cross-drainage structure with its span (or total) length eater than 6.0m and constructed to provide passage over the obstacles like rivers, depressions are gorges etc. rivers, depressions / gorges etc. are called bridges. Based upon the imposed traffic, topography / terrain e a road or railway bridge, overhead bridge or a sub-way.

Characteristics of an ideal Bridge:
Based on various aspects
1.) Approaches:
- No serious deviations from line of approach,
- Level ends on either bank,
-No curves, if any should blend well with surrounding,
- Aesthetic, fit well with the surrounding environment,

2.) Geometry structural Aspects:
- Enough width to cater expected traffic with ease,
- Adequate Strength to carry imposed loads safely,
- Adequate water way without disturbing natural flow,
- foundations on firm bases, type chosen and designed well
- Aesthetic, elegantly designed sections.
- Smooth passage for crossing public utilities,
- Level surface finish with no humps at approaches on
3) Economical Aspects:
- Economical in design, construction and maintenance,
- Site selected wisely w wisely to curtail to curtail unnecessary length & enforces,
- Justify socio-economic needs, Blc cast ratio.

Selection/choice of proper Bridge sites location
On the following aspects, an ideal location of the bridge site shall be selected.
1) Approaches:
- Reasonable proximity to main road with no shop curves at entrance and exit of bridge axis.
- Approach banks neither too high nor too exposed to build safe abutments, Approaches at banks should be well secured not breach, liable to get washed away by flash floods or major spills,
- Suitable slope and favorable rock orientation at approaches,
- Should provide shortest possible line of communication between demand and supply centres/area for maximum usage,

2) River properties:
- Straight reach of river with minimum disturbance/effect on flow due to the structure.
- Shortest Cross-section for shortest & safest bridge length.
- Steady river flow with no whirls, eddies and excessive turbulence to avoid excessive scour and construction problems.
- No meanderings present avoid normal shifting of regime.

3) Geological/other aspects:
- Firm high banks sufficiently above the HFL and need to be in erodible to avoid breaching of approaches.
- Should have suitable in erodible strata of hard bed most preferably rock at a reasonable and workable depth for the laying of foundations for piers and abutments,
- Minimum or free from expensive under water construction,
- Approach banks and protection works with minimum recurring maintenance problems and reasonably safe from flood damages.

Collectively, in broader sense, the key governing factors that affect the bridge site selection are:
-Hydrology and river geomorphology,
- Geotechnical aspects and geology,
- Socio-economic aspects
- Safety aspects

As such an expert team with multi-disciplinary members finally select a bridge axis giving rise to a:
"Safe-Reliable-Cost Effective Bridge".

Classification of Bridges:
Classification of various types of bridges is based upon various factors as discussed under:

1) Based upon Span

As per current revision of NRS; bridges as per span are of:

- Minor Bridges: Span length (20m & >6m, total length ≤20m
- Medium Bridges: Span length 20m, Total length >20m
- Major Bridges: Span length >20m Total length> 20m.

2) Based on Loadings:

- Major: HS 20-44 or IRC class AA or equivalent,
- Minor: HS 15-44 or IRC Class B or equivalent,
- Medium: HS 15-44 or IRC Class A or equivalent,

3) Based on type of structure

- T-Beam /simply supported bridge,
- Cantilever bridge,
- Arch bridge,
- Suspension or Suspended (Trail or motorable) bridge,
- Steel truss bridge,
- Cable stayed bridge,
- Movable bridge etc.

4) According to materials used:

- Rcc/ Psc bridges,
- timber bridges,
- Steel bridges,
- Masonry bridges etc.

5) Based on function:

- Aqueduct,
- Viaduct (Road, railway crossing over a valley),
- Pipeline Bridge,
- Pedestrian bridge, etc.

6) Based on Internal Span:

- Simply supported,
- Cantilever,
- Continuous .

7) Based on position of bridge floor:

- Half through bridge,
- Deck through bridge.

8) Based on Road Level w.r.t HFL:

- High Level bridge,
- Submersible bridge,

9.) Based on Degree of Redundancy:

- Determinate bridges,
- Indeterminate bridges,

10.) Based on type of service and duration of Use:

- Permanent bridge,
- Temporary bridge,
- Military bridge (Pontoons, bailey etc.)

Selection of a bridge type:

Suitable type of bridge is so selected as to carry the selection desired traffic, adequately strong to carry the incident of a roads, economical and aesthetically pleasing. Following are of the some notable factors that affect the type of bridge: bridge:

- In case of large navigational clearances, arch cantilever, suspension bridges are suitable
- For a "high level structure with uninterrupted traffic, cable stayed or cantilever or a series of simply supported bridges,

- climatic & environmental factors,
- Deck bridges for highways for better view
- Topography and soil condition,
- Type of anticipated traffic,

Choice of bridge type - cont...

- Hydraulic factors and river regime,
- Subsoil conditions If weak simply are preferred over continuous spans, are prepared over continuous spans.
- Availability of funds,
- Material availability and economy

Selection Criteria for Bridge Site

The choice of the right site is a crucial decision in the planning and designing of a bridge. It may not be possible always to have a wide choice of sites for a bridge. This is particularly so in case of bridges in urban areas and flyovers. For river bridges in rural areas, usually a wider choice may be available. The characteristics of an ideal site for a bridge across a river are:

- A straight reach of the river.
- Steady river flow without cross currents:
- A narrow channel with firm banks
- Suitable high banks above high flood level on each side.
- Rock or other hard in erodible strata close to the river bed level.
- Economical approaches danger of floods, the approaches should be free from obstacles such as hills,

frequent drainage crossings, scared places, graveyards or built-up areas or troublesome land acquisition

- Absence of sharp curves in the approaches;
- Absence of expensive river training works;
- Avoidance of excessive underwater construction.

Selection Criteria For Bridge Site

•For selecting a suitable site for a major bridge, the investigating engineer should make a reconnaissance survey to get impression of the landscape and to decide on the type of the structure to the site.

•Care should be taken to investigate a number of probable alternative sites and then decide on the site which is likely to serve the needs of the bridge at the least cost.

•A brief description of the reasons for the selection of a particular site should be furnished in the investigation report along with salient details of alternative sites investigated and rejected Selection Criteria for Bridge Site Preliminary Study(techno-economic Feasibility Survey)

•Different studies perform during PRELIMINARY SURVEY are:

•Topography
•Catchment area
•Hydrology
•Geo-technical data
•Seismology
•Navigation
•Construction resources
•Nearby bridges
•Traffic data

Choice of Bridge Foundation:

The excavation depth of bridge foundation has practical limitations depending upon the type of soil, presence of subsoil water level and ability of water to be pumped during excavation. The difficulty may also be encountered during the laying of concrete which should be laid in as dry condition as possible and the depth is limited below the low water level or subsoil water level.

1) Where very hard strata are available at a considerable depth but the expected scour is not high open foundation can be chosen at least 2-3 m below the expected sour level or lowest bed level.

2.) Where good bearing strata is not available at about 2-3 m below the bed and open foundation /excavation or cofferdams is likely to be costly, well or pile. foundation are preferred.

3) Where good bearing strata is not available at a shallow depth, if the problem is mainly about bearing and seepage, and possibility of soil caring into the open foundation or shoring becomes costly or inapplicable, Block foundation' (shallow well foundation) is used.

Advantages of using well foundation:
1) Provides a solid and massive foundation for heavy loads and a high horizontal thrust transmitted by the moving loads,
2) A larger cross-sectional area develops the total bearing Capacity much larger than what may be offered by a cluster of piles
3) Well can be sunk to any depth, if only open sinking is involved and maximum of 35 for pneumatic sinking,
4) Can be sunk through soil having boulders, Logs of woods and such other obstructions without causing damage to the structure,
5) Masonry CPCC/ RCC) in the steining of well is built in dry condition and the quality of the masonry or concrete can be assured, unlike in pile foundation.
6) Provides a very good grip when taken sufficiently deep and hence most suits to river beds with high scour.
7) Eccentric load on well cap, rise minimum eccentric effects.

Hence, the choice is mostly in favour of a well foundation where larger spans requiring deep foundation have to be provided However in some cases pile foundation is found to be more suitable over well as it has following benefits:
Less cost due to less concrete consumption,
Less time taken to construct,
No tilting and shifting problems.

Economical Span Length: or Number of Span
The number of spans for a bridge should be carefully decided by considering all the aspects of the bridges such as cost of construction, nature of flow, importance of bridges, material availability etc. Following points are important in deciding the number of spans for a bridge.

- Foundation for piers and abutments
- Aesthetic consideration
- The number of supports and their locations are so fixed as to be provide the most economical design of the bridges

The cost of a bridge is the summation of the cost of substructures and that of the superstructures. With the increase in span length, the total cost of the substructure decreases white that of superstructure is increased. The total cost of bridge can be expressed as:
$G_T = C_A + n.\ C_p + L.\ C_f + L.\ C_g$ – (1)
where, G= Total cost of bridge,
C_A = Cost of Abutments,
n. C_p= cost of 'n number of pies,
L = Length of the bridge,
C_f = Cost of flooring / finishing per unit length
C_g = Cost of main and Cross-girders (Superstructure)
L= length of a span.

Here,
N=no of piers $=\frac{1}{2}-1$
The cost of superstructures (C_g) is proportional to the length of the span i.e.
$C_g \propto l$
C_g=k.l-----(2)

Then,
$C_T = C_A + C_p\ (Ļ - 1) + L.C_F + L.\ kl$
$G = C_A + CP.\ L - C_p + L.\ C_F + L.\ kl$ -------(3)

The cost of the bridge will be minimum if
$$\frac{aC_t}{al} = 0$$
Then from eq^n (3)
$$\frac{aC_t}{al} = -C_p\frac{l}{l^2} + kl = 0$$

Or, $C_p = \frac{k.l.l^2}{L}$
or, $CP = Kl^2$
$= C_p = l.(kl) = l.C_g$---(5)

Eq^n (5) implies that the most economical bridge span is the one where cost of substructures is equal to that of the superstructures.

Lacuna/demerit of economic span

- The piers cause obstruction to flood water; therefore, the general thinking is to reduce the number of piers irrespective cost especially in the case of long span bridges and mighty rivers.
- If the economical span increase than a particularly value, the dead load of the bridge increases unnecessarily and due to that section of pier increases causing obstruction to flood waters and cost of foundations along with difficulties in installing proper foundation.
- Generally, the location of the pier is governed by the foundation conditions available across the channel. This refers to the safety of bridge and span length in then automatically fixed up irrespective of cost.
- The cost of river training works guide bunds spurs flooring is not consideration while considering economic span. For mighty/huge rivers this can be a significant cost.

Bridge Loadings:

The various types of loads that are likely to be imposed onto the bridge are:
1) Dead Load:
Dead load is a is the weight of permanent structures on the is it depends upon types of materials used.

- Initially a dead load is assumed. After the completion of design, it's rechecked. After revision if:
- Actual dead load effect on the member varies considerably w.r.t. assumed dead loads, the structure has to be redesigned.

2) Live Loads:

- Live loads are the dynamic loads on the bridge for which it is intended and are the main factors that govern the bridge design.
- The design is carried out on maximum expected loads so that lighter loads can be easily carried,

According to IRC, live loads are classified as follows:

a) IRC class AA Loading:
This is the heaviest type of loading generally used for bridges to be constructed in certain industrial areas / military operations involving large tanks etc. Such a design should also be checked with IRC class A loading as well:

IRC Class AA loading has two patterns:

I:> Tracked Type:

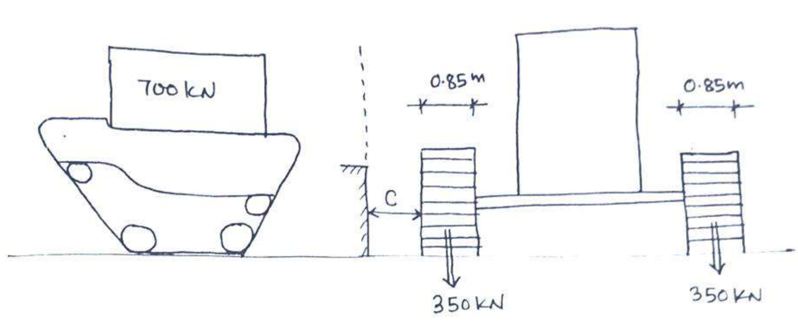


Fig: IRC Class AA (Tracked Type)

Value of C

1-lane = 0.30m

Multi-lane

<5.5m = 0.60m

>5.5m = 1.20m

II:> Wheeled Type:

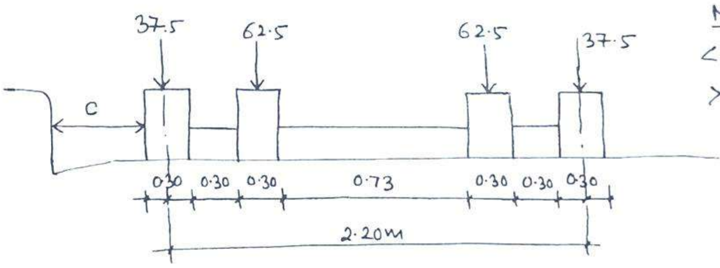


Fig: IRC Class AA - (Wheeled Type)

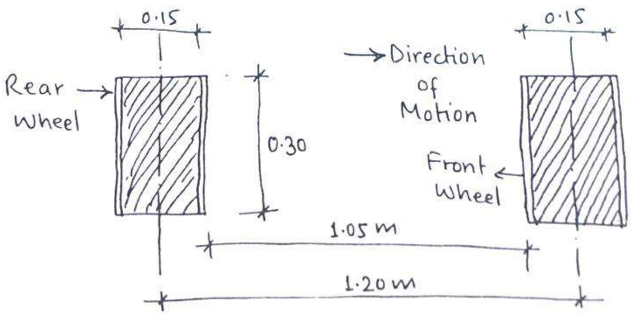


Fig: Wheel Configuration.

b) IRC Class A Loading:

IRC Class A is a standard loading comprising of the specified axle lengths and loads. Total length including trailers is equal to 25m and nose to tail spacing between Successive trains is $18.50m. When this load moves on a bridge it should be made sure that no other live load covers any part of the carriageway. Following fig. illustrates the loading pattern for class A & B (with different magnitudes given).

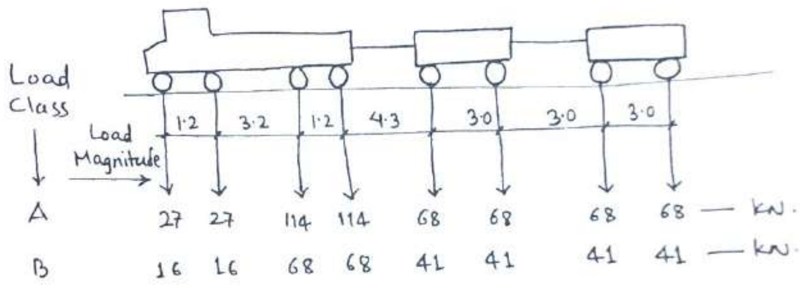


Fig: IRC class A & B Loads

C) Class B-IRC loading:

It's similar to class A type with small wheel Load magnitudes as shown in fig. above. It's this used in areas. temporary structures and in bridges at specified

d) IRC Class 70.R Loading:

The load has similar configuration as that of IRC class AA Loading but with the different features as follows:

Tracked:- Contact length=4.57m, nose~tail length = 7.92m minimum spacing between two vehicles = 30m.

Wheeled: - Length= 15.22m , 7 axles, Total weight 1oot.

Besides the above mentioned loads, following loads should also considered:

- Impact load , - Sewndary stresses
- Centrifugal forces, - Temperature effects,
- Wind load, - Buoyant forces
- Lateral laod, - water cument
- Longitudinal forces, - Erection stresses
- Seismic forces

Design Methods of Bridges:
Bridge design is done by various methods. However, based on the most frequent use and ease in design, following two methods are most widely used:
1) Effective width Method:
It is mostly used for one-way simply supported slabs,
The width of slab over which the action of load prevail is called as the "Effective width of Dispersion".

a)For simply supported slabs:
For a single concentrated load, effective width(beff) is:
Beff = k.x. (1-x/2)+bw where,
K=Constant (B/C yatio)
X=Distance of C.G. of load from nearer support,
L=Span length
Bw =width of dispersion of load on slab through wearing coat =w+2h, h=th. Of wearing coat

W=Contact width of wheel perpendicular to motion.
for two or more concentrated loads, in a line the Spanning direction, B.M. per unit width of the slab is separately calculated for each load as in single load,

for two or more load not in line in spanning direction: Effective width = sum of effective width of each load

(Resultant) -Width of overlap.
The slab so designed is however, tested for the two loads acting separately.

b) For Cantilever slab:

- For single concentrated load the effective width (beff) is:
  beff = 1.2x+ bw where,
  x= distance of load C.G. from face of fixed support.
- For two or more concentrated loads, if the effective width for a load overlaps the other, the resultant effective width (beff) is given by:
  beff = {[Effective width for each load) - overlap width,
  The slab so designed is checked separately for each load.

2) Pigeaud's Method:
Pigeaud's method is used for the slabs:
~Spanning in two directions,
~ Simply supported along all four edges,
~ Restrained corners,
~ Load placed symmetrically over well-defined area

- Pigeaud developed curves from which values of the moment coefficients can be derived which can be used to find the moments in two directions. Initially, these curves were developed for thin plates, but now they have been extended to concrete slabs as well
- Poisson's ratio for concrete is assumed to be 0.35.

The detailed procedure is described under:

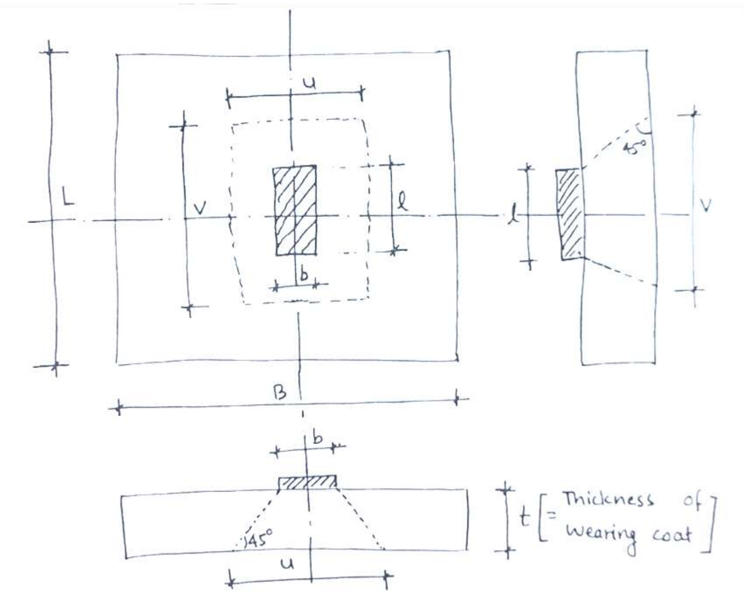


Fig. Dispersed Dimensions of Wheel Contact on slab

In Pigeaud's curves, for different values of aspect ratio K(=B/L), moment coefficients m1, m² along the two directions can be determined for the various values of U/B and V/L which can later be used to calculate moments.

Here, 'U' and 'v' are the dispersed dimensions of the contacts made by wheel on the wearing at of thickness 't' assuming the load being dispersed through wearing coat at an angle of 45°. Hence,
U=b+2t [2,b= Tyre contact dimensions along the]
v=l+2t span.

- Coefficients B/ V,V/L are calculated corresponding to which moment coefficients m1, and m2 are calculated in directions of respective orientations .
- Now, if w is the total load imposed on the slab of area l*b, the BM are given by:
  M1= W(m1, +0.15 m2)
  M2 = W (M2 +0.15 m2)

Distribution of Live Loads on Longitudinal Beams:

The moment in any bridge caused by live load depends upon the distribution of the live load on different members like beams, slabs, piers, abutments etc. interconnected to each other. In such a case, the supporting girders don't take the loads equally but the proportions in which they share the load depends upon the flexural stiffness of the deck and the position of the live load on the deck.
The two popular methods used to distribute the imposed load to supporting girders are:

I) Courbon's Methods:
Courbon's method assumes that the Cross-Girders are Infinitely rigid due to which no flexure is possible in deck slab. As per Courbon's Theory :

- A concentric load causes equal deflections in all girdess,
- For eccentric loads, the deflection on the side of eccentric load is greater than that of the other side.

Courbon's theory can be applied only under the following conditions:
→ Span to width ratio lies between 2~4,
→ At least five symmetrical girders are present,
→ The depth of cross girders is at least 0.75 times of that of the longitudinal girder.

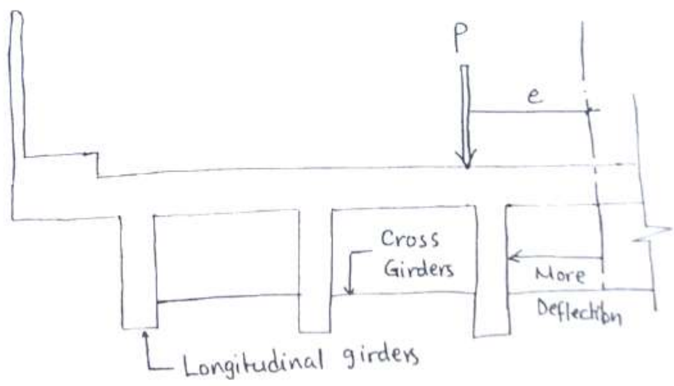


Fig. Deflection in Eccentric Loading System.

According to Courbon's Theory, the load shared by the girder 'i' is given by:

$$R_i \frac{P.I}{\in I} + \frac{PI_i}{\in I_i}[\frac{e.x_i \in I_i}{\in I_i.x_i^2}]$$

$$R_i = \frac{pI_i}{\in I_i}[1 + \frac{ex_i \in I_i}{\in I, x_i^2}]$$

Where,
P=Total live load
e= eccentricity from C.G. of deck slab,
xi = Distance of ith girder from CG. of deck slab
I= M.I. of girder considered.
If all the girders have the same cls,

$$R_i = \frac{pI_i}{\in I_i}\left[1 + \frac{ex_i \in I_i}{\in I, x_i^2}\right]$$

2.) Moment Distribution Method:
In this method, a moment distribution coefficient (k) is given by:

K= Load Carried by a specific Girder

Average Load per Girder

k=[P/n + P. e.xi]

$\overline{£Xi^2}$

p/n

$$k = P/n \left[1 + \frac{n.\ e.xi}{£Xi^2}\right]$$

p/n

$$k = 1 + \frac{h.\ e.xi.}{£xi^2}$$

There are two cases:

i)If 'n' number of wheels exist on the transverse deck,

$$k = \frac{£P}{n} \frac{[1+ n.e.xi]}{£Ii.xi^2}$$

ii) for girders having different values of M.I.,

$$k = \frac{£P}{n} [1+ \frac{n.\ e.\ ki.\ Ii]}{£Ii.xi^2}$$

Hydraulic factors that influence Bridge Design:

The hoydraulic parameters that influence the design of bridges are given below in sequential order:

Phase-I :Site Reconnaissance, review and analysis of the available river data are undertaken with a view to select the possible bridge location that are often Compatible with the shortest communication routes. Historical flood levels, current flow pattern, sediment nature etc. are studied carefully.

Phase-II: At each of the possible bridge site, topographic and hydraulic surveys are conducted to collect the hydraulic datas required for the design.

Phase-II from the available data, assessment of the following hydraulic parameters is done:
- Maximum flood flow - Bed and Bank features,
- Design flood flow. - Approach velocity & direction,
- Maximum flood levd - width of flood plain,
-Navigational Requirement - River meandering nature.

Phase- IV: During this phase, linear waterways, normal water depth, afflux, back water effect, flow velocity, river training schemes required are determined. This helps to determine bridge length, foundation, approx. minimum depth, span length, no. of piers.

Phase-V: Proper free board, vertical clearance, height of the bridge, hydrodynamic forces on the pier are estimated. It gives proper Location & geometry of piers. Phase- VI: For the proposed configuration of the bridge, normal scour, maximum scour, back water effect is computed. [Review of pier type and numbers final].

Seismic Analysis of Bridge:

- If the bridge is located in a region subjected to the earthquakes, allowance should be made in the design for incorporating the seismic forces and earthquake resisting features in the structural details of design
- The Seismic force is considered to be a function of

~ weight of the structure
~ Ground motion during earthquake,
~ Nature of vibration / Time- History,
~ Type of underlying / Resisting soil.

The seismic force comprises of both the horizontal and vertical components.

The horizontal seismic force (Feq). to be resisted can be computed from the equation:
Feq = 2. B.X.G . - where,
x= Horizontal seismic Coefficient depending on various zones, taken as 0.08 for Nepal Zone Iv=0.05 ~0.10.
B= A coefficient depending on the soil foundation systems, value ranges from 1.0~1.50.
X = A coefficient depending on the importance of the bridge [1.5 ~ important bridges,1.0~0 others]
G = Dead Load above the section considered.

- The value of horizontal seismic coefficient for below the scour depth is taken as zero if the horizontal force is taken to act through the C.G. of all the system under consideration. The direction of the force should be such that the resultant stresses in the members under consideration are maximum.
- The forces not considered simultaneously with seismic force are wind force and highest flood
- Seismic forces due to live loads force can be ignored when action in the direction of traffic while they should be given due consideration it the direction perpendicular to the traffic. Stresses due to seismic forces shall be computed for 50% of the design live load for road bridges.

- The following seismic forces on the substructure above the scour depth are to be considered:
  ~ The Hand V forces due to dead, live and seismic loads transferred to the substructures from the superstructure via bearings,
  ~H&V seismic forces due to self-weight applied at the centre of mass ignoring reduction due to uplift or buoyancy,
  ~ Hydrodynamic forces acting on piers and modified earth pressure on abutments due to earthquake.
- Piers should be checked for the above seismic assumed to act parallel to the current and traffic directions taken separately.
- For submerged portions of the pier, the hydrodynamic force v, assumed to act in a horizontal direction corresponding to that of the earthquake motion is given by : Vuo= A. $\propto$h. W where

A= A coefficient depending upon the ratio of weight of submerged portion of pier to the radius of enveloping cylinder,
$\propto$n= Horizontal seismic coefficient,
w = weight of water of enveloping cylinder,

Seismic Provisions:
Bridges in seismic zones II and III need not be designed for seismic forces if:
Span <l5.om, total length of bridge <60.00m.
IRC-G: 2014 latest Revision has given five zones for the seismic study i.e.
Zone - I, II, III, IV, & V
Vertical Seismic Coefficient = 0.5X Hor. Seismic Coeff. (AL)
For span >150m, special study is required i.e. it requires "site Specific seismic Criteria".
Feq. = $\propto$n (DL + LL) where

$$\propto n = \frac{\frac{\{Z\}}{2}\frac{\{Sa\}}{g}}{\{R/I\}}$$

Where,
2= Zone factor = 0.1, 0.16, 0.24 ,0.36 for zones I, II,III and IV respectively.
I= Importance Factor= 1.5 for important bridges/1.0 for others.
R= Response reduction factor = 2.5
Sa =Average Response acceleration coefficient for 5%. damping depending upon g T..
T= fundamental time period of bridge member,

values of So/g:
for rocky or hard soil sites:

$$\frac{Sa}{g} = \begin{cases} 51 + 15T & [0.0 \le T \le 0.10] \\ 2.50 & [0.10 \le T \le 0{:}40] \\ 1/T & [0.40 \le T \le 4.0] \end{cases}$$

→ For medium soil:

$$\frac{Sa}{g} = \begin{cases} 1+15T & [o.o \le T \le 0.10] \\ 2.50 & [0.10 \le T \le 0.40] \end{cases}$$

1.36/T [0.40 ≤T ≤4.0]
→ For Soff soil :
Sa=1+15T [0.0 ≤T ≤ 0.10]
g 2.50 [0.40 ≤T ≤0.40]
1.67/T [0.40 ≤T ≤4.0]

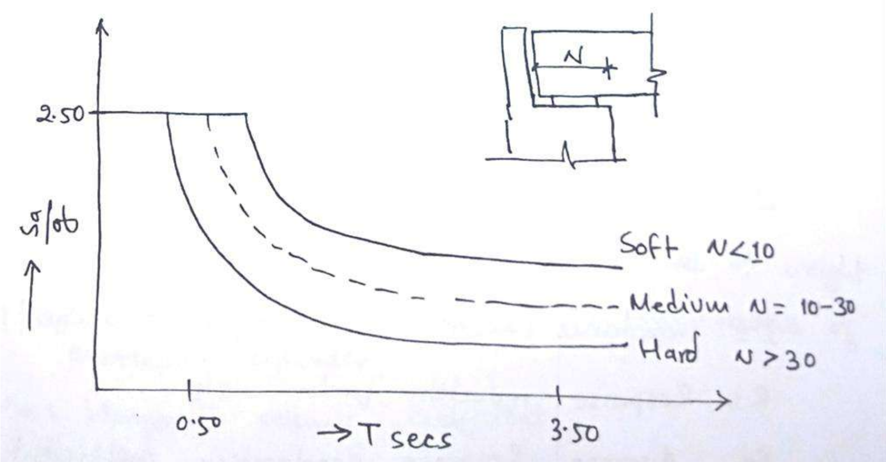


Fig: Response spectrum.

Dynamic Behaviour or Vibration of Bridges (Exam)

Moving loads on bridge decks causes the super structure comprising beams and slabs to deflect from its equilibrium position relatively quickly. The mass and inherent elasticity of the structure tends to restore the bridge deck to its equilibrium position thus causing a series of vibrations due to the motion of vehicle on the bridge deck. The effect of bridge deck vibrations results in

- Structural damage if not properly designed for vibration affects
- Causes unpleasant physiological and psychological reactions in humans, and
- Develops additional stresses of transient nature which are in addition the static effects.

The normal practice to cope these effects of dynamic loads is to provide for impact factors for live loads which amplify the design static loads by a certain percentage. Consequently, the bridges deck is rendered more rigid so that the dynamic effects are safely resisted with increased mass and elasticity of the structure.

Certain thumb rules incorporated in the codes include limiting the span and depth ratios of the deck and also limiting the deflection and span ratios. These above provisions are not based on the data of frequency and amplitude of vibrations of the structure and hence cannot be taken as guaranteed against the occurrence of undue vibrations even under normal loads.

Dynamic Response of Bridge Decks

Dynamic Response of Bridge Decks to moving loads depends on mass, stiffness, damping properties of the bridge and dynamic properties of the moving loads resulting in vibrations either at the natural frequency or at the frequency of the applied excited force.

The normal range of fundamental frequency of bridges varies between 1 to 20 cycles per second. This may coincide with the ranges of frequencies of moving vehicles resulting in the possibility of response loading to the failure of the bridge deck.

Empirical formula, $f = 94.5\ L^{-0.933}$, where L in span in m and Time period T= 0.004 to 0.0024L and L in feet.

Factor influencing bridge vibrations

- Natural frequencies of the vehicle system and the vehicle system and suspension systems.
- Speed of passing vehicles
- Ratio of vehicle to bridge deck weight
- Flexural rigidity and natural frequency of vibration of the bridge deck
- Type of bridge deck and approaches
- Improper functioning of expansion joints
- Frequency of live loads applications due to the passages of multi lanes
- Motion induced to bridges before applications of live loads particularly important for continuous spans

- The damping characteristic of the bridge and vehicle.

Approaches/Study of Bridge Vibrations

1. In situ test : actual vibration of bridge is measured by instruments/gauges
2. Codal provisions for dynamic effects
    - Impact factors as per IRC …
    - Limitations of the ratio of deflection to span
    - Restriction in the span/depth ratios
3. Practical calculation based on natural frequency and vibrations amplitude/ Leuzen's Criteria/British code
    - Estimate the maximum span deflection Dmm under a single 200 KN hypothetical point load at centre of span and cross section using the fully composite flexural rigidity of the deck section of full width (EI)
    - Estimate the fundamental natural frequency (N_1) of deck
      $N_1 = 2/L^2$ * square root of EIg/W where, L span in m, EI is flex, rigidity KN m^2 and W dead wt of deck including finishes KN/m

    - Take A = 0.4 D or 0.75 D if N_1 is more than 4 cycles/second and less than 4 cycles/second respectively. Whare A is maximum amplitude of vibration in mm
    - Estimate the maximum acceleration $A_{max}=40AN_1^2$
    - Ensure that the product A and A_{max} is not more than 3226 mm^2 per sec^2 and that the vibration characteristics from Lenzen's criteria is within desirable limits.

Issue in bridge management in Nepal

1. **On design**
    - **L**arge volume of design works
    - Redundant bridge design just to deceive the people
    - Lack of standard design
    - Lack of competent designer
    - Culture of manipulation in data/report etc
    - No system of learning mistakes
    - Design not attractive to engineers
    - River training works not designed properly
    - Hidden designer and team leader
    - Poor scour estimation
    - Soil test not appropriate
    - Span fixation not as per site condition
    - Survey work by practitioners
2. **Issue on the construction**
    - Layout problems i.e. level of bridge foundation/sub structure etc
    - Project without proper cash flow
    - Contractors lacking skilled manpower
    - Improper time allotment for project
    - Lack of quality conscience
    - Lack of modern equipment
    - Poor finish quality and QAP
3. **Issue on maintenance**
    - Low interest in maintenance and design capacity
    - High cost of proprietary works
    - Lack of proper norms and standard
    - Low Budget allocation

Tunnelling Engineering

A tunnel is a hole or an underground passage made without removing underlying /overlying rock or soil to provide a desired movement of people, material or vehicles. In other words, they are artificially prepared "Through Caves" that mainly provide an access for highway, railway, pedestrian, fresh water conveyance, cooling water supply, waste water collection, hydropower, utility conveyance etc.
Tunnels can be classified as follows:
On the basis of purpose:
- Traffic tunnels,
- Conveyance tunnels,
- Mining tunnels,

On the basis of pressure:
- Pressure,
- Free flowing

On the basis of Lining:
- Lined Canal/ Tunnel
- Unlined Canal /Tunnel

On the basis of shape:
- Circular
- Semi- Elliptical
- Horse-shoe shaped
- Caren D-shaped
- Rectangular

Supporting Arrangements:
- RSJ sections
- RCC
- shotcrete
- RSI with shotcrete.

Main Component parts of tunnel:
- Rib Beam,
- Rock Bolting,
- Shotcrete,
- Lining

Functional Classification of Tunnel:
Usually, the shape of the c/s is the primary basis for the functional classification of tunnels. Following are some of its types:
i)Circular Tunnels:

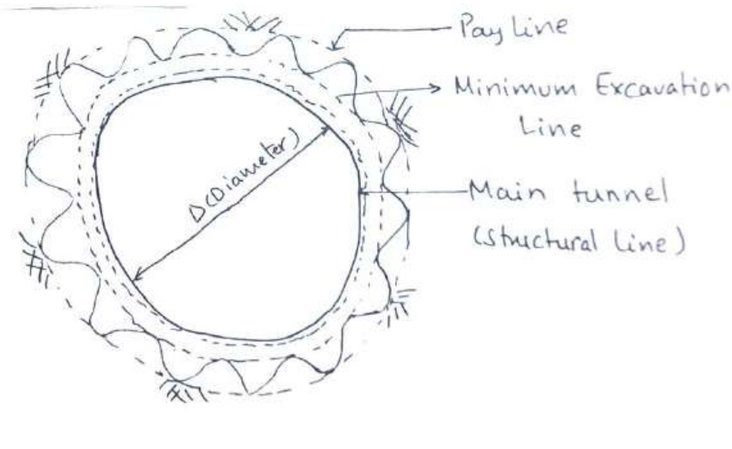
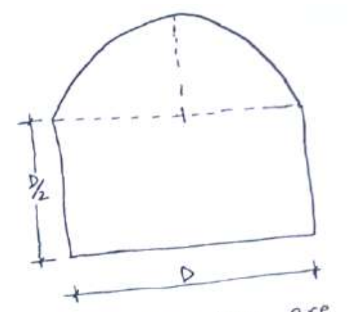


Fig: Circular Tunnel

- Most suitable from structural considerations,
- Excavation difficult for small CIs areas,
- Most suitable for high internal pressure and/or absence of good quality and/ or adequate amount of suck cover.

2) D-Shaped Tunnel:

- Most suitable in presence of good quality rock around specially with compact, dense sedimentary or igneous rocks.
- Provided where pressure due to external rocks & water is low. (only structural line are drawn here onwards)
- Lining is not provided.



(Only structural line are drawn hereonwards)

3) Semi- Elliptical type:
- stable type of c/s with shape of an arch nearly coinciding with the pressure lines.
- Hence, the arch section can be made thinner by keeping the stresses within the allowable limits.

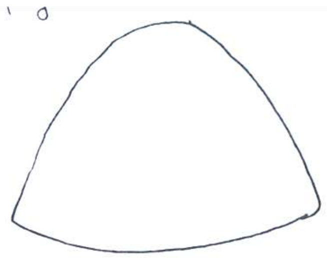


fig: Semi- Elliptical

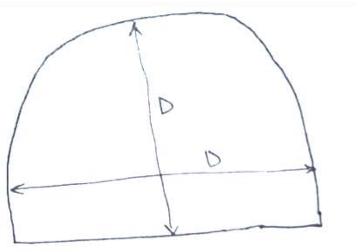
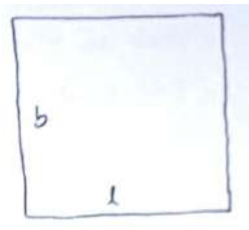


fig: Horse- shoe shaped

4.) Horse- Shoe Shaped:
- Combination of circular and D-shape,
- Good structural properties to resist pressure due to rock and water ,
- Most suitable for tunnel subjected to internal pressures and where moderately good rock is available.

5) Rectangular/Square:
- They are not very easy to construct but posess inferior structural properties and also they are difficult to construct
. - As such, they are rarely used.



A tunnel is needed when an obstacle in the form of a hill or rising ground is met within the alignment of a highway or railway track. The first tunnel, about 4000 years ago of a cross section of 3.6 m * 4.5 m; 910 meter long, was built in Babylon connecting two buildings.

In Europe the first tunnel was built by Roman Emperor Cloudius in 54 AD for carrying spring water through Apennines. The cross of the tunnel was 3.0 m * 1.8 m and its length was 5.8 Km. It was completed in 12 years by 30, 000 laborers.

Four types of tunnel sections which are famous in tunnelling:

1. Circular shaped tunnels
2. Elliptical
3. Horse-Shoe shape tunnels
4. Vertical walls with arched roof (D-Shaped tunnels).

- The shape of the cross section of a cement concrete lined tunnel will depend on the pressure of the ground which the lining must be able to resist and the purpose for which the tunnel is to be constructed.
- If the ground is solid rock, then any shape may be adopted but for soft ground such as soft clay or sand, the pressure from the sides as well from the top is to be resisted. In such difficult situations, circular cross section is best suited if it is able to serve the purpose of the tunnel.
- A circular tunnel, in general is not suitable for the highways because highways need a flat surface. Circular sections are more suitable for aqua-ducts.
- D-shaped tunnels have a horizontal base (flat invert), two vertical sides and an arched roof. Such tunnels are best suited as the vehicular tunnels. The semi-circular top acts as an arch, and thus takes and shifts the top soil load to the vertical sides and thus to the bed.
- If the ground bed is broken, subjected to the horizontal pressure, vertical wall sections of a vehicular tunnel may be replaced with a horse shoe section as it can resist the external pressure better.
- Circular and elliptical tunnels are popular for water(irrigation) and sewage conduits while the horse shoe and vertical wall sections (D-Shaped) sections are popular for vehicular tunnels depending upon the condition and type of ground.

Shaft, Pilot Tunnel

Shafts are the vertical tunnels, generally circular in section. In case of the hydro projects, you have to construct the surge shafts to prevent the water haemorrhage. In the highway projects surge shafts are constructed from the top to reach down to the main tunnel and provides the access path to the main tunnels.

A number of shafts may be constructed at places more than one in a long tunnel project, and work may be started from those numbers of places. Diameter of a shaft depends upon the purpose of the shaft, if a TBM is to be lowered to the main tunnel than it is necessary to make the shaft of the required size.

Similar to a shaft Pilot tunnel serves as the access tunnels to the main tunnels. The cross section of a pilot tunnel is usually 240 cm or a little bigger and are driven parallel to the main tunnel. The pilot tunnel is first driven to the full length of the tunnel and is connected to the center line of the main tunnel at many points. From these points, the work of the main tunnel may be started and also, they make is easy to take out the muck. Uses of the pilot tunnels may be summarized in the following points:

- It helps in providing proper ventilation to the main tunnel.
- It helps in removing the muck from the main tunnel quickly.
- It helps in providing proper lighting in the main tunnel.

Pilot tunnels also offers a path to reach to the main tunnel so that you can access it to go for the further construction. Pilot tunnels are constructed generally parallel to the main tunnel, and when in connects to the main tunnel path, you get two faces/two directions to excavate your main tunnel.

Driving Tunnel in rocks, sequence of construction operations

Actual sequence of the tunneling operations, will depend upon the site conditions, size of the tunnel and method of construction. However, the general sequence of the operations carried out during construction of a tunnel is as given below:

1. Setting up and drilling
2. Loading holes with explosives and firing them.
3. Ventilation and removing the dust after the explosion.
4. Loading and hauling muck.
5. Removing the ground water if necessity arises.
6. Erecting supports for sides and roofs in necessity arises.
7. Placing reinforcement.
8. Placing concrete lining.

There are several methods of tunnelling, the method to be selected for a particular site will depend upon the size of the bore, the equipment available, the condition of the formation and the extent to which the timbering is required. Tunnelling may be grouped into two groups:

1. Tunnelling in hard rocks

2. Tunnelling in soft rocks.

Tunnelling in hard rocks is carried by one the following methods:

1. Full face method
2. Heading and benching method
3. Drift Method
4. Pilot tunnel method
5. Perimeter method

Here we will discuss the first three methods in details.

Full Face Method

This method of tunnelling is adopted when the length of the tunnel is more than 3 meters. Large sized tunnels in rocks are always driven by this method. With the development of drill carriage this method is becoming more and more popular. In this method vertical columns are fixed to the face of the tunnel to which a large number of drills may be mounted or fixed at any suitable height as shown in the figure below. A series of drill holes are drilled at about 120 cm center to center in any number of desired rows, preferably in two rows. The size of the holes may vary from 10 to 40 mm. These holes are then charged with explosives and ignited. The muck is removed before the next operation of drilling holes.

Heading and Benching Method

Tunnel cross section is divided into two parts, the top portion of the tunnel is known as the heading and the bottom portion as bench. Usually, this method is adopted for railway tunnels. In this method of tunneling, top portion or heading will be about 3.70 to 9.6 m ahead of the bottom portion as shown in the figure below. In hard rock which may permit the roof to withstand without supports, the top heading generally is advanced by one round of bottom portion. If the rock is broken then heading may be driven well ahead of the bottom portion and after giving proper support to the roof, the bottom portion is completed. In hard rock the heading is bored first and the holes are driven for the bench portion at the same time as the removal of the muck. This required less explosive than the full-face method, but due to the development of the drill carriage or jumbo, the use of this method is decreasing.

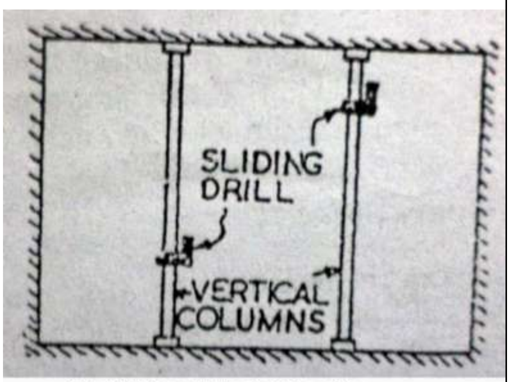


Fig. Full Face Method of Tunneling

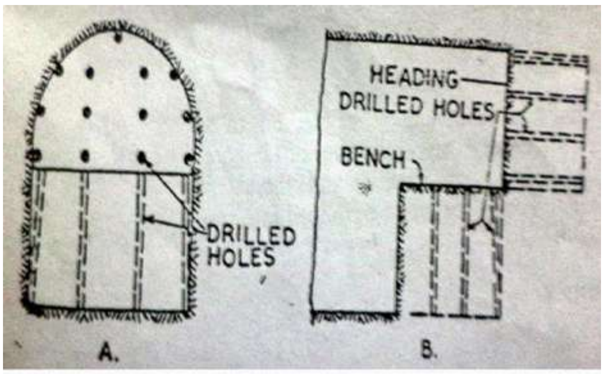


Fig. Heading and Benching (Tunneling)

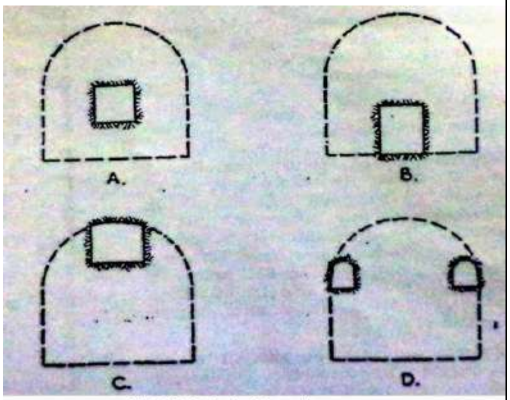


Fig. Drift Method of Tunneling

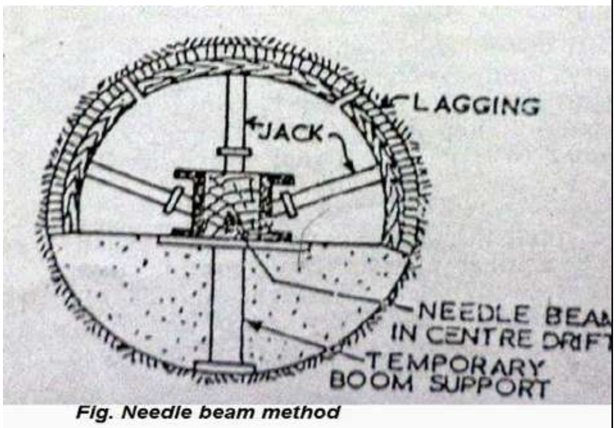


Fig. Needle beam method

Drift Method

Drift is a small tunnel, usually its size is 3m*3m. In driving a large tunnel, it has been found advantageous to drive a drift first through the full length or in a portion of the length of the tunnel prior to the excavating the full bore. The drift may be provided at the center, sides, bottom or top as desired. In this method after driving the drift, the drill holes are drilled all-round the drift in the entire cross section of the tunnel, filled with explosives and ignited. The rock shatters, the muck removed and the tunnel expanded to the full cross section.

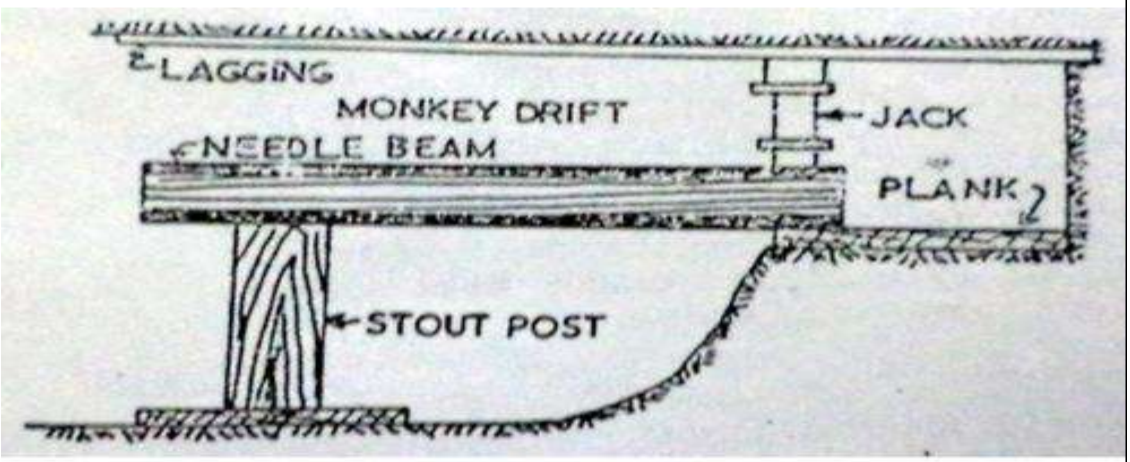


Fig. Needle Beam Method

Driving tunnels in soft ground

While tunnelling in soft grounds, explosives are not used and tunnelling is done with the hand tools such as pick-axes, shovels etc. During excavation operation supports for soil are required immediately depending upon the type of soil. In the old days, timber was the only material used for supporting soft ground till the introduction of the steel liner plates few years ago. As heavy supporting system is needed to support the roof and sides, there is more obstruction in the movement inside the tunnel, which reduces the progress of the work. Care should taken to ensure that all struts should be sufficiently strong to bear the pressure coming on them. The method to be adopted in the soft ground tunnelling depends upon the type of ground.

Needle beam method, sequence of construction operations

This method is useful for tunnelling in the soft ground whose roof soil can stand without support for few minutes. In this method 5 to 6 meters long R.S. joist or timber beams are required in addition to other timber boards and struts. This method requires large number of jacks which cause obstruction in the efficient working of the laborers. For tunnelling in soft ground, it is more economical than other methods.

- Sequence of Working:

1. First of all, a small drift of size of about 1*1 m is prepared on the working face of the tunnel.
2. The needle beam consisting of two I girders, bolted together with a wooden block at the center, is inserted in the drift and its roof is supported on lagging carried on the wooden segment as shown in the figure below. These segments are supported by jacks resting on the needle beam.

Needle beam method- 1

3. As shown in the figure below, the needle beam is placed horizontally, whose front-end rests on the drift itself and the rear end is supported on the vertical stout post, resting on the lining of the tunnel.

Needle beam -2

4. The jack is placed on the top of the beam (Needle Beam) to support the roof with lagging and then drift is widened sideways and the whole section is excavated. After excavating lining may be provided.

Compressed Air Tunnelling Method

This method is considered as most modern method of tunnelling in soft grounds having water bearing stratum. A compressed air is forced into the enclosed space to prevent the collapse of the roof and sides of the tunnel. Usually, air is used in conjunction with a shield and air-tight locks. However, numerous small tunnels have been driven using only linear plates or wood cants only. This method can be safely adopted if the air pressure is approximately 1 kg/cm^2. If the pressure is more than 1 kg/cm^2, the working hours should be reduced considerably which will increase the cost of tunnelling.

Application of the air pressure to the tunnelling is not so simple due to the following reasons:

1. The earth pressure varies from the top of the tunnel to the bottom of the tunnel.
2. As the pressure in the floor of the tunnel depends upon the nature of the strata, it is difficult to ascertain it theoretically.
3. The value of pressure varies with the moisture content in different strata, which is difficult to ascertain.
4. The compressed air will escape through the pores of the soil; hence air pressure will diminish continuously. Thus, the value of air pressure will have to vary from time to time to get a balanced value and the determination of this value depends more on experience than theoretical considerations.

This method is ideally suitable for clay formations which do not contain large number of pores and the pressure does not vary much from top of the tunnel to its bottom.

Engineering approach to seismic analysis and design of Tunnel

Earthquake effects on underground structures can be grouped into two categories: (1) ground shaking; and (2) ground failure such as liquefaction, fault dis- placement, and slope instability. Ground shaking, which is the primary focus of this report, refers to the deformation of the ground produced by seismic waves propagating through the earth's crust. The major factors influencing shaking damage include: (1) the shape, dimensions and depth of the structure; (2) the proper- ties of the surrounding soil or rock; (3) the properties of the structure; and (4) the severity of the ground shaking

Seismic design of underground structures is unique in several ways. For most underground structures, the inertia of the surrounding soil is large relative to the inertia of the structure. Measurements made by Oka- moto et a1. (1973) of the seismic response of an immersed tube tunnel during several earthquakes show that the response of a tunnel is dominated by the surrounding ground response and not the inertial properties of the tunnel structure itself. The focus of underground seismic design, therefore, is on the free- field deformation of the ground and its interaction with the structure. The emphasis on displacement is in stark contrast to the design of surface structures, which focuses on inertial effects of the structure itself. This led to the development of design methods such as the Seismic Deformation Method that explicitly considers the seismic deformation of the ground. For example, Kawashima, (1999) presents a review on the seismic behavior and design of underground structures in soft ground with an emphasis on the development of the Seismic Deformation Method.

The behavior of a tunnel is sometimes approximated to that of an elastic beam subject to deformations imposed by the surrounding ground. Three types of deformations (Owen and Scholl, 1981) express the response of underground structures to seismic motions: (1) axial compression and extension; (2) longitudinal bending (Fig); and (3) ova1ing/racking (Fig. 6). Axial deformations in tunnels are generated by the components of seismic waves that produce motions parallel to the axis of the tunnel and cause alternating compression and tension. Bending deformations are caused by the components of seismic waves producing particle motions perpendicular to the longitudinal axis. Design considerations for axial and bending deformations are generally in the direction along the tunnel axis (Wang, 1993).

Ovaling or racking deformations in a tunnel structure develop when shear waves propagate normal or nearly normal to the tunnel axis, resulting in a distortion of the cross-sectional shape of the tunnel lining. Design considerations for this type of deformation are in the transverse direction. The general behavior of the lining may be simulated as a buried structure subject to ground deformations under a two-dimensional plane- strain condition.

Diagonally propagating waves subject different parts of the structure to out-of-phase displacements (Fig.), resulting in a longitudinal compression—rarefaction wave traveling along the structure. In general, larger displacement amplitudes are associated with longer wavelengths, while maximum curvatures are produced by shorter wavelengths with relatively small displacement amplitudes (Kuesel, 1969).

The assessment of underground structure seismic response, therefore, requires an understanding of the anticipated ground shaking as well as an evaluation of the response of the ground and the structure to such shaking. Table 1 summarizes a systematic approach for evaluating the seismic response of underground structures. This approach consists of three major steps:

1. Definition of the seismic environment and development of the seismic parameters for analysis.
2. Evaluation of ground response to shaking, which includes ground failure and ground deformations.
3. Assessment of structure behavior due to seismic shaking including (a) development of seismic de- sign loading criteria, (b) underground structure response to ground deformations, and (c) special seismic design issues.

Design and Analysis Approaches

The different response characteristics of aboveground and underground structures suggest different design and analysis approaches:

- Force Method for Surface Structures. For aboveground structures, the seismic loads are largely expressed in terms of inertial forces. The traditional methods generally involve the application of equivalent or pseudo static forces in the analysis.

- Deformation Method for Underground Structures. The design and analysis for underground structures should be based, however, on an approach that focuses on the displacement/deformation aspects of the ground and the structures, because the seismic response of underground structures is more sensitive to such earthquake induced deformations.

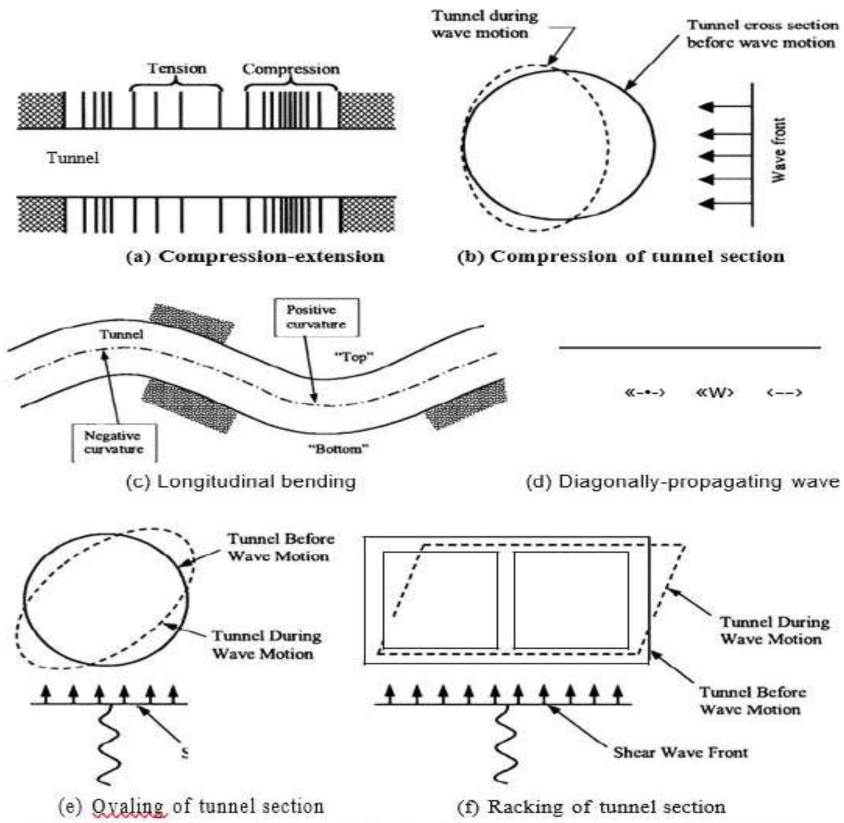
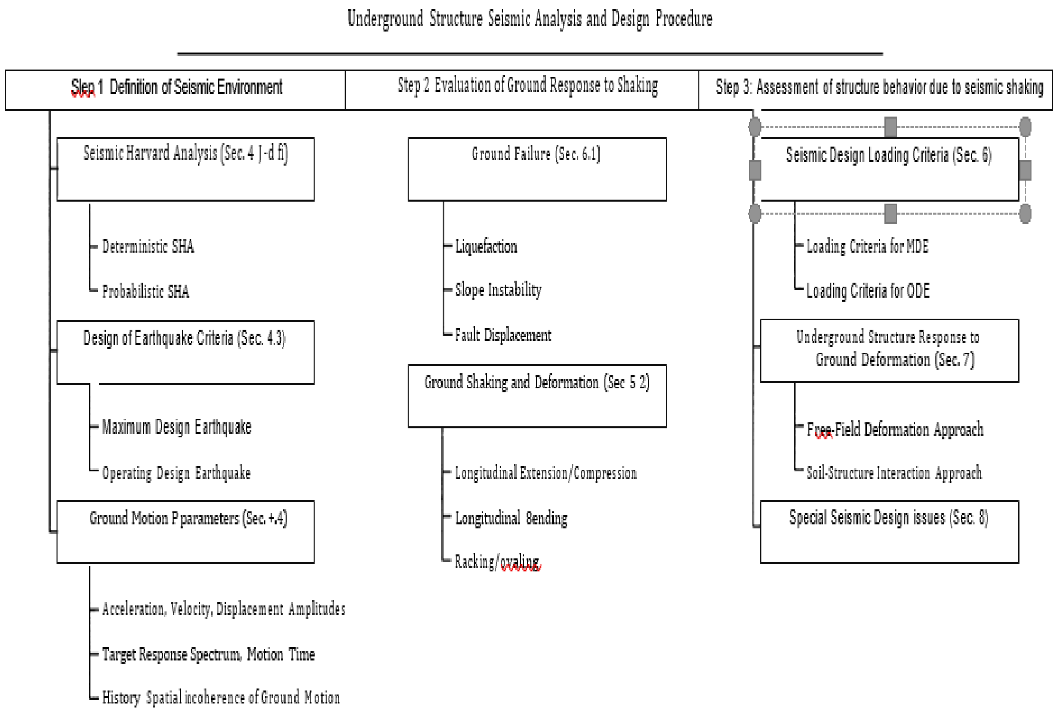


Fig. G. Deformation modes of tunnels due to seismic waves (alter Owen and Scholl, 19g1).

Table I

Seismic analysis and design procedure



Two Level Design Criteria

Based on the discussion presented above, it is apparent that current seismic design philosophy for many civil engineering facilities has advanced to a state that dual (two- level) design criteria are required. Generally speaking, the higher design level is aimed at life safety while the lower level is intended for continued operation (i.e., an economical design goal based on risk considerations). The lower-level design may prove to be a good investment for the lifetime of the structures.

The two-level design criteria approach is recommended to ensure that transportation tunnels constructed in moderate to high seismic areas represent functional adequacy and economy while reducing life-threatening failure. This design philosophy has been employed successfully in many of PB's recent transportation tunnel projects (LA Metro, Taipei Metro, Seattle Metro, and Boston Central Artery/Third Harbor Tunnel). In these projects the two design events are termed as:

- The Operating Design Earthquake (ODE), defined as the earthquake event that can reasonably be expected to occur during the design life of the facility (e.g., at least once). The ODE design goal is that the overall system shall continue operating during and after an ODE and experience little to no damage.
- The Maximum Design Earthquake (MDE), defined as an event that has a small probability of exceedance during the facility life (e.g., 5 percent). The MDE design goal is that public safety shall be maintained during and after an MDE.
- Note, however, that the design criteria aimed at saving lives alone during a catastrophic earthquake are sometimes considered unacceptable. There are cases where more stringent criteria are called for under the maximum design earthquake, such as requiring rapid repairs with relatively low cost. A good example would be the existing San Francisco BART structures. As described in Chapter 1, BART warrants such stringent criteria because it has an incalculable value as possibly the only reliable direct public transportation system in the aftermath of a catastrophic earthquake.

Therefore, the actual acceptable risk and the performance goals during and after an MDE depend on the nature and the importance of the facility, public safety and social concerns, and potential direct and indirect losses.

Loading Criteria

Maximum Design Earthquake (MDE). Given the performance goals of the MDE (i.e., public safety), the recommended seismic loading combinations using the load factor design method are as follows:

For Cut-and-Cover Tunnel Structures
U= D + L + Al + fi2 + EQ ……………… Eq. 2.1
Where U = required structural strength capacity
D = effects due to dead loads of structural components L = effects due to live loads
E1 = effects due to vertical loads of earth and water E2 = effects due to horizontal loads of earth and water EQ = effects due to design earthquake (MDE)
For Mined (Circular) Tunnel L/p
U —— D + L + EX + H + EQ…………..Eq. 2
where U. D, L, and EQ are as defined in Equation 2.1
EX = effects of static loads due to excavation (e.g., O'Rourke, 1984) H = effects due to hydrostatic water pressure

Comments on Loading Combinations for MDE

- The structure should first be designed with adequate strength capacity under static loading conditions.
- The structure should then be checked in terms of ductility as well as strength when earthquake effects, EQ, are considered. The “EQ" term for conventional surface structure design reflects primarily the inertial effect on the structures. For tunnel structures, the earthquake effect is governed by the displacements/deformations imposed on the tunnels by the ground.
- In checking the strength capacity, the effects of earthquake loading should be expressed in terms of internal moments and forces, which can be calculated according to the lining deformations (distortions) imposed by the surrounding ground. If the "strength" criteria expressed by Equation 2-1 or 2-2 can be satisfied based on elastic structural analysis, no further provisions under the MDE are required.
- Generally, the strength criteria can easily be met when the earthquake loading intensity is low (i.e., in low seismic risk areas) and/or the ground is very stiff.

- If the flexural strength of the tunnel lining, using elastic analysis and Equation 2-1 or 2- 2, is found to be exceeded (e.g., at certain joints of a cut-and-cover tunnel frame), one of the following two design procedures should be followed:

1. Provide sufficient ductility (using proper detailing procedure) at the critical locations of the lining to accommodate the deformations imposed by the ground in addition to those caused by other loading effects (see Equations 2-1 and 2-2). The intent is to ensure that the structural strength does not degrade as a result of inelastic deformations and the damage can be controlled at an acceptable level.

   In general, the more ductility is provided, the more reduction in earthquake forces (the "EQ" term) can be made in evaluating the required strength, U. As a rule of thumb, the force reduction factor can be assumed equal to the ductility provided. This reduction factor is similar by definition to the response modification factor used in bridge design code (AASHTO).
   Note, however, that since an inelastic "shear" deformation may result in strength degradation, it should always be prevented by providing sufficient shear strengths in structure members, particularly in the cut-and-cover rectangular frame.

2. Re-analyze the structure response by assuming the formation of plastic hinges at the joints that are strained into inelastic action. Based on the plastic-hinge analysis, a redistribution of moments and internal forces will result. If new plastic hinges are developed based on the results, the analysis is re-run by incorporating the new hinges (i.e., an iterative procedure) until all potential plastic hinges are properly accounted for. Proper detailing at the hinges is then carried out to provide adequate ductility. The structural design in terms of required strength (Equations 2-1 and 2-2) can then be based on the results from the plastic-hinge analysis.

   As discussed earlier, the overall stability of tunnel structures during and after the MDE has to be maintained. Realizing that the structures also must have sufficient capacity (besides the earthquake effect) to carry static loads (e.g., D, L, E1, E2 and H terms), the potential modes of instability due to the development of plastic hinges (or regions of inelastic deformation) should be identified and prevented (Monsees, 1991; see Figure 21 for example).

- The strength reduction factor, I , used in the conventional design practice may be too conservative, due to the inherently more stable nature of underground structures (compared to surface structures), and the transient nature of the earthquake loading.

- For cut-and-cover tunnel structures, the evaluation of capacity using Equation 2-1 should consider the uncertainties associated with the loads E1 and E2, and their worst combination. For mined circular tunnels (Equation 2-2), similar consideration should be given to the loads EX and H.

- In many cases, the absence of live load, L, may present a more critical condition than when a full live load is considered. Therefore, a live load equal to zero should also be used in checking the structural strength capacity using Equations 2-1 and 2-2.
  Operating Design Earthquake (ODE). For the ODE, the seismic design loading combination depends on the performance requirements of the structural members. Generally speaking, if the members are to experience little to no damage during the lower- level event (ODE). the inelastic deformations in the structure members should be kept low.

The following loading criteria, based on load factor design, are recommended:
For Cut-and-Cover Tunnel Structures

C/ = L0fiD + 1.3L + b›G/f1 + E2- + 1.3/1{?

(Eq. 2-3)

where D, L, E1, E2, EQ, and U are as defined in Equation 2-1.

b1 1.05 if extreme loads are assumed for E1 and E2 with little uncertainty.
Otherwise, use bt = 1.3.

For Mined (Circular) Tunnel Lining
U -— 10:3D + 1.3L + b2X + //-' + 1.36{? (Eq. 2-4)

where D, L, EX, H, EQ, and U are as defined in Equation 2-2.

b2 = 1.05 if extreme loads are assumed for E1 and E2 with little uncertainty.
Otherwise, use b2 1.3.

Comments on Loading Combinations for ODE

- The structure should first be designed with adequate strength capacity under static loading conditions.
- For cut-and-cover tunnel structures, the evaluation of capacity using Equation 2-3 should consider the uncertainties associated with the loads E1 and E2, and their worst combination. For mined circular tunnels (Equation 2-4), similar consideration should be given to the loads EX and H.
- When the extreme loads are used for design, a smaller load factor is recommended to avoid unnecessary conservatism. Note that an extreme load may be a maximum load or a minimum load, depending on the most critical case of the loading combinations. Use Equation 2-4 as an example. For a deep circular tunnel lining, it is very likely that the most critical loading condition occurs when the maximum excavation loading, EX, is combined with the minimum hydrostatic water pressure, H. For a cut-and-cover tunnel, the most critical seismic condition may often be found when the maximum lateral earth pressure, E2, is combined with the minimum vertical earth load, E1. If a very conservative lateral earth pressure coefficient is assumed in calculating the E2, the smaller load factor bt = 1.05 should be used.
- Redistribution of moments (e.g., ACI 318) for cut-and-cover concrete frames is recommended to achieve a more efficient design.
- If the "strength" criteria expressed by Equation 2-3 or 2-4 can be satisfied based on elastic structural analysis, no further provisions under the ODE are required.
- If the flexural strength of the tunnel lining, using elastic analysis and Equation 2-3 or 2- 4, is found to be exceeded, the structure should be checked for its ductility to ensure that the resulting inelastic deformations, if any, are small. If necessary, the structure should be redesigned to ensure the intended performance goals during the ODE.
- Zero live load condition (i.e., L = 0) should also be evaluated in Equations 2-3 and 2-4.

General Construction Methods

1. Cut and Cover Tunnelling

Cut and cover tunnelling is a common and well-proven technique for constructing shallow tunnels. The method can accommodate changes in tunnel width and non-uniform shapes and is often adopted in construction of stations. Several overlapping works are required to be carried out in using this tunnelling method. Trench excavation, tunnel construction and soil covering of excavated tunnels are three major integral parts of the tunnelling method.

Most of these works are similar to other road construction except that the excavation levels involved are deeper. Bulk excavation is often undertaken under a road deck to minimize traffic disruption as well as environmental impacts in terms of dust and noise emissions and visual impact.

Demerits with respect to Environment

- More dust and noise impact may arise, though these can be mitigated through implementation of sufficient control measures.
- Temporary decks are often installed before bulk excavation to minimize the associated environment impacts;
- Larger quantity of C&D Larger quantity of C&D materials would be generated from the excavation works, requiring proper handling and disposal.

2. Drill and Blast

This tunnelling method involves the use of explosives. Drilling rigs are used to bore blast holes on the proposed tunnel surface to a designated depth for blasting. Explosives and timed detonators are then placed in the blast holes. Once blasting is carried out, waste rocks and soils are transported out of the tunnel before further blasting. Most tunnelling construction in rock involves ground that is somewhere between two extreme conditions of hard rock and soft ground. Hence adequate structural support measures are required when adopting this method for tunnelling. Compared with bored tunnelling by Tunnel Boring Machine (see below), blasting generally results in higher but lesser duration of vibration levels. A temporary magazine site is often needed for overnight storage of explosives.

Benefit with respect to Environment

- Potential environmental impacts in terms of noise, dust and visual on sensitive receives are significantly reduced and are restricted to those located near the tunnel portal.
- Compared with the cut and cover approach, quantity of C&D materials generated would be much reduced.
- Compared with the cut-and cover approach, disturbance to local traffic and associated environmental impacts would be much reduced.
- Blasting would significantly reduce the duration of vibration, though the vibration level would be higher compared with bored tunnelling;

Demerit

- Potential hazard associated with establishment of a temporary magazine site for overnight storage of explosives shall be addressed through avoiding populated areas in the site selection process.

3. Bored Tunnelling

Bored tunnelling by using a Tunnel Boring Machine (TBM) is often used for excavating long tunnels. An effective TMB method requires the selection of appropriate equipment for different rock mass and geological conditions. The TBM may be suitable for excavating tunnels which contain competent rocks that can provide adequate geological stability for boring a long section tunnel without structural support. However, extremely hard rock can cause significant wear of the TBM rock cutter and may slow down the progress of the tunnelling works to the point where TBM becomes inefficient and uneconomical and may take longer time than the drill-and-blast tunnelling method.

Benefits:

- Potential environmental impacts in terms of noise, dust and visual on sensitive receives are significantly reduced and are restricted to those located near the launching and retrieval shafts.
- Compared with the cut-and-cover approach, disturbance to local traffic and associated environmental impacts would be much reduced.
- Compared with the cut-and-cover approach, quantity of C&D materials generated would be much reduced.

4. Sequential Excavation Method

This method is also known as the New Austrian Tunnelling Method (NATM). The excavation location of a proposed tunnel is divided into segments first. The segments are then mined sequentially with supports. Some mining equipment such as road headers and backhoes are commonly used for the tunnel excavation. The ground for excavation must be fully dry for applying the NATM and ground dewatering is also an essential process before the excavation. Another process relates to the ground modifications such as grouting, and ground freezing is also common with this method in order to stabilize the soil for tunnelling. This method is relatively slow but is found useful in areas where existing structures such as sewer or subway could not be relocated.

Benefits

- Similar to the drill-and-blast and bored tunnelling methods, only localised potential environmental impacts would be generated.

Demerits

- As the method is relatively slow, duration of potential environmental impacts would be longer than that of the other methods.

Survey of Tunnel Alignment :

An ideal tunnel alignment should have following points/ factors taken into due considerations:

-Straight,
- Short ,
- Easy ,
- Carefully selected entry and exit points.

However, the straight alignment may not always be a feasible one because of the following reasons:

- Unsuitable topography,
- Uneconomical and cumbersome geology, -
-Water: Heavy ground water and rock water loads,
-Rock mechanic properties not favourable,
-Creep or tectonic movement active fault in alignment.

To avoid construction difficulties following factors are to be given due consideration:

- Rock temperature,
- Presence of methane gas,
- Other geometric design criteria.

Geotechnical Investigation and Design of Tunnels:

A tunnel project must start with a comprehensive investigation of ground conditions by collecting samples from bore holes and by other available geophysical techniques. This will help to make a good choice of machineries to be used (or not), methods for excavation and type of ground support required thereby reducing the risk of encountering unforeseen ground conditions. In planning the route, the horizontal and vertical alignments will make use of the best ground and water conditions with enough preparations

Following stages can be followed:

1. Conventional desk and site studies may yield sufficient information to assess the factors like the blocky nature of rocks, the exact location of fault zones (in maps), or the stand-up times of the softer ground.
2. For more information, a pilot tunnel or a drift may be driven ahead of main tunnel drive. It gives overall info of the ground & other required parameters and the main drive will circumscribe this pilot channel. Alternatively, horizontal boreholes may sometimes be drilled.

3. Calculation of "Stand-up time" which is the amount of time up to which the tunnel will support itself without any added shuttles. It helps to figure out how much can be excavated before support is needed. This time is high for rocks & day and is low for sand/ fine soils.
4. Assessment of Groundwater Conditions is very important. This information helps the engineers to decide the actual Stand- up time and also based on this the preparatory works for suffering may be undertaken such that there are minimum hinderances during the actual construction.
5.The shape of the tunnel is highly dependent upon the materials /rocks /sorts of which the ground is made of. Tunnel shape is very important in determining the stand-up time.
Since the force from scanty is straight down on a tunnel, if the height is greater than the width, the stand-up time will increase making the construction easier and faster while the conditions are just vice-versa if the width of tunnel is greater than its height.

-Best sections are this circular, D-shaped, Semi- Elliptical Horseshoe shaped.
- The worst sections are square or rectangular.

Tunnel Drainage:
Tunnel involves underground construction where drainage problem is vital due to presence of surface and /or sub-surface / subsoil water. This may not only be achieved by grouting, water-proofing or lining as water way penetrate through the shrinkage cracks into the interior of tunnel. As such, drainage in a tunnel involves following:

1.Pre-Drainage:
Prior to the construction of tunnels, arrangements are made to prevent the water from interfering the construction work by:
- Diverting surface drainage from entering the tunnel,
- Providing counter weights against the hydraulic

2.) Dewatering:
The accumulated water during construction is accumulated at a certain point which is disposed by gravitational measures or by pumping. Following measures are applied:
- Removal of accumulated water by gravity or pumping,
- Provision of side drains whenever slope is available,
- Extra quantity beyond the Pauline shall not be constructed especially for construction of drains,
- Pumping devices should not be clogging type, additional pumps should be in standby in case of breakdown of working pumps,
- High technical input for high efficiency

3) Permanent Drainage :
In bored tunnels, water proofing is not possible. As such, effective quality control during the lining in construction period determines the quantity of permanent drainage works required later on. When water coming out is not much and not so serious, the cracks may be sealed off by some available means. Following measures are often applied:
- Provision of Longitudinal drain pipe,
- Lining of concrete,
- Continuous open gutters,
- Grouting with cement/chemicals.

Ventilation of Tunnel:
Tunnel may have accumulation of foul gases, used up air or ventilated air which should be removed by proper means of ventilation either by natural or artificial means. The natural methods are implied efficiently for short tunnels while long tunnels need artificial means.

The purposes of ventilation are:
- To replace foul used air by fresh air,
- To remove dust & harmful gases for safe working space,
- Supply oxygen for workers in the tunnel,
- To remove the excessive moisture,
- To reduce the temperature raised by diesel engines.

Types / Methods of Ventilation:
Ventilation is tunnels is achieved by following two types:
1.) Natural Ventilation,

2) Artificial ventilation.

1.) Natural Ventilation:
For short tunnels (with length < loom), with the straight alignment and uniform gradient, natural ventil Can be used otherwise presence of obstructions, curves, reduces the anticipated quantity of natural air.

- Natural drafts can be used for the purpose of natural ventilation which depends upon whether the traffic in tunnel is unidirectional or two-directional.
- Natural ventilation may be sufficient for a reasonably longer lengths for uni-directional traffic.

2.) Artificial/ Mechanical Ventilation:
Artificial / Mechanical means are used to control dust, moisture and temperature especially when the tunnels are of relatively longer lengths. Methods used are:
→ Blowing in of fresh air,
→ Exhausting of foul air,
→ Combination of blowing and exhausting system,

In the artificial means of ventilation following situations are observed:

- Normal Operation": – Air pressure relief.
- Congested Operation on Maintenance" - Heat removal
- Emergency Operating" - During mishaps inside tunnel, this is effective means to control smoke flare allow smoke free path for both patons & employees dine evacuation, fire-fighting

Means for Tunnel Ventilation System :(TUS):
1. Tunnel ventilation Fans - 2 tunnel ventilation fans of required capacities are installed in plant rooms near vent shafts.
2. Exhaust fan System:
3. Tunnel Booster fan system
4. Tunnel Ventilation Dampers
5. Ventilation Shafts
6. Ventilation Nozzles

Lighting of Tunnel:
Lighting is a very important aspect in the construction of tunnels to fully utilize the efficiency of manpower, equipments and materials involved in the construction with adequate safety. As stated by Is codes, the minimum requirements for lighting in a tunnel are:
1) Adequate Lighting (Minimum illumination of 100 lux) shall be provided in each and every point where the work is under progress,
2.) Any obstruction like jumbo, framework etc. should be cleary visible to avoid accidents during the hauling operations.
3) Incandescent lamps should be placed at the suitable intervals along the center of the roof of the tunnel,
4.) Supply voltage may be reduced from 230v to 250 v for lighting while 440 w may be provided for laid water proof cables,
5) The electric circuit shall have a number of independent circuits with separate set of isolators and fuse boxes to reduce chances of accidents due to short-circuit,
6) All haulage systems shall have their independent set of lighting system,
7) Flood lights in addition to normal lights shall be placed at suitable intervals.

Living in Tunnel:
Living is done in a tunnel for support using suitable system as per the site condition, Living is not meant for carrying direct load of the overlying rock/soil mass which is accomplished by Arch acting used support system. The Chief function of living are:

- Reducing the loss in system
- Protecting the still libs of arch system from deterioration
- Protect the, turbines, fans, exhaust systems el from loose rock particles falling into the water con tunnel and in case of conveyance tunnel, there rocks Can damage turbines at power Stations.
- Take internal pressure induced by water in can q water conveying tunnel
- Additional support to arch action or other support systems.
- Take stresses generated due to shrinkage & temperature changes in the concrete as it sets,
- Take Growling pressures
- Removal a air pressure after Living,

- Shears due to creep, squeeze or swelling q ground around the tunnel
- Take surface loads after the living is in place,

Living Methods & Selection of Efficient method:
Tunnel construction is highly complex process comprising & various natures g geology, geo techniques, work organization, economy etc. varying every sites. Along with the serviceability of the tunnel in a way term, safety f workers during construction and that of users during operation shall be taken parallel.

Living in Tunnels are the permanent methods... playing the main the for keeping the Tunnel from collapse thereby emerging. Safety. There are Technical & Non-Technical factors that affect the choice of type of Living,

Now for a controlling factor =i
& for a number of controlling factors,
if wn_i= Weighted Efficiency of a living method A for Controlling
factor=i
$WA_i=ED_{ai} * \frac{IP_i}{100}$ T=Max Eff. degree
Then $EP_A=\frac{\sum_{i=i}^{100} \in W_{Ai}}{T} * 100$

Various Living Methods:
Like we assign available A for a lining method, the various types of lining are:
- Natural Living, he Unsupported rock,
- Rock Reinforcement Living
- Shotcrete lining,
- steel Ribs,
- Monolithic Concrete,
- Segmental System
- Precast pipe segments

Construction of Tunnel:
Construction of tunnel is most usually done by the conventional method of drilling and blasting involving the following operations:
- Setting up and drilling cut holes, erasers, trippers,
- Loading of explosives,
- Defuming and ventilation,
- Checking of misfires,
- Scaling and removal,
- Mucking - removal of excavated material
- Erection of support system and dining if required.

Methods of Tunnelling:
The particular choice of method for tunnelling depends upon the nature of the strata and the geometry of the tunnel section. As such, there are following methods:

1) Tunnelling in firm Grounds:
Firm grounds are those lying between rock and soft soil categories. Based on available shape and size of the equipments, the following two methods are used:
a) Traditional / Conventional Methods:
Depending upon the type of strata, size of tunnel & method to be adopted, temporary supports of woods or permanent supports of steel are provided to support the excavation.

Following methods are used under this:
I) Full face Method: This method is used for relatively firm soil that can hold itself for sufficient time so that mucking & supporting operations can be done, specially when tunnels are of smaller sizes. Sequentially, the top section -I is cut and removed and then same applies to I & II as well.

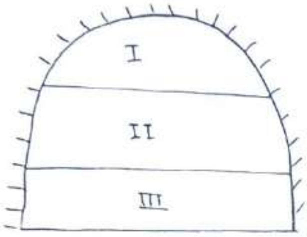


Fig. I. - Full face Method

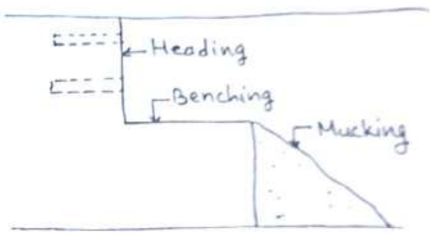


Fig. II - Heading & Bending Method

I) Top Heading and Benching Method:
- This method is used for relatively soft soils which is not firm enough to hold itself untill mucking & supporting,
- The top heading is first excavated with or without the blasting (minor) and it's supported to the full or half length of the tunnel before starting benching
- Thus the heading operation is always done prior to the benching operation. Benching of a convenient length, to support the excavated heading part, may be formed by excavating the full width of the tunnel above the springing. see. fig II

Draft Method:

- In the case of large size tunnel c/s, a pilot tunnel is made at the center or at sides, such a pilot tunnel is called as a "Drift".
- Drift helps to make suitable arrangements for supporting the excavations.
- Drift is then widened by drilling holes on its face as in fig. to extend to the full c/s of the tunnel.
- Based on their positions, drifts are of:
    - Plate Drift
    - Side Drift
    - Multiple Drift

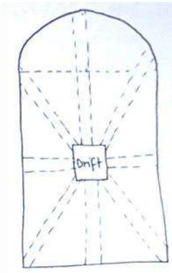
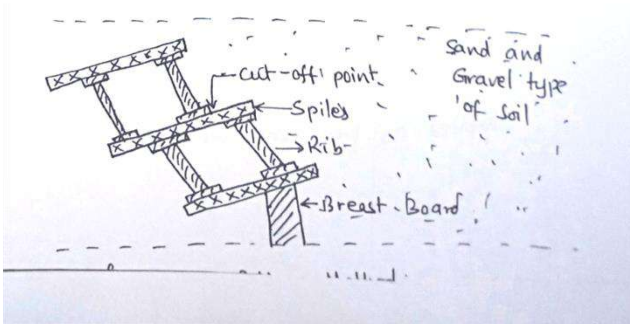


Fig: Drift Method

b) Excavation Method: This method is suitable for large tunnel in soft soil. In this method, the excavation is done and the arrangements for support are done simultaneously.
2) Tunnelling in soft soil:



Soft soils need instant support and hence blasting is not required in such soils. For this purpose, fore-poling method is used - The boards - Spiles - are driven into the ground to support the soil ahead. They are installed as far around the periphery as support is needed.
- The fore poles act as cantilevers beyond breasting and carry loads until steel rib supports its forward point.
- The breast board is then removed; excavation is done and new steel rib is created in position to move ahead.
- The process is repeated as we move further.

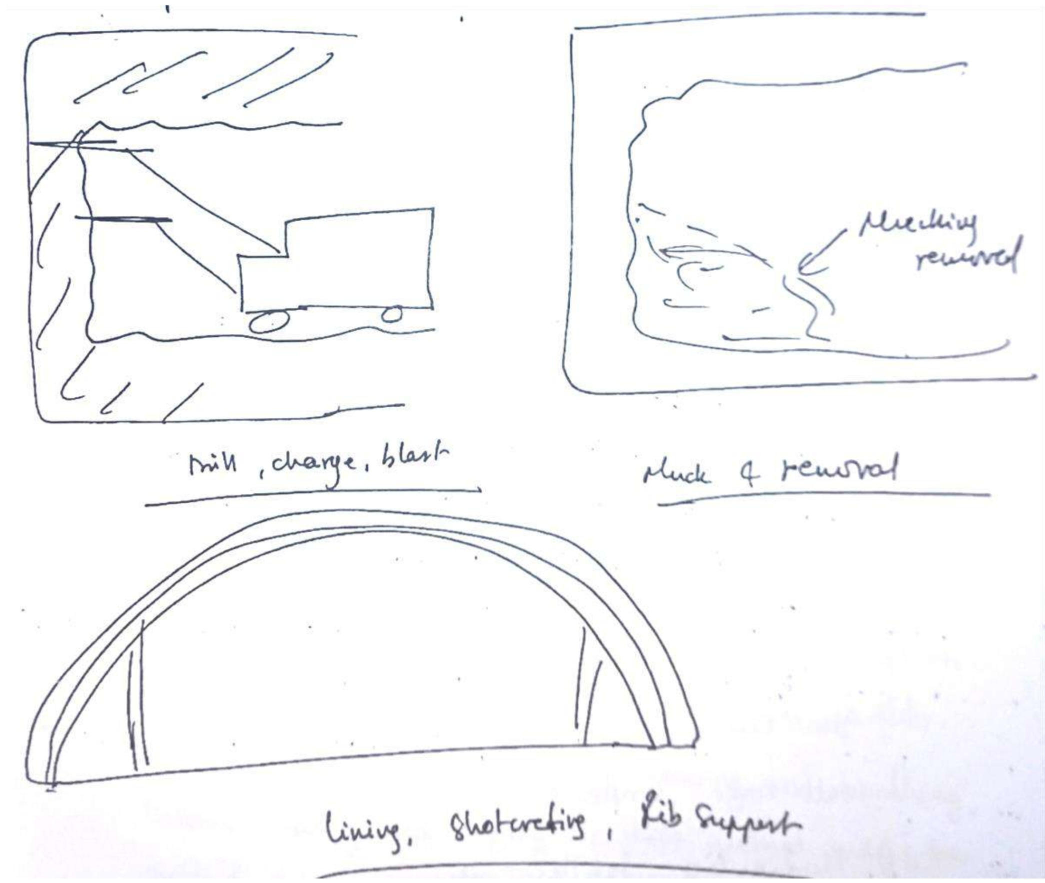
3) Tunnelling in Rocks:

- According to working plan, a drift may be prepared to expand up to the whole c/s or whole c/s is started at once as per the prevailing situations,
- Sequence and repetitions of actions like drilling, loading of explosives into the fire holes, blasting, mucking etc. is carried out until the work progresses further.
- Any method like full face, top heading and benching bottom heading and stopping or drift method may be implied as per convenience and site situations.

4) Other Methods:
There are several other methods as practiced worldwide which are of:
a.) Cut - and Cover Method:
For shallow tunnel where a French is excavated and then roofed over with an overhead support system strong enough to carry whatever is to be built above tunnel.
- It has two banc forms:
I.) Bottom - up Method,
II.) Top down method.

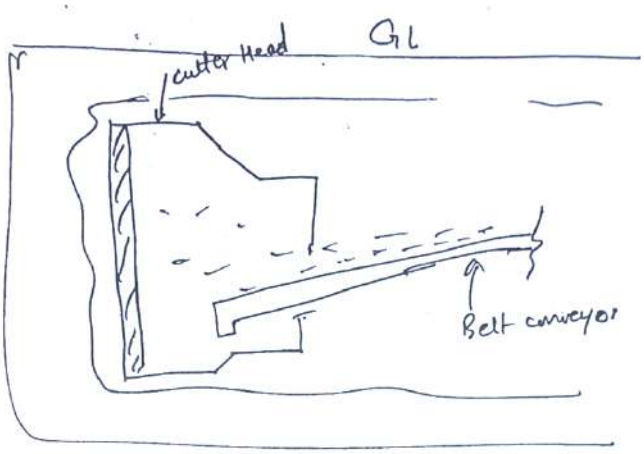
b) Bored Tunnels using TBM.
c) clay- kicking Method - manually digging of tunnels in Clayey scales which is silent and effective.
d) Shafts,
e) Sprayed Concrete techniques
f) Pipe Jacking / Box Jacking
g) Under water tunnels
h) open-building pit
i) wall-cover construction method
j) Hydraulic Splitter etc

2.) Tunneling in soft fails ... Continued
New Austrian Tunneling Method (NATM) /mountain Tunneling Method:
- It is based on a concept. whereby the ground (rock or soil) surrounding an underground opening becomes a load bearing structural component through activation of a lung like body of supporting ground
- The support resistance of the soil man should be presented by using additional support elements.
- Tunnel ribs & anchors act as main supporting features not thickness of living



ii) Shield Tuning Method:

-It uses a steel Tube steel Tube (shield) to In the ground and secure the safety of which are performed inside the shield.
- This prevents the ground from collapse.



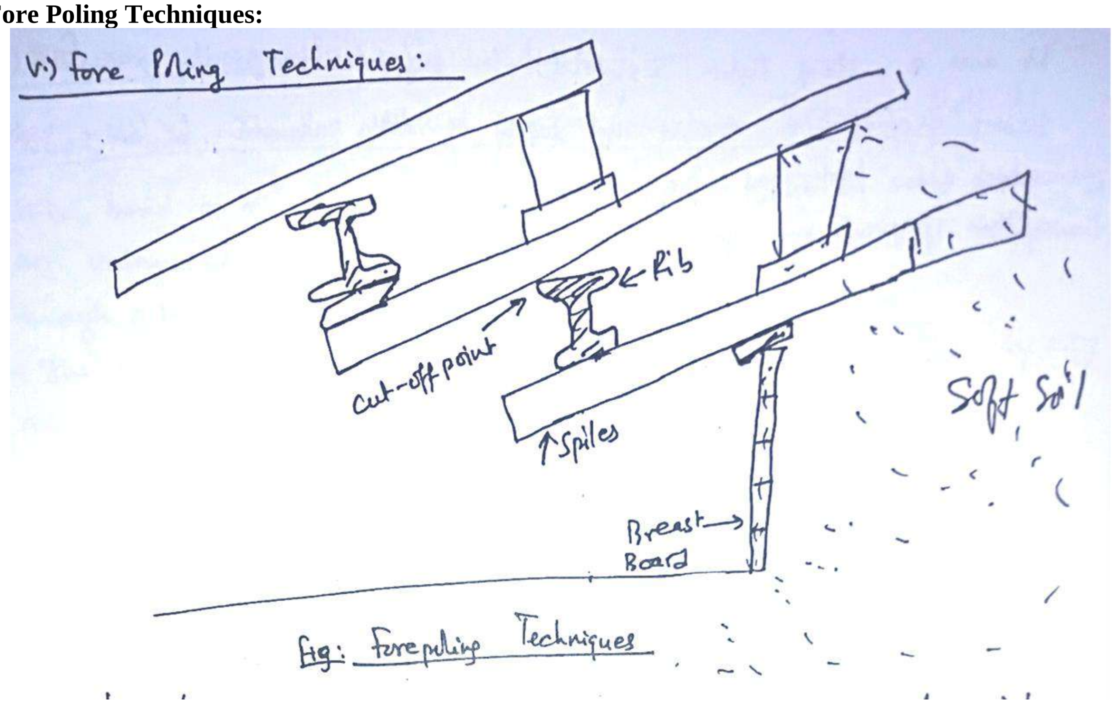
iii) Cut & Cover Method:

- for shallow tunnels, short lengths.
- A French is cut in the soil which is covered by some support capable of load bearing on it.
- The cutting can be done by
  a) Button up method
  b.) Top-down

iv) Immersed Tunnel Method:

- Immersed Tube construction have its elements built separately in a dry duck an shipyard. These are then taken to the site where trench have already been made to receive them.
- They are then immersed in the water and joined to each other to form a tunnel.

v) Fore Poling Techniques:



4) Tunneling Using TBM:

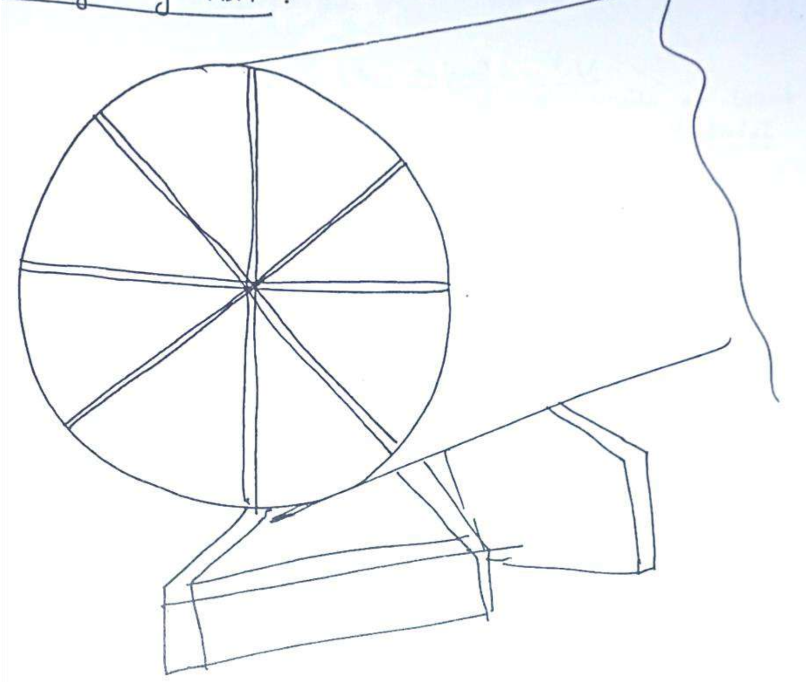


Fig: TBM

- TBM has revolutionized the tunnelling works, making them Safer & economical.
- Bering is done progressively ahead & the excavated soil is Carried for disposal.
- Rib supports, Livings, waterproofing, ventilations are done successively,

Tunneling Failures: Causes and remedies

Tunneling is one of the most intricate and expensive projects in engineering and construction. With increasing demands and the emphasis on reducing the travel time between any two places becoming a priority, the risks and challenges involved in the construction of tunnels have increased manifold.

The concept of tunnels was first executed in the year 1843 when the first underwater tunnel was constructed to connect the north and south bank of the River Thames in London. After a lot of hardship and a series of failures, though the tunnel was built successfully, it is still considered a financial failure.

In order to deal with these failures, extensive planning and surveying goes into tunneling projects. It is, therefore, important to understand the types of tunnel failure, their causes, and the remedial measures to prevent tunnel failure.

Types of Tunnel Failure, Causes, and their Corrective Measures

1. Ground Collapse near the Tunnel Portal

Cause for Ground Collapse

The reason for the collapse of the ground near the tunnel portal is due to the excessive build-up of pore water pressure, which could be due to heavy rainfall.

Corrective Measures

The umbrella technique which holds the material surrounding the periphery of the tunnel and reduces the risk of sudden collapse should be followed.

Wrapping and Twisting of Tunnel Support System

Reasons for Wrapping and Twisting

Due to the continuous ingress of water to the bottom of the tunnel portal, the bearing capacity of ground soil near the portal decreases, which causes the concrete lining to settle into the ground and therefore leads to the wrapping and twisting of the tunnel support system.

Corrective Measures

The portion which is subjected to the maximum stress level is the invert level of the tunnel; therefore, to protect the invert, a systematic approach in designing the drainage system should be followed.

Improper Blasting Techniques

Reasons for Improper Blasting

During the construction of a tunnel in mountainous regions, it is difficult to hold the tunneling process using Tunnel Boring Machines (TBM) due to the cost factor involved in the transportation of TBM and strengthening of the existing transportation system. Therefore, the alternative approach is adopted, i.e., the use of blasting for the cut and cover method.

If the blasting is not designed correctly, then it can lead to the squeezing and bursting of the rock mass, which may eventually lead to the complete collapse of the tunnel.

Corrective Measures

The blasting system should be designed in such a way that it incorporates all the functional parameters such as burden, stemming length, bench spacing, control of fly rock, etc.

Cavity Formation

Reasons for Cavity Formation

After the conclusion of the blasting process, cavities may generate in the surrounding rock mass. If the assessment of cavities in the alignment of the tunnel is not worked out before the advancement of each and every trail, then it can lead to the failure of the tunnel near the advancement portal, which consequently may increase the accident rate.

Corrective Measures

Before each and every advancement in the tunnel section, trail holes should be made, and if any cavity is observed, it should be filled with bentonite slurry

Presence of Fault and Fracture Zones

Reasons for Fault and Fracture Zones

Due to the blasting technique, the faults and fractures get loosened, and therefore the loosened rock mass creates an excessive shear force on the periphery of the existing tunnel, which can cause shear failure and cracks into the concrete lining.

Corrective Measures

During the construction of a tunnel, if any significant fault or fractures are present, then the alignment of the tunnel should be changed instead of proceeding with the same alignment. If alignment can’t be changed due to unavoidable reasons, then the spacing of fault should be monitored with proper monitoring equipment.

If it exceeds the permissible limit, then immediately, chemical stabilization (grouting) should follow. Near the fault or fracture regions, the strength of tunnel support should be higher than the normal capacity.

Heaving

Reasons for Heaving

After the commencement of the tunnel service, if swelling clay soil is observed above the tunnel crown, it will be subjected to hydrothermal pressure, which in turn, can cause an increase in the volume of soil particles, and therefore causing heaving at the base of the pavement surface.

Corrective Measures

Rock bolts or anchor bolts are very useful in case of swelling clay soils because they reduce the passive flow of material on the soil particles, and hence they should be placed around the periphery of the tunnel and also below the base of the pavement surface.

सन् १८२५ मा दक्षिणी लण्डन जोड्ने उदेश्यले प्रेरित भई बेलायती सिभिल एवं मेकानिकल इन्जिनियरले थेम्स नदीमा पहिलो सुरुंग निर्माण थालेको र आर्थिक कठिनाइका बावजुद १८४३ मा सम्पन्न गरेको |
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संसार कै सबैभन्दा लामो रेल चल्ने सुरुंग मार्ग ५७.५ कि.मि. स्विट्जरल्यान्ड (सन् २०१६ मा) हो भने १५००० कम भन्दा पनि बढी सुरुंग मार्ग चीनमा रहेको |

River Bank and River Training works

River training works are constructed for a variety of reasons, but the fundamental objective is to restrict horizontal movement of river channel by guiding and training the flow.

Objective of river training works
1. To train the river to flow in straight reach both U/S and D/S well as at the bridge site.
2. To deflect the flow of the river from the banks to prevent the erosion of the bank.
3. To provide the guide bund so as to confine the stream in the desired limits.
4. To provide the required depth at the bridge in case of navigational channels.
5. To confine the span to minimum.

River Bank may be failed by
1. Erosion of soil by river currents or waves
2. Excessive hydrostatics pressure in the material in the bank or sloughing of slop due to saturation of bank materials
3. Under mining the toe of bank due to high current, eddies etc.
4. Liquefaction and subsequent movement of soil mass by piping
5. Formation of sink hole due to water in the dispersive soil.

Type of river training works
1. Embankments
2. Guide banks or bund
3. Groynes or spurs
4. Pitching of banks and sub siding
5. Revetment work
6. Pitched islands
7. Cut-offs
8. Closing dykes

Techniques for Bank protection/Stabilization
Two broad ways such as the direct methods of protecting the slope and the indirect way by providing structure that extend into the stream channels and redirect the flow so that hydraulic forces at the channel's boundary are reduced to a non-erosive level. Among the direct method some of are
1. Self-adjusting armour made for stone or other materials.
2. Trench fill revetment/windrow revetment/longitudinal stone toe
3. Slope pitching
4. Lining with cement concrete
5. Spur/stud
6. Riprap
7. Launching apron
8. Flexible mattress etc.

Embankment
Embankment on either approach banks are provided to protect the adjoining area getting submergence.

Guide Banks

The main purpose of these banks is to divert the stream from comparatively larger area to the confined section under the bridge. These bunds are constructed in pairs on either banks and provide a streamline flow at the bridge site. It is made of earth and sometimes inner face is covered with stone or concrete block. The U/s length of bund is in between 1L to 1.1L times the length of the bridge while down stream length is usually kept 0.2 times the length of the bridge.

The radius of U/S side decide depth of scour as well as velocity of flow while D/S side is half of the U/S side. A free board of 1.2 to 1.5 m is provided above the HFL. An apron equal to 1.5 D should be provided at the toe of guide banks.

Pitching of banks and subsiding apron

The banks are very often protected by stone pitching, bushes, wood, plants, concrete blocks or grass. The slope of such pitching depends up on the material used for pitching. Proper care should be taken that toe is properly protected otherwise the pitching would be damaged/destroyed during flood.

The launching or subsiding apron of loose stone is therefore provided at the top of the river bank up to the required length in the river bed. For launching apron, if the average velocity up to 3.5 m/s, stone having weight 40 to 70 kg can be used and if the velocity is more than 3.5 m/s concrete block is useful.

Revetments

Failure of a revetment is often result of inadequate protection against scour at the toe of the revetment. There are various types of material used for revetment such as gabion filled with stones, sand bags, stone riprap, timber piles, bamboo piles, old tires, concrete slabs, concrete blocks and also combination of two or more of these materials.

Pitched islands

Pitched island is artificial island constructed in the river bed when it is required to prevent the flow of river getting confined to one bank only. The stone pitching used to form the island obstructs the flow of water which becomes turbulent. This results in the scouring of the bed. As the bed gets lower, the water from the other bank gets diverted to this bank and the flow along the far bank is reduced. Pitched island is protected by stone pitching.

Cut-offs (to control the meandering of the river)

Sometimes the river develops horse shoe hair pin ben during floods the area between the horse shoe gets submerged and the river starts flooding along the straight line. Due to the reduction in the length of the channels the slope becomes steeper and the portion U/S of the cut off undergoes erosion. As a result of this the D/S gets silted up and disturbance are caused in the river. If, however the straight portion is dug up, the river water will start along this straight portion and curved portion would be get silted up.

The chances of the river changing the courses are practically eliminated.

Closing Dykes

Sometimes the river flows in the main as well as in a subsidiary channel and the river has a tendency to change its course towards the subsidiary channel. This tendency of the river is checked by providing a closing dyke. It may be solid, permeable natural soil like brush wood, branches of trees et

The solid material stops the flow into subsiding channel while permeable materials reduce the velocity of water. As a result of this, the subsidiary channel gets silted up in course of time and the flow of river gets confined to the main channel.

Groynes/Spur/Stud

Groynes deflect or guide flow away from the vulnerable river bank. They can therefore be used both for bank protection and help maintain a navigational channel. It is made of timber, masonry, concrete or earth etc. Based on the orientation, it may be repelling, deflection or attracting spurs. Porcupine (tetrapod) is permeable spur which helps for siltation along the banks and made of bamboo, timber, gabion etc.

Point to be considered for Spur

1. Height of spur must be more or equal to maximum flood level
2. Launching must be provided sufficiently
3. Retard must be permeable.
4. The length of retard line should correspond to the amount of an eroded river bank that, it is to be recovered by deposition.
5. For velocity reduction along an eroding bank, retard should be placed in lines perpendiculars to the bank with line spacing about.

Design Consideration.

Spur length, L: generally, 1/3th of river width but not more than 200m

Spur Spacing: 3 to 4 L or LcotA, A is an angle deviation of spur orientation

Top width 3 to 6 m at formation level
Free board 1 to 1.5m above HFL or 1 in 500 yr return period flood
Side slope 2:1 to 1.5:1
Thickness of pitching for spurs (t) 0.06 $Q^{1/3}$, Q in Cum/sec.

CHAPTER 8 Economics, Finance and Administrations

Highway Economics

"It is not wealth of nation that build roads, but the roads that build the wealth of Nation" …..John Kennedy (US, President)

The Highway or transportation economic is a branch of economic that deals with allocation of resources with in the transport sector for cost effective and efficient mode of transport system and has strong linkage with civil engineering.

Principle of Highway Financing /Guideline of Highway Financing

- Sustainable highway financing should be done through user pay principle.
- Equity, simplicity, public good, value and flexibility are the five users fee principle.
- If one is considered about efficiency and fairness, the user pay principle, charged at levels corresponding to the economic benefits received from public goods, or services and this should be guiding principle in charging for highway user free against economic benefit.
- Highway pricing in theory serves three distinct principles i.e., financial (means to collect funds to pay for provision of highway services), efficiency (to reduce traffic congestion and increase mobility of efficient mode), equity (to discourage over utilization of highway space)
- The basic guideline involved in designing a highway pricing include marginal cost pricing, ability to pay principle, net benefit principle, full pricing.

These guidelines are practice through a variety of pricing methods. The overall objective must be ensuring the use of highway space in an effective, efficient and equitable manner consists with the social economic and environment needs of present and future generation.

Revenue collection and Financing in Highway

Sources of revenue (Beneficiary pay principle shall be adopted)

- User fee: fare, toll, maintenance, parking fee, congestion fee etc.
- Vehicle and fuel tax: registration and renew, fuel tax, special infrastructure development tax like Budhigandaki.
- Driving license and renew
- Property tax
- Development tax
- Value captured

Financing

- Regular government budget from internal revenue
- Internal loan
- Bilateral/multilateral grant.
- Loan from bank and other public fund like Sanchyakosh/Nagarik lagani kosh
- International loan such as ADB/WB/JICA
- Domestic bond
- PPP model etc.

Recommendation/Strategy for financing

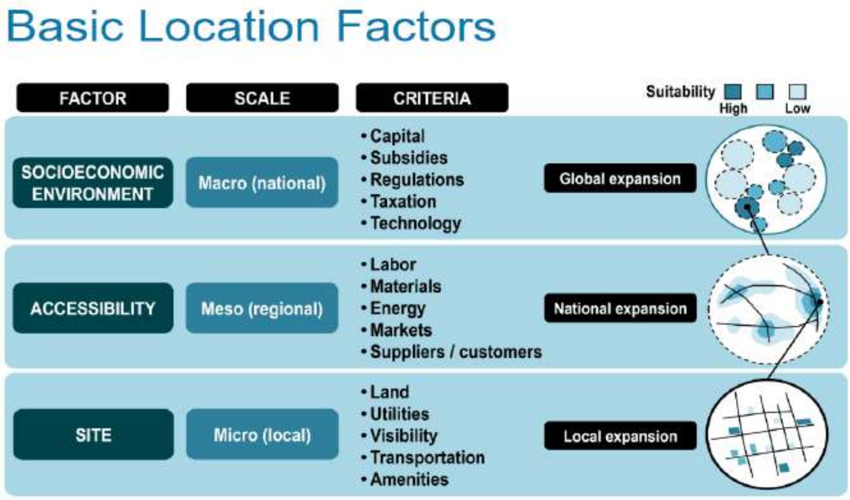
- Recognize transportation as an investment rather than as a cost.
- Think strategically in making transportation investment. All local roads, by pass, freeways, rail roads and ports are not equal investment in some will yield much greater benefit to the economy than investment in others. Example, Core Road Network in Nepal is only near about 25% (3500 KM) of SRN/NH.
- Think beyond jurisdictional boundaries. Freight does not stop at boarders. It does little good for one country to have wonderful transport system, if the nest has bottleneck.
- Think multimodally.
- Make some tough decisions with appropriate data analysis for long term future.

Economic importance of the Transportation

The economic importance of the transportation industry can thus be assessed from a macroeconomic and microeconomic perspective:

- At the **macroeconomic level** (the importance of transportation for a whole economy), transportation and related mobility are linked to a level of output, employment, and income within a national economy. In many developed economies, transportation accounts for between 6% and 12% of the GDP. Further, logistics costs can account for between 6% and 25% of the GDP. The value of all transportation assets, including infrastructures and vehicles, can easily account for half the GDP of an advanced economy.

- At the **microeconomic level** (the importance of transportation for specific parts of the economy), transportation is linked to producer, consumer, and distribution costs. The importance of specific transport activities and infrastructure can thus be assessed for each sector of the economy. Usually, higher income levels are associated with a greater share of transportation in consumption expenses. On average, transportation accounts for between 10% and 15% of household expenditures. In comparison, it accounts for around 4% of the costs of each unit of output in manufacturing, but this figure varies greatly according to sub-sectors.



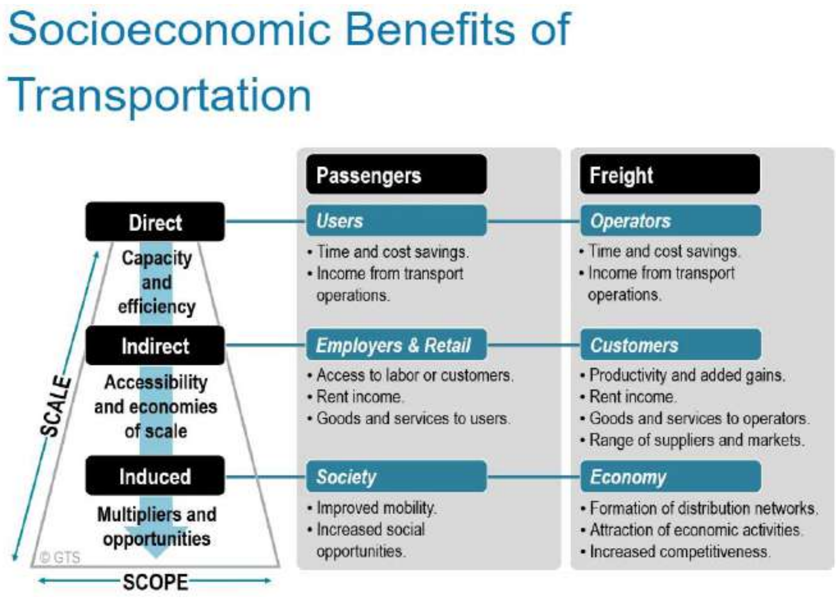
Economic Returns of Transport Investments

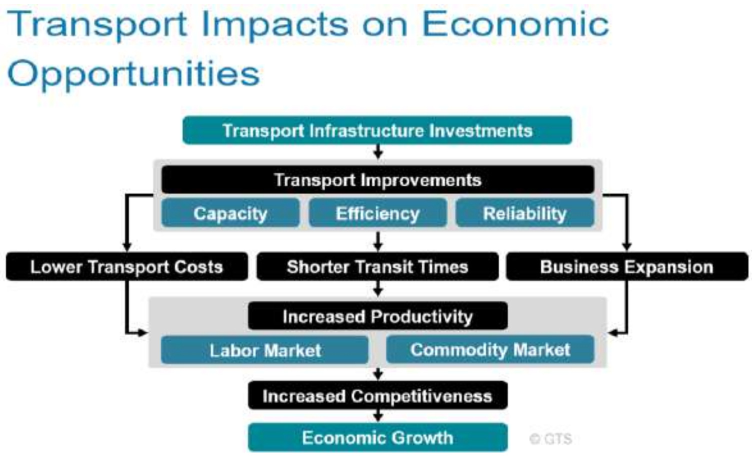
Positive impact

The added value and employment effects of transport services usually extend beyond those generated by that activity; **indirect effects** are salient. For instance, transportation companies purchase a part of their inputs (fuel, supplies, maintenance) from local suppliers. The production of these inputs generates additional value-added and employment in the local economy. In turn, the suppliers purchase goods and services from other local firms. There are further rounds of local re-spending, which generate additional value-added and employment. Similarly, households that receive income from employment in transport activities spend some of their income on local goods and services. These purchases result in additional local jobs and added value. Some of the household income from these additional jobs is spent on local goods and services, thereby creating further jobs and income for local households. As a result of these successive rounds of re-spending in the framework of local purchases, the overall impact on the economy exceeds the initial round of output, income, and employment generated by passenger and freight transport activities. Thus, from a general standpoint, the economic impacts of transportation can be **direct, indirect, and induced**:

- **Direct impacts.** The outcome of improved capacity and efficiency where transport provides employment, added value, larger markets, as well as time and costs improvements. The overall demand of an economy is increasing.
- **Indirect impacts.** The outcome of improved accessibility and economies of scale. Indirect value-added and jobs are the result of local purchases by companies directly dependent upon transport activity. Transport activities are responsible for a wide range of indirect value-added and employment effects, through the linkages of transport with other economic sectors (e.g. office supply firms, equipment and parts suppliers, maintenance and repair services, insurance companies, consulting, and other business services).
- **Induced impacts.** The outcome of the economic multiplier effects where the price of commodities, goods, or services drops and their variety increases. For instance, the steel industry requires the cost-efficient import of iron ore and coal for the blast furnaces and export activities for finished products such as steel booms and coils. Manufacturers, retail outlets, and distribution centers handling imported containerized cargo rely on efficient transport and seaport operations.

Transportation links together the factors of production in a complex web of relationships between producers and consumers. The outcome is commonly a more efficient division of production by the exploitation of comparative geographical advantages, as well as the means to develop economies of scale and scope. The productivity of space, capital, and labor is thus enhanced with the efficiency of distribution and personal mobility. Economic growth is increasingly linked with transport developments, namely infrastructures, but also with managerial expertise, which is crucial for logistics. Thus, although transportation is an infrastructure intensive activity, hard assets must be supported by an array of soft assets, namely labor, management, and information systems. Decisions must be made about how to use and operate transportation systems to optimize benefits and minimize costs and inconvenience.





Negative impact

A common expectation is that transport investments will generate economic returns, which in the long run, should justify the initial capital commitment. Like most infrastructure projects, transportation infrastructure can generate a 5 to 20% annual return on the capital invested, with such figures often used to promote and justify investments. However, transport investments tend to have **declining marginal returns (diminishing returns)**. While initial infrastructure investments tend to have a high return since they provide an entirely new range of mobility options, the more the system is developed, the more likely additional investment would lower returns. At some point, the marginal returns can be close to zero or even negative. A common fallacy assumes that additional transport investments will have a similar multiplying effect than the initial investments had, which can lead to capital misallocation. The most common reasons for the declining marginal returns of transport investments are:

- **High accumulation of existing infrastructure**. Where there is a high level of accessibility and where transportation networks that are already extensive, further investments usually result in marginal improvements. This means that the economic impacts of transport investments tend to be significant when infrastructures were previously lacking and tend to be marginal when an extensive network is already present. Additional investments can thus have a limited impact outside convenience.
- **Economic changes**. As economies develop, their function tends to shift from the primary (resource extraction) and secondary (manufacturing) sectors towards advanced manufacturing, distribution, and services. These sectors rely on different transport systems and capabilities. While an economy depending on manufacturing

will rely on road, rail, and port infrastructures, a service economy is more oriented towards the efficiency of logistics and urban transportation. In all cases, transport infrastructure is important, but their relative importance in supporting the economy may shift.

- **Clustering**. Due to clustering and agglomeration, several locations develop advantages that cannot be readily reversed through improvements in accessibility. Transportation can be a factor of concentration and dispersion depending on the context and the level of development. Less accessible regions thus do not necessarily benefit from transport investments if they are embedded in a system of unequal relations.

Therefore, each transport development project must be considered independently and contextually. Since transport infrastructures are capital intensive fixed assets, they are particularly vulnerable to **misallocations and malinvestments**. The standard assumption is that transportation investments tend to be more **wealth-producing** as opposed to **wealth consuming** investments such as services. Still, several transportation investments can be wealth consuming if they merely provide conveniences, such as parking and sidewalks, or service a market size well below any possible economic return, with, for instance, projects labeled "bridges to nowhere". In such a context, transport investment projects can be **counterproductive** by draining the resources of an economy instead of creating wealth and additional opportunities.

Since many transport infrastructures are provided through public funds, they can be subject to pressure by special interest groups, which can result in poor economic returns, even if those projects are often sold to the public as strong catalysts for growth. Further, large transportation projects, such as public transit, can have inadequate cost control mechanisms, implying systematic budget overruns. Infrastructure projects in the United States are particularly prone to these engineered fallacies. Efficient and sustainable transport markets and systems play a key role in regional development, although the causality between transport and wealth generation is not always clear. To better document and monitor the economic returns of transport investments, a series of indicators can be used, such as transportation prices and productivity. Investment in transport infrastructures is thus seen as a tool of regional development, particularly in developing countries.

5. Mobility in Lifestyle: If different regions of the country are well connected with suitable transportation facility, then people from one part of the country can go to other parts of the country quite easily and effectively. It will transfer mobility in the lifestyle of common people.
6. Agricultural and Industrial Development: Through transportation facility different agricultural and industrial inputs can be carried up to agricultural and industrial estates for production. Such a situation helps to promote agricultural and industrial development.
7. Sustainable Economic Development: Appropriate transportation facility helps to create an equitable distribution of national output, promotes tourism, agricultural and industrial development. All these components through transportation facilities help to create and maintain sustainable economic development

Role or Importance of transportation in the economic development of Nepal

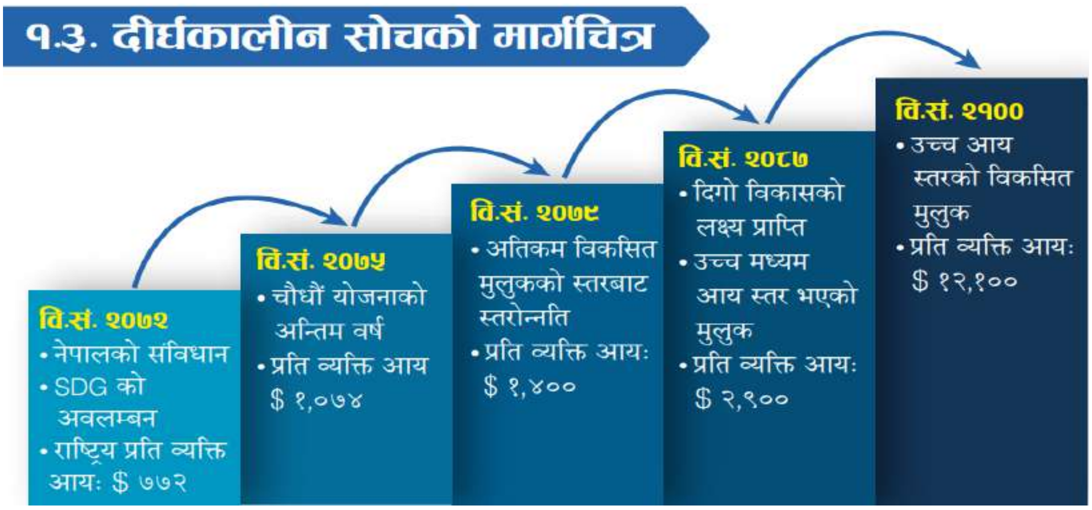
Transportation is the process of carrying people and goods from a place to another. Transportation is one of the major prerequisites of economic development. Several goods need to be transferred from a place to another for the fulfillment of daily needs or industrial needs. Similarly, import and export of commodities, capital, and manpower are possible only due to transportation facilities.

For the transfer of factors of production from a place to another, there is the need for transportation. Furthermore, the finished goods need to be transferred to the market (local, national and international) for their sale/ trade which is possible due to transportation. Thus, transportation is the infrastructure of development that promotes efficient mobility of the factors and output.
1. Equitable Distribution of National Output: Nepal is a mountainous country and due to its geographical disadvantage, the production of one region is not properly distributed to other parts of the country. However, a suitable transport facility helps to distribute National Product in the best possible manner.
2. Market Expansion: The domestic market in the Nepalese economy is confined to some limited places due to the lack of appropriate transportation facilities. However, if different potential places of Nepal are properly connected then the product of one region can easily be sold in other regions. It helps to promote market expansion.
3. Tourism Development: Nepal is known for its natural beauty all over the world. If all the tourist places are linked with transportation facility, then tourism development will be promoted in Nepal.
4. Increase in Domestic and Foreign Trade: The commercial product from one part of the country can easily be exported to various domestic markets as well as foreign markets through the availability of a dependable transportation facility

१५ औ आवधिक योजना, राष्ट्रिय योजना आयोग आदि सम्बन्धि बिषयबस्तु

दीर्घकालीन सोंच २१००

सम्बृद्ध नेपाल सुखी नेपाली : समुन्नत, स्वाधीन र समाजबाद उन्मुख अर्थतन्त्र सहितको समान अवसर प्राप्त, स्वास्थ्य, शिक्षित, मर्यादित, उच्च जीवनस्तर भएका सुखी नागरिक बसोबास गर्ने मुलक



१.४. दीर्घकालीन राष्ट्रिय रणनीति

१) तीव्र, दिगो र रोजगारमूलक आर्थिक वृद्धि

२) सुलभ तथा गुणस्तरीय स्वास्थ्य सेवा र शिक्षाको सुनिश्चितता

३) आन्तरिक तथा अन्तरदेशीय अन्तरआबद्धता एवम् दिगो शहर/बस्ती विकास

४) उत्पादन र उत्पादकत्व अभिवृद्धि

५) पूर्ण, दिगो र उत्पादनशील सामाजिक सुरक्षा तथा संरक्षण

६) गरिबी निवारण र आर्थिक सामाजिक समानता सहितको न्यायपूर्ण समाज निर्माण

७) प्राकृतिक स्रोतको संरक्षण र परिचालन तथा उत्थानशीलता विकास

८) सार्वजनिक सेवाको सुदृढीकरण, प्रादेशिक सन्तुलन र राष्ट्रिय एकता सम्बर्द्धन

१.५. रुपान्तरणका प्रमुख सम्वाहक

१. गुणस्तरीय एकीकृत यातायात प्रणाली, सूचना प्रविधि तथा सञ्चार पूर्वाधार र बृहत् सञ्जालीकरण

२. गुणस्तीय मानवपुँजी निर्माण, उद्यमशील कार्य संस्कृति विकास र सम्भावनाको पूर्ण उपयोग

३. जल विद्युत उत्पादन वृद्धि र हरित अर्थतन्त्र प्रवर्द्धन

४. उत्पादन, उत्पादकत्व र प्रतिस्पर्धात्मक क्षमता अभिवृद्धि

५. गुणस्तरीय पर्यटन सेवाको विकास र विस्तार

६. आधुनिक, दिगो र व्यवस्थित शहरीकरण, आवास र बस्ती विकास

७. प्रादेशिक र स्थानीय अर्थतन्त्रको विकास र सुदृढीकरण तथा औपचारिक क्षेत्रको विस्तार

८. सामाजिक संरक्षण र सुरक्षाको प्रत्याभूति

९. शासकीय सुधार र सुशासन अभिवृद्धि

दीर्घकालीन लक्ष्य हासिल गर्ने प्रमुख आधारहरू

१. राज्यका नीति र मौलिक हक प्राप्त गर्न उच्च र दिगो आर्थिक वृद्धिको आवश्यकता ।

२. राजनीतिक तथा नीतिगत स्थिरता कायम भई आर्थिक समृद्धि उन्मुख अवस्था ।

३. समष्टिगत आर्थिक स्थायित्व कायम गरी सार्वजनिक, निजी, सहकारी र सामुदायिक क्षेत्रको लगानी वृद्धि गर्ने उपयुक्त वातावरण ।

४. जनसाङ्ख्यिक लाभ र प्राकृतिक स्रोत-साधनको महत्तम उपयोग ।

५. ज्ञान, सीप, पुँजी तथा प्रविधि, पूर्वाधार र उर्जा विकास गरी उत्पादन र उत्पादकत्वमा वृद्धि ।

६. वि.सं. २०८७ सम्म दिगो विकास लक्ष्य हासिल गर्ने राष्ट्रिय प्रतिबद्धता ।

७. विकास कार्यक्रमको कार्यान्वयनमा तीव्रता प्रदान गर्न आयोजना बैंक, आयोजना पूर्व तयारी र अनुगमन तथा मूल्याङ्कन कार्यको सुदृढीकरण ।

८. अनौपचारिक अर्थतन्त्रलाई क्रमशः औपचारिक अर्थतन्त्रमा रुपान्तरण ।

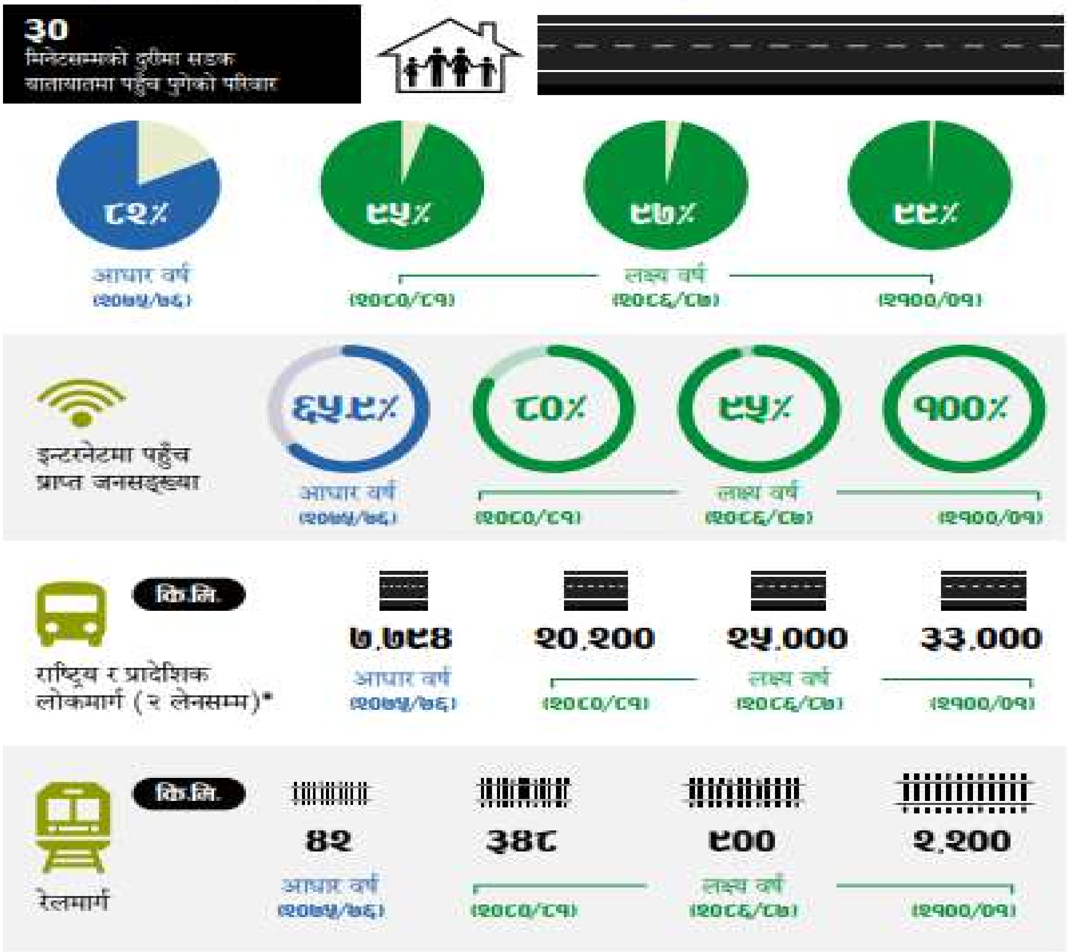
९. राष्ट्रिय प्राथमिकता प्राप्त क्षेत्रमा विदेशी लगानी आकर्षित गर्न आवश्यक सुधार र एकद्धार प्रणाली अवलम्बन ।

१०. ज्ञानमा आधारित अर्थतन्त्रको विकास र समृद्धि ।

घ. पूर्वाधार क्षेत्र

- ३५ हजार मेगावाट जलविद्युत र ५ हजार मेगावाट वैकल्पिक उर्जा उत्पादन
- प्रतिव्यक्ति उर्जा खपत ३,५०० किलोवाट घण्टा
- राष्ट्रिय रणनीतिक महत्वका सडकलाई एसियाली हाइवे मापदण्ड अनुरुप चारदेखि आठ लेनसम्म निर्माण र विस्तार
- रेल, जल, हवाई, केबलकार र रोपवे लगायतका यातायात पूर्वाधारलाई एकीकृत यातायात प्रणालीमा आबद्धता
- केन्द्र र प्रदेश तथा प्रदेश राजधानीहरुबीच द्रूत यातायात सेवा विस्तार

३. सर्वसुलभ आधुनिक पूर्वाधार एवम् सघन अन्तरआबद्धता



नतिजा सूचक	एकाइ	आधार वर्ष (२०७५/७६)	लक्ष्य		
			२०८०/८१	२०८६/८७	२१००/०१
सडक घनत्व	कि.मि. प्रति वर्ग कि.मि	०.५५	०.७४	०.८५	?
राष्ट्रिय लोकमार्ग (२ लेनमाथि, द्रुतमार्ग समेत)	कि.मि.	९६	१,१७४	१,६००	३,०००
विद्युतमा पहुँच पुगेको जनसङ्ख्या	प्रतिशत	८८	१००	१००	१००

नोट : *कालोपत्रे सडक।

२.३ चुनौती तथा अवसर

चुनौती

- समन्यायिक आर्थिक वृद्धि र नागरिकको जीवनमा गुणात्मक सुधार गर्नु
- गुणस्तरीय भौतिक पूर्वाधारको विकास र उपभोगमा वृद्धि गर्नु
- दक्ष मानव संसाधनको विकासद्वारा उत्पादनशील रोजगारीको अवसर वृद्धि गरी जनसाङ्खिक लाभको उपयोग गर्नु
- वित्तीय संघीयताको कुशल कार्यान्वयन गरी समष्टिगत आर्थिक स्थायित्व कायम गर्नु
- संघ, प्रदेश र स्थानीय तहको कार्य जिम्मेवारी पुरा गर्न साधन-स्रोतको लागत अनुमान, वितरण र जनशक्ति एवम् संस्थागत प्रबन्ध गर्नु

अवसर

- संघ, प्रदेश र स्थानीय तहमा क्रियाशील सरकार र संस्थागत स्थायित्व
- तहगत सरकारका बीचमा दिगो विकास, समृद्धि र सुशासनका क्षेत्रमा प्रतिस्पर्धी भावना
- उपलब्ध जनसाङ्ख्यिक लाभलाई मुलुकको विकासमा उपयोगको उच्च सम्भावना
- लगानी केन्द्रित गर्न सहज वातावरण निर्माण
- प्राकृतिक, भौगोलिक, जैविक, पर्यावरणीय तथा सामाजिक साँस्कृतिक विविधताको बहुआयामिक उपयोग
- निजी क्षेत्रको लगानी, व्यावसायिकता र प्रतिस्पर्धात्मक क्षमता अभिवृद्धि र सामुदायिक क्षेत्रको उत्पादनशील क्षेत्रमा परिचालनद्वारा राष्ट्रिय पुँजी निर्माण

२.८ दिगो विकास लक्ष्यको आन्तरिकीकरण

- दिगो विकास लक्ष्यको आन्तरिकीकरण तथा स्थानीयकरणमा विशेष जोड (दिगो विकास)
- आर्थिक वृद्धि, रोजगारी, उत्पादन तथा उपभोग, औद्योगीकरण र शहरीकरणसँग सम्बन्धित योजनाका लक्ष्य र रणनीतिहरू
- लैंगिक समानता, समावेशीकरण, सुशासन तथा सामाजिक सुरक्षासँग सम्बन्धित लक्ष्य तथा रणनीतिहरू
- गरिबी, भोकमरी, खानेपानी र ऊर्जा जस्ता मानव सभ्यताका आधारभूत पक्षसँग सम्बन्धित लक्ष्य तथा रणनीतिहरू
- स्वास्थ्य तथा शिक्षा क्षेत्रसँग सम्बन्धित लक्ष्य तथा रणनीतिहरू
- प्राकृतिक स्रोत व्यवास्थापन तथा उत्थानशीलतासँग सम्बन्धित लक्ष्य तथा रणनीतिहरू
- सार्वजनिक, निजी, सहकारी, सामुदायिक क्षेत्र लगायतका आन्तरिक र बाह्य सरोकारवालासँग समन्वय र साझेदारीसँग सम्बन्धित लक्ष्य तथा रणनीतिहरू

४.४ वैदेशिक लगानी

सोच

वैदेशिक लगानी परिचालन मार्फत् प्रतिस्पर्धी एवम् गतिशील राष्ट्रिय अर्थतन्त्र निर्माण ।

लक्ष्य

वैदेशिक लगानी आकर्षण र अभिवृद्धि गरी उत्पादन, उत्पादकत्व र प्रतिस्पर्धात्मक क्षमता विकास गर्ने ।

उद्देश्य

१) नेपालमा भित्रिने प्रत्यक्ष वैदेशिक लगानीलाई उच्च र दिगो बनाउनु ।
२) वैदेशिक लगानीको माध्यमबाट पुँजी, प्रविधि, प्राविधिक सीप तथा व्यवस्थापकीय कौशल भित्र्याउनु ।
३) उपयोगमा नआएका प्राकृतिक स्रोतको उपयोग र पूर्वाधार विकास गर्नु ।

रणनीति

१) कानूनी, संरचनागत तथा प्रक्रियागत सुधार र सरलीकरण गरी लगानीमैत्री वातावरण सिर्जना गर्ने ।
२) तुलनात्मक लाभ, उत्पादनमूलक तथा रोजगारमूलक क्षेत्रमा लगानी आकर्षित गर्ने ।
३) स्थानीय स्रोत-साधन र सीपको उपयोग तथा प्रादेशिक सन्तुलन कायम हुने गरी लगानी परिचालन गर्ने ।
४) वैदेशिक लगानी परिचालनको लागि आर्थिक कूटनीति उपयोग गर्ने ।
५) लगानीको प्रवेश, अनुमति, सञ्चालन, बहिर्गमन सम्मका सेवा र सुविधा एकै स्थानबाट उपलब्ध गराउने ।

अपेक्षित उपलब्धि

७.२ यातायात पूर्वाधार

७.२.१ सडक

सोच

सघन, सन्तुलित, सुलभ, सुरक्षित, गुणस्तरीय एवम् दिगो सडक पूर्वाधारको विकास ।

लक्ष्य

राष्ट्रिय सडक सञ्जालको विस्तार गरी आर्थिक-सामाजिक विकास, व्यापार सहजीकरण मार्फत आर्थिक समृद्धि हासिल गर्ने ।

उद्देश्य

१) कुल यातायात खर्च न्यूनतम हुने गरी सडक सञ्जालको सन्तुलित विकास तथा विस्तार गर्नु ।
२. सडक पूर्वाधारको संरक्षण, मर्मत-सम्भार र सडक सुरक्षा गरी सहज सवारी आवागमन सुनिश्चित गर्नु ।

रणनीति

१) प्रादेशिक सन्तुलन कायम हुने गरी उच्च क्षमताका द्रुतमार्ग, भूमिग मार्ग, भाया-डक्ट लगायतका आधुनिक संरचना सहित सडक सञ्जाल विकास गर्ने ।
२) संस्थागत क्षमता विकासलाई प्राथमिकता दिई आधुनिक प्रविधिव अधिकतम उपयोग गर्ने ।
३) सरकारी स्रोतमाथिको निर्भरता घटाई लगानीका वैकल्पिक स्रोत जुटाउने ।
४) सडकको डिजाइन, निर्माण, मर्मत-सम्भार तथा सडक सुरक्षाका लागि आधुनिक प्रविधिको उपयोग तथा यान्त्रीकरणमा जोड दिने
५) प्राकृतिक प्रकोप तथा जलवायु प्रतिकूलताका सम्भाव्य असर वा हानी नोक्सानी न्यूनीकरण गर्ने ।

अपेक्षित उपलब्धि

	आधार वर्ष २०७५/७६	लक्ष्य २०८०/८१
कुल गार्हस्थ्य उत्पादनमा यातायात क्षेत्रको योगदान (प्रतिशत)	५.१	४.९
सडक घनत्व (कि.मि. प्रति वर्ग कि.मि)	०.५५	०.७४
राष्ट्रिय राजमार्ग (दुई लेनसम्म, कालोपत्रे) (कि.मि.)	५,५९४	१२,३००
राष्ट्रिय राजमार्ग (दुई लेनमाथि, द्रुतमार्ग समेत) (कि.मि.)	९६	१,१७४
प्रादेशिक राजमार्ग (कालोपत्रे) (कि.मि.)	१,८००	७,९००

७.२.३ रेल यातायात

सोच

भरपर्दो, सुरक्षित, पहुँचयोग्य, वातावरणमैत्री रेल यातायात प्रणालीको विकास ।

लक्ष्य

सुरक्षित, भरपर्दो र पर्यावरणमैत्री राष्ट्रिय रेल सञ्जाल निर्माण गरी सामाजिक, आर्थिक र भौगोलिक विकासमा सन्तुलन कायम गर्ने ।

उद्देश्य

) रेल यातायात विस्तार गरी अन्तरदेशीय व्यापार पहुँच विस्तार बढाउँदै आर्थिक सामाजिक एकीकरणमा योगदान गर्नु ।
) भौगोलिक सन्तुलन र विकासमा योगदान पुग्ने गरी भरपर्दो र सुरक्षित रेलसेवा सञ्चालन गर्नु ।

रणनीति

१) रेलमार्गको सम्भाव्यता अध्ययन गरी राष्ट्रिय आवश्यकता पहिचान, विकास र विस्तार गर्ने ।
२) रेल विभागको संस्थागत क्षमता अभिवृद्धि गर्ने । रेल यातायातको पूर्वाधार विकास तथा सञ्चालनमा वैकल्पिक स्रोत प्रवर्द्धन गर्ने ।

अपेक्षित उपलब्धि

रेलमार्ग (कि.मि.)

४२	३४८
२०७५/७६ आधार वर्ष	२०८०/८१ लक्ष्य

७.२.४ जल यातायात

सोच

सुलभ र किफायती यातायातको भरपर्दो विकल्पको रूपमा जल यातायातको विकास ।

लक्ष्य

आन्तरिक र समुद्रसम्म जल यातायातको विकास मार्फत पर्यटन प्रवर्द्धन एवम् व्यापार सहजीकरण गर्ने ।

उद्देश्य

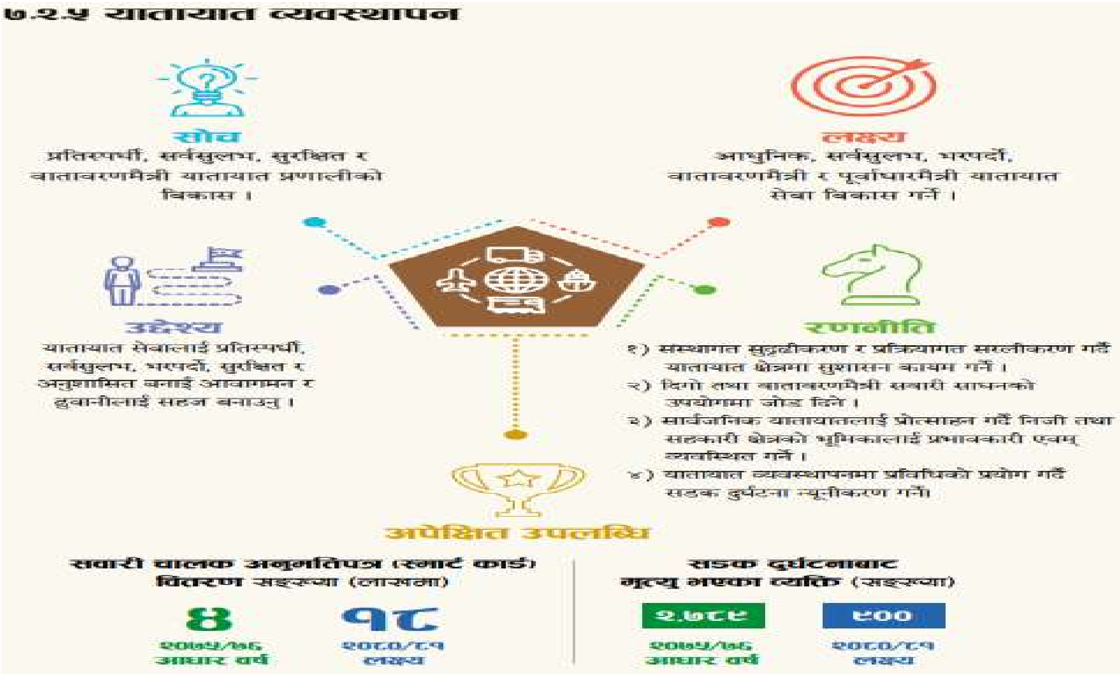
आन्तरिक, क्षेत्रीय र अन्तर्राष्ट्रिय जलमार्गको प्रयोग गरी राष्ट्रिय अर्थतन्त्रमा योगदान पुऱ्याउनु ।

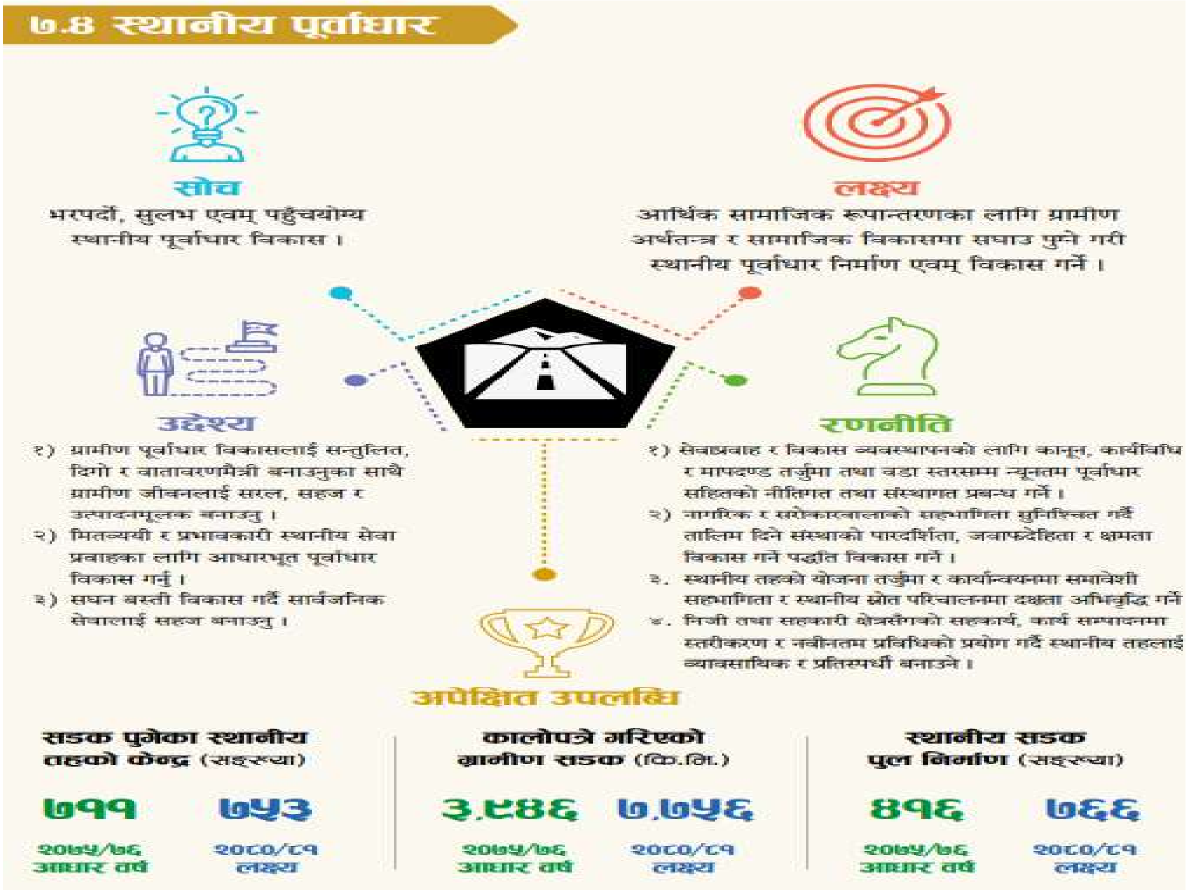
रणनीति

१) आन्तरिक तथा समुन्द्रसम्म पहुँचका लागि जल यातायातको विकास र विस्तार गर्ने ।
२) जल यातायात विकासको लागि निजी एवम् अन्य क्षेत्रको लगानी आकर्षित गर्ने ।
३) संस्थागत, व्यवस्थापकीय र प्राविधिक क्षमता विकास तथा अभिवृद्धि गर्ने ।

अपेक्षित उपलब्धि

कोशी, कालीगण्डकी, नारायणी र कर्णाली नदीहरुमा जल यातायात संचालन भएको हुनेछ ।





राष्ट्रिय गौरव र रुपान्तरणकारी आयोजनाहरु भन्नाले कस्तो आयोजनालाई बुझिन्छ ? यिनीहरुको सफल कार्यान्वयन किन हुन् नसकेको हो ? व्यावहारिक उतर दिनुहोस |

१५ औ आवधिक योजनाले सम्बन्धित मन्त्रालयको सिफारिस, स्रोत लगानीको सुनिश्चितता भएको, वातावरणीय अध्ययन भएको, विस्तृत आयोजना प्रतिवेदन तयार भएको आयोजना मध्ये क्षेत्रगत, रणनीतिक, दिगो बिकासका लक्ष्य, लैंगिक समानता आदिमा गर्ने योगदानको आधारमा राष्ट्रिय योजना आयोगले राष्ट्रिय प्राथमिकता आयोजनाको रुपमा बर्गीकरण गर्न सक्ने व्यवस्था रहेको छ |

नेपाल सरकारले पहिलोपल्ट आ.व. २०६८/०६९ देखि विभिन्न दृष्टिकोणले महत्वपूर्ण देखिएका १७ वटा आयोजनाहरुलाई राष्ट्रिय गौरवका आयोजनाका रुपमा बर्गीकरण गरेको विभिन्न समयमा थप सहित हाल सम्म २४ वटा राष्ट्रिय गौरवका आयोजनाहरु रहेकामा १८ वटा मात्र संचालनमा छन् | १५ औ आवधिक योजनाले राष्ट्रिय गौरवका आयोजना हुनलाई आर्थिक सामाजिक बिकासमा योगदान, बृहत पूर्वाधार निर्माण, सांस्कृतिक तथा वातावरण संरक्षण सम्बन्धि रणनीतिक महत्वलाई आधार मान्ने गरेको छ |

त्यसैगरी १५ औ आवधिक योजनाले लिएका राष्ट्रिय लक्ष्य हासिल गर्न, बृहत प्रभाव पार्ने, सवल अर्थतन्त्र, प्रादेशिक सन्तुलन र दोहोरो अंकको आर्थिक वृद्धिमा योगदान गर्ने र विशिष्ट प्रकृतिका आयोजनालाई रुपान्तरणकारी आयोजनाको रुपमा राखेको छ | रुपान्तरणकारी आयोजनाका लागि आवश्यक शर्तहरु निम्नानुसार छन् |

१. GDP मा ०.५ % प्रतिवर्ष योगदान दिने
२. २० हजार कार्यान्वयनको चरणमा र ४० हजार निर्माण सम्पन्न पश्चात रोजगारी सिर्जना गर्ने
३. बिषयगत/क्षेत्रगत उपलब्धिमा २०% योगदान दिने
४. १० लाख जनसंख्या कार्यान्वयनको चरणमा र २० लाख जनसंख्या निर्माण सम्पन्न पश्चात लाभान्दित गर्ने
५. प्रादेशिक सन्तुलन कायममा योगदान गर्ने

यी माथिका शर्त र आधारलाई आत्मसाथ गरेको हुनुपर्ने आयोजनाहरुको प्रगतिको दयनीय रहेको र केही आयोजनाहरु (जस्तै बुढी गण्डकी) दलीय चक्रव्यूहमा फसेका छन् | लुम्बिनी विमानस्थल, भेरी बबई डाइभर्सन बाहेक अन्य आयोजनाहरु समयमै नसकिने, लागत भन्दा बढी खर्च हुने र अन्तमा असफल हुने निश्चित छ | यसका पछाडी परियोजना व्यवस्थापन दक्षता र नैतिकताको अभाव सहित निम्न कारणहरु रहेका छन् |

१. आयोजनाको पहिचान र छनौटमा समस्या : आयोजनाहरुको मापदण्ड, आर्थिक, सामाजिक, रणनैतिक लगायतका लाभ विश्लेषण नगरी Quick planning and budgeting गर्ने प्रवृति सहित राजनीतिक तथा दलीय आधारमा खल्तीबाट Black Box model अनुरुप आयोजनाहरु छनौट गर्नु |
२. आयोजनाको पूर्वतयारीमा समस्या : जग्गा प्राप्ति, साइट क्लियर नगरी, वातावरणीय अध्ययन प्रतिवेदन स्वीकार नहुदै, लगानीको मोडालिटी तयार नहुदै, निर्माण सामग्रीको उपलब्धता बारे यकिन नगरी कार्यान्वयनमा हतारिनु |

३. परियोजना व्यवस्थापनमा समस्या : दक्ष र नैतिकतायुक्त, नेतृत्वलिने परियोजना व्यवस्थापक नियुक्त नहुनु, कागजी बजेट सुनिश्चितताको आधारमा, बैदेशिक स्रोतहरु यकिन नगरी वा नेपाल सरकारले गर्नुपर्ने शर्त पुरा नहुदै, पुर्व तयारी नहुदै स्वार्थअनुकूल Specification, योग्यता निर्धारणका शर्त, हचुवाको भरमा ठेक्काको म्याद निर्धारण, विश्लेषण बिना प्याकेज र स्लाइस आदि गरी ठेक्का लगाउने प्रवृति, QAP बारे अस्पष्ट हुनु, प्रयोगशालाको व्यवस्था नहुनु, समयमा भुक्तानी, सुपरभिजन,रेकर्ड,प्रतिउतर वा निर्णय आदि नगर्नु ।

४. निर्माण सामग्रीको उपलब्धता : निर्माणजन्य उधोगको अभावले नदिजन्य निर्माण सामग्री र गुणस्तरीय निर्माण सामग्रीको समयमा प्राप्त हुन् नसक्नु ।

५. निर्माण व्यवसायीको क्षमता र आधुनिक प्रविधियुक्त निर्माण उपकरणको समस्या : न्यून निर्माण क्षमता, धैरै ठेक्का अगोटने प्रवृति, निर्माण क्षेत्रलाई उधोगको रुपमा विकास नगरी पारिवारिक व्यवसायको रुपमा विकास गर्ने प्रवृति रहनु, प्राविधिक जनशक्तिको कमि, कठिन काममा भारतीय कामदारमा भर पर्नु, नयाँ र आधुनिक निर्माण उपकरण जस्तै ट्रेन्च कटर, Pile Boring Machine, अस्टरबर्ग सेल, precast technology, Concrete Paver, infra-doctor आदि प्रयोगमा नल्याउनु, ठुला नि.व्य.हरुले ठेक्का आफू लिने तर पेटी वा सब contractorलाई बिचमै बेच्ने प्रवृति आदि ।

६. परियोजनालाई स्रोत दुरुपयोगको माध्यम मान्नु : परियोजनालाई राजनीतिक, प्रशासन, निजि क्षेत्र सबै बाट आर्थिक लाभ लिने स्रोत का रुपमा दुरुपयोग गर्नु जस्तै चमेलिया, मेलम्ची का गाडीहरु मन्त्री र उच्च सरकारी पदाधिकारीले प्रयोग गर्नु ।

७. निकायगत समन्वयको समस्या र असहयोग : सार्वजनिक खरिद कार्यालयले समय सापेक्ष खरिद सम्बन्धि, खरिद विधि सम्बन्धि कागजात, मापदण्ड, प्राबिधिक निर्देशिका तयार नगर्नु, अनुगमनको नाममा नियामक निकायहरुले खरिदकै चरणमा, निर्माणकै चरणमा महिनौ सम्म निर्णय नदिने प्रवृति, समयमा बजेट फुकुवा, निकासा, सोघभर्ना नदिने वा आर्थिक बर्षको अन्तमा बजेट दिने, रुख कटानको वा राष्ट्रिय बन प्रयोगको स्वीकृतीमा बर्षौ लाग्ने प्रवृति, खरिद प्रशासनमा अदालतको प्रवेश तथा मध्यस्तताको निर्णयमा सबै तहको अदालत जाने प्रवृति र समयमा निर्णय नहुने समस्या ।

८. नीति नियम, प्राविधिक समस्या र प्रक्रियागत समस्या: डिजाइन तथा पूर्वानुमान गरिएको भन्दा फरक अवस्था कार्यस्थलमा देखिनु, कार्यान्वयन चरणमा नयाँ थप क्रियाकलाप वा डिजाइन परिवर्तन हुनु, कार्यस्थलमा उत्तम प्राविधिक समाधान भन्दा राजनीतिक परिवेश हावी भइ प्रियताको मार्गमा राजनीतिक नेतृत्व उभिनु, लागत अनुमान, डिजाइन सदर, म्याद थप. भेरियेशन स्वीकृत गर्ने प्रक्रिया र निर्णय गर्ने अधिकार माथिल्लो निकायमा केन्द्रीकरण हुनु, बाह्य स्रोतमा निर्माण हुने परियोजनामा ऋण सम्झौताका शर्तका कारण संलग्न अन्तराष्ट्रिय नि.व्य. हरुलाई कारवाही गर्ने प्रक्रिया झन्झटिलो हुनु, निर्माण खरिदसंग सम्बन्धित व्यवस्थाहरु ऐन, नियमावलीको असल मनसाय सहित राखेका प्रावधानहरु हचुवाको भरमा छिटो छिटो परिवर्तन वा संसोधन हुनु, नुन देखि सुन सम्म, सियो देखि बोइंग सम्मको खरिद प्रक्रिया एकै किसिमको

हुनु, राष्ट्रिय गौरव र रुपान्तरणकारी भनिएका आयोजनाहरुले कुनै बिशेष सहुलियत प्राप्त नगर्नु |

९. सामाजिक मूल्य, मान्यता र संस्कृतिजन्य समस्या: परियोजनामा नागरिक सहभागिता न्यून हुनु वा नहुनु, पुर्वाधारहरु सामाजिक मूल्य मान्यता स्वीकार गर्ने बिषयबस्तुहरु सम्बोधन नहुदा जनताले बिश्वास र अपनत्व ग्रहण नगर्नु, विविध किसिमका चाडबाडका लागि बिदा र कार्यस्थलमा छुट्टी गर्ने परम्परा कायम रहनु |

१०. भौगोलिक, भौगर्भिक र जलबायु परिवर्तन सहितको मौसमी समस्या :हिमाली पहाडी, भिरालो सतहमा काम गर्दा ढिलो हुने, मौसमी समस्याका कारण निर्माण सामग्रीको उपलब्धता, दुवानी र काम गर्ने समय कम पाउनु, जलबायु परिवर्तनका कारण काम गर्ने सिजनमा समेत अतिबृष्टि, अनावृष्टि हुनु आदि |

११. अनुगमन, मूल्यांकन र पृष्ठपोषण तथा दिगोपना सम्बन्धि समस्या : परियोजना आफैको र नियामक निकाय समेतको अनुगमन र मूल्यांकन कर्मकाण्डी र देखावटी, औपचारिकता र तिर्थाटनमा सिमित, नाम मात्रको कार्य सम्पादन सम्झौता, अनुगमन र मूल्यांकनबाट दण्ड र पुरस्कार सहित व्यवस्था लागू नहुनु, भविष्यमा हुने उस्तै गल्ती गरिरहनु, निर्माण तथा मर्मतका असल अभ्यासहरुको निरन्तरता नदिनु आदि

१२. परियोजनामा संलग्न कर्मचारीको व्यावसायिकता, पेशागत आंचारसहिता, नैतिकता, सदचारिता र निष्ठाको अभावले गैरनैतिक स्वार्थ तथा आर्थिक अपचलनमा केन्द्रित रहनु, आफ्नो जिम्मेवारी र उतरदायित्वबाट पन्छिने समस्या आदि |

१३. प्राकृतिक बिपत तथा Force majeure जस्तै भुकम्प, नाकाबन्दी, Covid, ठुलो पहिरो, लागायतका मानवीय क्षमता भन्दा बाहिरका समस्याहरु |

पन्ध्रौ आवधिक योजनाको लक्ष्य र प्रगति

१५ औ आवधिक योजनाले सम्बन्धित मन्त्रालयको सिफारिस, स्रोत लगानीको सुनिश्चितता भएको, वातावरणीय अध्ययन भएको, विस्तृत आयोजना प्रतिवेदन तयार भएको आयोजना मध्ये क्षेत्रगत, रणनीतिक, दिगो बिकासका लक्ष्य, लैंगिक समानता आदिमा गर्ने योगदानको आधारमा राष्ट्रिय योजना आयोगले राष्ट्रिय प्राथमिकता आयोजनाको रुपमा बर्गीकरण गर्न सक्ने व्यवस्था रहेको छ |

नेपाल सरकारले पहिलोपल्ट आ.व. २०६८/०६९ देखि विभिन्न दृष्टिकोणले महत्वपूर्ण देखिएका १७ वटा आयोजनाहरुलाई राष्ट्रिय गौरवका आयोजनाका रुपमा बर्गीकरण गरेको विभिन्न समयमा थप सहित हाल सम्म २४ वटा राष्ट्रिय गौरवका आयोजनाहरु रहेकामा १८ वटा मात्र संचालनमा छन् | १५ औ आवधिक योजनाले राष्ट्रिय गौरवका आयोजना हुनलाई आर्थिक सामाजिक बिकासमा योगदान, बृहत पूर्वाधार निर्माण,

सांस्कृतिक तथा वातावरण संरक्षण सम्बन्धि रणनीतिक महत्वलाई आधार मान्ने गरेको छ | त्यसैगरी १५ औ आवधिक योजनाले लिएका राष्ट्रिय लक्ष्य हासिल गर्न, बृहत प्रभाव पार्ने, सवल अर्थतन्त्र, प्रादेशिक

१५ औ योजनाको नतिजा सूचकको चालु आ.व. चौथो त्रैमासिकसम्मको प्रगति स्थिति-सडक विभाग

क्र.सं.	नतिजा सूचक	एकाइ	आधार वर्ष (२०७५/७६)	२०७७/७८		२०७८/७९		जिम्मेवार निकाय
				लक्ष्य	प्रगति	लक्ष्य	प्रगति	
१	राष्ट्रिय राजमार्ग (दुई लेनसम्म कालोपत्रे)	कि.मी.	५९९४	८४९४	६८४७	९७९४	७२३७	भौ.पू.त.या./स.वि.
२	राष्ट्रिय राजमार्ग (दुई लेनमाथी द्रुतमार्ग समेत)	कि.मी.	९६	२२५	१९२	३४५	२०४	भौ.पू.त.या./स.वि.
३	राष्ट्रिय राजमार्ग (नयाँ ट्र्याक निर्माण, वार्षिक)	कि.मी.	२६०	३५०	९२	४००	१४५	भौ.पू.त.या./स.वि.
४	राष्ट्रिय राजमार्ग पुनर्स्थापना तथा पुनर्निर्माण (वार्षिक)	कि.मी.	१८२	२२५	४७४	२२५	१५५	भौ.पू.त.या./स.वि.
५	राष्ट्रिय राजमार्ग आवधिक मर्मत सम्भार (वार्षिक)	कि.मी.	३२०	७२९	४२४	७५०	२५०	भौ.पू.त.या./स.वि.
६	राष्ट्रिय राजमार्ग नियमित मर्मत सम्भार (वार्षिक)	कि.मी.	९१५५	७१८७	७१८७	७२००	७८००	भौ.पू.त.या./स.वि.
७	सडक पुल निर्माण	वटा	३००	३००	१९२	३००	२८२	भौ.पू.त.या./स.वि.

सन्तुलन र दोहोरो अंकको आर्थिक वृद्धिमा योगदान गर्ने र विशिष्ट प्रकृतिका आयोजनालाई रुपान्तरणकारी आयोजनाको रुपमा राखेको छ |

नेपालको बार्षिक बजेटमा बिनियोजन भएको बजेटको एक तिहाई भन्दा कम पुँजीगत बजेट, खर्च न्यून हुनका कारण विश्लेषण गर्दै यसमा गर्नुपर्ने समयसापेक्ष सुधारहरु बारे राय दिनुहोस | वा

नेपालको विकासमा योजना निर्माण, कार्यान्वयन समयमा सम्पन्न नहुनुको कारण हरु बारे चर्चा गर्नुहोस् |

बार्षिक बजेटको करिव एकतिहाई बजेट मात्र पुँजीगत बजेटको रुपमा विकास कार्यक्रमहरुको लागि बिनियोजन भएको बजेटको खर्च अवस्था हेर्दा विगत दस वर्षको औसत पूँजीगत खर्च गर्ने क्षमता ६० देखि ७५ प्रतिशतको हाराहारीमा रहेको छ भने औसत बजेट (चालु र पुँजीगत बजेट) खर्च गर्ने क्षमता ८३ प्रतिशत रहेको छ। संघीय शासनको चार वर्षको अनुभवमा पनि सो दर बढ्न सकेन । सोझै जनतासम्म पुग्ने विकास (पूँजीगत) बजेट न्यून खर्च भए पनि धान्नै नसक्ने गरी चालु (साधारण) खर्च बढिरहेको छ। कुल बजेटको दुईतिहाइ रकम दैनिक प्रशासनिक, कर्मचारीको तलबभत्ता लगायतका साधारण काममा खर्च भइरहेको छ। राजस्वले साधारण खर्च धान्न कठिन हुने स्थिति दीर्घकालीन आर्थिक वृद्धिका लागि चुनौतीपूर्ण मानिन्छ। तर, सरकारले यसको नियन्त्रणका लागि खास पहल गरेको छैन।

१. विकासका लागि कम रकम विनियोजन हुने र त्यसमाथि विनियोजित रकम नै खर्च नहुने परिपाटीले विकासको अवसरलाई झन् पर धकेलिरहेको छ। निजी लगानीलाई समेत प्रोत्साहित गर्ने पूँजीगत खर्च नै नहुनु रोजगारी सिर्जना र आर्थिक विस्तारका दृष्टिले अत्यन्तै चिन्ताजनक अवस्था हो ।

२. परियोजनाको कुल लागतको ३० प्रतिशत श्रम खर्च हुने अर्थशास्त्रीय मान्यताका आधारमा हेर्दा पनि पूँजीगत खर्च पर्याप्त नभएर हरेक वर्ष हजारौं नेपालीले रोजगारीको अवसर गुमाइरहेका छन् ।
३. नेपालको वर्तमान अवस्थामा थप १ प्रतिशत आर्थिक वृद्धिदर हासिल गर्न रु.१ खर्ब ६० अर्बभन्दा बढी पूँजीगत खर्च गर्नुपर्छ। यसले कमजोर उत्पादकत्व र पूँजीको दक्ष प्रयोग हुन नसकेको देखाउने
४. अहिलेको समग्र परियोजना छनोट र कार्यान्वयनको पद्धतिमा ठूलो समस्या छ ।

समस्याको मूल कारण विश्लेषण

१. विकास प्रक्रियामा देखिएको केन्द्रीकृत सोच र मानसिकता नै पूँजीगत खर्च गर्न नसक्ने र गरेको पनि गुणस्तरीय नहुने समस्याको मूल कारक हो ।
२. विकास प्रशासन कर्मचारीले मात्र गर्ने हो भन्ने १९६० को दशकको शास्त्रीय मान्यतामा रुपान्तरण गरिएन । कर्मचारीतन्त्रको क्षमता र नैतिकताको रुपान्तरण नगरी संघीय शासनको भार बोकाइयो । विकासका नीतिगत र संस्थागत अवरोधहरु हटाउने क्षमता र नैतिकता राजनीतिमा भएन । योजना र बजेट विनियोजन गरेपछि स्वत विकास हुन्छ भन्ने मनोविज्ञान राजनीतिक नेतृत्वमा देखियो ।
३. संघीय संरचनाको पहिलो ५ वर्ष पूरा हुनै लाग्दा समेत आयोजनाहरु हस्तान्तरण भएका छैनन् । जबकि २०७६ मा नै मापदण्ड बनाइएको थियो ।
४. संघ प्रदेश र स्थानिय तह समन्वय र अन्तरसम्बन्ध ऐन २०७७ को दफा ४ १ ले साझा अधिकारमध्ये एकभन्दा बढी प्रदेश र तह समेट्ने आयोजनाहरु मात्र संघमा राख्ने भनेको छ तर टोलमा बाटो बनाउने खुद्रे योजना समेत संघ र प्रदेशबाट सञ्चालित भइरहेका छन् ।
५. प्रदेश र स्थानीय तहहरुलाइ हस्तान्तरण गरिनुपर्ने शिक्षा,स्वास्थ्य, बन, कृषि, भूमि, सिंचाइ लगायतका कार्यक्षेत्रहरु र संगठनहरु पनि हस्तान्तरण भएकै छैनन् ।

पूँजीगत खर्च कम हुनुका अन्य कारणहरु

१. आयोजनाको पहिचान र छनौटमा समस्या : आयोजनाहरुको मापदण्ड, आर्थिक, सामाजिक, रणनैतिक लगायतका लाभ विश्लेषण नगरी Quick planning and budgeting गर्ने प्रवृति सहित राजनीतिक तथा दलीय आधारमा खल्तीबाट Black Box model अनुरुप आयोजनाहरु छनौट गर्नु ।
२. आयोजनाको पूर्वतयारीमा समस्या : जग्गा प्राप्ति, साइट क्लियर नगरी, वातावरणीय अध्ययन प्रतिवेदन स्वीकार नहुदै, लगानीको मोडालिटी तयार नहुदै, निर्माण सामग्रीको उपलब्धता बारे यकिन नगरी कार्यान्वयनमा हतारिनु ।
३. परियोजना व्यवस्थापनमा समस्या : दक्ष र नैतिकतायुक्त, नेतृत्वलिने परियोजना व्यवस्थापक नियुक्त नहुनु, कागजी बजेट सुनिश्चितताको आधारमा, बैदेशिक स्रोतहरु यकिन नगरी वा नेपाल सरकारले गर्नुपर्ने शर्त पुरा नहुदै, पुर्व तयारी नहुदै स्वार्थअनुकूल Specification, योग्यता निर्धारणका शर्त, हचुवाको भरमा ठेक्काको म्याद निर्धारण, विश्लेषण बिना प्याकेज र स्लाइस

आदि गरी ठेक्का लगाउने प्रवृति, QAP बारे अस्पष्ट हुनु, प्रयोगशालाको व्यवस्था नहुनु, समयमा भुक्तानी, सुपरभिजन,रेकर्ड,प्रतिउतर वा निर्णय आदि नगर्नु ।

४. निर्माण सामग्रीको उपलब्धता : निर्माणजन्य उधोगको अभावले नदिजन्य निर्माण सामग्री र गुणस्तरीय निर्माण सामग्रीको समयमा प्राप्त हुन् नसक्नु ।

५. निर्माण व्यवसायीको क्षमता र आधुनिक प्रविधियुक्त निर्माण उपकरणको समस्या : न्यून निर्माण क्षमता, धेरै ठेक्का अगोटने प्रवृति, निर्माण क्षेत्रलाई उधोगको रुपमा विकास नगरी पारिवारिक व्यवसायको रुपमा विकास गर्ने प्रवृति रहनु, प्राविधिक जनशक्तिको कमि, कठिन काममा भारतीय कामदारमा भर पर्नु, नयाँ र आधुनिक निर्माण उपकरण जस्तै ट्रेन्च कटर, Pile Boring Machine, अस्टरबर्ग सेल, precast technology, Concrete Paver, infra-doctor आदि प्रयोगमा नल्याउनु, ठुला नि.व्य.हरुले ठेक्का आफू लिने तर पेटी वा सब contractorलाई बिचमै बेच्ने प्रवृति आदि ।

६. परियोजनालाई स्रोत दुरुपयोगको माध्यम मान्नु : परियोजनालाई राजनीतिक, प्रशासन, निजि क्षेत्र सबै बाट आर्थिक लाभ लिने स्रोत का रुपमा दुरुपयोग गर्नु जस्तै चमेलिया, मेलम्ची का गाडीहरु मन्त्री र उच्च सरकारी पदाधिकारीले प्रयोग गर्नु ।

७. निकायगत समन्वयको समस्या र असहयोग : सार्वजनिक खरिद कार्यालयले समय सापेक्ष खरिद सम्बन्धि, खरिद विधि सम्बन्धि कागजात, मापदण्ड, प्राबिधिक निर्देशिका तयार नगर्नु, अनुगमनको नाममा नियामक निकायहरुले खरिदकै चरणमा, निर्माणकै चरणमा महिनौ सम्म निर्णय नदिने प्रवृति, समयमा बजेट फुकुवा, निकासा, सोघभर्ना नदिने वा आर्थिक बर्षको अन्तमा बजेट दिने, रुख कटानको वा राष्ट्रिय बन प्रयोगको स्वीकृतीमा बर्षौ लाग्ने प्रवृति, खरिद प्रशासनमा अदालतको प्रवेश तथा मध्यस्तताको निर्णयमा सबै तहको अदालत जाने प्रवृति र समयमा निर्णय नहुने समस्या ।

८. नीति नियम, प्राविधिक समस्या र प्रक्रियागत समस्या: डिजाइन तथा पूर्वानुमान गरिएको भन्दा फरक अवस्था कार्यस्थलमा देखिनु, कार्यान्वयन चरणमा नयाँ थप क्रियाकलाप वा डिजाइन परिवर्तन हुनु, कार्यस्थलमा उत्तम प्राविधिक समाधान भन्दा राजनीतिक परिवेश हावी भइ प्रियताको मार्गमा राजनीतिक नेतृत्व उभिनु, लागत अनुमान, डिजाइन सदर, म्याद थप. भेरियेशन स्वीकृत गर्ने प्रक्रिया र निर्णय गर्ने अधिकार माथिल्लो निकायमा केन्द्रीकरण हुनु, बाह्य स्रोतमा निर्माण हुने परियोजनामा ऋण सम्झौताका शर्तका कारण संलग्न अन्तराष्ट्रिय नि.व्य. हरुलाई कारवाही गर्ने प्रक्रिया झन्झटिलो हुनु, निर्माण खरिदसंग सम्बन्धित व्यवस्थाहरु ऐन, नियमावलीको असल मनसाय सहित राखेका प्रावधानहरु हचुवाको भरमा छिटो छिटो परिवर्तन वा संसोधन हुनु, नुन देखि सुन सम्म, सियो देखि बोइंग सम्मको खरिद प्रक्रिया एकै किसिमको हुनु, राष्ट्रिय गौरव र रुपान्तरणकारी भनिएका आयोजनाहरुले कुनै बिशेष सहुलियत प्राप्त नगर्नु ।

९. सामाजिक मूल्य, मान्यता र संस्कृतिजन्य समस्या: परियोजनामा नागरिक सहभागिता न्यून हुनु वा नहुनु, पुर्वाधारहरु सामाजिक मूल्य मान्यता स्वीकार गर्ने बिषयबस्तुहरु सम्बोधन नहुदा

जनताले बिश्वास र अपनत्व ग्रहण नगर्नु, विविध किसिमका चाडबाडका लागि बिदा र कार्यस्थलमा छुट्टी गर्ने परम्परा कायम रहनु ।

१०. भौगोलिक, भौगर्भिक र जलबायु परिवर्तन सहितको मौसमी समस्या :हिमाली पहाडी, भिरालो सतहमा काम गर्दा ढिलो हुने, मौसमी समस्याका कारण निर्माण सामग्रीको उपलब्धता, दुवानी र काम गर्ने समय कम पाउनु, जलबायु परिवर्तनका कारण काम गर्ने सिजनमा समेत अतिबृष्टि, अनावृष्टि हुनु आदि ।

११. अनुगमन, मूल्यांकन र पृष्ठपोषण तथा दिगोपना सम्बन्धि समस्या : परियोजना आफैको र नियामक निकाय समेतको अनुगमन र मूल्यांकन कर्मकाण्डी र देखावटी, औपचारिकता र तिर्थाटनमा सिमित, नाम मात्रको कार्य सम्पादन सम्झौता, अनुगमन र मूल्यांकनबाट दण्ड र पुरस्कार सहित व्यवस्था लागू नहुनु, भविष्यमा हुने उस्तै गल्ती गरिरहनु, निर्माण तथा मर्मतका असल अभ्यासहरुको निरन्तरता नदिनु आदि

१२. परियोजनामा संलग्न कर्मचारीको व्यावसायिकता, पेशागत आंचारसहिता, नैतिकता, सदचारिता र निष्ठाको अभावले गैरनैतिक स्वार्थ तथा आर्थिक अपचलनमा केन्द्रित रहनु, आफ्नो जिम्मेवारी र उतरदायित्वबाट पन्छिने समस्या आदि ।

१३. प्राकृतिक बिपत तथा Force majeure जस्तै भुकम्प, नाकाबन्दी, Covid, ठुलो पहिरो, लागायतका मानवीय क्षमता भन्दा बाहिरका समस्याहरु ।

उपायहरु

१. माथि उल्लेख भएका समस्याहरु समाधान गर्न नीतिगत, कानूनी, र संरचनागत बिषयबस्तुमा सुधारात्मक उपायहरु लागू गर्ने ।

२. परियोजना छनोट गर्दा पूर्व संभाब्यता अध्ययन डिपिआर निर्माण तथा साइट क्लियर गरेर मात्र बजेट बिनियोजन गर्नुपर्छ ।

३. हरेक तहका सरकारहरुले अनिवार्य रुपमा परियोजना बैंक निर्माण गरेर मात्र सो बाट योजना निर्माण गर्ने बाध्यकारी ब्यवस्था गर्नुपर्छ ।

४. आयोजना व्यवस्थापन कानून तर्जुमा गरी कार्यान्वयनमा ल्याउन धेरै ढिलो भइसकेको छ। यस कानूनमा आयोजना कार्यान्वयनमा प्रत्यक्ष संलग्न पदाधिकारी एवं ठेकेदार र परामर्शदातालाई तोकिएको जिम्मेवारीप्रति उत्तरदायी बनाउने, केन्द्रले कार्यान्वयनको चरणमा रहेका साना तथा मझौला आयोजनाहरू स्थानीय तह र प्रदेशमा हस्तान्तरण गर्ने एवं खर्चको गुणस्तर र समयलाई केन्द्रविन्दुमा राखेर आयोजना कार्यान्वयन गर्न सकियो भने आगामी दिनमा पूँजीगत खर्च बढ्ने छ ।

५. प्रक्रिया र पद्धतिका मसिना कुरा केलाएर अप्ठ्यारा नसुल्झाएसम्म विकासको अवरोध कायम हुने भएकोले निर्देशनको साटो काम किन हुन सकेन भनेर अनुगमन र मूल्यांकन प्रभावकारी बनाउनुपर्छ

६. सार्वजनिक खरीद ऐनले उत्पन्न गरेको अप्ठेरो के हो भन्ने पहिचान गरेर समस्यालाई सम्बोधन गर्नैपर्छ।

७. ठेक्का प्रणालीमा पनि पुनरावलोकनको आवश्यकता छ। ठेकेदारले समयमा काम अगाडि नबढाए, बीचैमा छोडे वा कुनै किसिमले ठेक्का तोड्नुपरेमा उसले गरेको कामको मूल्यांकन गरी क्षतिपूर्ति भराई बाँकी भुक्तानी दिने प्रावधान लागू गर्नुपर्छ। बाँकी कामको हकमा सोही बाँकी ठेक्का रकममा नेपाल राष्ट्र ब्याङ्कले प्रकाशन गर्ने वार्षिक राष्ट्रिय मूल्यवृद्धि सूचकांक अनुसार वृद्धि गरी दोस्रो कम ठेक्का कबोल गर्ने ठेकेदार वा त्यसले नचाहेमा तेस्रोलाई दिने व्यवस्था गर्ने र मूल्यवृद्धिबाट बढ्ने रकम ठेक्का तोडिने ठेकेदारसँग क्षतिपूर्तिको रूपमा असुल उपर गर्ने व्यवस्था गर्नु उपयुक्त हुन्छ।

८. पहिलो चौमासिक अवधिमा कुनै आयोजनाको कार्यान्वयन प्रक्रिया अगाडि नबढेमा तत्काल स्वतः बजेट तान्ने गरी अन्यत्र दिन सकिने व्यवस्था विनियोजन ऐनमै गर्ने, पूर्व योग्यता निर्धारणको माध्यमबाट ठेक्का लगाउने प्रणालीले मूल्यमा प्रतिस्पर्धा नहुने र मिलेमतोमा आयोजना बाँडफाँड हुने जस्ता विकृतिहरू पनि देखिएका छन्। यस प्रक्रियामा संशोधन गरी आयोजना कार्यान्वयनमा बढीभन्दा बढी ठेकेदारले प्रतिस्पर्धा गर्न पाउने किसिमको बनाउनुपर्छ।

९. सवारी साधन, कार्यालयका सामान, जग्गा, सफ्टवेयर जस्ता स्थिर सम्पत्ति र सामग्रीहरूको खरीदबाट पूँजीगत खर्च वृद्धि हुनुलाई प्रगति मान्ने मान्यताबाट बाहिर निस्किएर आयोजना प्रमुख, विभागीय प्रमुख र सम्बन्धित लेखा उत्तरदायी अधिकारीलाई आफ्नो दायित्वप्रति कानूनी रूपमै जवाफदेही बनाउन सकिएन भने बजेट कार्यान्वयनका समस्या ज्यूँका त्यूँ रहनेछन्।

१०. राष्ट्रिय सतर्कता केन्द्रबाट आयोजनाको निर्माण गुणस्तरको प्राविधिक परीक्षण गर्ने जिम्मेवारी कुशलतापूर्वकवहन गर्न सकेमा गुणस्तरीय निर्माणको आशा राख्न सकिन्छ ।

११. प्रधानमन्त्रीको अध्यक्षतामा रहेको राष्ट्रिय विकास समस्या समाधान समितिलाई अझ् बढी सक्रिय बनाई यसैको मातहतमा रहने गरी प्रभावकारी अनुगमन संयन्त्र निर्माण गर्ने, राष्ट्रिय योजना आयोगले यस समितिका निर्णय र निर्देशन कार्यान्वयनको नियमित अनुगमन गर्ने, अन्य विषयगत मन्त्रालय, प्रधानमन्त्री कार्यालय र अर्थ मन्त्रालयसँग समन्वय गरी संयुक्त अनुगमन प्रणालीको विकास गर्ने जस्ता कार्यलाई प्राथमिकताका साथ कार्यान्वयन गर्नुपर्छ ।

१२. सार्वजनिक खरीद ऐन संशोधन गर्दा सबै वस्तु तथा सेवा र निर्माणको खरीद प्रणाली एउटै नगराई अहिले देखिएका समस्यालाई ध्यानमा राखी फरक-फरक किसिमको प्रक्रिया र विधि अपनाउन सक्ने र ठेकेदारले एक पटकमा बढीमा पाँच वटा मात्र ठेक्काको काम गर्न पाउने गरी संशोधन गर्नु उचित हुन्छ |

१३. निगरानी गर्ने निकायले पनि काम शुरू नगर्दै वा कार्यान्वयनको चरणमा रहेको बेलामा फाइल झिकाई छानबिन गर्नुभन्दा काम सम्पन्न भएपछि विस्तृत छानबिन गर्दा कार्यान्वयनमा बाधा पुग्दैन |

१४. बजेट खर्च नहुनुमा मूल जिम्मेवारी राजनीतिक नेतृत्वको भए पनि कर्मचारीतन्त्रले पनि अवरोध गरिरहेको देख्छन्। "समग्र विकास प्रशासन नै यति अक्षम भइसकेको छ कि त्यसलाई आमूल सुधार नगर्दासम्म प्रतिफल आउँदैन |

१५. विकास प्रशासनका कर्मचारीलाई जवाफदेही र परिणाममुखी बनाउन सेवासुविधा तथा वृत्तिविकासलाई परिणामसँग जोड्ने प्रणाली आवश्यक रहेको |

१६. पूर्वतयारी नै नगरिएका आयोजनालाई रकम विनियोजन गर्ने पद्धति हटाउन र कर्मचारीलाई जवाफदेही बनाउने प्रणाली बनाउन आवश्यक छ।

Organizational Capacity and Institutional Strengthening

Organizational Capacity is the level of an organization's capability to deliver services and products that not only satisfy present customer expectations, but continually anticipate future marketplace opportunities. Key among the primary components of capacity is those associated with the human side of performance. These include the traditional classification of knowledge, skills, and abilities. These elements contribute substantially to an organization's capacity and serve as the primary focus of its capabilities.

Key Dimensions of Organizational Capacity

The different aspects of organizational capacity can be organized into five categories or “dimensions.”

- Organizational Resources: Organizational resources consist of the concrete materials and tangible assets that support programs, practice improvements, and service delivery. They encompass adequate and stable funding, staffing, facilities and equipment, technology, informational resources, and program materials. Adequate resources enable an organization to meet ongoing needs and targeted improvements. For example, to implement a new project, a company may need additional staff to provide services, additional office space for the new staff, project materials that guide service delivery, data collection tools and equipment to track and assess services, and funding to pay for these and other assets. All these organizational resources will contribute to the company's ability to implement and sustain the new project and, ultimately, to achieve the desired outcomes. In many cases, adding new staff and facilities may not be feasible, so the company may need to reassign or realign organizational resources to meet the needs of a new project.
- Organizational Infrastructure: Organizational infrastructure consists of the systems, protocols, and processes that give structure to the organization, support its key functions, and embed routine practice. Infrastructure may include the policies and operating procedures that guide practice and build a shared understanding of how to deliver services. Infrastructure also includes systems for operations — from human resources, training, supervision, and ongoing communication systems to data, evaluation, and continuous quality improvement (CQI) systems. An organization’s structures, processes, and systems institutionalize practices, procedures, and rules to ensure their consistent execution regardless of staff or leadership changes. The organizational infrastructure also supports the organization in carrying out its vision, mission, goals, and values. Organizational infrastructure often sets the foundation for other organizational capacities. For example, recruitment and staff selection processes lead to the availability of adequate workforce resources. Similarly, training systems help build staff knowledge and skills.
- Organizational Knowledge and Skills: Organizational knowledge and skills consist of the essential expertise and competencies needed to perform work. Think of this as the organization's “know-how.” For an employee, this includes understanding and application of effective knowledge and practice, decision-making, management, and competence. For managers and administrators, it also includes knowledge and skills related to leadership, management, critical analysis, policy making, workforce development, and change management.
- Organizational Culture and Climate: Organizational culture and climate consist of shared values, norms, attitudes, and perceptions that influence how people in an organization behave. An organization's priorities, leadership commitments, and staff motivation reflect its culture and climate. For new programs and practices, an company's culture and climate may affect how people accept and support change. While people often use the terms “culture” and “climate” interchangeably, Charles Glisson, a leading researcher in this area, makes the following distinction:
  - Organizational culture refers to the shared behavioral expectations and norms in a work environment. This is the collective view of “the way work is done.”
  - Organizational climate represents staff perceptions of the impact of the work environment on the individual. This is the view of “how it feels” to work at the agency (e.g., supportive, stressful).
- Organizational Engagement and Partnership: Organizational engagement and partnership consist of collaborative relationships within an organization and with external partners, and community to support

service integration and inform improved practices. Productive relationships involve building trust, seeking feedback, and actively collaborating toward shared objectives. While organizational engagement and partnership often require structures to facilitate collaboration (e.g., interagency agreements), the structures are part of organizational infrastructure. This dimension features the resulting relationship and collaboration between the partners

Institutional Strengthening

Institutional capacity building (ICB):

Institutional strengthening is about increasing the capacity or ability of institutions to perform their functions. There is a particular focus on improving governance.

Building and maintaining the institutional capacity of an organization is essential to sustainable development of the country. It is the process through which individuals, organizations and societies obtain, strengthen and maintain the capabilities to set and achieve their own development objectives.

Capacity building (or capacity development) is the process by which individuals and organizations obtain, improve, and retain the skills, knowledge, tools, equipment, and other resources needed to do their jobs competently. It allows individuals and organizations to perform at a greater capacity (larger scale, larger audience, larger impact, etc).

Capacity building is currently one of the leading issues in the development of the road sector in developing countries and transition countries. Yet the concept of capacity building remains complex and difficult to grasp and put into practice.

The concept and definition of capacity building

The ICB position paper states that ICB encompasses three main activities:

- skill upgrading,
- procedural improvements, and
- organizational strengthening

This is the most frequent definition found in World Bank documents. Thus, road sector related ICB refers to investment in people, institutions and practices that will enable developing countries and transition countries to achieve their road sector development objectives. Defined in this way, ICB occurs by acquiring resources (human, financial, networks, knowledge, systems and culture) and integrating them in a way that leads to change in individual behavior and ultimately to more efficient and effective operations of institutions and organizations.

However, ICB also has to do with two types of that are emphasized; **tangibles and non-tangibles**.

1. **The tangibles** include physical assets such as infrastructure, machinery, natural resources, health of the population and education. Organizational structure and systems, legal frameworks and policies are also included in this category. The tangibles can be referred to as hard capabilities. These are factors that generally are amenable in either physical terms or in terms of indices.

2. The intangibles on the other hand, have to do with social skills, experience, creativity, social cohesion, social capital, values, motivation, habits, traditions, institutional culture etc., and hence can be referred to as soft capabilities. These are normally difficult to quantify. Others may term these capabilities as core capabilities as they refer to the creativity, resourcefulness and capacity to learn and adapt of individuals and social entities.

In ICB, the intangibles are as important as the tangibles because they determine how well a given society uses the other resources at its disposal. They are what allow them to realize their human and social potential to the highest possible level. To achieve a proper and balanced ICB a balance is required between the tangibles and intangibles. This is illustrated in figure 1. What the figure illustrates is that, institutional development is more likely to succeed if it promotes both the tangibles (technical competencies and organizational framework) and intangibles (social arrangements).

Strategies for capacity building:

In the following some ICB strategies that have been used in the past in developing countries are discussed in the light of the definition of ICB with the two axes.

1. Financial assistance and supply of physical resources

- In this strategy, simple lack of resources, either financial or physical assets, are seen as the major lack of institutional capacity. This strategy is prevalent among many aid agencies throughout the world. This strategy has in the past dominated development aid.
- The rationale of this strategy is that the concerned institution lacks adequate supplies or finances to achieve its efficiency.
- The strategy for the donors is then to provide more equipment, more funds for operating costs, salary payments, more buildings, trained staff etc. so as to improve the conditions for capacity development.
- It has the advantage that, for donors it is relatively easy to implement and, furthermore does not intrude much into the affairs of participants.
- In several circumstances, the provision of funds, training and machinery has helped institutions develop and in particular get through critical periods.
- However, this strategy may not function well. There is the risk that the resources supplied may be appropriated by officials of the institutions for their own personal benefits. In other circumstances, the supply of resources may make the institutions donor-dependent also in the long run. The supply of resources becomes pay-offs rather than incentives and does not lead to a sustained development of the institutions.
- Returning to the illustration in figure 1, this strategy definitely improves only one of the axes; the tangibles, and therefore will not promote ICB appropriately.

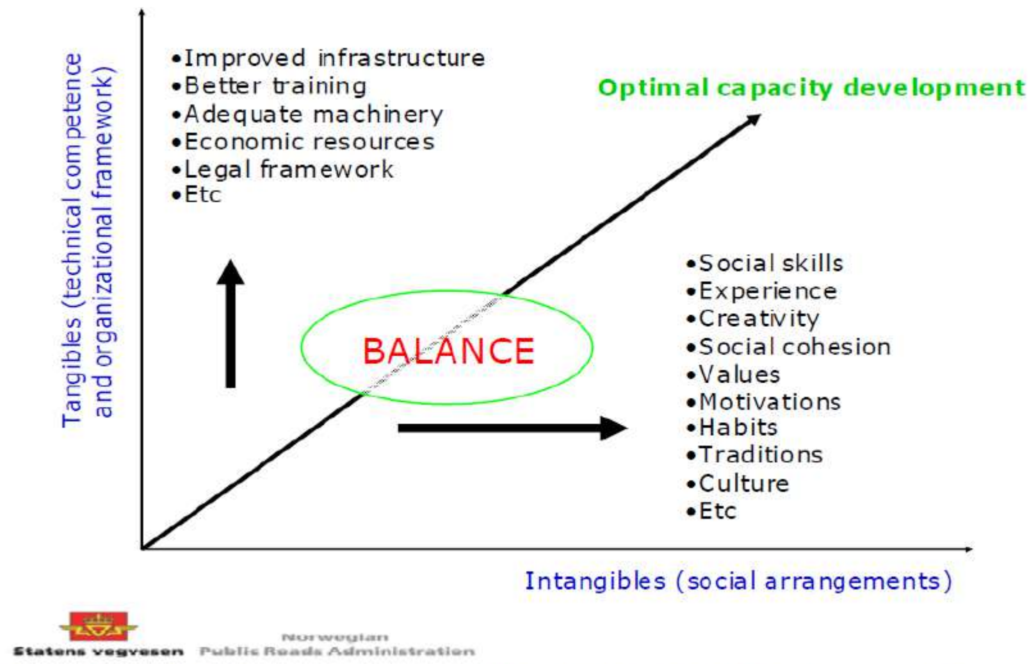


Figure 1 - Balance between intangibles and tangibles in ICB

2. Improving the organizational and technical capabilities of institutions:

- This strategy has the aim of improving the personal, technical and organizational capabilities of the institutions so that they better perform what is already being attempted.
- It is thus a variant or a subset of the strategy above with the difference that it is motivated by lack of technical capabilities and proper institutional structure rather than resources.

- In the road sector in particular, this strategy has become common, and it is the one mostly considered as capacity building approach.

Activities included are such as:

i. technical assistance in terms of personnel,
ii. technical training of local personnel either locally or in form of scholarships abroad,
iii. improvement of management and financial systems, and
iv. improved working conditions.

- This strategy has definitely improved technical capabilities of many institutions, at least in the short term. The value of training and skill improvement are undoubtedly important for capacity development and should be encouraged.
- It also remains true that many developing countries suffer from poorly performing organizations and lack of trained staff and proper management systems. However, this strategy may also be inefficient in promoting institutional development. Many institutions are under constraints far beyond what can be termed tangibles and what technical support is not about. Such constraints may include politics, motivation, culture etc., which may prevent institutions and individuals from performing regardless of their technical skill levels. The current situation, after so many years of emphasis on education and training as a means of developing capacity, reveals that skills and training has become less of a constraint in many countries than what was the case 15-20 years ago.
- What should matter now is the utilization and retention of the already available capacities. That can only be achieved if the intangibles discussed above are considered seriously. Again, it is the mix of the two axes in figure 1 that can lead to optimal capacity development.

3. Setting strategic goals for an institution

- The problem is that institutions do not have clear directions or cannot define a consistent direction. Take the case of a road traffic directorate. Should the capacity building be traffic safety, increased supply of roads, and environmental improvement in cities, economic development or all? And further, pressure from the different groups may be enormous, each wishing to achieve their own goals. Or, there may be no consensus in the political system about the purpose of the institution.
- The aim of the strategy is to help induce a policy or a general direction that can guide actions and the development of capacity in the long term.
- The advantage with this strategy is that it is simple. Ideas developed can be compared to experiences elsewhere. The problem, however, is whether the intangibles really are taken into account in an appropriate way. Otherwise, it will most likely result into a failure.

4. Strengthening the larger system, networks and organizational framework

- This strategy aims to help a group of institutions to work together to carry complex tasks such as national budgeting, national health plans and national transport plans. The system lacks the organization or its sub-units to perform these functions. Or the interrelationship between actors in the sector/system needs reshaping to perform their functions.
- For this strategy to work well, focus must be both on the interrelations between the organizations and individuals and groups of individuals. Again, the two axes explained above are important. Perhaps this strategy is the most complex one for development organizations to accomplish.

Optimizing monitoring and evaluation (M&E) for capacity-building:

- **What they want to achieve:** Capacity-building providers need to have a clear, stated rationale for carrying out capacity-building, and a clear idea of what they want to achieve, both in the medium and in the long term.
- **Be clear about the purpose of M&E** – e.g., is it for accountability to donors, or to learn and improve performance? – As this will influence the approaches and methodologies used.
- **Measure contribution:** Where multiple interventions are spread out over time, it may be useful to start by trying to evaluate change at an individual, organizational or even societal level, and then work backwards to identify what contributed to those changes.

- **Changes:** Distinguish between measurable changes and changes that can only be illustrated. Establish an agreement with all concerned about how far M&E should go in terms of measurement, and at what levels.
- **M & E:** Carry out M&E alongside capacity-building support.
- **Demonstrate the scale of change:** It is unlikely that any capacity-building provider working with various organizations or individuals will be able to get away with purely qualitative or anecdotal reporting. At some stage it will be necessary to produce some figures to demonstrate the scale of change.
- **Pace of change:** Capacity-building providers should be cautious about predicting the pace of change within organizations, especially when logical frameworks or project proposals encourage unrealistic expectations. They can influence the pace of change but have no absolute control over it

Some common lessons learned:

- This review reveals that the term capacity building is perceived in different ways, and in most cases, it addresses technical competence and organizational issues while the social and cultural setting is often ignored or underestimated.
- **Key factor leading to success:** From the case studies, it is possible to identify some key factors leading to success in achieving capacity development objectives. These factors seem to be: long-term involvement; demand-driven assistance; interventions adapted to the level of development and absorption capacity of the institutions involved; and focus on human resources development.
- **Results are not impressive:** Looking at the scores on institutional development impact, the results are not impressive as long as the projects have capacity building as a main objective. The scores vary from modest to substantial.
- **Shortcoming:** Some factors seem clearly to cause shortcomings or failures of interventions unless they are taken into account. An important factor in this respect is the need for a proper understanding/competence of institutional reform processes and capacity building. Further, human resources development is needed to help develop new institutional arrangements, and this aspect is often underestimated.
- **Low salary level:** Low salary levels of the public sector also seem to cause problems in achieving results. These are far from competitive with salary levels of the private sector, and apart from facing problems with recruiting and retaining qualified staff, low salary levels make government organizations prone to corruption and misappropriations.
- This requires expertise in reform processes both at the sector-level and the macro-level.
- **Reform process:** This review also shows that the time required for institutional reform processes to yield results should not be underestimated. Complex bureaucratic structures and decision-making processes easily hamper reform processes.
- **Sustainability:** Lastly, the sustainability of institutional reform processes appears to strongly depend upon political commitment, stakeholders' ownership of the objectives and processes, and mechanisms to secure and allocate human and financial resources.

Process for capacity building: -

Under the UNDP's 2008–2013 "strategic plan for development", capacity building is the "organization's core contribution to development." The UNDP promotes a capacity-building approach to development in the 166 countries it is active in. It focuses on building capacity at an institutional level and offers a six-step process for systematic capacity building. The steps are:

1. Conducting Training Need Assessment (TNA)

2. Engage stakeholders on capacity development

An effective capacity building process must encourage participation by all those involved. If stakeholders are involved and share ownership in the process of development they will feel more responsible for the outcome and sustainability of the development. Engaging stakeholder's who are directly affected by the situation allows for more effective decision-making, it also makes development work more transparent. UNDP and its partners use advocacy and policy advisory to better engage stakeholders.

3. Assess capacity needs and assets

Assessing preexisting capacities through engagement with stakeholders allows capacity builders to see what areas require additional training, what areas should be prioritized, in what ways capacity building can be incorporated into local and institutional development strategies. The UNDP argues that capacity building that is not rooted in a comprehensive study and assessment of the preexisting conditions will be restricted to training alone, which will not facilitate sustained results.

4. Formulate a capacity development response

The UNDP says that once an assessment has been completed a capacity building response must be created based on four core issues:

- **Institutional arrangements:** Assessments often find that institutions are inefficient because of bad or weak policies, procedures, resource management, organization, leadership, frameworks, and communication. The UNDP and its networks work to fix problems associated with institutional arrangements by developing human resource frameworks "cover policies and procedures for recruitment, deployment and transfer, incentives systems, skills development, performance evaluation systems, and ethics and values."
- **Leadership:** The UNDP believes that leadership by either an individual or an organization can catalyze the achievement of development objectives. Strong leadership allows for easier adaption to changes, strong leaders can also influence people. The UNDP uses coaching and mentoring programmers to help encourage the development of leadership skills such as, priority setting, communication and strategic planning.
- **Knowledge:** The UNDP believes knowledge is the foundation of capacity. They believe greater investments should be made in establishing strong education systems and opportunities for continued learning and the development of professional skills. They support the engagement in post-secondary education reforms, continued learning and domestic knowledge services.
- **Accountability:** The implementation of accountability measures facilitates better performance and efficiency. A lack of accountability measures in institutions allows for the proliferation of corruption. The UNDP promotes the strengthening of accountability frameworks that monitor and evaluate institutions. They also promote independent organizations that oversee, monitor and evaluate institutions. They promote the development of capacities such as literacy and language skills in civil societies that will allow for increased engagement in monitoring institutions.

5. Implement a capacity development response

Implementing a capacity building program should involve the inclusion of multiple systems: national, local, institutional. It should involve continual reassessment and expect change depending on changing situations. It should include evaluative indicators to measure the effectiveness of initiated programs.

6. Evaluate capacity development

Evaluation of capacity building promotes accountability. Measurements should be based on changes in an institutions performance. Evaluations should be based on changes in performance-based around the four main issues: institutional arrangements, leadership, knowledge, and accountability.

Area of institutional strengthening:

To strengthen the ability of the institution in following sector:

- Transport planning;
- Project costing and financing;
- Commercialization of transport operations;
- Investment management;
- Social and environmental management; and
- Project Management
- Planning, Design and Supervision
- Procurement
- Land Acquisition/ Resettlement
- Environmental Management
- Training & Capacity Building
- Social Assessment

- Community Participation Processes
- Institutional Strengthening
- Human Resources Development
- Integrated Rural Access Planning
- Cost-Benefit Analysis

Before Implementation of any project Identification of Institutional and Training Requirements is necessary:

Apart from the technical and economic feasibility, the feasibility study shall assess institutional and training requirements. The following guidelines apply:

- The existing organizational structure, staffing, roles and responsibilities and O&M systems and budget of the owner of the completed works shall be assessed.
- The additional responsibility, O&M workload and budget requirement due to the proposed project shall be assessed.
- The requirement for additional staff, and their job responsibilities, to be employed either permanently for the operation of the new works, or temporarily for the duration of the project only shall be assessed.
- Training needs for existing staff and any additional staff shall be assessed.
- The availability of in-house, in-country or external sources to provide the necessary training shall be identified.
- The institutional strengthening and training component within the project shall be recommended.
- The cost of such training and institutional strengthening shall be estimated.
- A staffing plan during the project and for post-project O&M shall be recommended.

Arbitration Act and Dispute related issue

Claim and Dispute Resolution

Claims arises when the Contractor believes he has been impeded in some way from works according to the contract.

Causes	Potential Responsibility
Delay in obtaining possession and access to the site	Employer
Delay in obtaining work permits, custom clearance	Employer
Delay in obtaining drawings and instructions	Consultant
Delay of commencement or completion of works by others	Employer
Delay in Payment	Employer
Mismatch in quantities/Variation	Consultant
Design, layout error	Consultant
Extension of Time	Employer/Consultant/ Contractor
Interpretation of specification	Consultant
Unusual Weather Conditions	None
Strike and Civil disturbances	None

Construction Claim Management Phases

1. Claim Prevention

- The claim prevention process is activated at Pre-tender and Contract Formulation phases of a project. Contract documents project plans and scope of work should include all requirements related with the project because after the award of contract the opportunity to prevent claim comes to an end.

2. Claim Mitigation

- Construction activities are generally performed in highly sensitive and outdoor environments. It is better to minimize the possibilities of occurring claim all through the progression of the contract. A well-defined scope, responsibilities and risks will help to decrease the possibility of occurrence of claims. Also risk management plans play important roles in the phase of claim mitigation.

3. Claim Identification and Quantification

- Claim identification can be done by analyzing both the scope of work and the provisions of the contract. Inputs of the claim identification process are the scope of work, contract terms, definition of extra work and definition of extra time requested. Once an activity is identified as a claim, it will be quantified in terms of additional payment or a time extension to the contract completion or other milestone date. In this phase, schedule and critical path analysis should be made in order to calculate the delay of the project. In addition to that, additional direct and indirect costs originated from the claimed activity should be calculated.

4. Claim Resolution

- Claim resolution is a step-by-step process to resolve the claim issues. Depending on the resolution terms of the contract, negotiation, mediation, arbitration and litigation processes will be conducted.

Claiming Procedure

- Start keeping a detailed record simultaneously with occurrence of an event which gives rise to claim
- Give a notice of intention to claim within stipulated time
- Act on the Consultant's instructions regarding additional records needed to substantiate the claim
- Submit a claim with supporting information within the time limit
- For an event with continuing effect, submit an interim account of claim on regular basis
- Include an application for payment in addition to actions

Contents of Contractor's claim document:

1. Background
   - ✓ Provide historical data affecting the subject matter of the claim
   - ✓ Make all necessary references to other documents for appreciation of the background
2. Contractual Argument
   - ✓ State the particulars clause or clauses on which the claim is founded
   - ✓ Set out a logical argument in detail so that the Consultant and Employer may understand the claim
   - ✓ Refer to similar known settled claims in the country under similar contracts
3. Supporting Data, Site records, Photographs, Site diaries, Daily Weather Reports
   - ✓ Consultant's site instructions, Working Drawings, Minutes of Meeting, Visitor's Register
   - ✓ Quality control documents, work program, correspondences. Plants, records, Fuel and labor records
4. Financial Comparison
   - ✓ Comparison between the cost anticipated by the contractor during the bid with the cost actually incurred
   - ✓ Effect of circumstances giving rise to claim

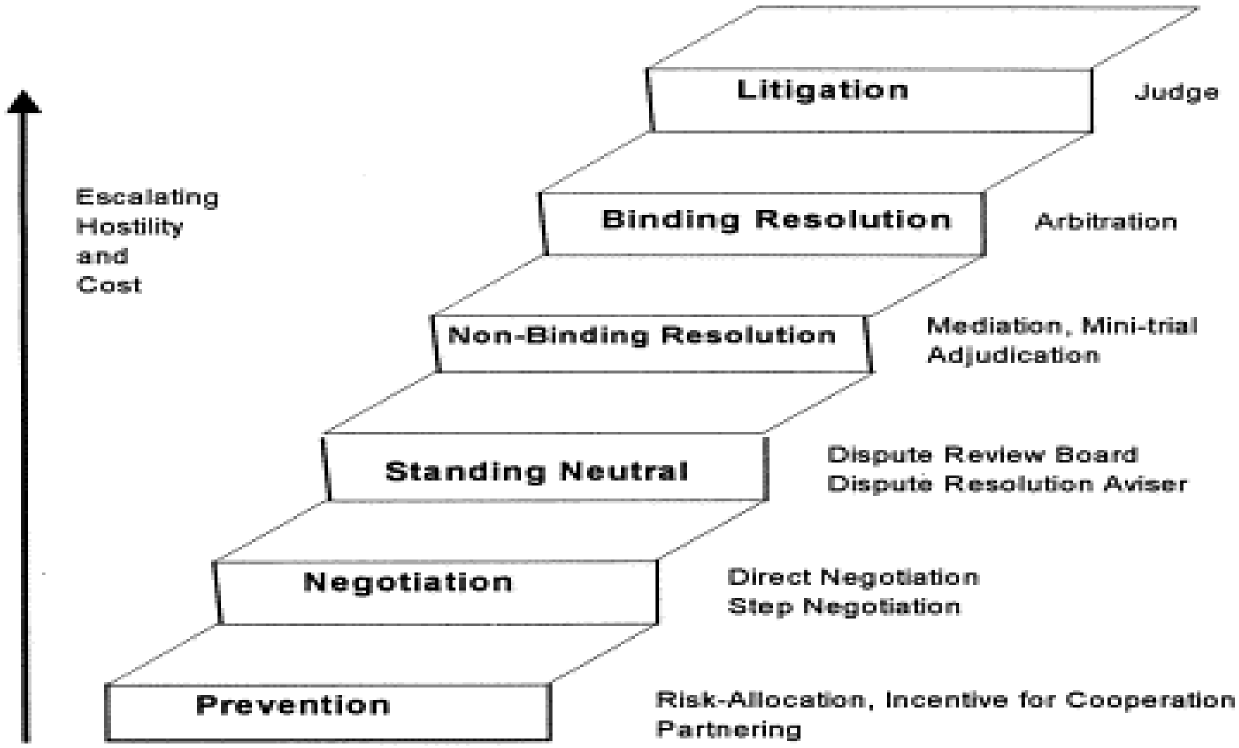
- ✓ Dispute: A 'disagreement' between Employer and the contractor over the payment of money, the adjustment or interpretation of contract terms, any claims arising out of or relating to any aspect of a solicitation, bid, or failure to conduct a solicitation or bid, any decision to award, deny, suspend or cancel, terminate or not renew, any contract or agreement.
- ✓ Dispute Resolution Procedures: Apply to and shall constitute the exclusive procedure for resolution of all claims, disputes, complaints and Dispute Resolution Requests of any kind filed by an Aggrieved Person relating in any way to any agreement entered into by the Vendor.

What is Dispute Resolution

- Dispute resolution refers to the processes by which disputes are brought to an end.
- Dispute Resolution occur through:

1. A negotiated outcome: Parties concerned sort out things themselves
2. A mediated outcome: Parties use the services of an independent mediator to help them arrive at their own agreement, or
3. An arbitrated or adjudicated outcome: An independent arbitrator or court determines how the dispute is to be resolved and makes a binding decision or order to this effect.
4. Dispute resolution or Dispute settlement is the process of *resolving disputes* between parties.

5. The term *dispute resolution* is sometimes used interchangeably with conflict resolution, although conflicts are generally more deep-rooted and lengthier than disputes.
6. Dispute resolution techniques assist the resolution of antagonisms between parties that can include citizens, corporations, and governments.



Forms of Dispute Resolution

- Dispute resolution ranges from informal, non-legally binding methods to more structured legal procedures.
- All of them apply to workplace conflict, and all of them can help organizations avoid lawsuits and other legal battles.
- Some of the most common forms of conflict resolution are negotiation, mediation, arbitration and mediation-arbitration
- All of them focus on solving the conflict with the best interests of all parties involved in mind and avoiding court.
- Simple Dispute/s: Disputes if not too severe, simple negotiation might suffice. With this process, the conflicting parties agree to discuss their concerns with each other openly.
- Suggestions: Parties might share precisely what actions, practices or policies they are upset about and make suggestions about how the dispute/s can be resolved.
- Compromise for Comfort: As part of the dispute resolution, the involved parties typically agree to work together to find a compromise with which they all feel comfortable.
- Informal Process: There will be a meeting between the conflicted parties and a member of the senior management.

Best Practice Dispute Resolution Outcomes

Best Practice should be:

- Quick - the issues should be resolved quickly rather than allowing them to escalate through inaction.
- Fair - all relevant parties should be consulted so that all sides of the story are taken into account.
- Handled sensitively - disputes should, where possible and appropriate, be resolved in a confidential context in order to minimize impact on employees not affected by the dispute.
- Transparent - the procedure should be made known to every employee.
- Dispute resolution procedures should not interfere with the continued operation of the business where possible.
- Continue during Dispute Resolution Process: Any dispute resolution clause in an agreement, contract or policy should require that work is to continue normally during the dispute resolution process subject to any reasonable concerns about health and safety.

Dispute Resolution: Processes

Dispute resolution processes fall into two major types:

- Adjudicative processes: Such as litigation or arbitration, in which a judge, jury or arbitrator determines the outcome.
- Consensual processes: such as collaborative law, mediation, conciliation, or negotiation, in which the parties attempt to reach agreement.

Not all disputes, even those in which skilled intervention occurs, end in resolution.

Dispute resolution is an important requirement in international trade, including negotiation, mediation, arbitration and litigation.

Dispute Resolution: Mediation

- Goal of mediation: It is for a neutral third party to help disputants come to a consensus on their own.
- Rather than imposing a solution, a professional mediator works with the conflicting sides to explore the interests underlying their positions.
- Mediation can be effective at allowing parties to vent their feelings and fully explore their grievances.
- Working with parties together and sometimes separately, mediators can try to help them hammer out a resolution that is sustainable, voluntary, and nonbinding.

Dispute Resolution: Arbitration

- A neutral third party serves as a judge who is responsible for resolving the dispute.
- The arbitrator listens as each side argues its case and presents relevant evidence, then renders a binding decision.
- The disputants can negotiate virtually any aspect of the arbitration process, including whether lawyers will be present at the time and which standards of evidence will be used.

Dispute Resolution: Litigation

- The most familiar type of dispute resolution, civil litigation typically involves a defendant facing off against a plaintiff before either a judge or a judge and jury.
- The judge or the jury is responsible for weighing the evidence and making a ruling. The information conveyed in hearings and trials usually enters, and stays on the public record.
- Lawyers typically dominate litigation, which often ends in a settlement agreement during the pretrial period of discovery and preparation.

Mechanism for Dispute Settlement (PPA-Sec.58)

- Amicable Settlement: Any dispute arising between the Public Entity and the construction entrepreneur in connection with the implementation of the procurement contract shall be settled amicably.
- Arbitration: If the dispute could not be settled through amicable settlement, then the contract agreement should state that the dispute is settled through arbitration as per the prevailing law (Arbitration Act 2055).

Provision Relating to Dispute Resolution

- Dispute Resolution (Rule 129): A procurement contract may provide a mechanism for a resolution of dispute by stating the amicable settlement meetings and decision procedure, application procedure and subject of dispute resolution through amicable settlement as per the section 58 of the PPA 2058.
- Dispute Resolution Through Arbitration (Rule 135): If the dispute could not be resolved through the amicable settlement as per rule 129, shall initiate the proceedings of resolving such a dispute by means of an arbitration in accordance with law in force.

Dispute Settlement & Procedures (SBD)

- Amicable Settlement: The Employer and the Contractor shall attempt to settle amicably by direct negotiation any disagreement or dispute arising between them under or in connection with the Contract.
- Period to refer Arbitration: Any dispute between the Parties as to matters arising in the Contract which cannot be settled amicably within thirty (30) days after receipt by one Party of the other Party‘s request for such amicable settlement may be referred to Arbitration within 30 days after the expiration of amicable settlement period.
- Procedures of Arbitration: Arbitration shall be conducted in accordance with the arbitration procedures published by the Nepal Council of Arbitration (NEPCA) at the place as mentioned in SCC.

Arbitration Act, 2056 (1999)

- "Agreement": A written agreement reached between the concerned parties for a settlement through arbitration of any dispute concerning any specific legal issue that has arisen or may arise in the future under a contract or otherwise.
- "Dispute": A dispute which can be settled through arbitration under Arbitration Act.
- Counter-claim: means a claim made by the Respondent on the Claimants.
- "Rejoinder": A claim to the counter-claim by the Claimants.

"Arbitrator": An arbitrator appointed for the settlement of a dispute and the term also includes a panel of arbitrators

Disputes to be Settled through Arbitration (Sec.3)

- Procurement Agreement has Arbitration Clause: In case any agreement provides for the settlement of disputes through arbitration, the disputes connected with that agreement or with issues coming under that

agreement shall be settled through arbitration according to the procedure prescribed in that agreement, if any, and if not, according to this Act.
- File Price in case of concerned parties to a civil suit of a commercial nature which has been filed in a court and which may be settled through arbitration according to prevailing laws, file an application for its settlement through arbitration, such dispute shall also be settled through arbitration.

Number of Arbitrators
- Arbitrator Number/s: The number of arbitrators is as specified in the agreement. In case the agreement does not specify the number of arbitrators, there shall ordinarily be three arbitrators.
- Turn into Odd: In case the number of arbitrators appointed under the agreement is an even one, it shall be turned into an odd one by designating an additional arbitrator chosen by them.

Appointment of Arbitrator
- Appointment of Arbitrator: The process of appointing arbitrators must be started within 30 days from the date when the reason for the settlement of a dispute through arbitration arises.
- In case the agreement mentions the names of arbitrators, they themselves shall be recognized as having been appointed as arbitrators.
- Separate Provision: If agreement has made any separate provision for the appointment of arbitrators, arbitrators shall be appointed accordingly.
- Each Party to Appoint: Each party shall appoint one arbitrator each and the arbitrators shall appoint the third arbitrator who shall work as the chief arbitrator.

Appointment of Arbitrators by Court:

Appointment by Court: The circumstances:
- In case no arbitrator can be appointed upon following the procedure contained in the agreement.
- In case the agreement does not mention anything about the appointment of arbitrators.

CV Details: Must explicitly mention the full name, address, occupation and the field of specialization of at least three persons who can be appointed as arbitrator, and also be accompanied by a copy of the agreement.

Submission of Claims, Counter-Claims, objections or Rejoinders
- Submission of Claims: The claimant shall submit its claim mentioning the details of the subject-matter of the dispute and the remedy sought, along with evidence, and also supply a copy thereof to the other party within the time limit mentioned in the agreement, if any,
- If there is no time limit mentioned then within three months from the date when a dispute requiring arbitration has arisen in case only the name of the arbitration has been mentioned in the agreement without mentioning any time limit, and from the date of appointment of the arbitrator in case the arbitrator has been appointed after the dispute has arisen.
- Objection to Claim: Other party shall submit its objection to it within 30 days from the date of receipt of the claim, unless otherwise provided for in the agreement.
- Counter Claims: In case it submits a counter-claim also, the arbitrator shall provide a time limit of 15 days to claimant submit its rejoinder over such counter-claim. In case a rejoinder is so submitted a copy thereof shall be supplied to the party making the counter claim.
- Time Extension: The circumstances beyond its control, it may submit an application to the arbitrator for an extension of the time limit within 15 days from the date of expiry of the time limit, explicitly mentioning satisfactory reasons for its failure to do so. The arbitrator may, if he/she finds the reasons mentioned in the application to be satisfactory, extend the time limit for not more than seven days.
- Documents in Full: While submitting claims, counter-claims, objections or rejoinders all documents, as well as evidence substantiating them, if any, shall also be submitted.
- Copies to Other Party: Each party submitting documents to the arbitrator in connection with arbitration proceedings shall supply copies thereof to the other party.

Power of the Arbitrator to Determine Jurisdiction (Sec 16)
- Jurisdiction: If arbitrator has no jurisdiction over the dispute which has been referred to him/her for settlement, or that the contract because of which the dispute has emerged is itself illegal or null and void, it may claim so before the arbitrator. The arbitrator shall take a decision on his/her jurisdiction or the validity or effectiveness of the contract before starting the proceeding on the matter referred to him/her.
- Time of Appeal to Court: Any party is not satisfied with the decision taken may file an appeal with the Appellate Court within 30 days from the date of decision, and the decision taken by that court on the matter shall be final.

Arbitrators to Follow Substantive Law
- The Nepal Law shall be the substantive law to be followed by the arbitrator, except when otherwise provided for in the agreement.

- The arbitrator may settle the dispute according to the *principle of justice and conscience* (Ex aqua et bono) or *natural justice* (amiable compositor) only when explicitly authorized by the parties to do so.
- The arbitrator shall settle the dispute according to the conditions stipulated in the concerned contract.
- Arbitrator shall also pay attention to the commercial usages applicable to the concerned transaction.

Arbitrators Decision Time Period

- Arbitrators should take decision as provided for in the agreement.
- If time is not mentioned in the agreement, then the arbitrator shall pronounce the decision ordinarily within 120 days from the date of submission of documents (Sec 24).
- In case any issue requiring arbitration is found to be inextricably linked with any other issue on which the arbitrator cannot pronounce the decision, the arbitration shall not pronounce decision on that issue (Sec 24).
- If arbitrator cannot take a decision, the arbitration must inform the concerned parties accordingly.
- The concerned party may file a complaint to the Court within 35 days from the date of receipt of a notice as per the prevailing law.

Matters to be mentioned in Decision (Sec. 27)

- Arbitration Issues: Brief particulars of the matter referred to for arbitration.
- Jurisdiction of Arbitration: Grounds for deciding that the matter falls under the jurisdiction of arbitration.
- Reasons & Grounds of Decision: Arbitrator's decision, and reasons and grounds for reaching that decision.
- Determine the Amounts/ validate Issues: Claims which must be realized or amounts which must be compensated.
- Interest / Additional Interest: Interest on amount to be realized, and the additional rate of interest to be charged with after the expiry of the time limit for implementing the decision of the arbitrator in the event of the limit mentioned in section.
- Place and date of decision.

Decision Invalidation Circumstances (Sec. 30)

- Time of Appeal to Invalidate: Any party dissatisfied with the decision taken by the arbitrator may, if one wishes to invalidate the decision file a petition to the High (Appellate) Court along with the related documents and a copy of the decision within 35 days from the date the decision heard or notice received thereof. Petition shall also supply a copy of that petition to the arbitrator and the other party.
- Petitioners to Prove: In case a petition is filed in the High (Appellate) Court the petitioner need to prove that the arbitration decision contains matters that invalidate decision or issue an order and need to have a fresh decision be taken

Implementation of Award (Sec.31)

- Implementation Time of Decision: Concerned parties shall be under obligation to implement the award of the arbitrator within 45 days from the date when they receive a copy thereof.
- Implementation of Award by Court: In case a award cannot be implemented within the time limit as above, the concerned party may file a petition to the District Court within 30 days from the date of expiry of the time limit prescribed for that purpose to implement the award.
- In case such a petition is filed, the District Court shall implement the award ordinarily within 30 days as if it was its own judgment.

Cost of Arbitration Proceedings/ Arbitrator's Remuneration

- Fixed Amount: Parties seeking arbitration must pay to the arbitrator the amount fixed their in consultation with parties for conducting the arbitration proceedings.
- Proportionate Expenses: Each party shall bear the expenses required for the arbitration proceedings in the proportion prescribed by the arbitrator taking into account the relevant circumstances.
- Arbitrator's Remuneration: Shall be as prescribed in the agreement.
- If remuneration is not mentioned in the agreement: Concerned parties shall pay the remuneration fixed by the arbitrator in consultation with them. Paid as a full payment or advance payment.

Dispute Settlement Perspectives in Nepal

- In Nepal, the provision of arbitration was introduced in 1957, while the Development Committee Act 1956 was amended.
- The provisions were confined up to the dispute to which the Development Broad is a party to the contract.
- Real practice of dispute settlement through arbitration was stated after the enhancement of Nepal Arbitration Act 1981 (Now, Arbitration Act 1998)- This is based on UNCITRAL model law.
- Nepal has very short history of modern arbitration concept. Before enactment of the Arbitration Act 1981, arbitration was carried out through a local celebrity when it becomes necessary to settle the disputes

between the villagers and it has been in practice for a long time. Slowly business people felt necessary of a quick and cheap methodology of settling disputes and came up with arbitration proceedings.

- The new act stated that the disputes arising out of the agreement made with foreign donor agency shall be settled through arbitration, So, some examples of excessive delay up to four or five years for the settlement of disputes.
- It was felt as expensive as well as cumbersome and has adverse effect on the main purpose of arbitration.
- To solve the problems associated with arbitration and to assist in the development of adequate infrastructure, Nepal Council of Arbitration (NEPCA) was established in 1991 through initiation of non - government sector.
- It is important to understand the problem related to dispute and try to mitigation it in construction contract in the context of Nepal.

Causes for Emergence of Disputes in Nepal

- A dispute arises when a demand is made by a party and denied by the other and the contradiction is not accepted by the demanding party (either employer or contractor).
- Dispute originates due to disagreement on a decision or action taken by one party on the ground of effect to be borne by the other as consequence of the decision.
- In construction projects in all sector of development either completed or ongoing have suffered from time and cost overrun.
- A major reason for this is poor management of contract resulting in disputes leading to intermittent stoppage of works or slow progress or even abandonment of work requiring fresh call of tenders to engage a new contractor for execution.

Major Causes of Disputes in Nepal (Road Project/s)

Generally: four areas of disputes- contract document, force measure, timely action, and project characteristics

- Change of material Source
- Inadequate design and site information
- Commencement and Delay information
- Unforeseen physical / Site condition resulting to variation
- Strikes, Bandh, Riot (disturbance) or Disorder
- Delay in decision making and settlement of dispute
- Possession of site and Access to site
- Unusual weather condition and Inflation
- Unavailability of fuel and Construction material

Problematic Areas for the claim and disputes

- Engineer doesn't work impartial and do not fulfill their responsibility promptly.
- Contractors generally do not fulfill or are reluctant to perform contractual obligations.
- Employers are not prompt in decision making for any problems.
- Employers are not very serious toward fulfillment of their contractual obligation.
- Incorrect and inconsistent Drawing.

Dispute/ Claims Resolution Practices in Nepal

- Due to small size of construction industry of Nepal, the problems associated with disputes are not so similar to developed countries.
- A common problem generally found in Nepalese context is launching many claims but abandoned at last.
- Main reason of such abandonment is due to Employer dominated contact documents, Contractor's right minimally protected and low level of knowledge regarding contractual rights and obligation among the contracting parties.
- Neither employer nor contractor gives adequate attention about status of contract documents before entering into the contract Which, generates adequate ground to gives rise of many problems during contract execution.
- Due to no adequate provision incorporated in contract to tackle the probable situation liable to dispute, its resolution seems very difficult.
- Party-initiating disputes, a contractor has only two options these are:
  - Abandon the claims or disputes or
  - Go to litigation in court.
- Court Process being contractor is compelled to choose former one other very time consuming wise he suffers of payment delay of due amount.
- The main reason of delay was improper provision of disputes resolution in contract clause.
- The clause prevented to enter into arbitration process unless the work is completed.

Recommendation to Reduce Disputes in Nepal

- Proper Site Investigation: Claims arising from unforeseen physical conditions can be reduced by comprehensive site investigation during the phase of details design preparation.
- Risk and Budget: The employer / executing agency should prepare to bear all risk and allocate with add proper budget in contingencies for the issues arises from disputes / claims.
- Realistic BoQ & Periods: Consultants (i.e., Engineer) should ensure that BOQ and contract periods, which specified in the bid documents, are realistic and take account of existing site conditions.
- Facilitate regular execution work and make prompt decisions: Consultants (i.e., Engineer) should provide any information with corrected drawings timely on site to facilitate regular execution work and make prompt decisions regarding the technical and contractual issues by taking employer approval where necessary in specified time as required.
- Organize a kick off meeting: Consultants (i.e., Engineer) should organize a kick off meeting with contractors to confirm material availability, constructability and other constraints flagged up by contractors before their site mobilization.
- Better to establish a dispute settlement unit should be established to amicably (negotiation) settle any disputes before referring to contractual authority.
- Regular Management and Site Meetings involving employer, engineer and contractor. The time periods may be once a week, two weekly or monthly meetings among them.
- Recording of every minute of meeting and issues for the future reference regarding EoT, Price Adjustment, determine compensating events and even force majeure etc.
- Strictly adhere the Work Schedule and make contract administrator / coordinator responsible for non-performing of contract and punishing the contractor as per agreement.

Value Engineering
Introduction / Definition:

Value Engineering is defined as a systematic application of recognized techniques, knowledge and skills to identify the function of a project, product, service or a process to improve performance, quality and for life-cycle cost thereby establishing a "true worth" for that function It aims at generating alternatives through the use of creative thinking, providing the needed functions, reliably, at the lowest possible overall cost. It deals with optimization of the available resources for helping "good" be better" The value engineering / analysis system is constituted of the following components:

- An organized review" to improve value by using a multi-displined team of specialists knowing various concepts of the problem being studied.
- A function-oriented approach" to identify & analyse" the essential functions of a system product or service being studied and the cost associated therein.
- Creative thinking using recognized techniques to explore alternative ways of performing the functions at a lower cost or to otherwise improve the design.
- "Judgment thinking" finally to arrive at a final decision as to how proceedings can be done for the optimized use of the functions.

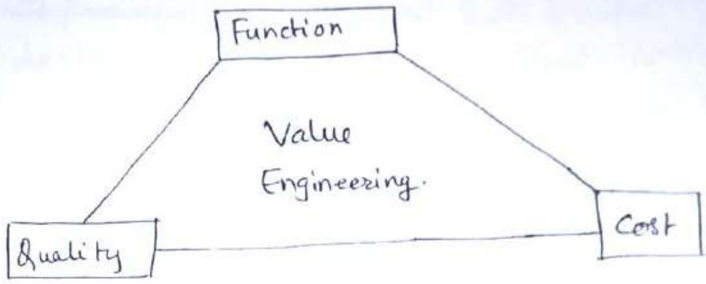
Thus, value engineering needs to provide at least showing three functions:
Co-corporate level leadership for implementation, A cohesive approach to UE initiation and integration,
- Centralized accountability to achieve these functions, it requires:
- Preparing policies and procedures, Training staffs / motivating them for the best, - Creating program visibility and aware
- Developing proposals for identified project opportunities,
- Reporting the efforts of the program,
- Quantifying the results and the benefits,
- Recognizing success.

Value engineering is predicated to the fact that people spend their money to accomplish functions rather than simply to obtain the ownership of it. These multidimensional functional needs of the people must be carefully and independently anodized so that they can be obtained in a most economical manner with minimal disturbance to the environment.

What value Engineering isn't?

Value engineering is not just good engineering. It is not a suggestion program and it is not routine project or plan review. It is not typical cost reduction in that it doesn't "Cheapen" the product/service nor does it "cut comers" Value Engineering simply answers the question "what he will accomplish the purpose

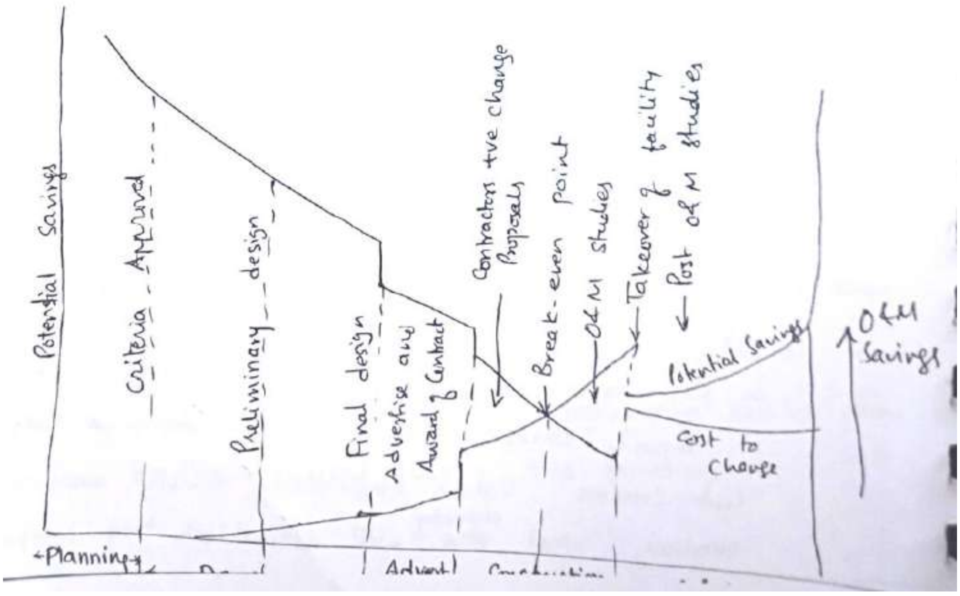
Thus VE is a balance between function, quality and cost



$$\text{Best Value}_{\text{worth}} = \frac{\text{Function} + \text{Performance} + \text{Quality}}{\text{Cost}}$$

The functions, performance and quality must meet owner's minimum requirements.

Q. When to apply Value Engineering for Maximum Saving??
Ans: During Planning phase (see fig):



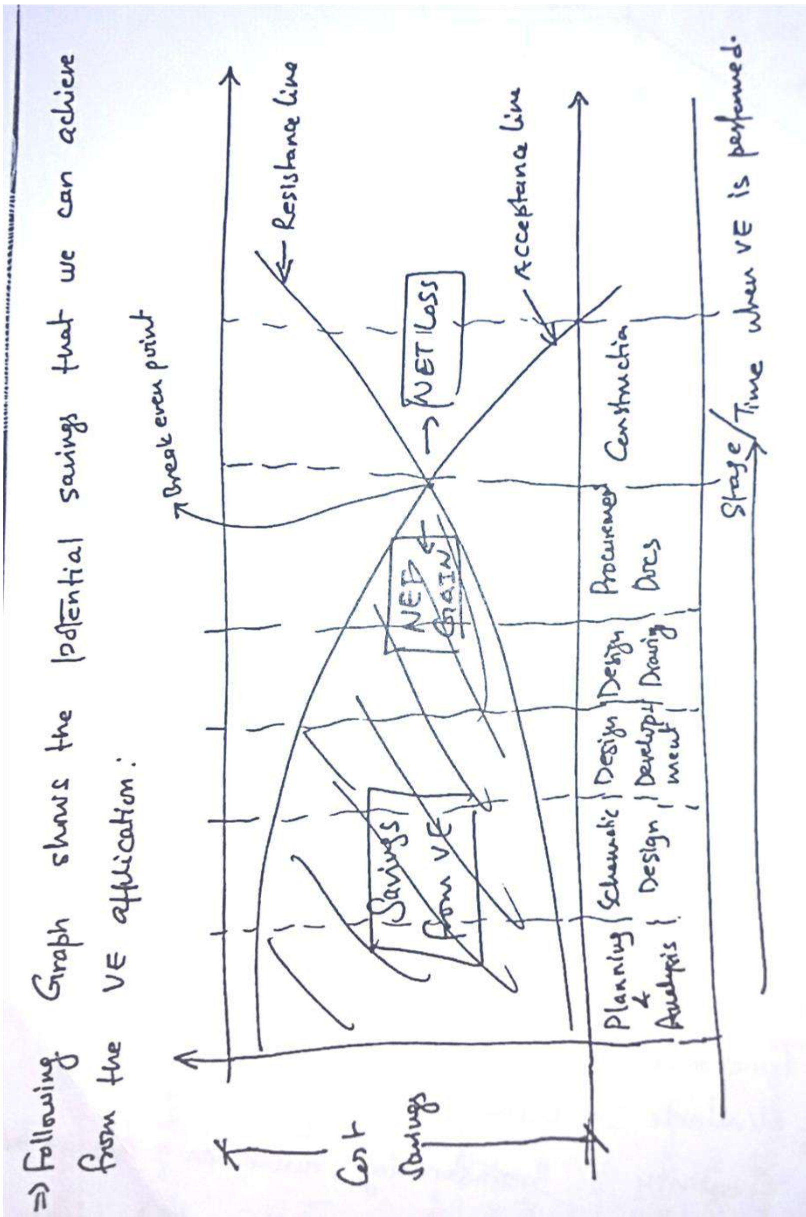
Flow chart of Job plan for VE

Job Plan

Phase 1	Information ↓
Phase 2	Function Analysis Phase ↓
Phone 3	Creativity Phase ↓
Phase 4	Evaluation ↓
Phase 5	Development Phase ↓
Phase 6	Presentation phase ↓

Phan-1: Information Plan: Project familiarization, true needs of the project determined, area of high cost Low worth are identified.

Phase-2: Functional Analysis: Review, analyze, improve eliminate or create Phone-3: Creativity : Brainstorming association of creative proposals
Phare-4: Evaluation : Evaluating & selecting best ideas.
Phase-5: Development Alternative designs, comparisons, summaries.
Phase-6: Presentation Repost with necessary elements for implementation.



Causes of Poor Value/Roadblocks to cost effectiveness:

The practice of VE doesn't imply that there may be intentional gold plating, conscious neglect of responsibility, or unjustifiable error/oversight by the design team. VE simply recognizes that social, psychological and economic conditions of that may inhibit good value. Following is some of the common reasons of poor value: -

- Lack of information usually caused by shortage of time. Too many decisions based on feelings rather than facts.
- Wrong beliefs, insensitivity to public needs or unfortunate experience with similar products I processes used in unrelated prior applications,
- Habitual thinking rigid application a standards, atoms and tradition without consideration a changing function, technology and value.
- Risk of personal loss, the ease and safety experienced in adherence to established procedures and policy.
- Reluctance to seek advice, failure to admit ignorance of certain specialized aspects of project development.
- Negative attitudes, failure to recognize creative innovativeness,
- Over specifying for unnecessary tolerances & fine finishes where they are not required.
- Poor human relations, lack of good communication, misunderstanding, jealoury and normal unnecessary fiction between people which usually maximizes unnecessary cost.

Regarding Bridge failures:
-DoR undertakes almost 3000 bridges, 2200 of them in SrN and 800 in LRN.

Major Problems:
- Approach Road and River Training works failure in Completed and undergoing bridges.
- Foundation failure in Completed of undergoing bridges,
- Skying/false works failure a bridges undergoing const" of the superstructure,
- Others.

To study about the major problems and find rectification Strategy for has recently formed a Committee under the leadership & DOG, Bridge Branch along with other Superintendent Engineers & Divisional Engineers. The report is however yet to come best so far as our experience is construction following things should be taken under construction.

1. Allow almost natural water flow in all the Spans, don't allow debris to accumulate Constricting the river flow has impacted in additional scour and temporary supports to the staying (false/work gets washed away, the bridge gets collapsed. Never block river fully for false work.

2. Don't conduct works of superstructures after Baisakh. If unavoidable take datas from Department of Hydrology & Metrology & work accordingly,

3) Make design approved person of false workers mandatory.
4) Department of roads has entered into the advanced technology for bridges including Nature Arch Bridge, Suspension Bridge, Arch Bridge, Continuous phrases Bridge, Integral Bridge et. for which our manpower's are not sufficient trained. Experts should be hired to train them.
5) Contractors are seen to undertake construction worker at any time. so 1 bridge I Engineer policy is mandatory for this DoR Capacity may not be sufficient. A such
engineers should be hired, trained and deployed.
6) Tests Compliance according to QAP
7. Giving preference to well foundation for deep foundation design as pile foundations are being undergoing uncertainties during construction Norms for full casing to be approved 8 for file foundation.
8. Proper study of Catchment Area to observe debris 1 flow which impacts hugely in bridge design.
9. Designs to be adopted considering Climate charge. Eg: Melamchi & Manang floods, the discharge į which can't he predicted by conventional Hydrology studies
10. Hydrology studies are not realistic. Empirical formulae o have been derived from the machior of other countries which doesn't give realistic datas. for Nepal should coordinate with water and Energy Commission Secretariat (WECS) to develop Manuals and Guidelines to find out waterway scourdopth etc. in care of Nepal.
11. In Design of Build projects, complicated Designs are put o forward. To approve such bridges, a panel of experts should review their design prier to approval like in other countries.
12. In specialized bridges, provision should be made such that p a contractor won't be able to undertake on the certain number of bridges only. Aft without finishing such
13. Rewards & bonus system for Contractors completing bridges IP before due date should be institutionalized.
14) Consultants to be made more responsible. For the Geotechs, Structural Engineers, Hydrologists Civil Engineers whose names are mentioned in the report, their presence to be made mandatory during presentation of design approval.

Three Sub Heads:
1. Design related
2. Work Processing & execution
3. False work related

Kathmandu - Terai Madhesh fast Track (KTFT-RP)
It's a Mega Highway project prioritized as a "National hide Project haring Strategic Significance.
- Handed over to the Nepal Army by GON, MOPIT officially on 27th Shrawan 2074

DPR & Alignment:
The DPR & LIFF RP was prepared by soosung Engineering Co.ltd South Korea Co. ltd South korea and was approved on pit Bhadra 2016 by GoN

Alignment Details:

Total length = 72-5 km
kathmandu = 3.9 km
Lalitpur = 6.9 km
Makawanpura = 55.7 km
Bara =6 km
Total = 72.5 kun

- Originates at Sano Khokana , travels through Chhaimale, Gausel, Malta, Budune, Chhatiwan and reaches Niggadh to connect Mahendra Highway.
- Shortens the travelling distance by 193 kms and saves the travelling time by 4 hours or more.

Progress:

- Land Acquisition works 90.77%
- Forest Clearance works - 94 %.
- Track all opened
- Physical progress - Almost 12%
- Financial progress Almost 10%:

Salient features Summary:

Road Category - Asian Highway Class A.
Total length 272-5 kms
Carriageway - 4 lane divided Carriageway, width 3.75m
-2 lane Carriage way (2.9 kus)
- Tunnel 2 lane Carriageway

Formation Width - Plains Rolling ~ 27m
- Hill & Mountain 25m

Row - 50m for 0+000 to 9+000
- 100m for 9+000 to 72+507

Bridges width = 11.30m total

Total length = 72.507 m.
~ Total Roadway length = 55.50 km.
~ Total Tunnel length = 6-41 km

Tunnel -1 @ Mahadev Dada = 3.355 km
Tunnel -2 @ Dhedre Dada = 1.63 km
Tunnel -3 @ Lane Dada = 1.43 km

Clear width = 9.5m, clear Height = 55m
Total Bridge Nos = 87
Major Bridges =49
Special =16
Minor = 22
Total Bridge length = 10.596 kms

Hulaki foruanga (National pride)

- loads that connect Terai - Madhesh Region
Tolal length = 1857.42 km.
E/W length =975 km
Other service wads = 882.42 km

747.26 km Blactopped
610 km under construction

Total no of bridges = 250
Under Construction = 72.00
Completed = 101

Under design Approval = 70

Project offices: - 6 Nos.

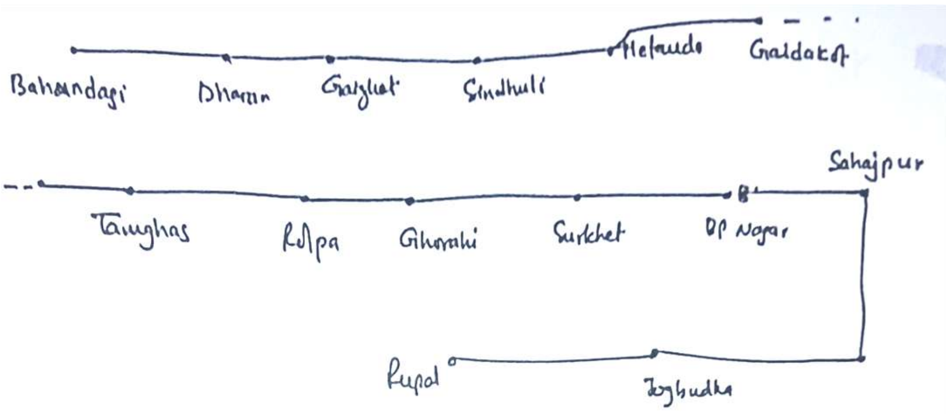
P. office at Itahari
P. office at Janakpur
P. office at Birgunj
P. office at kapilvastu
P. office at Nepalgunj
P. office at Nepalgunj
P. office at Dhangadhi

- Estimated cast = 65 Arab 20 gr.
Progress Till Date = 68%

→ Problems:
cow Budgeting
- EEA at Reserves

Madan Bhandari Highway

NH-09



- Total length = 1382 kms
Priject offices at
- Damak, Jhapa
- Gaighat, udaypur
- Hetauda, Makawanpur
- Tamghas, Gulmi

Other are looked after by division offices.

Mid hill Highway:
Started in P.Y. 2064/65 with an amim to complete or before F.Y. 2073/74
Total length 14.17km, Bridges =137
Revised target to complete the project within 2079/80
From the date 2075/9/1, five mill hill project directions was formed and 5 major offices were established at:

- Panch thar,
- Kavrepalanchok
- Gorkha
- Parbat and
- Dailekh

- Project cost = 84 Arab 33 Crores

- Proven till date = 63%
- Blacktopped a 651 km,
Bridges Completed = 90 us.
- Alignment: Salient points a under following projects
1) Panchthar = chinobhanjyang ,- Basantapur - Hile-leguwaghat
2) kaure = Diktel - Ghermi - Sindhuli - Dolalghat
3) Gorkha : Patibhanjyang - Arughat - Palungtar - Bherletar
4) Passat - Yamdi - Naya Pul - Bustibang
5) Dailetch in Patihalne (Rukum) - Sengaun - keskeisann – Lahore - lamghat Dailekh. - Achham - Doti -Baitadi (Jhulaghat)

Nagdhunga Tunnel:
Nanganghat Mungling. Nauluse Anythinga - kathmandu, the main head that conneel mayor cities places of Nepal with Kathmandu.
With aim to construct tunnel eusinal put forward from MapIT, Dose to the ministing show based in different survey Conducted betureen 2013, February to March 2015
- Censhuction of this tunnel is expected to ease the entry relides in the very clumsy and from Nauhise to Thankot (Nagdhunga)

Components of the project:
Tunnel of total length 2.18 km with
- ~ Double lane Carriageway, with width of 3.50 m/lane
- One Rumble strip lane of 1.5m
- 0.5m wise with longitudinal Drainage facility (side Drain) on either side.

• Approach road ~ 2.32 km east ~0.565 km west
• Fast portal & west portal
• 3 bridges 2 underpasses 1 overpass
• 1 flyover being constructed in Nepal for the first time.
• 24 hrs running toll stations at both ends.
• 24 hrs ventilation system & lighting system

Emergency Rescue System : To facilitate the entry to main and in case of any emergency within 7 minutes an evacuation tunnel is constructed. It is connected to main tunnel @ Spacing & 375m through Cross passage.

Funding:
- From Government of Nepal through JICA (soft Loan) approved on December 2016.
- Total Cost = 20.6 Arab out of which
~ JICA Funding = 15-8 Arab
~ Grow Funding = 4.8 Arab

Consultants: To carry out Detailed Design Contractor evaluation & selection, Construction Supervision; work execletion etc. DoR, DCID has appointed (selected the consultant IV NK-EJEC-NCC in association with GEOLE 4 ITECO-Nepal

Contractors.
- Hojma 4 Corporation Japan
- Contract Agreement : September 2019
- One date of Completion : April 2023 (42 month)

Work progress: main works
- Drilling & blasting being degree for tunnelling works:
- West Portal:
- Working audit tunnel-120m
- Main tunnel -194m
- Evaluation tunnel -204m

East Portal:
- Main tunnel -109m
- Evaluation tunnel -378m

Problems:

- Covid-19 Pandemic
- Land Acquistim issues at east portal are, Balambu and chandragiri are.

N-S Condors:
1. koshi Corridor
- khandban - kimathanlca =162 km
- 2065/66 ~ 2080/81
- cast 16.20 Arab
- Progress = 24 %

2.) Kalijanda ki consider
a) Gaidakot - Lampun - Pipaldada - Ramdi- Maldhunga
(length = 245 km)
- 66 /67 to 80/81
-cost = 20∆2 Arab.
- Progress - 27.5%

b.) Beni - Jonson -kordla = 199 km.
- 2073/74 to 79/80
- cost = 6.78 Arab
- Project = 70%

3.) Kanali Conidor :
Hilsa - simikot – Salisalla = 145 km
2069/70 to 2079/80
Cost = 4:10 Arab
Progress = 28%

N-S Corridor

With on immense need of developing equilibrium in infer and export of Nepal between India and China, developing of the N-S corridors has got high priority Cogently. Due to monopoly of India boarders located in Terai Region over the Nepalese economy, India have been being haugh at some moment causing the blockades and all. This leads to the importance opening and upgrade of all routes possible to link Nepal with China for creating an environment of economical equilibrium and competition as well along with need of friendly environment with China that needs to be depends.

Objective:

- Developing the status of the regions lying in the neighborhood of the various identified alignment in terms of economy, social, cultural, political, tourism, educational aspects.
- Overall development in equilibrium
- Creating trade routes with china
- Providing transport facilities for the people lying in the extreme (remote north of Nepal)

Identified routes along N-S corridor:
a) Projects of National Importance (P_1)
Route 1

- Nawalparasi (Gaidakot)- Palpa (Ramdi)- Gulmi (Ridi)
- Baglung (Palung)- Mustang boarder (Korola)
- 435 km total length, track opened- 303 km

Route 2

- Baglung and Gulmi Section
- Total length of 76 km track opened by Nepal Army
- Total cost including revision = Rs. 2530.46 crores

2.) Karnali Corridor
Route 1

- Khulalu - Simikot (200km), work ongoing by Nepal Army

Route - 2

- Hilsa (Tibet Bosder) - Simikot (88 km), DOR

- Total Cost including Revision = Rs. 410.30 Cores

3.) Koshi Corridor

- Sankhuwasabha (Basantapur) - kimathanka (Tibet Boarder) out of total 162 km length, 77 km track opened.
- Total Cost including Revision = Rs. 205.93 Crores.

b) Other Ongoing Projects (P2) :

1. Tamakoshi-Lama bagar - China Border,
2. Jiri - Salleri - Tingri (Tibet),
3. Taplejung - olangchungola
4. Nyakhelagna - Lagna - Tibet Border (Mugal)
5. Nalyang Bhanjyang - Chhekampa - Chumchet - Sirdiba
6. limilapcha - sinikot.

7 Saljhandia Sandhikharka - Dhorpatan

There is an immense need to upgrade the following road return works at the earliest which are damaged by earthquake

1. Sindhupalchowk – Tatopani Border
2. Nuwakot - kerung
3. 11 kilo chhepetar - warpak – Tibet Border

Challenges

1. Conflicts in compensation /land acquisition along the alignment,
2. Lack of construction materials,
3. Due to geographical situation, cold climate only & months are Available for work,
4. Lack & Blasting materials, need of presence of Nepal Any during blasting operations takes time,
5. Low bidding Contractor's Bid Capacity evaluation problems,
6. Lack of transportation vehicles for good supervision
7. Lack of technical manpower.

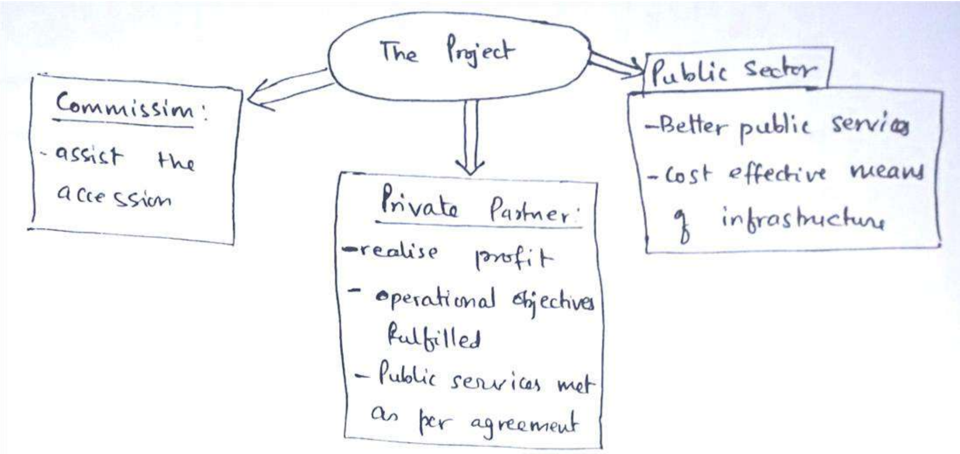
Public Partnership (PPP)

Recent years have seen a marked increase in cooperation between he public and private sectors for the development of and operation o a wide range of economic activities in the field of environment, and several other fields. Such a partnership in economic development activities between public and private sector is referred The PPP concept was driven by the limitations in tout stands to cover investment needs along with the effects to the quality and efficiency public services. The principal roles a private sector in PPP schemes were assumed to be to provide:

- Additional capital,
- Alternative management and implementation skills,
- value added to the consumer and the public at large,
- Better identification of needs and optimal use of resource.

Success a ppp projects, the increasing availability of private sector funds able to adopt a high risk profile and a generalized global trend to privatize utilities has resulted in attempts to introduce the PPP concept in transforming economies of various countries worldwide. This is because of

- an enormous financing requirement in infrastructure development sector to upgrade and entered network for effective public service.
- Large financial shortage in available public funds and ability of donors to cover costs which needs additional funding resources.
-



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- Fig.: PPP Relationship

-
- **Advantages of ppp:**
- 1) Acceleration of infrastructure provision ,
- 2) faster implementation,
- 3) Reduced whole life cycle costs,
- 4) Better risk allocation ,
- 5) Better incentives to perform,
- 6) Improved Quality of services,
- 7) Generation of additional revenues,
- 8) Enhanced public management,
- 9) Enhanced economic growth
- 10. Greater efficiency in the use of limited resources
- 11) Generating commercial value from public sector assets

Forms/Types of PPP:
A ppp is a partnership between the public sector and private sector for the propose of delivering a project or a service traditionally provided by the public sector. Appropriately constructed and designed ppp schemes can thus generate substantial benefits for consumers and taxpayers.

It should however, be understood that ppp process is extremely dynamic and that the particulars of most arrangements ae tailored to the specific circumstances involved. Ppps thus recognize that both parties have certain advantage relative to the other in the performance of specific tasks. By allowing each sector to do what it does best, public services and infrastructures can be movided in the must affective and economical manner. There can therefore, be no 'one geraic' or 'best' model of ppp structure nor does the commissioning of individuals structures.

The various models er types of PPP are:
1. Traditional public sector Procurement
   - Design a Build
   - Design on Bid Build
2. Build operate - Trans for (BOT)
   - "Turnkey Delivery
   - " Design - Build- operate - transfer
3. Design build- Finance – Operate (DBFO) concession:
   - Build~ own~ operate~ Transfer (Boot)
   - Boot Concession
   - maintenance concession
4. Build – own – operate (BOO)
   - Divestiture (share of public assets to private sector)
   - Asset capitalization

Choice of a model and Its effectiveness depends on:
1. Adequate legal provisions, policies
2. Open market Access
   - Fair and open participation with equal treatment

- Transparent public procurement procedures
- Application of public procurement directives

3. Adherence to principles:
   - no over compensation
   - Grants matched to real needs
4. Protection of public interests
   - Quality service delivery ~ Justified value for money
   -Public participation ~ employment, socio-econ. Dev.
   - Re-negotiate/re-balance contracts.
5. Define optimum level of grant financing
   - Grants method to real needs – maximize use of limited funds,
   - do not distort market operation etc.

Considerations for a Successful ppp

1. Legal & Policy level Considerations:

- Separate sale of laws & regulations for separates types of procurement methods
- Land Acquisition policies
- Financial policies for Capital grant, revenue, fax incenting, foreign exchange, Loon guarantee, performance guarantee
- Contractual policy like relief in force Measure, Equity participation Concession/ Contract Agreements

2.) Institutional & structural considerations:

- Develop systems & structures to reduce complexity
- Ensure that the structures are manageable by size and complexity,
- Develop effective Institutional & regulatory structures

3.) The Conceptual Considerations:

- Recognize and Understand objectives
- Ensure that a full Understanding of the timing is achieved.
- Access skills and expertise of public sector to develop and implement ppp, integrating private sector expertise if needed.

4.) Procedural considerations:

- select PPP most suitable for the local settings & project characteristics.
- Ensure additional value of money over traditional practices to maximize
- benefits for both public & private sectors
- Include public participation in monitoring / over sighting functions.
- Develop trust between all parties for effective participation.

This PPP project cycle goes through following stages:

1.) Preliminary Stage:

- Policy preparation, Institutional Arrangements, Experience Analysis
- Prepare National I local legislative & regulatory structures.

2.) Project Identification: (- suitability Assessment)

- -Cots and benefits, desired gains
- Private sector interest analysed,
- True cost of services estimated,
- obstacles and constraints (if any),

3.) Project appraisal :

- Select PPP type & define PPP structure
- Need assessments, expectations
- PPP components
- Budgeting, Risk allocation,

4) Design of Agreement:

- Integration of PPP into design,
- Select procurement procedure and design,
- agreement of National Authorities and funders,
- Financial and sector economic appraisal

5.) Procurement:

- Tender, evaluation, negotiation, contracting
- open and transparent process,
- Detailed recording.

6) Implementation:

- Effective implementation structures for construction, operation, Monitoring, Evaluation & Contract management,
- Effective working relationships.

Also, for effective implementation & PPP, legal and regulatory measures shall be enforced by government to support the successful execution of ppp in:
- Land Acquisition
- Capital grant and other support,
- Revenue guarantee
- foreign Exchange
- Tax incentives,
- Loan guarantee,
- Relief in force majeure
- Equity participation
- Performance guarantee
- legal instruments
- statutory rules,
- Concession / Contract Agreements.

Definitions of QA and QC
- **Quality Assurance (QA)** refers to the process used to create the deliverables, and can be performed by a manager, client, or even a third-party reviewer. Examples of quality assurance include process checklists project audits and methodology and standards development.
- **Quality Control (QC)** refers to quality related activities associated with the creation of project deliverables. Quality control is used to verify that deliverables are of acceptable quality and that they are complete and correct. Examples of quality control activities include inspection, deliverable peer reviews and the testing process.
- **Quality control** is about adherence to requirements. Quality assurance is generic and does not concern the specific requirements of the product being developed **Quality assurance** activities are determined before production work begins and these activities are performed while the product is being developed. In contrast, Quality control activities are performed after the product is developed.

Comparison chart

Parameters	Quality Assurance	Quality Control
Definition	QA is a set of activities for ensuring quality in the processes by which products are developed.	QC is a set of activities for ensuring quality in products. The activities focus on identifying defects in the actual products produced
Focus on	QA aims to prevent defects with a focus on the process used to Make the product. It is a proactive quality process.	QC aims to identify (and correct) defects in the finished product. Quality control, therefore, is a reactive process.
Goal	The goal of QA is to improve development and test processes so that defects do not arise when the product is being developed**.**	The goal of QC is to identify defects after a product is developed and before it's released.
How	Establish a good quality management system and the assessment of its adequacy. Periodic conformance audits of the operations of the system.	Finding & eliminating sources of quality problems through tools & equipment so that customer's requirements are continually met.
What	Prevention of quality problems through planned and systematic activities including documentation.	The activities or techniques used to achieve and maintain the product quality, process and service.
Responsibility	Everyone on the team involved in developing the product is responsible for quality assurance.	Quality control is usually the responsibility of a specific team that tests the product for defects.

Example	Verification is an example of QA	Validation/Software Testing is an example of QC
Statistical Techniques	Statistical Tools & Techniques can be applied in both QA & QC. When they are applied to processes (process inputs & operational parameters), they are called Statistical Process Control (SPC); & It becomes the part of QA	When statistical tools & techniques are applied to finished products (process outputs), they are called as Statistical Quality Control (SQC) & comes under QC
As a tool	QA is a managerial tool	QC is a corrective tool

Road Assets Management:
Road Transportation system ensure mobility access to social life enabling integration because their performance is essential for all citizens to have a quality life along with economic competitively and sustainable development.

Read Assets Management is this process of keeping not only the loads but all the subordinating, suffering & ancillary structures intact envying safe, easy, economical & comfortable serviceability, of road infrastructures at all times. As such it is said that " Read Asset Management is a permanent process". It goes through the following steps:

- Establish a complete inventory of all road networks with all its elements
- Provide a clear picture of the current condition / performance of a load network,
- Conduct regular surveys to predict future demand of traffic and service needs
- Estimate the current valuation of all Road Assets.
- Estimate maintenance needs and costs
- Prioritize objectives related to desired quality and performance of read network
- Set up funding resources for regularly and timely maintenance and/or upgrading of Road Assets,
- Develop a sustainable road's policy and innovation in research and innovation.
- Implement coherent and balanced policy for preservation of road asset at all levels.
- Define a strategy for the implementation of RAM plan.

Road Asset Management System CRAMS):
Road transportation system ensure mobility, access to social life enabling integration because their performance is essential for all citizens to have a quality life along with economic competitiveness and sustainable development.

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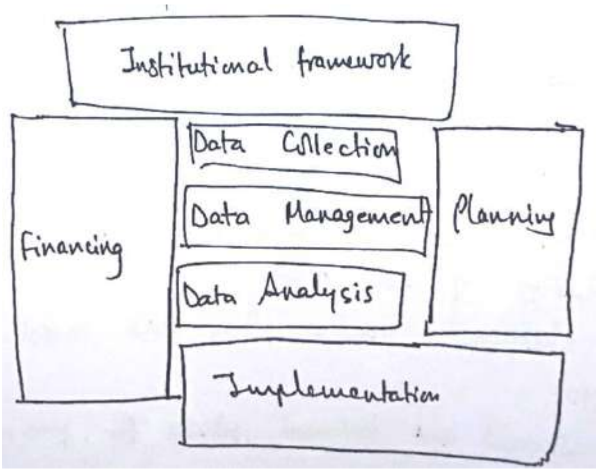
- Estimate maintenance needs and costs.
- Prioritize objectives related to desired quality and performance of road network.
- Set up funding resources for regularly and timely maintenance and/or upgrading of road assets.
- Develop a sustainable road's policy and invest in research and innovation.
- Implementation coherent and balanced policies for preservation of road asset at all levels.
- Define a strategy for the implementation of RAM plan.

Road Assets management System (RAMS):
RAMS is considered to include any system that is used to cs/leet, stare, analyse & process the road and bridge inventory Condition, traffic related data for road planning and programming purposes. RAMS includes:

- Data collection :collection of unchangeable data like road surface, alignment, topography etc and variables like road condition, traffic etc.
- Data Management: Avails all the collected data together for planning & monitoring.
- Data Analysis: Optimization of collection to result required funding allocation.

following are the entities required:
- Institutional framework
- financing
- Planning
- Implementation



RAM

Following are considered as best practices in introducing and developing road assets management:

1. Limit the data to be collected:
    - collect only what is required at an appropriate level g accuracy,
    - Ensure data is in a correct format & reliable.
    - Introduce proper quality control procedures,

2. Make the database easy to use
    - Easy to use & understand the well-structured data.
3. Start with a simple software,
4. Institutionalize from start
5 Publish Annual Performance Statistics,
6. Integrate into decision making process,
7. Provide sufficient and predictable funding,
8. Separate management from implementation,
9. Ensure high a level support,
10. Continue development Support "Develop the works, implementation Capacity,

Chapter 9 Convention and Implementation

NEPAL'S CONNECTIVITY WITH NEIGHBOURING COUNTRIES

WHAT ARE PARAMETERS OF CONNECTIVITY

- **Road/ Rail**
- **Waterways (including inland water)**
- **Air connectivity**
- **Transmission lines, energy grids, energy trading, energy market**
- **Information Highways, ICT, Optical Fiber networks**
- **Oil and Gas pipelines**
- **Soft connectivity- policies and agreements**

CONNECTIVITY ALSO INCLUDES

- **Economic Corridors**
- **Trade and investment zones**
- **Policy harmonization**
- **Regional economic integration**
- **People-to-people connectivity, cross-border movement, tourism**

CATEGORIES OF CONNECTIVITY

- **Hard connectivity-** infrastructure (road, rail, transmission lines, optical fiber, pipelines, waterways, air connectivity etc.)
- **Soft connectivity-** agreements (e.g. trade, transit and transport agreements), policy harmonization, **customs cooperation, and other border procedure, movement of people etc., enabling institutions etc.**

IMPORTANCE OF CONNECTIVITY

- Improves economic integration
- Facilitates trade, transit and investment
- Boosts tourism
- Increases opportunities for business
- Enhances people-to-people contacts
- Enhances competitiveness in trade and investment
- Contribution to environmental, food and energy security
- Contributes to inclusive economic growth

LEVELS OF CONNECTIVITY

- Bilateral
- Sub-regional
- Regional
- Inter-regional e.g., Asia-Pacific

CONNECTIVITY WITH INDIA

- Open border, many customs points
- Integrated border check-points
- Oil and gas pipelines
- ICT connectivity (optical fiber connection)
- Transmission lines: Dhalkebar-Muzafarfur line (140 km), Butwal-Gorakhpur transmission line (135 km proposed)- under MCC
- Air connectivity
- Modi's "HIT formula"/ faded
- Proposals for railway extension to border cities/ KTM-Raxaul

CONNECTIVITY WITH CHINA

- **Agreement for Trans-Himalayan Multidimensional Connectivity (road, rail, air transmission lines, optical fiber network, etc.)**
- **Transit Agreement and its Protocol – ports and points for transit: 6 border points , 4 sea ports (Tianjin, Shenzhen, Lianyungang and Zhanjiang) , 3 land ports (Lanzhou, Lhasa and Xigatse)**
- **Proposals for railway extension**
- **Proposal for road extension and tunnels**
- **Flights to and from China**
- **BRI- also a connectivity blueprint/ opportunity for missing links**

OPPORTUNITIES AVAILABLE UNDER THE BELT AND ROAD INITIATIVE (BRI)

- BRI will “help meet infrastructure gaps, connect countries supply and value chain, increase in trade and employment and boosting economic growth”- IMF
- Fund for infrastructure projects / banks and institutions
- Opening up of markets
- Connectivity
- More investment
- Economic integration
- People-to-people contacts

FACTORS AFFECTING THE SUCCESS OF THE BRI

- Strategic objectives versus economic objectives
- Superpower rivalry/ Strategic competition
- Uncertainty of cooperative international environment
- Political controversy and backlash (e.g. Malaysia)
- Hype of the “debt trap”
- Delay in project selection / implementation

ISSUES TO BE CONSIDERED UNDER BRI PROJECTS

- Economic viability, not political preference for project selection
- Complementarity with other initiatives
- Debt sustainability
- Transparency
- Focus on missing links
- Using transformative opportunity/not fear

SAARC CONNECTIVITY

- SAFTA
- SATIS
- SAARC Investment agreement (proposed)
- SAARC Multi-modal transport study
- SAARC Regional Transport Agreement (proposed)
- SAARC Framework Agreement for Energy Cooperation (2018)
- People-to-people contacts

MULTI-MODAL TRANSPORT AND CONNECTIVITY

- SAARC Regional Multi-modal Transport Study (2006)
- 10 regional road corridors, including
- Karachi-Lahore-New Delhi-Nepalgunj-Kathmandu (3,147 km)
- Kathmandu-Kakarbhitta-Phulbari-Banglabandh-Dhaka-Chittagong or Mongla (1,442 km)
- Kathmandu-Kakarbhitta-Phuentsoling-Thimpu (1.011 km)

- Kathmandu-Birgunj- Kolkata-Haldia (1,323 km)
- Kathmandu-Bhairahawa-Sunauli Lucknow

MULTI-MODAL TRANSPORT AND CONNECTIVITY

- SAARC Regional Multi-modal Transport Study (2006)
- 5 regional rail corridors including: Brigunj-Raxaul-Kolkata-Haldia, Birgunj-Raxaul-Katihar-Rohapur-Chttgong with links to Jogbani
- 2 regional inland waterway corridors
- 10 maritime gateways
- **16 aviation gateways**

REGIONAL INITIATIVES AND CONNECTIVITY NETWORKS.

- Bangladesh-China-India-Myanmar (BCIM) Corridor
- China-Pakistan Economic Corridor (CPEC)
- Bangladesh-Bhutan-India-Nepal (BBIN) –transport agreement, South Asia Sub-Regional Economic Cooperation (SASEC)
- BIMSTEC Transport Infrastructure and Logistics Study (2009)
- Asian Highway, Trans-Asian Railway, Asia-Pacific Information Super Highway (UNESCAP)

SOUTH ASIA SUB-REGIONAL ECONOMIC COOPERATION (SASEC)

- Started as South Asia Sub-Regional Cooperation, Growth Quadrangle between Nepal India Bhutan and Bangladesh under SAARC
- Political differences- changed to SASEC under ADB support Invested $ 12.5 billion (2002-2019) in 55 projects, 17 related to Nepal
- Focus on transport connectivity, transmission master plan, trade and transit facilitation, economic corridors, investment in infrastructure, information highways, customs harmonization
- Connectivity projects including the improvement of the East-West Highway, Roads improvement to border connectivity,

  BBIN
- Bangladesh Bhutan India and Nepal sub-regional economic cooperation
- BBIN Motor Vehicles Agreement (2015)- includes passenger, personal and cargo vehicles across borders
- ADB to provide Secretariat support and help implement the MVA
- Bhutan yet to ratify
- Can boost connectivity

TRADE AND INVESTMENT ZONES

- SAFTA
- BIMSTEC free trade agreement
- SATIS (proposed)
- Regional Investment Treaty (proposed)
- Investment Zones
- Requires other forms of connectivity

ECONOMIC CORRIDORS

- Transport corridor augmented with economic infrastructure, trade and investment facilitation, integrated borders
- Strong basis for connectivity
- Infrastructure, distribution networks
- Harmonization of infrastructure (e.g. broad and narrow gaze railways)
- Enabling policy framework and policy harmonization, policy reform
- Stimulating trade (free trade zones) and investment
- Hubs for manufacturing, services etc.
- Boosting productivity and economic growth
- Economic corridors help regional economic integration (constitute building blocks of regional cooperation)

BILATERAL AND REGIONAL TRANSIT AND TRANSPORT AGREEMENTS

- Importance of smoother transit for integration of the LDCs and for better trade
- Transit as trade facilitation in the SAFTA
- Bilateral transit agreements with India, China and Bangladesh
- Need for a regional transit agreement

- Focus on regional economic integration and economic corridors
- Important for landlocked countries like Nepal
- Bilateral and regional transport agreements (BBIN, SAARC, BIMSTEC)

CONNECTIVITY: LANDLOCKED TO LAND-LINKED

- Regaining Nepal's historic significance in entrepot trade
- Inclusion in the OBOR network, missing links
- Clearer concept of transit economy
- Policy harmonization, bilateral and regional agreements
- Investment in connectivity infrastructure
- Trilateral cooperation, clearing political sensitivities
- More in-depth study, not just slogans
- More proactive diplomacy
- Implementation of agreements
- Action-plan and projects
- Utilization of windows of funds, accessing various funds (e.g., BRICS Bank, Silk Road Fund, AIIB)

PROBLEMS IN CONNECTIVITY

- Fragmented surface transport networks
- Ineffective and weak transport agreements
- Weak air connectivity
- Poor state of infrastructure
- Geographical barriers
- Political issues /lack of political consensus, linking connectivity to political issues (e.g. 5G contract)
- Absence of policy harmonization
- Weak regional cooperation/ Least integrated region
- Non-utilization of/ weak access to available funding
- Non-implementation of reports (SRMTS, Asian Highway etc.)
- Too many proposals of others, not our own, not implemented
- Strategic disorientation

Challenges in Cross Border and Transit Transport by Road

- The Bangla bandha port was formally inaugurated in May 2004 but has not been fully functional owing to the absence of a transit agreement for the use of Indian territory as a transport route for Bangladeshi, Nepalese and Bhutanese trade cargoes.
- Absence of regional transit trade
- Nepali transport trucks are not allowed entry into Bangladesh and must exchange their cargo at the "zero point" of the Indo-Bangladesh border.
- Facilitating transportation of goods in transit for intra –regional as well as extra-regional trade in keeping with the spirit of Article V of the General Agreement on Tariffs and Trade (GATT) relating to "Freedom of Transit"
- Lack of cooperation and integrated approach among border agencies
- Provision of multimodal transport facility (with rail transit, regular container train in the region)
- High trade transaction costs (transport costs slow down regional integration)
- No fast-track lane and priority of goods in transit to cross the border
- Strengthen cross-border infrastructure (move from road corridors to economic corridors)
- Import and export trade is imbalanced.
- Nepalese trade is mostly inclined with India and China

CONNECTIVITY: WAY AHEAD

- Operationalization of available connectivity and transport transit networks (e.g., ports and routes)
- A connectivity blue print for South Asia (ASEAN has its connectivity master plan)
- Implementation of transit and other agreements with China
- Regional transit and transport agreements
- Connectivity thrust on the BBIN, BIMSTEC and SAARC
- Gaining from BRI – establishing missing links, clarifying myths of debt trap, economic viability of projects, political consensus
- Connectivity-driven approach to development
- A connectivity blueprint of our own
- Partnering in initiatives with connectivity elements (BRI, MCC)
- Policy harmonization/ Soft connectivity
- Implementation of free trade agreements (SAFTA)

- Integration into the supply and value chain
- Regional investment protection treaties
- Strategic prioritization of connectivity

Strengthening connectivity of countries in South and Central Asia, particularly Landlocked and Least Developed Countries, to link with sub-regional and regional transport and trade networks.

Regional connectivity: SWOT Analysis

Strengths

- Political willingness for regional collectivity
- Significant amount of transport initiatives (14 initiatives)
- IFI's involvement
- Significant amount of success stories, case studies and best practices
- Willingness for cooperation (between Central Asian countries)
- Knowledge sharing and capacity
- Trade promotion
- Existence of regional and international legal instruments

Weaknesses

- Lack of implementation mechanisms and financial resources
- Lack of preparing bankable projects
- Lack of corridor concept
- Significant amount of transport initiatives (14 initiatives)
- Political willingness
- Missing links
- Harmonization of border-crossing procedures
- Lack of attracting cargo
- Lack of awareness of business community

Opportunities

- Involvement of shippers and cargo movers
- Euro-Asian region: Significant amount of developing countries
- Technology and GIS applications
- New approaches from IFI's (holistic approach, i.e. not only infrastructure development but also tackling of soft barriers such as cross-border facilitation)
- Integrated services and marketing tools
- R&D and Innovation actions
- Exchange of experience between countries

Threats

- Significant amount of transport initiatives (14 initiatives)
- Lack of financial resources
- Lack of innovative ways to finance projects
- Lack of capacity to prepare bankable projects
- Physical security
- No cooperation and strict initiative focus
- No political willingness
- Protracted/ unresolved conflict
- Bureaucratic processes between states
- Political preferences in the classification of project prioritization

Action Plan

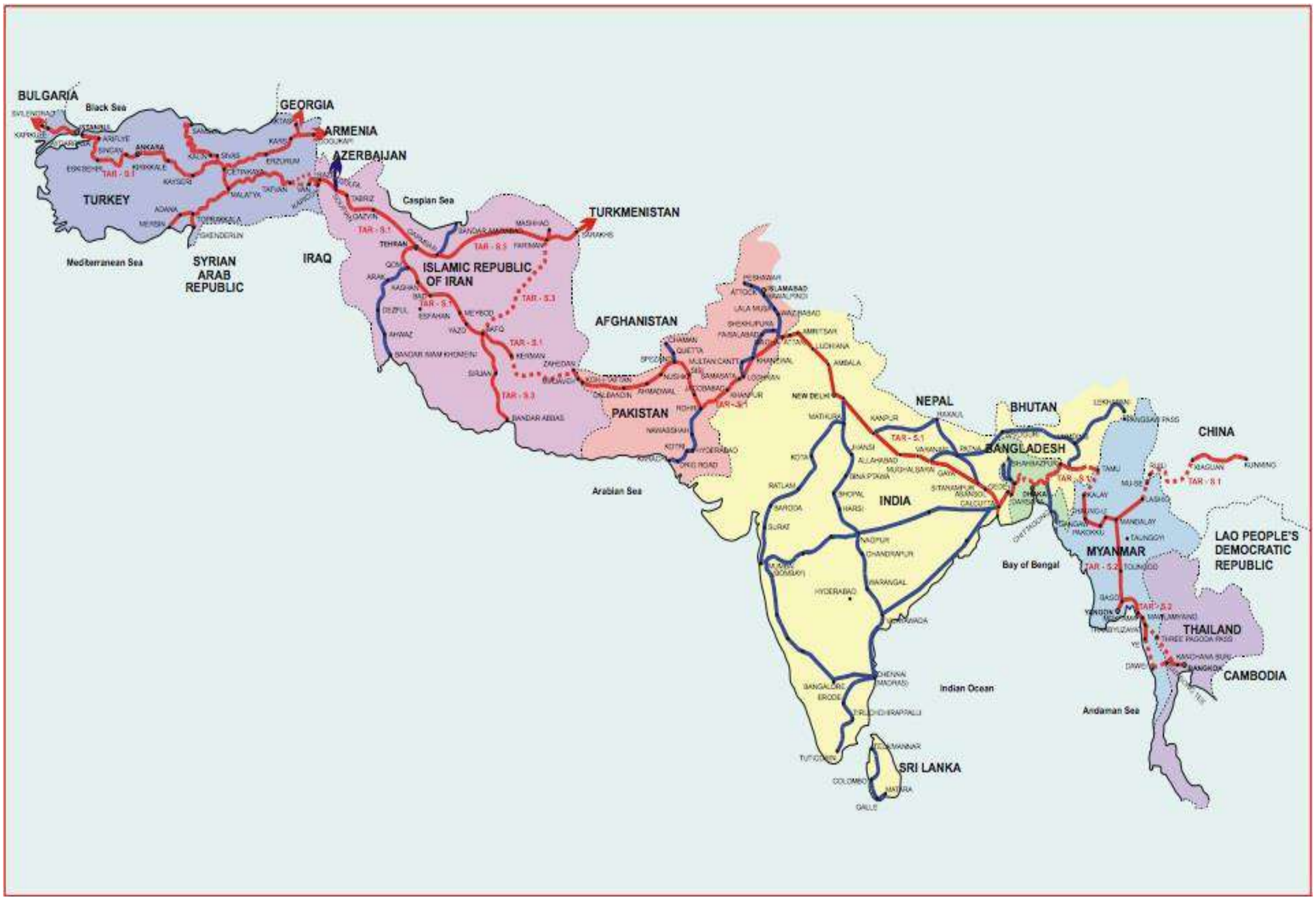
- A **detailed analysis** of current transportation needs and current/future transportation flows should be conducted.
- **Multi-modal transport solutions** (with emphasis on rail-road or RoRo-road) should be promoted.
- Local chambers of commerce and freight forwards should be actively involved in order to attract cargo.
- A **marketing plan** should be developed for promoting corridor services. Furthermore, this marketing plan that will deal with the promotion of rail freight transportation services should be disseminated via the chambers of commerce (to their members).
- Emphasis should be given to **cargo** (e.g. cotton, oil, etc.) that can be transported by rail transportation effectively (in terms of cost, damage, and loss).
- A **monitoring mechanism** should be developed for the implementation of international convention and agreements as well as for monitoring of cross-border procedures.
- UN should cooperate with regional organizations to **monitor the implementation of cross-border procedures** and the facilitation of these procedures.
- **Accessibility and road safety** are of paramount importance and should be taken into consideration for the growth of regional connectivity.
- **Regular capacity building meetings** with all relevant stakeholders should take place focusing on transport corridors' operation and further development of services provided by the corridor operators.
- **Managers from railway operators** of each corridor should meet frequently in order to align their operations and offer a single-window transportation service to local and regional companies.
- The organization of a **global conference** in order to promote the actions that have already taken place towards regional connectivity is also an action that could benefit the regional development of the countries.
- Participation in platforms such as the **International Transport Infrastructure Observatory** of

UNECE should be warranted in order to ensure cooperation among the different transport development initiatives, preparation of bankable projects, promotion of integrated services.

- Last but not least, **best practices and success stories** that have already proven the merit of transport regional connectivity should be promoted and disseminated via various channels.

Trans Asian Railway

- ECAFE launched the Trans Asian Railway (TAR) project with a view to providing for a 14,000 route km rail connectivity between Singapore and Istanbul.
- The network would facilitate the huge prospective increases in international trade by providing a continuous, cost effective rail link between Asia and Europe as well as to improve the economies and accessibility of landlocked countries.
- As the concept conceived fifty years ago, somewhat amplified 25 years later, the Southern corridor would run from Europe to Southeast Asia, connecting Turkey, Iran, Pakistan, India, Bangladesh, Myanmar, and Thailand, and, via Malaysia, to Singapore/Indonesia.
- Fifty long years have passed by – the original TAR network (Southern corridor) has been long deliberated and discussed.
    - Not even a trial train has moved.
- In the meanwhile, things have moved fast far along the north, scripting a new, bold narrative.
    - China has operated over 1,700 container carrying trains over the Northern corridor.
- The Eurasian land-bridge today pulsates with immense new possibilities and promises.
- China's Belt and Road Initiative sets a new paradigm for global logistics infrastructure and institutions.
- Pending the construction of Kunming-Myanmar, Thailand-Myanmar, Bangladesh-Myanmar, India-Myanmar missing links, Southern corridor can work from near Dhaka to Istanbul/Europe via Zehedan.
- The 8,900 km (4,070 km broad gauge or 1,676 mm, and 4,830 km standard gauge or 1,435 mm) Dhaka-Delhi-Lahore-Zahedan-Istanbul rail corridor commands a unique advantage of only one transhipment at break-of-gauge at Zahedan, and no missing link en route.
- Container carrying trains have been already running on the 6,540 km Islamabad-Tehran-Istanbul rail corridor via Zahedan
- Demonstration container trains from Dhaka to Delhi, to Lahore, to Koh-i-Taftan, to Zahedan are indeed overdue.
    - The sub-regional rail link as an important component of TAR Southern corridor includes about 4,070 km BG network (278 km Dhaka-Darsana/Gede section in Bangladesh, 1,975 km Gede-Kolkata-Delhi-Amritsar-Attari route in India, 1,730 km Wagah-Koh-i-Taftan link in Pakistan, and 92 km Mirjaveh-Zahedan link in Iran), and 4,830 km SG corridor (2,480 km Zahedan-Razi route in Iran, and 2,355 km Kapikoy-Kapikule route in Turkey).
    - **At long last it appears the trial container train on Dhaka-Kolkata-Delhi route will soon run.**



Trans Asian Railway Projects

रेशम मार्ग, ओवर (Silk Road and OBBR) र नेपाल

- इसा पूर्व १३० तिर हान् बंश शासित चीनको व्यापार अहिलेको भारत, ग्रिस हुदै अन्य युरोपेली देशसम्म फैल्लिएको जुन चौधौ शताब्दी सम्म चलेको इतिहासमा उल्लेख भएको पाइन्छ |
- सन् १४११ मा चिनिया नौसेना अध्यक्ष चेंग हे ले श्रीलंकाको समुद्रीतटीय सहारा गालेमा एक भाषणमा पर्सियाली र चनिया भाषामा व्यापारका मध्यम बाट शान्तिपूर्ण विश्व बनाउन हिन्दु देवता संग आशिर्बाद मागेको र व्यापारमा प्रयोग गर्ने बाटो नै पछि रेशम मार्ग भएको |
- अंग्रेजी भाषामा सिल्क रोड, इकोनोमिक बेल्ट, ट्वेन्टी फस्ट सेन्चुरी मेरीटाइम, सिल्क रोड, द बेल्ट एंड रोड, बान बेल्ट वान रोड, बेल्ट and रोड इनिसियेटिभ जस्ता धेरै अवधारणा प्राचीनकालदेखि सिल्करोड वा रेशम मार्गमा आधारित छ |
- रेशम मार्ग प्राचीन तथा मध्यकालीन व्यापारिक मार्गहरुको संजाल हो | यो मार्गको बिस्तार पूर्वी एसिया देखि मध्य एसिया हुडौ भूमध्य सागर सम्म फैलिएको थियो |
- उन्नाइसौं शताब्दीको मध्यमा जर्मन भूगर्भविद् फर्दिन्यांड यो रिक्थोफेन्ले सो मार्ग बाट अधिकांश चिनिया रेशमकै व्यापार बढी हुनाले यसको नाम रेशम मार्ग राखेका हुन् |
- चार हजार माइलको सो मार्ग भएरै रेशम, सेरामिक्स भाडा आदिको व्यापार गरिन्थियो | चिनिया रेशमको नरमपना र सौन्दर्य प्रति रोमनी हरु (रानी क्योलोपेत्रा समेत) मुग्ध हुन्थे | पछि यसको उत्पादन तरिका बारे अन्य देशले पनि थाहा पाएपछि यस मार्गको महत्व घट्यो |
- विश्वको सबैभन्दा ठुलो पार्टी, चिनिया कम्नियुष्ट पार्टीको १९ औ महाधिबेशनले प्राचिनकालिन रेशम मार्गको नयाँ अवधारणा Belt and Road Initiative पार्टी विधानमै राखी कार्यान्वयन गर्नुपर्ने अवधारणा पारित गरेको |

- ओवर चिनिया विकासको मुख्य रणनीति र ढांचाक रुपमा आएको छ जुन एतिहासिक अवधारणा चिनिया राष्ट्रपति सि झिनपिंनले सन् २०१३ मा ल्याउनु भएको हो | यसले छिन् र बाँकि विश्वका रुपमा रहेको युरेसिया जमिनमा आधारित सिल्क रोड/economic belt र समुद्रमा आधारित मेरीटाइम सिल्क रोडको बिचमा सम्पर्क र सहयोगलाई जोड दिएको छ |
- यसले एसिया र युरोपका ८० भन्दा बढी राष्ट्रहरुलाई समेट्ने जसमा दक्षिण, पूर्वी, मध्य, पश्चिम एसिया देखि मध्यपूर्व र पूर्वी तथा मध्य युरोप समट्ने छन्| यो मार्गकाइ पुनस्थापना गरी चीनको अन्तर्राष्ट्रिय व्यापार र राजनीतिक सम्बन्ध बढाएर मुलुकको आन्तरिक विकास र वैदेशिक नीति सफल बनाउने रणनीति र ढांचा समेत हो |
- BRI को पाँच उदेश्य चीन सरकारले राखेको पाइन्छ जसमा
  - Multi model connectivity: road, rail, air, energy, pipeline, transmission line
  - उदार र कुनै अवरोध बिना व्यापार
  - वितिय एकीकरण जस्तै एक देशबाट अर्को देशमा financial transection मा सहजता
  - नीतिगत समन्वय: BRI संग जोडिने देशमा नीतिगत समानता ल्याउने
  - जनता र जनता बीच समबन्ध्को विकास र बिस्तार गर्ने
- चीनकै पहलमा ४० अर्ब अमेरिकी डलर को रेशम मार्ग कोषको स्थापना भएको र यो कोष अति आवश्यक ठानिएको र न्यून आर्थिक क्षमता भएको मुलुकमा लह=लगानी गर्ने उदेश्य राखेको |
- सन् २०१५ को बोआवो एसिया मन्चमा मुख्य मन्तब्य दिदै ओवरका परिकल्पनाकार चिनिया राष्ट्रपतिले Belt and Road निर्माण संयुक्त परामर्श, संयुक्त निर्माण र संयुक्त बांडफांडको सिद्धान्त प्रति दृढ रहेको र यो बन्द भन्दा खुला र समाबेशी भएको जसमा चीन मात्र नभई Belt and Road मा पर्ने धैरै मुलुकको यसमा सामुहिक सहभागिता आवश्यक रहेको भनाई राखेको | साथै यस अन्तर्गत धैरै योजना बनाइएको र तिनको कार्यान्वयन समेत शुरु भएको भन्दै चाईना पाकिस्तान इकोनोमिक करिडोर लाई उदाहरण दिदै यो रणनीति होइन्, कार्यक्रम हो र साबिक लागि अवसर भएकोले सहकार्य र खुलापनको नमुना भएको उल्लेख गरेको |
- BBIN अन्तर्गतको सडक संजाल पनि Belt and Road परियोजना अन्तर्गत रहेको र यसले भारत र भुटानलाई एकै ठाउमा आएको पुष्टि |
- हाल सम्म करिव ८६ राष्ट्र संग १०० सहयोग सम्झौता भैसकेको |

नेपालको सन्दर्भ

- ओवरमा MoU मा भएको नेपाल र चीन बिचको हस्ताक्षर बाट यातायात संजाल, व्यवस्थापकीय प्रणाली, पूर्वाधारको बिकासका लागि रेल मार्ग, सडक, नागरिक उड्डयन,पावर ग्रिड, सूचना संचार, संस्कृति, लगानी जस्ता क्षेत्रआ सहकार्य हुने सम्झौतामा उल्लेख भएको |
- अहिले पनि हामि सार्क, बिमस्टेक, WTO, लगायतका सदस्य छदैछौ तरपनि हाम्रो व्यापार र बाणिज्य प्रवर्धन अपेक्षित प्रगति उन्मुख छैन | यसैले BRI प्रति उत्साहित हुदै गर्दा हामीले उधोग धन्दा विस्तार, उत्पादन वृद्धि, रोजगारी सिर्जना, आयमुलक र व्यवहारिक सोंच लाई बढावा दिनुपर्ने देखिन्छ | BRI आफै परिणाम होइन यो त मौका चाहिँ अवश्य हो त्यसैले यसको सार्थक प्रयोगबाट परिणाम सकारात्मक परिणाम निकाल्नु पर्छ |
- बिकासको आधार पूर्वाधार भए पनि पूर्वाधारको लगानीले दिने प्रतिफलको दर र त्यसको दिगोपना महत्वपूर्ण हुन्छ | यातायातलाई पूर्वाधारको पनि आधार मानिन्छ | निर्माण अवधिको असंख्य रोजगार देखि निर्माण पछिको सेवा सम्म पूर्वाधारको प्रत्यक्ष लाभ नै अर्थतन्त्र बिअक्सका आधारहरु हुन् |
- WB को “Thumb Rule” अनुसार पूर्वाधारको एक डलर लगानीले दुई डलरको आर्थिक प्रतिफल दिन्छ | उर्जा, यातायात, आवास आदि पूर्वाधार हरुमा निरपेक्ष रहेर आजकाल विकास आयोजनाहरुमा यो सवा स्वीकार्य सिद्धान्त भैसकेको छ | यधपी पूर्वाधार आयोजनका आ आफ्नै विशेषता, चुनौती र अवसरहरु

हुन्छन नै ।

- यातायात लगायतका सार्वजनिक पूर्वाधारका संरचनाको प्रतिफल तत्कालिन प्रत्यक्ष नाफामा भन्दा पनि दीर्घकालीन र राष्ट्रिय लाभमा बढी देखिन्छ । उदाहरणको लागि सन् २००० मा संम्पन्न डेनमार्कको कोपेनहेगन र स्वीडेनको महानगर जोड्ने ओरेसुंड क्षेत्रको पुल निर्माण पछि यसको आर्थिक प्रभाव मूल्यांकन ८ अर्व डलर थियो, त्यस्तै ५५ कि.मि मकाउ जोड्ने पुल चीनले बनाएको बाट २०% कुल अर्थतन्त्र बढ्ने अनुमान ।
- WB को प्रक्षेपण अनुसार यदि न्यून यातायात पूर्वाधारको मापदण्ड पुग्ने हो भन्ने अफ्रिकामा ४०% उत्पादकत्व बढ्ने अनुमान र आजको यहि यातयात जोड्ने संजाल बाट सम्बृद्धि हासिल गर्ने चीनको उदेश्य ।
- नेपालको यातायातका सन्दर्भमा कुरा गर्दा, द्रुत गतिमा सुधारोन्मुख र विस्तार भैरहेकोले आन्तरिक यातयात र अधिक जनसंख्या रहेको सहरहरु बिचको यातायात प्रणालीमा व्यापक सुदृढ र नयाँ प्रणालीको बिकासको आवश्यकता देखिन्छ । यसका साथै देशको धैरै जनसंख्या ओगट्ने ग्रामिण क्षेत्रको यातायात नीतिमा पनि परिवर्तन र अनुसन्धानको खाँचो देखिन्छ ।
- ओवरमा नेपालले हस्ताक्षर गरेको मौकालाई “क्यास” गर्न नेपाल चीन बिचको अन्तरसीमा व्यापार बाणिज्य बृधिका लागि बिध्यमान रसुवागडी केरुंग, कोदारी खासा दुई नाका बाहेक मुस्तांगको कोरला लिची, हमालको हिल्सा शेरा, सखुवासभाको किमाथांका लेंदुग, ओलांगचुंगगोलाको टिपताला रिवाबजार, गोर्खाको लज्यांग भन्ज्यांग कुंगटांग र दोलखाको लामाबगरको लाप्ची फालेक समेत ६ नाका व्यापारिक दृष्टिकोण बाटै खोल्नुपर्ने देखिन्छ ।
- ओवरमा नेपालको प्राथमिकताका क्षेत्रहरु केरुंग काठमाण्डौ पोखरा लुम्बिनी रेलमार्ग, बाहिरी चक्रपथ, नेपाल चीन विधुत प्रसारण लाईन, सुनकोशी मारिन डाईभर्सन, प्राविधिक शिक्षालय, औषधि आपूर्ति, रासायनिक मल कारखाना, ठुलो शहरमा पूर्वाधार निर्माण आदि हुन् ।

नेपालको लागि ओवर प्रवेशका अवसर र चुनौतिहरु

अवसर

- BRI आफै परिणाम होइन यो त मौका चाहिँ अवश्य हो त्यसैले यसको उपयोगबाट परिणाम सकारात्मक परिणाम निकाल्नु पर्छ ।
- ओवरमा नेपालले हस्ताक्षर गरेको मौकालाई “क्यास” गर्न नेपाल चीन बिचको अन्तरसीमा व्यापार बाणिज्य बृधिका लागि बिध्यमान रसुवागडी केरुंग, कोदारी खासा दुई नाका बाहेक मुस्तांगको कोरला लिची, हमालको हिल्सा शेरा, सखुवासभाको किमाथांका लेंदुग, ओलांगचुंगगोलाको टिपताला रिवाबजार, गोर्खाको लज्यांग भन्ज्यांग कुंगटांग र दोलखाको लामाबगरको लाप्ची फालेक समेत ६ नाका व्यापारिक दृष्टिकोण बाटै खोल्नुपर्ने अवसर देखिन्छ ।
- ओवरमा नेपालको प्राथमिकताका क्षेत्रहरु केरुंग काठमाण्डौ पोखरा लुम्बिनी रेलमार्ग, बाहिरी चक्रपथ, नेपाल चीन विधुत प्रसारण लाईन, सुनकोशी मारिन डाईभर्सन, प्राविधिक शिक्षालय, औषधि आपूर्ति, रासायनिक मल कारखाना, ठुलो शहरमा पूर्वाधार निर्माण गर्ने अवसरको रुपमा लिनुपर्ने छ ।

चुनौतीहरु

- भारत र जापानले यतिबेला चीनको यस परियोजनालाई काउन्टर दिन उद्दत देखिन्छ । उतरपूर्वी एसियाली, दक्षिणपूर्वी र दक्षिण एसियाली साना मुलुकहरुमा आफ्ना connectivity परियोजना बढाउने प्रतिष्पर्धा नै देखिन्छ । एसिया अफ्रीका ग्रोथ करिडोर (Bottom up approach मा आधरित र आफ्नो अनुकुल प्रयोग गर्ने उदेश्यक साथ) ४० अर्ब डलरको परियोजनाकोलागी जापानले ३० अर्ब दिने घोषणा गरेको ।
- भारत, जापान र अमेरिकाको साझा बुझाई के छ भन्ने चीनले सो परियोजना मार्फत व्यापार भन्दा पनि सैन्य र राजनीतिक प्रभाव बढाउन खोजेको छ त्यसैले रोक्न खोजेको देखिन्छ ।
- जापानको मुख्य उदेश्य बंगलादेश, भारत, म्यानमार र थाईल्याण्ड बिचमा connectivity बढाउने र विशेषगरी

नेपाल र भुटानलाइ समुन्द्री तटीयमा बढी पहुँच दिने योजना राखेको देखिन्छ ।

- क्षेत्रिय बाहेक दिदेशीय तथा त्रिदेशीय connectivity project हरु नयादिल्लीको चाँसोको बिषय बनेको देखिन्छ । पछिल्लो समय भारत थाईल्याण्ड म्यानमार राजमार्गको निर्माणको तयारी गरेको र अफगानिस्तान तथा ने मुलुकहरु संगको connectivity लाई प्राथमिकतामा राखेको देखिन्छ ।
- एसियामा देखिएको यो प्रतिष्पर्धा यस क्षेत्रका नेपाल जस्ता कम बिकशित मुलुकहरुको लागी अवसर र चुनौती दुवै भएकोले दुवै ध्रुवसंग राम्रो डिल गरेर आगाडी बढाउन सक्नु नै नेपालको विदेश नीतिको मुख्य चुनौती रहेको देखिन्छ ।
  - राजनीतिक अस्थिरता
  - भ्रष्टाचार
  - सुरक्षा (चीनको मुख्य उदेश्य)
  - वातावरणीय ह्रास र स्थानीय संस्कृतिमा पर्ने दवाब
  - सूचना संचार र प्रविधिले ल्याउने थप चुनौती आदि
- त्यसैले ओवर प्रवेशसंगै नेपालले अवसर संगै जोडिएर चुनौतीलाइ सामना गर्न दिपक्षिय र राष्ट्रिय तहमा बलिया संयन्त्रहरु तयार गर्न आवश्यक छ । त्यस्ता संयन्त्रहरुमा सरकारको साघुरो दायराबाट बाहिर निस्केर बृहत नागरिक स्तर तथा प्राज्ञिक तह समेत समेट्न जरुरी देखिन्छ ।

OPPORTUNITIES AVAILABLE UNDER THE BELT AND ROAD INITIATIVE (BRI)

- BRI will “help meet infrastructure gaps, connect countries supply and value chain, increase in trade and employment and boosting economic growth”- IMF
- Fund for infrastructure projects / banks and institutions
- Opening up of markets
- Connectivity
- More investment
- Economic integration
- People-to-people contacts

FACTORS AFFECTING THE SUCCESS OF THE BRI

- Strategic objectives versus economic objectives
- Superpower rivalry/ Strategic competition
- Uncertainty of cooperative international environment
- Political controversy and backlash (e.g. Malaysia)
- Hype of the “debt trap”
- Delay in project selection / implementation

ISSUES TO BE CONSIDERED UNDER BRI PROJECTS

- Economic viability, not political preference for project selection
- Complementarity with other initiatives
- Debt sustainability
- Transparency
- Focus on missing links
- Using transformative opportunity/not fear