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HIGHWAY

Chapter 3. Economic Aspects and Pavement Management System (PMS)





Contents

- The contents under this chapter:
  - Economic Aspect of Road Construction
  - Labour based Road Construction
  - Pavement Management System (PMS) Overviews

3.1. Economic Aspect of Road Construction

Economic Aspect of Road Construction can be expressed in terms of **Life Cycle Cost (LCC)**

Life Cycle Costing

- **What is Pavement Life Cycle Costing?**
  - **An economic analysis**
  - **Compares design or rehabilitation alternatives**
  - **Considers all significant costs**

- **Analysis approaches**
  - **Deterministic (without variability)**
  - **Probabilistic (with variability)**

We will use the deterministic approach for simplicity

Life Cycle Costing

- **Cost components of LCC:**
  - Agency Costs
  - User Costs

Life Cycle Cost Analysis /LCCA/

- **Agency Costs**
  - **Planning and Design Costs**
  - **Initial construction costs**
  - **Rehabilitation costs**
  - **Maintenance**

User Costs

- Types : -
  - **User delay costs**
  - **Vehicle operating costs**
  - **Crash costs**
  - **Damage to freight**

User Costs

- Costs incurred by user over analysis period
- Different models are available for calculation
- May overwhelm overall LCC (particularly on high volume roadways)
- Should keep separate from other costs

Salvage Value

- **Residual Value**
  - Actual generated value
  - e.g., recycling
- **Serviceable Life**
  - Ratio of remaining years to life, times cost

Discount Rate

- Discount Rate
  - Time value of money
  - $1 today is not worth $1 a year from now
- Significant effect on LCCA
- Should reflect long-term historical trends
- Discount Rate = (Int – Infl)/(1 + Infl) = ~ (Int – Infl)

Int= Interest rate (Treasury Note)

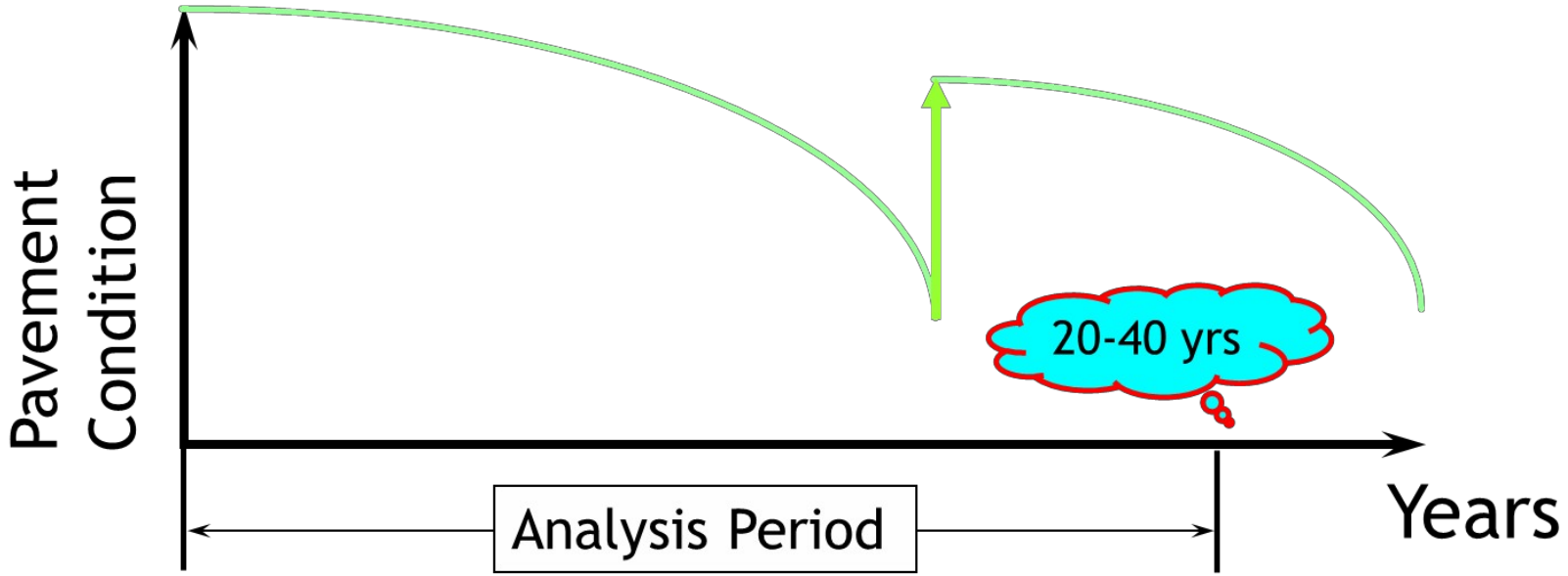
Infl= Inflation rate (Chamber of Commerce)

- Agencies suggest values 3% to 5%

Analysis Period

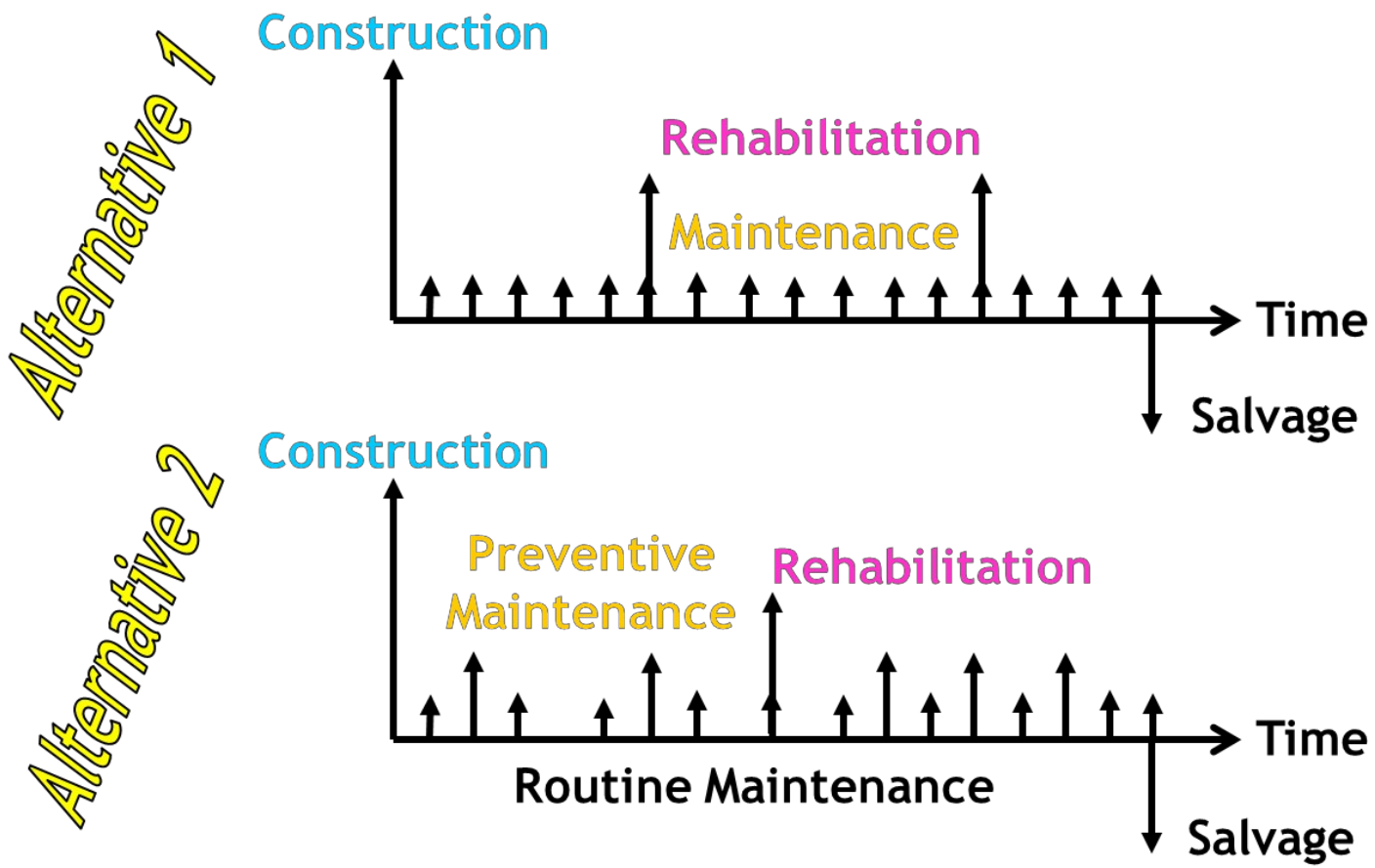
- Time period over which future costs are evaluated
- Long enough
  - To reflect cost differences
  - To force use of rehab. alternative
- Short enough to have reliable forecast

Analysis Period



Include at least one Rehab.

Significance of LCCA

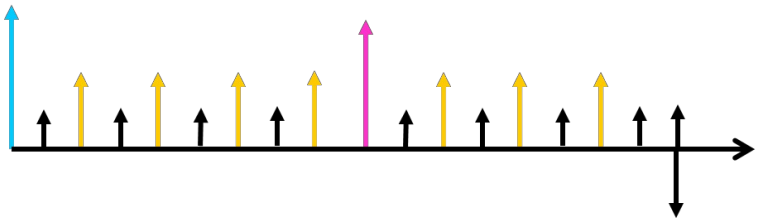


Analysis Methods

- **Analysis Methods**
  - **Present worth method**
  - **Equivalent uniform annual cost method**

Present worth method

Takes a series of costs:



And convert costs to one point in time:



Analysis Methods

- **Time Value of Money**

2015



$100

4 % Discount

Rate

2025



$148

$$100(1+0.04)^{10}=148$$

Analysis Methods

- **Present Worth Factor**

$$PWF = \frac{1}{(1+i)^n}$$

where

i = discount rate

n = year of expenditure

Analysis Methods

- **Present Worth Cost (PWC)**

$$PWC = InitialCost + \sum_{1}^{n} FutureCost[\frac{1}{(1+i)^n}]$$

$$- SalvageValue[\frac{1}{(1+i)^n}]$$

where

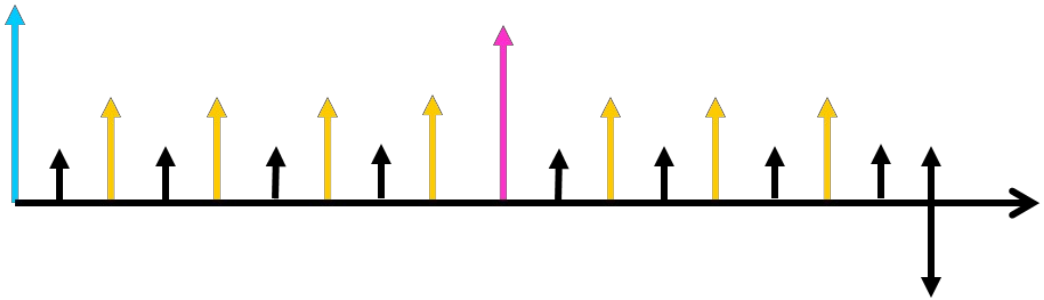
i = discount rate

n = year of expenditure

Analysis Methods

- **Equivalent Uniform Annual Cost Method**

Takes a series of costs:



And convert costs to an equivalent series of equal payments:



Analysis Methods

- **Equivalent Uniform Annual Cost Method**

$$EUAC = PWC.\frac{i(1+i)^n}{(1+i)^n - 1}$$

$$(CRF)_n = \frac{i(1+i)^n}{(1+i)^n - 1}$$

CRF = Capital recovery factor

3.2. Labour Based Road Construction

- Construction technology:
  - An "appropriate" technology is that is defined as one both technically and economically efficient for a defined level of quality
  - In each case, the appropriate mix of labour and machines will be determined by:
    - the technical nature of the project,
    - available resources,
    - Prevailing prices and
    - the socio-economic environment in which the

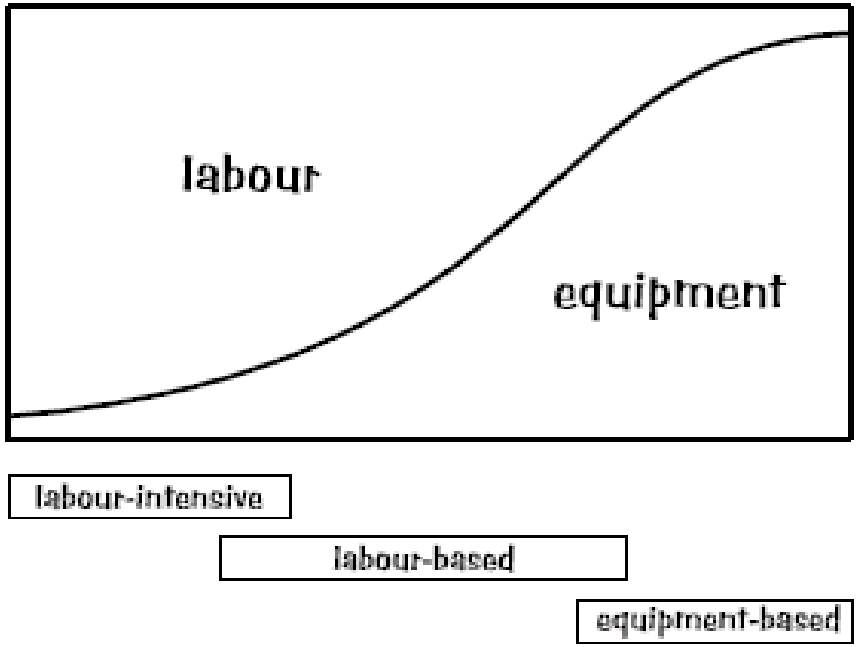
Introduction

- Equipment based – capital intensive – heavily dependent on foreign exchange for import of equipment, spare parts, and fuel.

- Labour-based technology can be defined as the construction technology which, while
  - maintaining cost competitiveness and
  - acceptable engineering quality standards,
  - maximizes opportunities for the employment of labour (skilled and unskilled) together with the support of light equipment and

Introduction

- The present trend is to
use local resources
- This will help to use cost effectively the limited foreign exchange
- It also provides employment opportunity for the



Choice

- The choice of labour-based technology depends on:
  - Government attitude,
  - Economic level,
  - Comparative costs
    - For the machine-based – related costs
    - For labour-based – wage rate, and productivity.
  - Appropriate administrative and financial procedures,
  - Relevant management and technical training,
  - Labour availability

Choice

Type and location of projects

- **labour-based is best suited** for construction programs
  - comprising a large number of small,
  - technically simple, and
  - geographically dispersed road projects.

Construction involving the movement of large quantities of materials over large distances, or substantial production within a short period of time, is best carried out by **mechanical equipment.**

For example, premixed asphalt requires equipment if high quality is required, but for gravel roads, all or nearly all activities can be done by labour.

Choice

- Many engineers will claim that there are serious limitations to the use of labour-based works technology. The most important criticisms are:
  - Speed: the speed of labour-based works depends on two factors:
    - the *productivity* of the labour and
    - the *numbers* of workers engaged.
  - Quality:
- The competitiveness and quality of labour-based projects is determined by:
  - the availability of suitably trained supervisory staff,
  - the introduction of appropriate planning, programming and control systems,
  - the use of incentive schemes, and
  - the availability of adequate hand tools and light equipment.

Design

- In general, labour-based methods require a somewhat different approach to the design of roads
- Road location and alignment are of particular importance when applying labour-based work methods
- Similarly, it is necessary to adapt a road cross- section which is appropriate to the labour-based technology.

Technical Issues:

Earth Work

- For labour-based methods:
  - Longitudinal haulage of earthworks should be limited by moving soil sideways, and
  - construction in weak soils and rock is avoided where possible.
- Labour-based construction requires light compaction equipment. There are basically four methods of compaction:
  - manually or mechanically operated tampers or rammers,
  - deadweight rollers,
  - vibrating compaction, or
  - natural compaction.

Technical Issues: Pavements

- Gravel roads: natural gravels are the most economical to use as they can be laid without any double handling. Fine gravels are easier for labourers for surface finish than gravels containing large stones. It is important to note that labour-based methods cannot produce high standard of surface as a skilled grader driver.
- Soil stabilization: hand mixing is not sufficient and in cement stabilization the
cement reacts and sets too quickly, lime dust may create health problem.
- Surface dressing: may be carried out by labour and the quality is almost as good as by mechanized methods if properly managed.
- Premixed asphalt: hot premix can be done by labour-based methods, but the working conditions for labourers is not good and at the time it is not possible to obtain the same quality as produced by machinery. Cold mix is better suited for hand mixing.

Tools and Equipment

- An appropriate range of tools should be provided so that labour-based methods can be most effective for different activities and conditions.
- The guide to Tools and Equipment published by ILO provides optimum design and quality standards for a wide rang of hand-tools and light equipment.
- For earth moving, there is a close correlation between the preferred equipment and the length of the haul.

Examples: Head-basket: ---- for 30 m or less

- Wheelbarrows: ----------for hauls greater than 20-30 m
- Animal carts: ---------- for intermediate haul distances
- Tractor trailer :---------- for long haul distances
- Two w ---- for long haul distances
- Truck for very long haul distances

Distance	*Transport*
10 – 150 m	Wheelbarrows
150 – 2000 m	Animal Carts
500 – 8000 m	Tractors & Trailers
1000 -	Trucks

Organization and Motivation

- It is recommended that the labourers be organized in
  - 1 Engineer ---------- → 2-3
  - 1 senior supervisors --→ 2-4
  - 1 site supervisors -----→ 4-5
  - 1 gang leaders --------- → 20-25
- It is very essential that training courses are given at various levels (management, supervisors, workers) as required for labour based construction methods.
- For the labour-based methods to be effective, payment methods,

and working conditions are very important factors

Technical and Economic Feasibility

- The technical and economic feasibility of Labour based methods explained in terms of: -
- Quality and Suitability
- Cost
- Completion Time

Quality and Suitability

Quality

- Activities for which labor-based methods produce better quality results than equipment-based include:
  - creating embankments on very soft ground,
  - producing drainage systems,
  - undertaking shallow excavations with a high water table,
  - selecting materials when excavating,
  - exploiting small quarries, and
  - performing routine maintenance on gravel

Quality and Suitability

Suitability or ease of production

- labor is better suited to produce the longer-lasting trapezoidal drains than is equipment, which can often produce only V-shaped drains.
- labor-based methods are more suitable for rehabilitating and maintaining narrow, winding roads in densely-populated urban areas, because bulldozers cannot maneuver well in such situations.

Cost

- Financialconsiderations are crucialin determining the feasibility of labour substitution.
- The financial feasibility of labor-based methods is a function of many factors, including:
  - the availability of labor,
  - the wage rate for unskilled labor,
  - the supply of equipment and spare parts,
  - the productivity of labor, and
  - the nature of the works to be executed (including the type of works, its location, the

Completion Time

- Theoretically, one could deploy enough labor on a project to finish it in the same time that equipment-based methods would require.

- Practically, however, when using labor-based methods,

the completion time is constrained by: -

- the availability of labor and
- the size of the works.

3.3. PMS Overview

Definitions:

Pavement Management

- *"Pavement Management is a program for improving the quality and performance of pavements and minimizing costs through good management practices"*

Pavement Management Systems

- *"A Pavement Management System is a set of defined procedures for collecting, analyzing, maintaining, and reporting pavement data, to assist the decision makers in finding optimum strategies for maintaining pavements in serviceable condition over a given period of time*

Introduction

Pavement Materials	**Classification, quality assurance testing (specifications), material design**
Pavement Design	Design of Structural layers for New Pavements and Pavement Rehabilitation Assess in-situ pavement material properties and layer thickness
Pavement Construction	Construction practices of New Pavements and Pavement Rehabilitation including specification development and quality assurance
Pavement Management	**Monitoring Post-construction condition, timing preventive maintenance and rehabilitation treatments, and economic analysis of alternatives**
Pavement Research	Research to improve all of the above

Introduction

- PMS cannot make final decisions, it can provide the basis for an informed understanding of the possible consequences of alternative decisions.

A PMS does NOT make decisions, Managers DO!

PMS Levels

Network

- bird’s eye view of network pavements as a whole.
- statewide pavement condition summary
- budget estimate
- performance prediction

Project

- assist designers in maintaining, or constructing, rehabilitating a section of roadway.
- preventive maintenance
- resurfacing or reconstruction
- treatments options along the project

PMS Subsystems

PMS DATA

- Inventory
- Condition - Pavement Evaluation
- History – Initial, PM, RM, Rehab, Reconstruction
- Traffic
- Costs

MODELING - ANALYSIS

- Serviceability Rating
- Performance Predictions
- Economic Analyses-Budgeting / Programming

DATA MANAGEMENT

- Relational Databases

PMS Data Collection

Data Types

- Inventory,
- Pavement Condition
- Traffic/Loads,
- Costs - Construction, PM, RM, Rehab, Reconstruction
- History – Initial Const, PM, RM, Rehab,Reconstruction (Last Treatment)

PMS Data Collection

Example : - **Inventory Data**

- Route Number
- Route Type (Interstate, Urban, Rural)
- Functional Class
- Length
- Divided/Undivided Route Section
- Pavement Type
- Number of Lanes and Widths
- Shoulder Type and Width

PMS Data Collection

Pavement Condition Evaluation

- Pavement Roughness Or Ride Quality
- Surface Distress
- Rutting
- Skid Resistance
- Structural Capacity

PMS Data Collection

Need for Annual Condition Surveys (Ride Quality, Surface Distress, Rutting, Friction)

- Evaluating current condition of pavement
- Determining rates of deterioration
- Determine Project future conditions
- current and future maintenance & rehabilitation needs
- Determining future cost of repairs

Pavement Condition Survey Equipment

Profiler

roughness, distress, rutting, noise, pavement cracking



Skid Trailer

Pavement friction



GPR

Layer Thickness



FWD



Structural Capacity

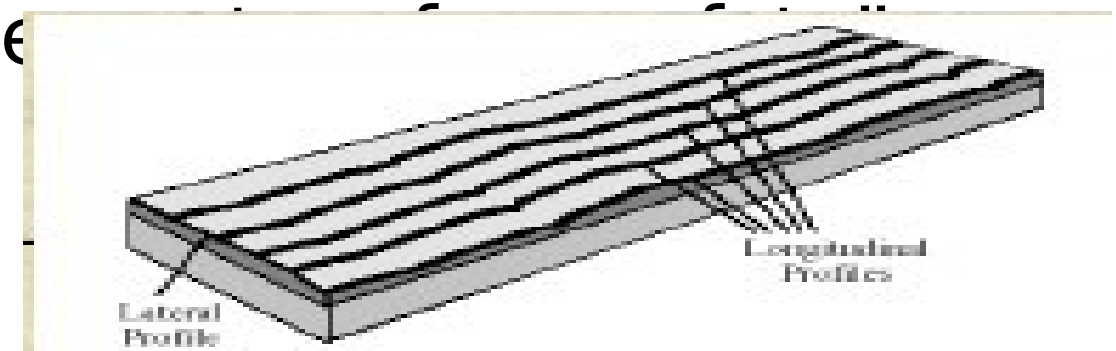
Equipment Demo

Last Day

Pavement Condition Evaluation

Road Roughness

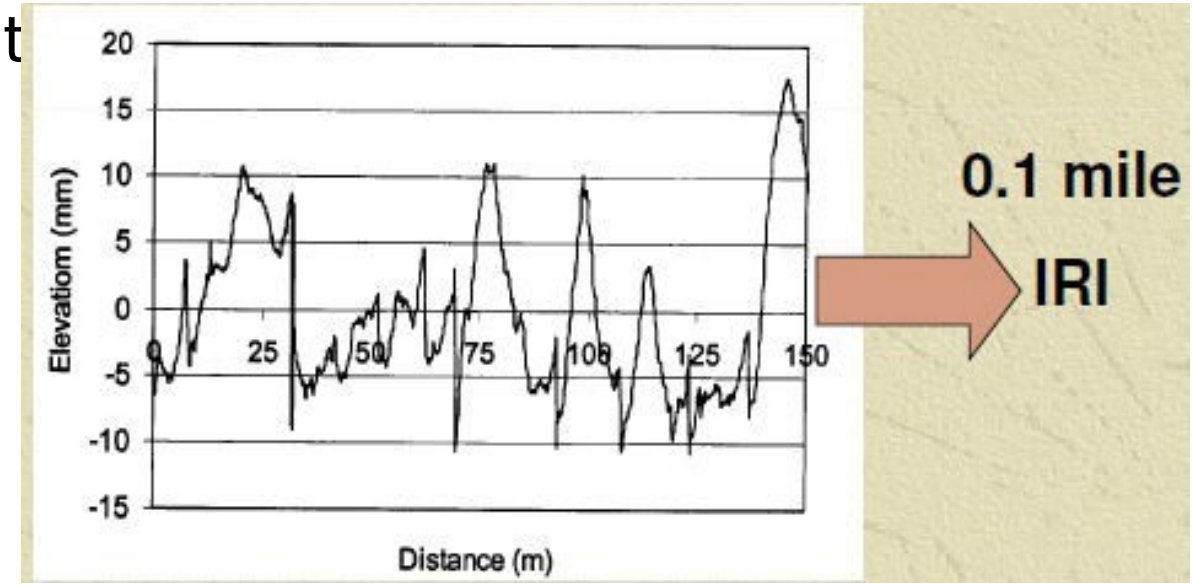
- "road "road roughness is the irregularities in the pavement surface affecting user comfort and safety”
- Due to variations in horizontal, vertical, and Transverse profiles
- Ride quality - user perception of pavement roughness pave



Pavement Condition Evaluation

Ride Quality index

- Measure Pavement Wheel Path Profile(s) to assess Pavement Ride Quality
- Convert Pavement Wheel Path Profile (L&R) to Pavement Ride Qualit



Pavement Condition Evaluation

Surface Distress

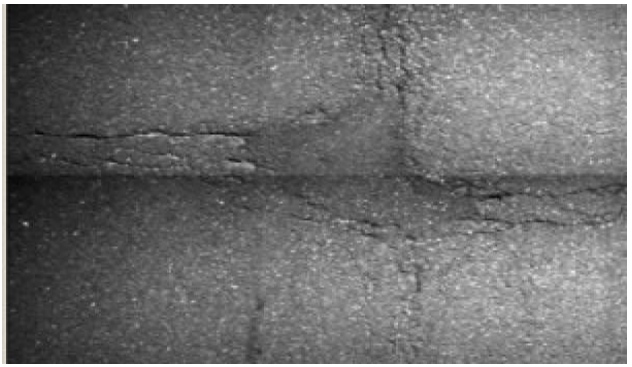
Description

- Type of distress (cracking, patching, rutting)
- Severity (crack width, condition assessment)
- Extent (percentage of the pavement length)

Data Collection

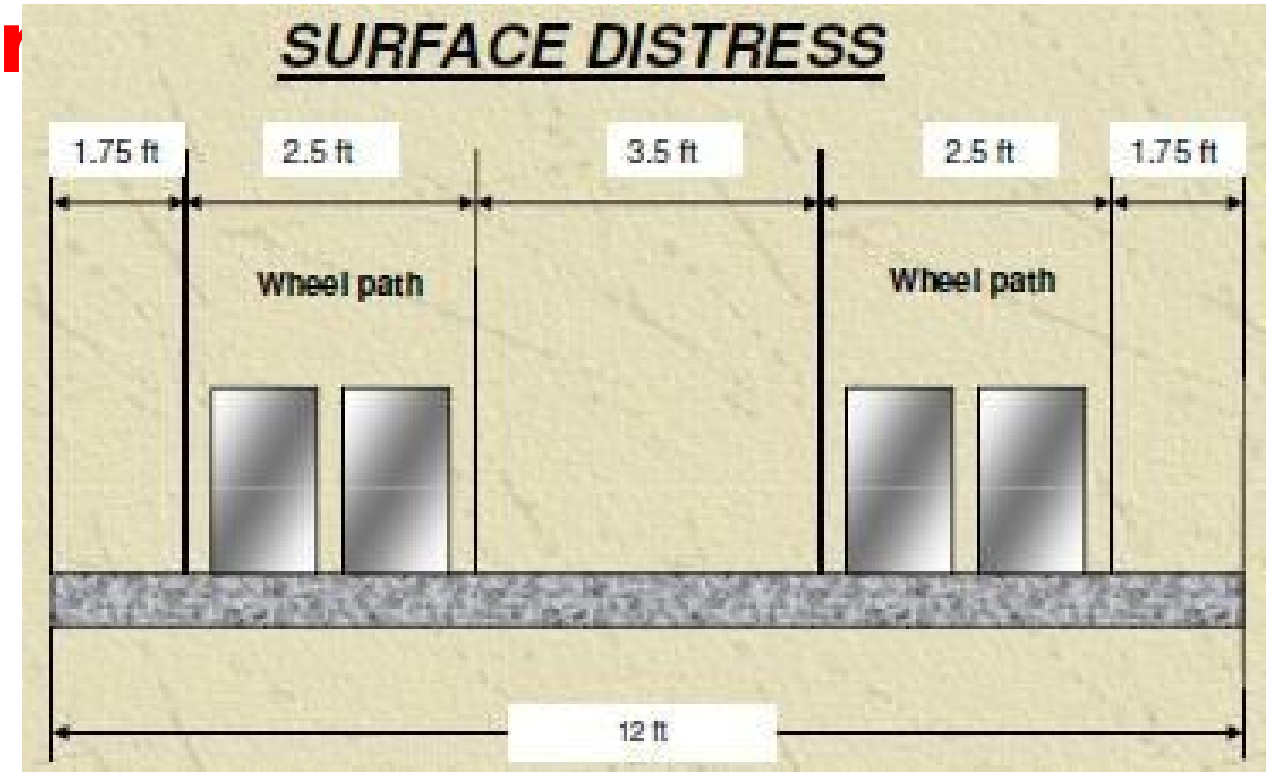
- Continuous - windshield survey (computer rater keyboard, and video)





Pavement Condition Evaluation

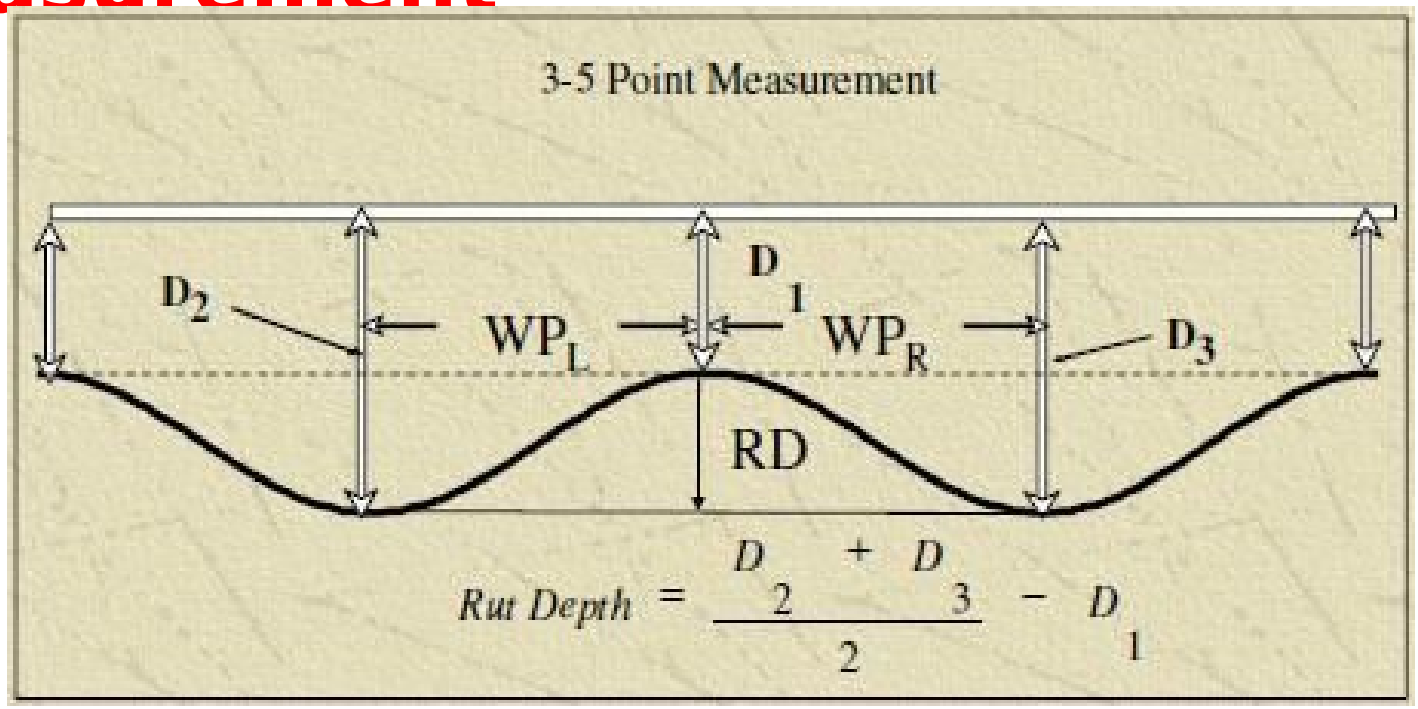
Surface Distr



Load Associated vs. Non-Load Associated Location

Pavement Condition Evaluation

Rut Depth Measurement



Pavement Condition Evaluation

Skid Resistance

Description

- Assessment of pavement surface friction (based on the coefficient of friction of the tire)

Data Collection

- Continuous - ASTM E274 (lock wheel) skid





Questions?