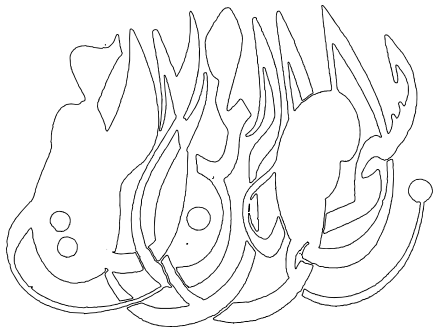


Modeling
of
Pavement Performance,
Priority Ranking, and Budget
Optimization
for
Road Network

## *INTRODUCTION*

- Pavement is an important asset.
- Huge investment.
- Functions of pavements.
- Need for pavement evaluation.

## *OBJECTIVES*

The main objective of this study is to develop an optimum models for pavement maintenance management system for the conditions of the Kingdom of Saudi Arabia.

## *OBJECTIVES...*

- Development of pavement performance prediction models.
- Development of pavement maintenance priority ranking procedures.
- Formulation of an optimization process for optimal maintenance funds allocation.
- Validation and verification of the above developed models and procedures.

## Work Plan

**PHASE I: INFORMATION COLLECTION**

1. Study Area Definition
2. Pavement Condition Data
3. Traffic Data
4. Environmental Data
5. Pavement-History Related Data

**PHASE II: MODELING**

| **Performance Prediction** | **Priority Ranking** | **Maintenance Optimization** |
|---|---|---|
| 1. Parameters Definition | 1. Parameters Definition | 1. Parameters Definition |
| 2. Model Formulation | 2. Model Formulation | 2. Model Formulation |

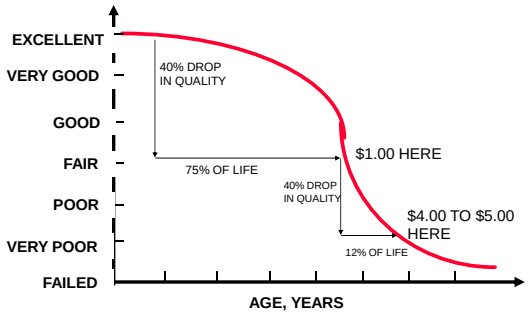
**PHASE III: MODELS VALIDATION**

1. Selection of Pavement Sections
2. Model Validation and Calibration

## *PROBLEM STATEMENT*

- Huge Investment in Pavements
- Huge Maintenance Needs
- Specific Conditions
  - Harsh Environment (Temp., Preceptation., Salinity)•
  - Pavement Deterioration Rate & Specific Phenomena•
  - High Traffic Loads•
  - Cultural and Traditional Factors•
- Scarcity of Pavement Modeling
- Development of PMS in Saudi Arabia

## Pavement Life Cycle





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## *LITERATURE REVIEW*

- The Importance of PMS.
- PMS Activities.
- Pavement Deterioration.
- Pavement Maintenance.
- Status of PMS in Saudi Arabia.

## *LITERATURE REVIEW*

- The Importance of PMS.
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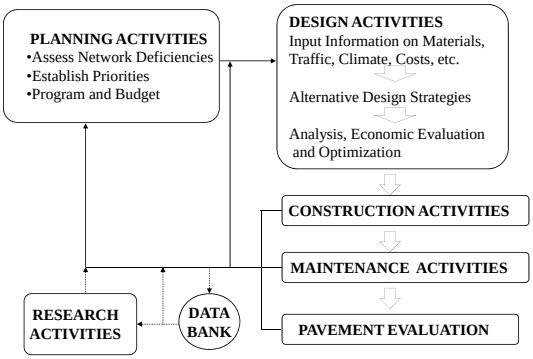
## *WHAT IS PMS ?*

PMS is defined as the effecient coordination of different activities in pavement sector, such as: planning, design, construction, maintenance, evaluation, and research.

## PMS Activities

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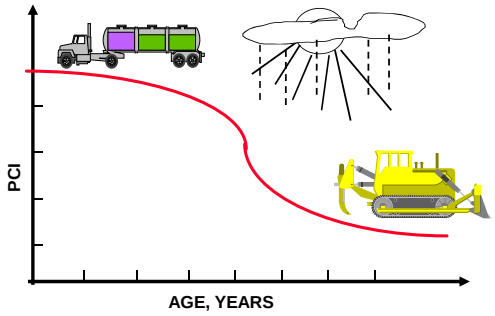
## Pavement Deterioration



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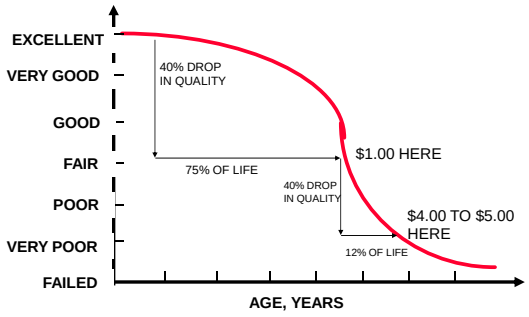



## *LITERATURE REVIEW*

- The importance of PMS.
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## SAUDI EXPERIENCE IN PMS

- KING FAHD UNIVERSITY
- KING SAUD UNIVERSITY
- MINISTRY OF COMMUNICATION
- MUNICIPALITY OF RIYADH
- SAUDI ARAMCO

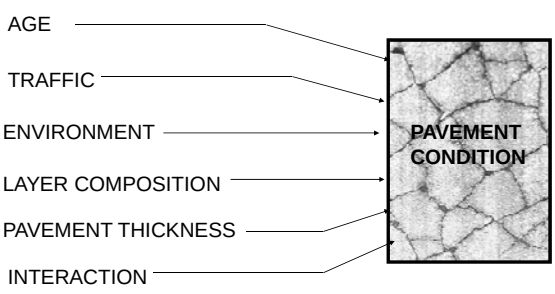
## *EXPECTED BENEFITS*

- Better Understanding of Pavement Behavior.
- Rational Priority Ranking for Maintenance.
- Cost-effective Maintenance Funds Spending.
- Integration of Models in an Optimum PMS.

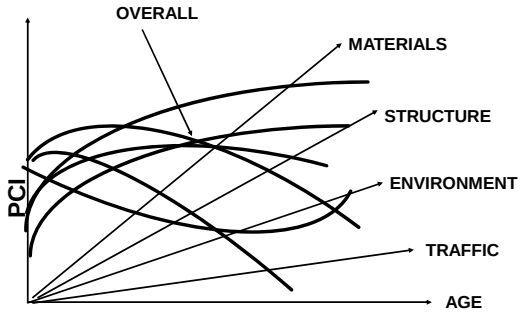
## Pavement Performance Modeling

A true performance prediction model is the one that can calculate the expected serviceability-time (or traffic) relationship over entire design period, and also include the effects of any major rehabilitation.

## Pavement Condition Modeling




## PERFORMANCE PREDICTION




## Pavement Performance Modeling Categories

Data-wise:

1. Purely Mechanistic
2. Mechanistic-Empirical
3. Regression
4. Subjective

Analysis-Wise:

1. Deterministic
2. Probabilistic

## Proposed Performance Model

**PCI = f (AGE, THICH, SUB, TRAF, TRUCK, TEMP, DRAIN, SUBT, SUBT, INTR)**

WHERE:
PCI = PAVEMENT CONDITION INDEX
AGE = TIME FROM CONSTRUCTION DATE OR MAJOR REHABILITATION
THICK = ASPHALT LAYER THICKNESS
SUB = SUBBASE THICKNESS
TRAF = AVERAGE DAILY TRAFFIC
TRUCK= PERCENTAGE OF TRUCKS IN THE TRAFFIC MIX
TEMP = MAX. PREVAIL TEMP.
DRAIN = DRAINAGE CONDITION
SUBT = SUBBASE TYPE
SUGT = SUBGRADE TYPE
INTR = INTERACTIONS OF THE ABOVE FACTORS

**HYPOTHESIS: RED**: PROPORTIONAL, **GREEN**: INVERSLY PROPORTIONAL

## Performance Modeling

1. Regression Analysis
   - (Linear, Nonlinear, Combination)
2. Sampling
   - (Required No. of Data Points)
3. Model Statistical Evaluation
   - (Model Adequacy Tests)

## Sample Size Determination

| | | | |
|---|---|---|---|
| AC Thick1 | AC Thick2 | AC Thick3 | **3** |
| SUBT1 | SUBT2 | | **2** |
| SUBGT1 | SUBGT2 | | **2** |
| TRAFF1 | TRAFF2 | TRAFF3 | **3** |
| TRUCK1 | TRUCK2 | TRUCK3 | **3** |
| TEMP1 | TEMP2 | | **2** |
| DRAIN1 | DRAIN2 | | **2** |

T O T A L COMBINATION = **432**

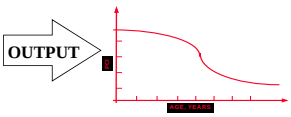
MIN OF 3 ENTRIES PER LEVEL, OVERALL = **1296**

**Pavement Performance Modeling**

INPUTS

| | |
|---|---|
| A/C Layers Thickness (cm): | 10 |
| Subbase Thickness (cm): | 20 |
| Subbase Type (1:Stabilized, 2: Unstabilized): | 2 |
| Subgrade Condition (1:Good, 2:Poor): | 1 |
| Drainage Condition (1:Acceptable, 2:Unacceptable): | 1 |
| Temperature Zone (1:Hot, 2:Moderate, 3:Cool): | 2 |
| Traffic (ADT: 1:Low, 2:Medium, 3:High) | 3 |
| Percentage of Trucks (%): | 30 |

OUTPUT



**0 = 100**
**1 = 80**
**3 = 75**
**4 = 60**
**5 = 50**
**6 = 40**
**7 = 20**

## Pavement Maintenance Prioritization

Prioritization is a systematic process that determine the best ranking list of candidate sections for maintenance based on specific criteria. It ranks these sections in an order of importance or urgency for repair.

## Prioritization Methods

1. Simple Subjective Ranking
2. Composite Index Methods
3. Ranking Based on Economics
4. Optimization Methods.

## Proposed Priority Ranking Model

$PI = \sum W_i * F_i$

Where:

PI = Priority Index (out of 100)

$W_i$ = Weight Priority Factor

$F_i$ = Priority Factor (out of 100)

$\sum W_i$ = 100%

## Priority Ranking Factors

1. **Pavement Condition**
2. **Operating traffic**
3. **Percentage of trucks**
4. **Riding Quality**
5. **Safety Conditions**
6. **Overall Maintenance Cost**
7. **Overall Importance**

**HYPOTHESIS: RED: PROPORTIONAL, GREEN: INVERSLY PROPORTIONAL**

## Proposed Priority Questionnaire

| Factor | Description | Importance Weight (%) |
|---|---|---|
| 1. Road Class | Major/Minor road; arterial, collector, or local; Commercial or Residential | 10 |
| 2. Pavement Condition | Existence of pavement defects in the road surface such as cracking, rutting, potholes, settlements, and others. | 30 |
| 3. Riding Quality | Existence of bumps, longitudinal corrugation, and unevenness in the road surface that cause high stresses to vehicles and discomfort to the road users (drivers and passengers); High road roughness. | 15 |
| 4. Safety Conditions | Smoothness of the road surface that causes safety hazards to vehicle stopping and braking; Low skid resistance or surface friction; High accident rates (head to back type). | 10 |
| 5. Maintenance Cost | The overall maintenance cost for the road section in need of maintenance, this includes closing and detouring costs. | 15 |
| 6. Importance to Community | Overall importance to community determines by its distance from official buildings or important locations such as hospital, schools, etc. See Part II. | 20 |
| **OVERALL** | | **100** |

## Proposed Priority Questionnaire

| Factor | Description | Importance Weight (%) |
|---|---|---|
| 1. Road Class | Major/Minor road; arterial, collector, or local; Commercial or Residential | 15 |
| 2. Distance from CBD | The distance from down-town or City Business Center determines the importance of the road section. | 10 |
| 3. Distance from official buildings (IMARAH, etc.) | If the road section under consideration passing through an official complex may call for higher priority. | 20 |
| 4. Operating Traffic | Higher traffic volume roads calls for higher priority | 25 |
| 5. Percent of truck traffic | In some roads, presence of high truck traffic may call for higher priority. | 10 |
| 6. Distance from other important buildings | Other buildings such as Civil Defense, Hospitals, Schools, etc. may call for higher maintenance priority | 20 |
| **OVERALL** | | **100** |

## Priority Ranking Modeling

1. Factor Normalization
   - (100-POINT Scaling)
2. Factor Weight Calculation
   - (Effect of Qualification & Established Crireria)
3. Model Evaluation

## PRIORITY INDEX EXAMPLE

| FACTORS | VALUES | WEIGHTS |
|---|---|---|
| PCI | 70 | 0.10 |
| TRAFFIC | 40 | 0.10 |
| TRUCKS | 20 | 0.05 |
| RIDING QUALITY | 70 | 0.15 |
| SAFETY | 30 | 0.20 |
| COST | 80 | 0.15 |
| IMPORTANCE | 50 | 0.25 |

PI = 75*0.10+40*0.10+20*0.05+70*0.15+30*0.20+80*0.15+50*0.25

PI = 53

## Maintenance Optimization

The systematic process to measure and adjust a policy, program, or funds allocation to produce the maximum benefits at the minimum cost.

## Proposed Optimization Procedure

1. Pavement Network Sectioning
2. Setting Planning Horizon
3. Maintenance Strategies Defined
4. PCI Prediction for Sections Over Years
6. Feasible Maintenance Plans
7. Priority Index Determination
8. Maintenance Plans Costs
9. Maintenance Plans Effectiveness
10. Optimization Run

## Proposed Optimization Model

$$\text{Maximize} \quad \sum_{i=1}^{m} \sum_{j=1}^{k} \sum_{t=1}^{T} X_{ijt} \cdot E_{ijt}$$

Subject to:

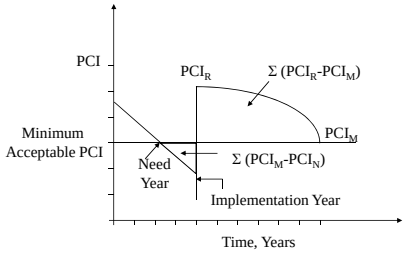
$$\sum_{i=1}^{m} \sum_{j=1}^{k} X_{ijt} \cdot C_{ijt} \leq B_t \qquad \text{for } i=1, 2,..., m$$

$$\sum_{t=1}^{T} \sum_{j=1}^{k} X_{ijt} = 1 \qquad \text{for } t=1, 2,..., T$$

$$X_{ijt} = 0 \text{ or } 1$$

B: Budget E: Maint. Effectiveness, C: Maint. Cost,
m: No. of sections, k: No. of Maint. Plans, T: No. of years
Xijk : Variable to be obtained.

## Maintenance Effectiveness




$$E = \left[ \sum_{R=RY}^{RM} (PCI_R - PCI_M) - \left( \sum_{N}^{RY} (PCI_M - PCI_N) \right) \right] * T * L$$

## OPTIMIZATION EXAMPLE

## MAINTENANCE PLANS

**PLANS**

PLAN 1: DO NOTHING, ROUTINE MAINT., ROUTINE MAINT.
PLAN 2: ROUTINE MAINT., DO NOTHING, ROUTINE MAINT.
PLAN 3: MAJOR MAINT., DO NOTHING, DO NOTHING.

**COST**

PLAN 1: SR 20,000
PLAN 2: SR 25,000
PLAN 3: SR 40,000

**EFFECTIVENESS**

PLAN 1: 150
PLAN 2: 200
PLAN 3: 250

## OPTIMIZATION EXAMPLE

VARIABLES

| Section Number | Year 1 | | | 2 | | | 3 | | | 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maint. Plan No. | | | Maint. Plan No. | | | Maint. Plan No. | | | Maint. Plan No. | | |
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 1 | $X_{111}$ | $X_{121}$ | $X_{131}$ | $X_{112}$ | $X_{122}$ | $X_{132}$ | $X_{113}$ | $X_{123}$ | $X_{133}$ | $X_{114}$ | $X_{124}$ | $X_{134}$ |
| 2 | $X_{211}$ | $X_{221}$ | $X_{231}$ | $X_{212}$ | $X_{222}$ | $X_{232}$ | $X_{223}$ | $X_{223}$ | $X_{233}$ | $X_{214}$ | $X_{224}$ | $X_{234}$ |
| 3 | $X_{311}$ | $X_{321}$ | $X_{331}$ | $X_{312}$ | $X_{322}$ | $X_{332}$ | $X_{313}$ | $X_{323}$ | $X_{333}$ | $X_{314}$ | $X_{324}$ | $X_{334}$ |
| 4 | $X_{411}$ | $X_{421}$ | $X_{431}$ | $X_{412}$ | $X_{422}$ | $X_{432}$ | $X_{413}$ | $X_{423}$ | $X_{433}$ | $X_{414}$ | $X_{424}$ | $X_{434}$ |

OUTPUTS

| Section Number | Year 1 | | | 2 | | | 3 | | | 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maint. Plan No. | | | Maint. Plan No. | | | Maint. Plan No. | | | Maint. Plan No. | | |
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| 2 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 |
| 3 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 4 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |

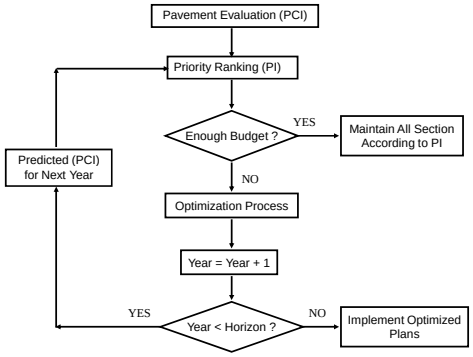
## NEEDED INFORMATION

1. Maintenance Strategies Adopted Locally.
2. Feasible Maintenance Plans
3. Acceptable Level of Pavement Condition
4. Maintenance Strategies Cost
5. Other Measures of Effectiveness (if any)
6. Budgeting Schemes

## POTENTIAL SOURCES

MOC, MOMRA, S-ARMCO, LOCAL HIGHWAY AGENCIES, UNIVERSITY RESEARCHERS, ETC.

## Modeling Integration

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# THANKS