Lecture 4

Pavement Maintenance Planning

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PRIORITY RATING AND PRIORITISATION INDEX FOR PROGRAMMING IN PAVEMENT MANAGEMENT

Objective: To establish relative priority ranking of candidate projects for pavement rehabilitation and maintenance programs.

Based on
- ♦ Overall conditions of individual pavement segments
- ♦ Relative operational importance of pavement segments
- ♦ Criteria derived from subjective judgement of engineers

Example **Weighted sum method**

$$P = 0.1\,S_1 + 0.25\,S_2 + 0.2\,S_3 + 0.2\,S_4 + 0.3\,S_5$$

Each S_i is the distress rating (e.g. over a scale of 0 to 1) for a different pavement defect.

Example **Factored Product (Ontario)**

$$PCI = 100\sqrt{(0.1\,RCI)\,(205 - DMI)/205} \qquad 0 \le PCI \le 100$$

where DMI = Ontario Distress Manifestation Index; Riding Comfort Index RCI = 26.64 – 7.34 log 10 (RMSVA)

Priority Rating & Prioritisation Index

Considerations in Establishing Priority Ratings:

(1) Routine maintenance activity type
- Preventive vs. corrective
- Effect on pavement condition restoration
- Effect on extending service life

(2) Highway functional class
- Expressways, major arterials, collections, secondary roads
- Airport runways, taxiways, parking aprons

(3) Pavement distress condition – severity, extent

(4) Seasonal effect – suitability of activity at different times of year

(5) Climate & environmental factors (e.g. wet tropical climate vs. temperate climate)

(6) Maintenance practice and policy

(7) Miscellaneous factors
- Safety considerations
- Environmental concerns
- Political influence

Priority Rating & Prioritisation Index

Example:

Texas Prioritisation Index (PINDEX)

Possible values of PINDEX

Fatigue Cracking Category	PSI Category			
	V. Good	Good	Fair	Poor
Excellent	8	22	42	82
Very Good	12	26	46	86
Good	26	40	60	100
Fair	46	60	80	120*
Poor	86	100	120*	160*

* If PINDEX > 100, replace by PINDEX = 100

Priority Category = 1 if Adjusted PINDEX ≥ 60

2 ≥ 28 but < 60

3 < 28

Priority Rating & Prioritisation Index

Example: **Texas Prioritisation Index (PINDEX)** *(cont'd)*

PINDEX = (PSI Assigned Value) + (Cracking Assigned value) $\leq$ 100

(A) Serviceability	PSI Range	Assigned Numerical Value
Very Good	3.8 – 5.0	6
Good	2.8 – 3.7	20
Fair	2.0 – 2.8	40
Poor	below 2.0	80

(B) Fatigue Cracking	Severity	Extent (%)	Assigned Numerical Value
Excellent	Slight	10	2
Very Good	Slight	10 – 25	6
	Moderate or Severe	10	
Good	Slight	25 – 49	20
	Moderate or Severe	10 – 25	
Fair	Slight	50	40
	Moderate or Severe	25 – 49	
Poor	Moderate or Severe	50	80

Priority Rating & Prioritisation Index

Example: Texas Prioritisation Index (PINDEX) *(cont'd)*

Adjusted PINDEX = PINDEX x Adjustment Factor

Function Class	ADT	Factor
Interstate	High Medium Low	1.00 0.95 0.88
Principal Arterial	High (>15,000) Medium (5,000-15,000) Low (<5,000)	0.93 0.87 0.80
Minor Arterial	High (>12,000) Medium (4,000-12,000) Low (<4,000)	0.83 0.75 0.68

Function Class	ADT	Factor
Major Collector	High (>8,000) Medium (2,000-8,000) Low (<2,000)	0.73 0.65 0.60
Minor Collector	High (>5,000) Medium (1,000-5,000) Low (<1,000)	0.60 0.53 0.45
Local	High (>3,000) Medium (500-3,000) Low (<500)	0.55 0.45 0.35

Priority Rating Methods

(A) Group Consensus of Subjective Judgement

1. ***Group Deliberation*** on every priority rating to achieve a consensus of opinion among a selected number of experts, involving face-to-face discussion and reasoning.

   Disadvantages:
   - ♦ Influence of a high status individual
   - ♦ Ego commitment
   - ♦ Group pressure for conformity

2. ***Delphi Approach***
   a) Select a group of experts
   b) Approach each expert individually for priority ratings
   c) Compute the means of priority rating for each item, and feedback to individual experts for further opinions
   d) Successive iterations of this process are made until consensus is reached

Example: Priority ratings for pavement maintenance Changi Airport

Priority Rating Methods

(B) Survey-Based Evaluation of Priority Rating

(Ref: Paper "Priority Rating of Highway Routine Maintenance Activities)

-- directly reflecting opinion of maintenance personnel

Priority Rating = f { Type of maintenance activity; Highway class; Pavement distress condition}

Model 1 $F_{ijk} = (f_1)_i \times (f_2)_{jk}$

Model 2 $F_{ijk} = 10 \{(W_1 \times (f_1)_i + W_2 \times (f_2)_{jk}\} / (W_1 + W_2)$

where F_{ijk} = priority rating for maintenance activity i on highway class j with distress severity level k, $1 \leq F_{ijk} \leq 100$

$(f_1)_i$ = priority score for maintenance activity i in relation to other maintenance activities, $1 \leq (f1)i \leq 10$

$(f_2)_{jk}$ = priority score for combination of highway class j and distress severity level k in relation to other combinations, $1 \leq (f_2)_{ijk} \leq 10$

Priority Rating Methods

(C) Priority Rating by Neural Networks

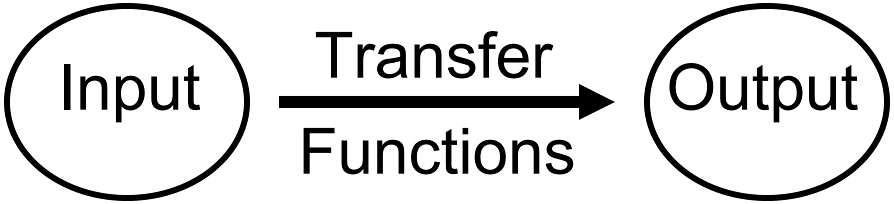
Concept of Neural Network Operations

Aim: To mimic (simulate) the decision-making process of human beings in arriving at the priority ratings of pavement distress.

Mechanism: A neural network, through repeated training using user fed inputs and expected outputs, develops a set of input-output transfer functions so as to minimize errors in predictions

Minimising of global errors:

$$\sum_k \{d_k - O_k\}$$



where d_k = expected value, and O_k = predicted value

- Does not require mathematical equations to relate pavement conditions and other relevant factors to priority ratings.
- Details of transfer functions established within neural networks are not known to users.

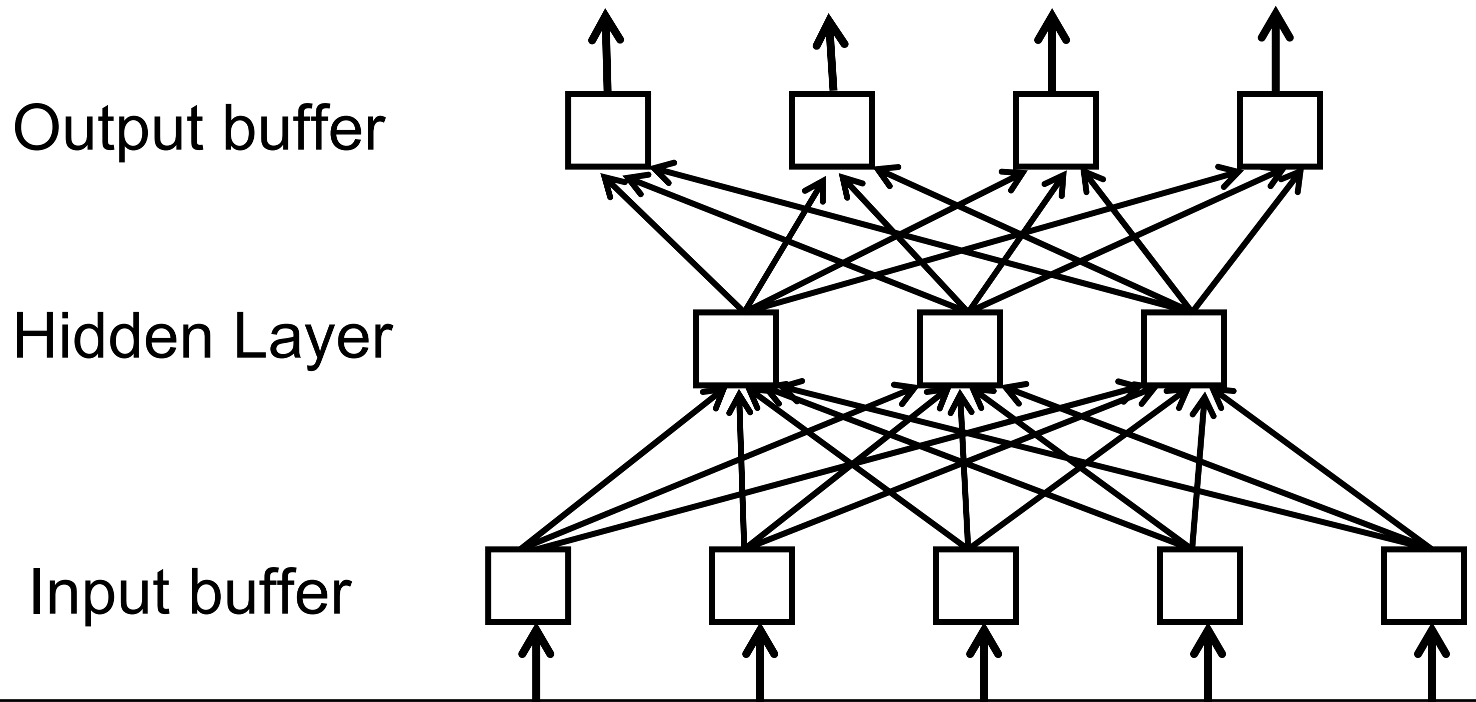
Priority Rating Methods

(C) Priority Rating by Neural Networks *(cont'd)*

Neural Network Layer Structure

A neural network consists of many processing elements organised into layers with full or partial connections between successive layers.

- Input Buffer – receives input data
- Output Buffer – holds output response
- Hidden layers – contains intermediate processing elements



Priority Rating Methods

(C) Priority Rating by Neural Networks *(cont'd)*

Learning/Training Process

- Known input data and output response
- Forward processing creates connecting weights in transfer function from a layer to the next layer.
- Errors at the output buffer are ***propagated backward*** to adjust the connecting weights.
- Steps 2 and 3 are repeated to minimize the errors of response at the output buffer.

This process is called ***supervised learning***. The connecting weights are the memory units of a neural network.

Priority Rating Methods

(C) Priority Rating by Neural Networks *(cont'd)*

Updating

A neural network can be periodically updated by re-activating training phase with new data, to reflect changes due to

- ♦ Improvement in maintenance technology
- ♦ New pavement materials or designs
- ♦ Shifts in maintenance strategy

OPTIMAL USE OF HIGHWAY FUNDS

PAVEMENT MAINTENANCE MANAGEMENT SYSTEMS (PMMS)

Effect of Maintenance on Pavement Performance

Performance of pavement is affected by :

- Timing of maintenance/repair
- Frequency of maintenance/repair
- Extent of maintenance/repair
- Type of maintenance/repair

Objectives of PMMS :

To provide highway maintenance managers an effective tool to formulate a good routine maintenance programme so as to maintain and preserve the road network under their charge at or above a desired standard within the budget allocated.

Performance Measure for Pavements
-- Concept of PSI-ESAL Loss

PSI-ESAL loss as a representation of pavement damage/ deterioration, and hence a measure of pavement performance.

Advantages :

1. It offers a quantitative performance measure that covers the entire analysis period;
2. It measures pavement performance quantitatively on the same time frame basis as that used for evaluating loads and environmental effects;
3. It can be related to level of pavement routine maintenance;
4. It can be used to assess the effectiveness of pavement routine maintenance work.

Multi-Objective Problem

Based on user-defined objective function

Examples of objective function:

- Maximize production
- Minimize cost
- Maximize utilization of manpower
- Maximize utilization of equipment
- Maximize utilization of allocated budget
- Maximize network pavement condition
- Maximize pavement service lives

Complexity of PMMS Problems

"Combinatorial explosion" of the feasible solution space.

Example: A typical problem at network level covers

4 road types (i = 4)
4 pavement repair activities (j = 4)
3 levels of distress severity (k = 3)

So there are altogether (4 x 4 x 3) = 48 work categories.

Consider a planning period of 45 workdays, and assuming each work category may be assigned any integer value from 0 to 45 workdays, the total number of possible solutions is equal to 46^{48} or 6.4×10^{79}.

This would require a modern super-computer many years to enumerate all the possible solutions.

Concept of Equivalent Workdays

It is possible to derive performance standards of maintenance activities, and express all workloads in terms of equivalent workdays.

$$\text{Equivalent workdays } W_{ijk} = \frac{\text{Workload in conventional unit } P_{ijk}}{\text{Performance standard } U_{ijk} \text{ (unit / workday)}}$$

It provides a common basis of reference for measuring the workload requirements of different maintenance activities

The table attached shows common work measurement units for some of the maintenance activities.

The ***objective function*** $\Sigma\,\Sigma\,\Sigma\, W_{ijk}F_{ijk}$ is the sum of equivalent workday units of maintenance activities each weighted by an appropriate priority factor.

Typical formulation for optimization :

- **Maximize (Maintenance Work Production)**

Subject to :

- Mandatory repair and maintenance work
- Budget constraint
- Manpower availability
- Equipment availability
- Material availability
- Rehabilitation constraints

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