Lecture 3

Pavement Condition Surveys

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Pavement Condition Survey

Pavement condition varies with time. Survey needed periodically to:

- Provide data for maintenance planning
- Provide data for improving construction & maintenance techniques
- Provide data for pavement performance assessment
- Provide information for updating network improvement programmes

Pavement Condition Survey

Condition Category	Pavement Condition Parameter
1. Safety	• Skid resistance measurements • Accident rate
2. Structural capacity	• Cores • Deflection measurements
3. Serviceability	• Surface roughness measurements • Panel rating
4. Distress	• Distress condition survey (automated nondestructive survey; manual measurements; visual inspection; photo-logging)

PAVEMENT DISTRESS SURVEY

Assessment of Pavement Distresses

1. Identify type of distress
2. Record location of distress
3. Measure dimensions of distress
4. Assess distress severity
5. Determine extent affected (or density of distress)
6. Recommend possible remedial actions

Types of Flexible Pavement Distresses

1. Cracking Alligator cracking Longitudinal cracking Transverse cracking Block cracking Multiple cracking Slippage cracking Shrinkage cracking Reflection cracking Random cracking	**2. Surface Distortion** Rutting Shoving Corrugation Swelling Depression Imprint
3. Surface Disintegration Pot-holes Stripping Ravelling	**4. Miscellaneous** Bleeding Polishing Patch deterioration

Types of Rigid Pavement Distresses

1. **Cracking**
   - Longitudinal cracking
   - Transverse cracking
   - Corner cracking
   - Diagonal cracking
   - D cracking
   - Shrinkage cracking
   - Block cracking
   - Random cracking

2. **Surface Disintegration**
   - Potholes
   - Scaling
   - Pop-outs
   - Punchout
   - Ravelling

3. **Surface Distortion**
   - Warping
   - Rutting
   - Settlement

4. **Joint-Related Defects**
   - Faulting
   - Blow-up
   - Pumping
   - Spalling
   - Joint separation
   - Loss of sealing materials
   - Joint shattering

5. **Miscellaneous**
   - Polishing
   - Patch deterioration

Types of Pavement Distress Survey Procedure

- Detailed visual inspection and physical measurement (on foot)
- Visual inspection from slow-moving vehicle (or bicycle) plus physical measurement
- Windscreen survey (slow speed, or traffic speed)
- Photologging method
- Videotaping method
- Image processing techniques

Distress Severity is a function of :

- Type of pavement (flexible, rigid, block etc)
- Structural design of pavement
- Age of pavement
- Functional classification of read/airport pavement (e.g. expressway, industrial road, city streets; runway, taxiway, parking bay etc)
- Location of distress
- Prevailing climate condition
- Road users' expectation
- Design level of service by road authority

Examples of Pavement Distress Ratings

Distress	Severity Definition		
	Texas	Washington	Ohio
Alligator cracking	Verbal Slight Moderate Severe	Verbal Hairline Spalling Spalling	Verbal Low Medium High
Rutting	Verbal Slight Moderate Severe	Average Width 1/4 – 1/2 in. 1/2 – 3/4 in. Over 3/4 in.	Verbal Low Medium High
Transverse cracking	Verbal Slight Moderate Severe	Average Width 1/8 – 1/4 in. > 1/4 in. Spalled	Verbal Low Medium High
Longitudinal cracking	Verbal Slight Moderate Severe	Average Width 1/8 – 1/4 in. > 1/4 in. Spalled	Verbal Low Medium High

Examples of Pavement Distress Density

Distress	Density Definition		
	Texas	Washington	Ohio
Alligator cracking	% of Area 1 – 5% 6 – 25% +25%	(Wheel track/station area 1 – 24% 25 – 49% 50 – 100%	Verbal Occasional Frequent Extension
Rutting	% of Area 1 – 15% 16 – 30% +30%	Measured Average depth	Verbal Occasional Frequent Extension
Transverse cracking	No./station 1 – 4 5 – 9 10+	Number per station 1 – 4 5 – 9 10+	Verbal Occasional Frequent Extension
Longitudinal cracking	Linear feet per station 10 – 99 100 – 199 +200	Linear feet per station 10 – 99 100 – 199 +200	Verbal Occasional Frequent Extension

Issues with Distress Condition Rating

- There exist different criteria and guidelines
- Based on experience and subjective judgment
- Climatic and traffic related
- Related to pavement design and construction technology

End results :

- Discrete grouping with artificial boundaries
- Concealed differences within and between groups
- Consequences on effectiveness of maintenance unknown

Distress Condition Rating using Fuzzy Mathematics

Problems with traditional subjective distress rating methods:

(1) The difference between two distresses may be negligible, yet they could end up being classified in two severity categories (i.e. in low and medium severity, or in medium and high severity)

(2) Each severity level covers a rather wide range. For example, rut depths of 11 mm and 20 mm may both be classified as medium severity.

Actual relative severity of different distresses not adequately represented

i.e. Exaggerating minute differences in some instances, while concealing major differences in other instances

Possible improvements by applying **Fuzzy Logic**:

- Subjective nature of distress assessment can be reflected
- Uncertainty of evaluators can be represented
- Different opinions of different evaluators can be considered
- Artificial discrete grouping can be avoided

Introduction to Fuzzy Set Theory

Useful mathematical model for natural language estimates and subjective opinion.

Degree of Membership

- It measures the extent to which an element belongs to a fuzzy set. (It measures the plausibility of an element being in a particular set)
- It is always a real number between 0 and 1, [0, 1]

Example: Given a fuzzy set A

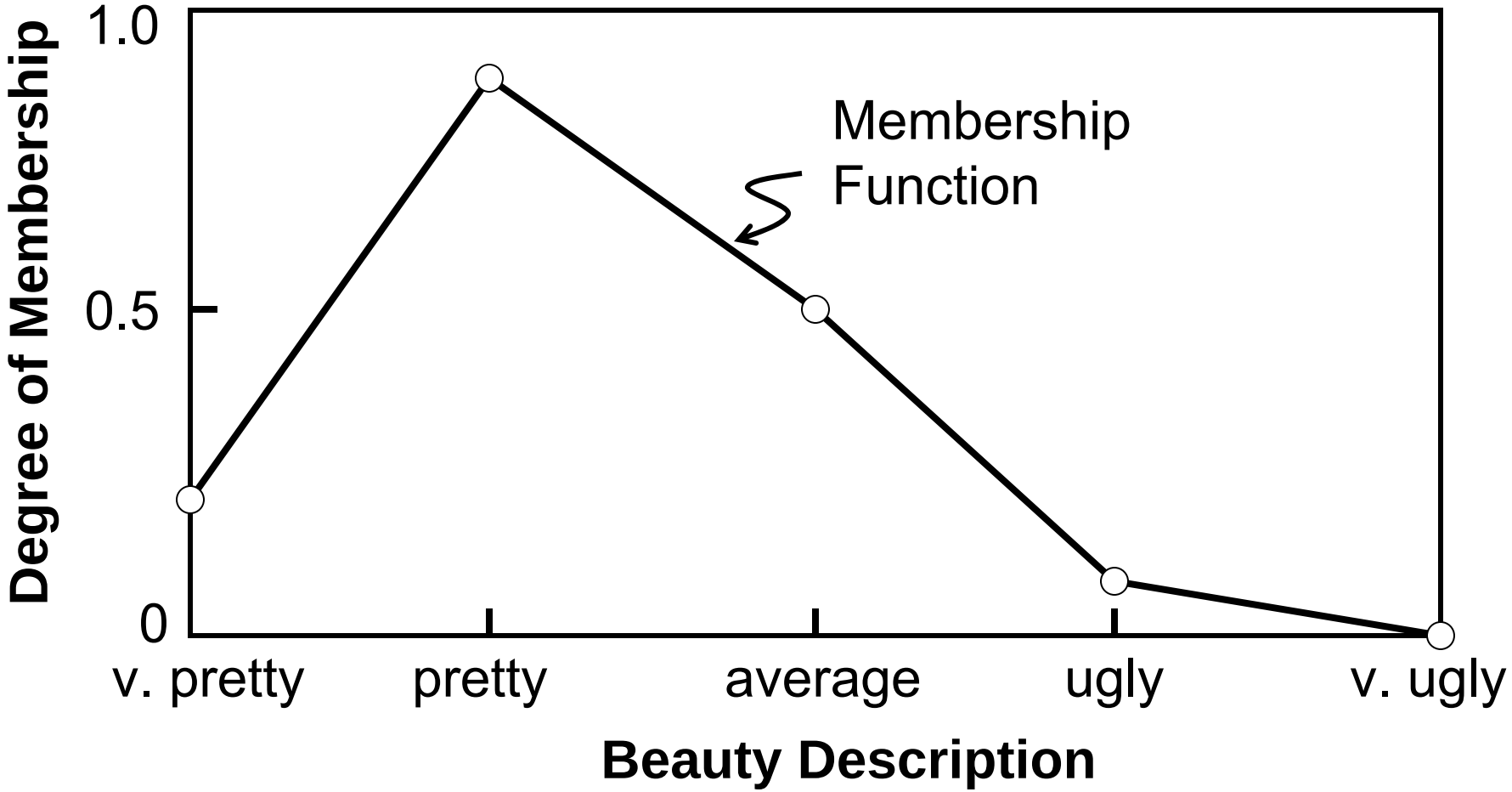
a is present with degree of membership 1.0
b is present with degree of membership 0.9
c is present with degree of membership 0.2
d is present with degree of membership 0.7
e is present with degree of membership 1.0
f is present with degree of membership 0

We write fuzzy set A = { 1/a, 0.9/b, 0.2/c, 0.8/d, 1/e, 0/f }

Example:

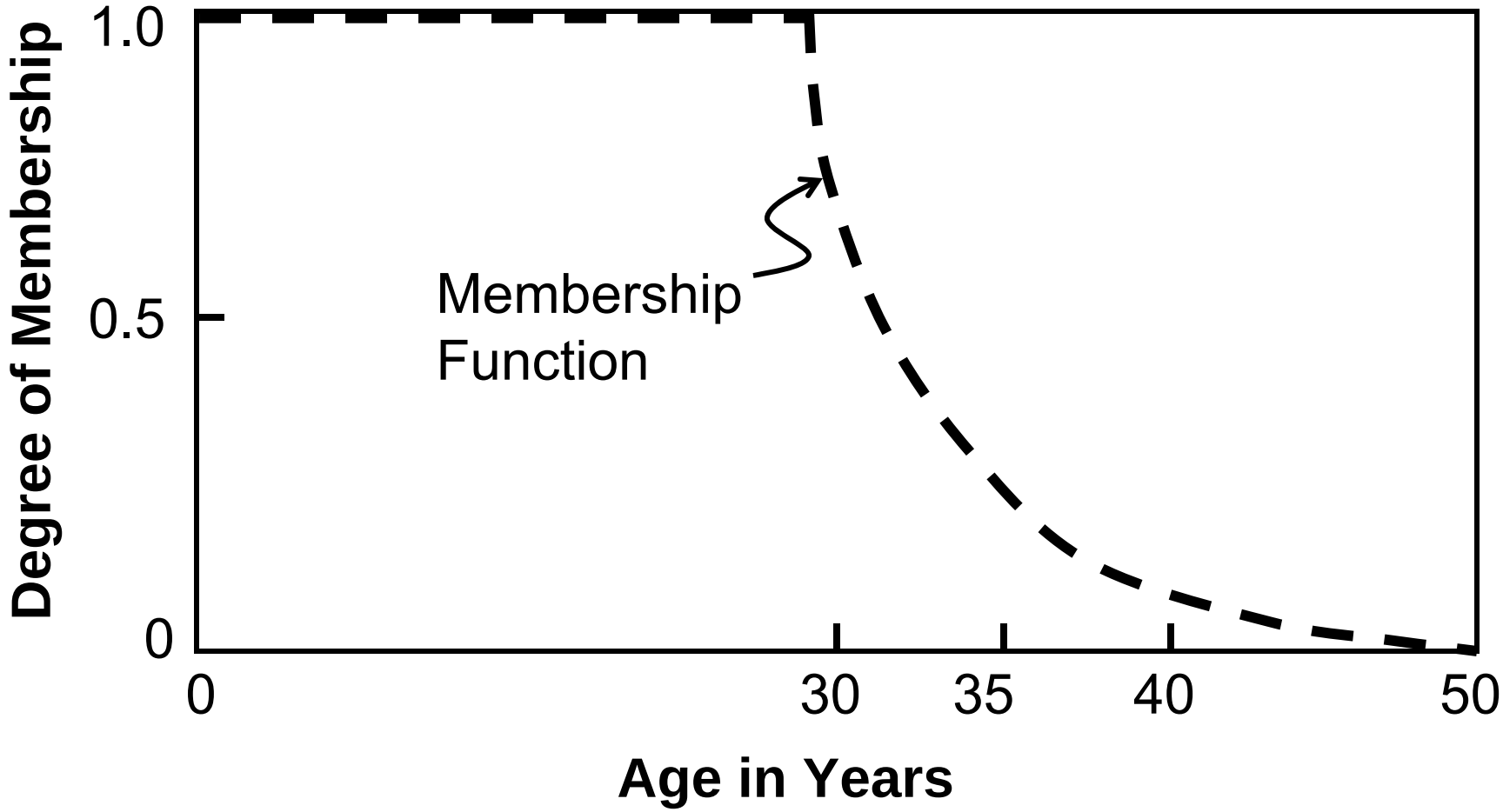
A is a fuzzy set that describes the beauty assessment by a judge

A = { 0.2/very pretty, 0.9/pretty, 0.5/average, 0.1/ugly, 0/very ugly }



Note: The universe from which a fuzzy set is constructed needs not be finite.

Example: Membership function for a fuzzy set describing the imprecise term ‘young’:

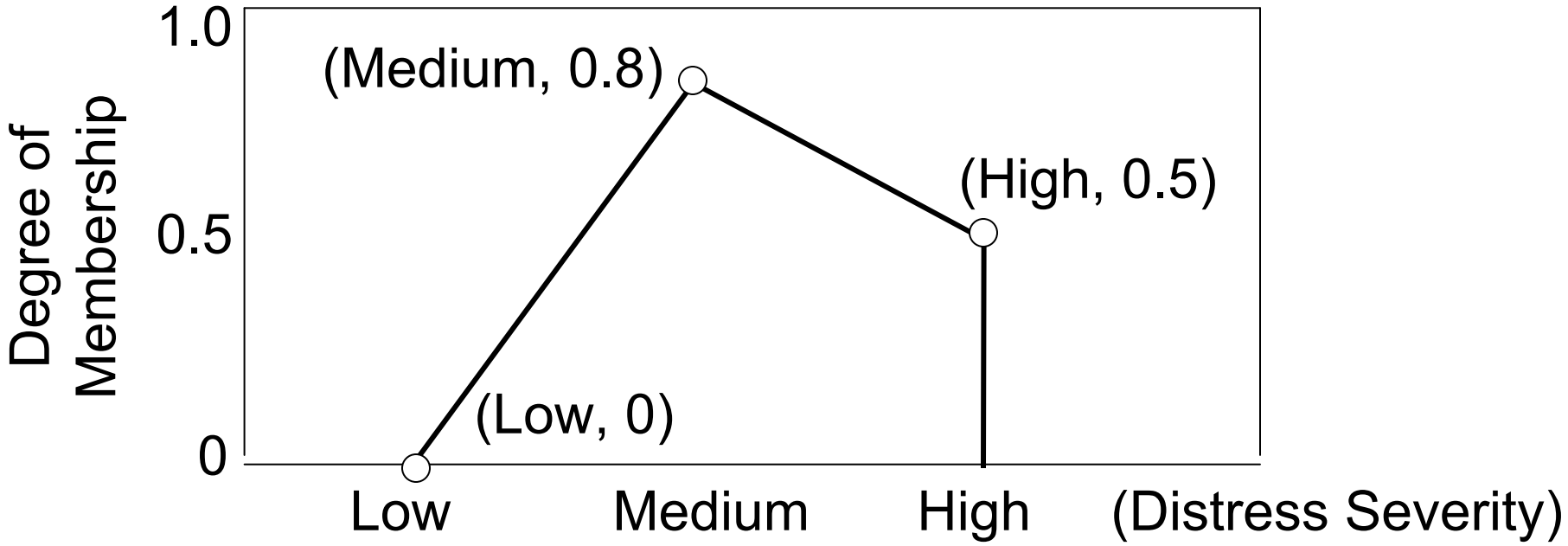


Example of Fuzzy Mathematics Application :

Severity levels defined in terms of maintenance needs

Severity Level	Maintenance Needs
Low	No maintenance treatment needed, monitoring is necessary
Medium	Maintenance treatment needed
High	Mandatory repair required

$A_{(rut)}$ = { 0/Low, 0.8/Medium, 0.4/High}



Determination of Membership Grade of a Distress

(1) Each engineer i provides his fuzzy assessment
(x_i/Low, y_i/Medium, z_i/High)

(2) Combined assessment of all engineers involved
(X/Low, Y/Medium, Z/High)

$$X = \frac{\sum(W_i * x_i)}{\sum W_i} \qquad Y = \frac{\sum(W_i * y_i)}{\sum W_i} \qquad Z = \frac{\sum(W_i * z_i)}{\sum W_i}$$

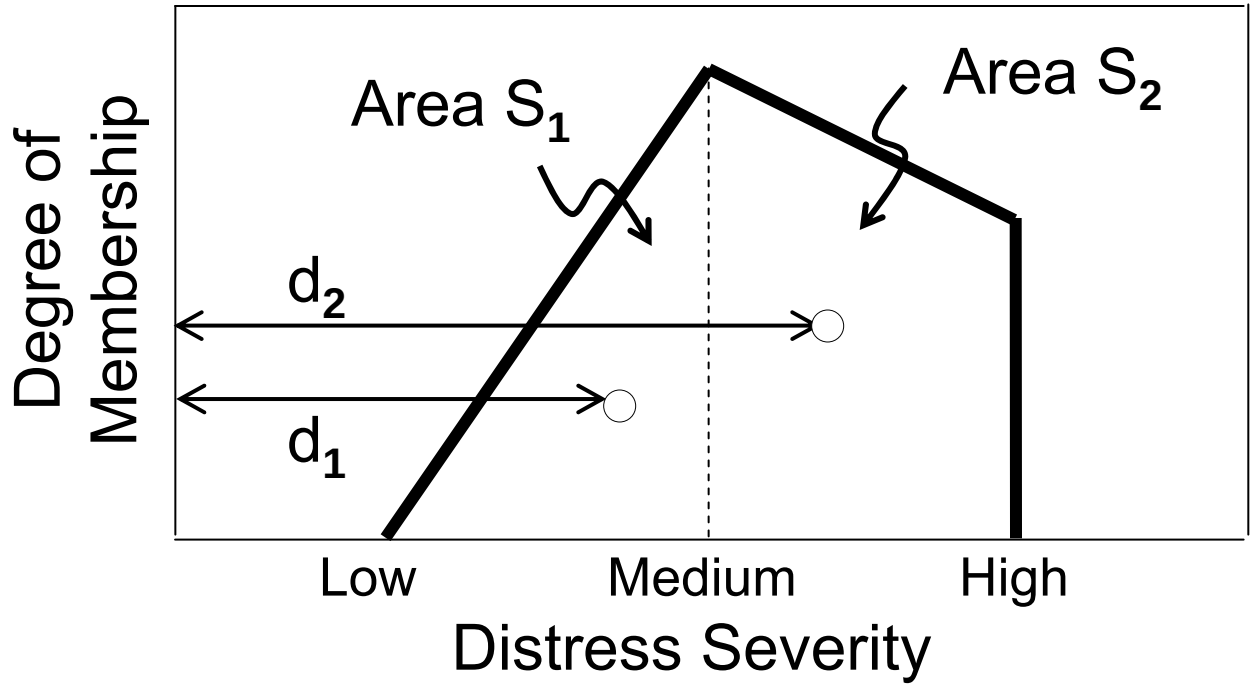
where W_i represents the weight of engineer i. Usually equal weights are given to all engineers. However, if inexperienced engineers or supervisors are involved in the assessment, lower weights may be assigned to them.

Computation of Distress Rating Score

For easy understanding and application in maintenance planning, it is desirable to have a numerical rating score rather than a membership function. This can be achieved by adopting the concept of ***Grade Distance D*** for a membership function.

$$D = \frac{\sum(S_i * d_i)}{\sum S_i}$$

S_i = area of sub-area i, d_i = distance from the vertical membership axis to the geometric center of sub-area i.



The Grade Distance D for a distress membership function gives the rating score for the distress concerned.

References

- Chapter 19 “Highway Condition Surveys and Serviceability Evaluation” in The Handbook of Highway Engineering, edited by T. F. Fwa. (2006)
- Fwa T. F. and Shanmugam R. (1998) Fuzzy Logic Technique for Pavement Condition Rating and Maintenance-Needs Assessment. Proceedings, 4th Int. Conf. on Managing Pavements, Durban, S. Africa.