MODULE 11

OPTIMIZATION

Instructional Objectives

- Understand philosophy of optimization
- Identify concepts involved in optimization analysis
- Identify types of models used in optimization analysis

Optimization

- Uses sophisticated mathematical modeling techniques for the analysis
- Multi-step process
- Provides improved benefit to agencies

Optimization Analysis Steps

- Determine agency goals
- Establish network-level strategies that achieve the goals
- Select projects that match the selected strategies

Optimization Considerations

- Other techniques are easier to understand
- Loss of control perceived
- Requires individuals with backgrounds in mathematics, statistics, and operations research
- Consistency in data is more important
- Requires sophisticated computers

Is Optimization Appropriate?

- **Select prioritization if:**
  - Management wants to exercise significant control over the planning and programming exercises.
- **Select optimization if:**
  - Management wants to take a global view and is willing to put substantial faith in a system.

Objective Function

- **Used to express an agency goal in mathematical terms**
- **Typical objective functions**
  - Minimize cost
  - Maximize benefits
- **Identify/define constraints**

Markov Transition Probability Matrix

Current State	Future State			
	1	2	3	4
1	0.2	0.4	0.3	0.1
2		0.2	0.6	0.2
3		0.1	0.3	0.6
4			0.1	0.9

Markov Assumptions

- **Future condition is independent of past condition**

Other Parameters

- **Transition costs must be defined**
  - Life-cycle costs
  - Present worth analysis typically more common
- **Heuristic approaches reach near optimal solutions**
  - ICB Ratio

Example of a Markov Decision Process

- **Assumptions**
  - 100 mile network
  - Two condition states: good (1) or bad (2)
  - 80% of the network is in good condition
  - 20% of the network is in poor condition
  - Two maintenance activities are considered: Do Nothing (DoNo) and Overlay (Over)

Transition Probability Matrix

	To Condition States			
From Condition States	Do Nothing		Overlay	
	1	2	1	2
1	0.6	0.4	0.95	0.05
2	0.01	0.99	0.8	0.2

Network Conditions - Year 1
Strategy = Overlay All Bad

	To Condition States	
From Condition States	1	2
1	80%*0.6 = 48	80%*0.4 = 32
2	20%*0.8 =16	20%*0.2 = 4
Total	64%	36%

Network Conditions - Year 2
Strategy = Overlay All Bad

	To Condition States	
From Condition States	1	2
1	64%*0.6 = 38.4	64%*0.4 =25.6
2	36%*0.8 =28.8	36%*0.2 = 7.2
Total	67.2%	32.8%

Network Conditions - Year 3
Strategy = Overlay All Bad

	To Condition States	
From Condition States	1	2
1	67%*0.6= 40.2	67%*0.4= 26.8
2	33%*0.8= 26.4	33%*0.2 = 6.6
Total	66.6%	33.4%

Example Cost Data

Condition State	Action	Initial Cost	Annual Maintenance Cost	Total Cost
1	Do Nothing	$ -	$ 2,000	$ 2,000
2	Overlay	$ 10,000	$ 100	$ 10,100

Policy Costs - Year 1
For Repair Strategy

Condition State	# of km	Action	Cost ($000)	Total Cost ($000)
1	80	Do Nothing	$160	$362
2	20	Overlay	$202	

Policy Costs - Year 2
For Repair Strategy

Condition State	# of km	Action	Cost ($000)	Total Cost ($000)
1	64	Do Nothing	$128	$492
2	36	Overlay	$364	

Policy Costs - Year 3
For Repair Strategy

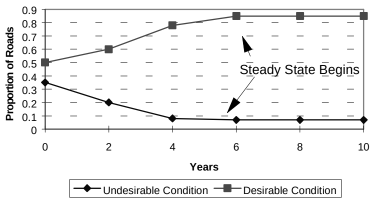
Condition State	# of km	Action	Cost ($000)	Total Cost ($000)
1	67	Do Nothing	$134	$467
2	33	Overlay	$333	

Simulation Objectives

- **Identify the policy with the minimum expected cost after the system reaches steady state.**
- **Establish desired long-term performance standards and minimum budgets to achieve standards or short-term objectives to reach steady state within a specified period at a minimum cost.**

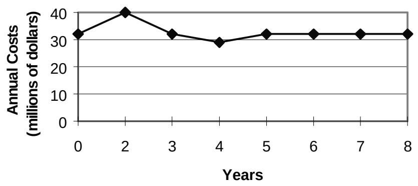
Example Network Performance

Projected Performance



Example Budget Expenditures

Projected Maintenance Budget



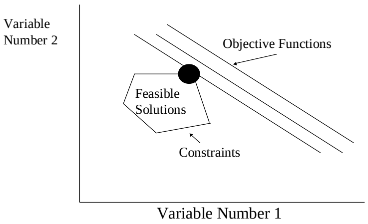
Markov Approach

- **Advantages**
- **Disadvantages**

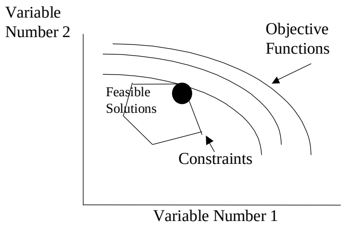
Mathematical Programming Methods

- **Linear programming**
- **Non-linear programming**
- **Integer programming**
- **Dynamic programming**

Linear Programming



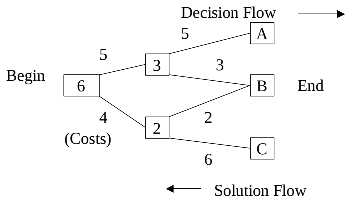
Non-linear Programming



Integer Programming

Projects	Do Nothing	Seal	Overlay
1	0	1	0
2	1	0	0
3	0	0	1
4	0	1	0

Dynamic Programming



Selecting the Appropriate Programming Method

- **Function of:**
  - Type of variables in analysis
  - Form of objective function
  - Sequential nature of decisions
- **Typical approaches:**
  - Linear programming most common
  - Dynamic programming second most common approach
  - Non-linear third most common approach
  - No agency is using integer programming

Markov Implementation Steps

- **Define road categories**
- **Develop condition states**
- **Identify treatment alternatives**
- **Estimate transition probabilities for categories and alternatives**

Markov Implementation Steps (cont.)

- **Estimate costs of alternatives**
- **Calibrate model**
- **Generate scenarios**
- **Document models**
- **Update models**

Case Study - Kansas DOT

- **System Components**
  - Network optimization system (NOS)
  - Project optimization system (POS) (was not fully operational in 1995)
  - Pavement management information system (PMIS)

Overview of KDOT Data Collection Activities

- **Collect pavement distress information**
- **Monitor rutting**
- **Collect roughness data**

KDOT M&R Programs

- **Major Modification Program**
- **Substantial Maintenance Program**

KDOT Databases

- **CANSYS**
- **PMIS**

KDOT NOS Analysis

- **216 possible condition states**
- **Primary influence variables:**
  - Indices to appearance of distress
  - Rate of change in distress
- **Rehabilitation actions based on one of 27 distress states**
- **Linear programming used to develop programs to maintain acceptable conditions for lowest possible cost**

KDOT POS Analysis

- Projects from NOS are investigated in more detail using POS
- Identify initial designs to maximize user benefits

KDOT System Development

- Issue paper
- PMS Steering Committee
- Pavement Management Task Force
- Consultant

Summary

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