Optimizing Environmental Sustainability and Public Benefits of Transportation Network Programs

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Optimizing Environmental Sustainability and Public Benefits of Transportation Network Programs

Introduction

Sector Source

Transportation 28%
Residential & Commercial 10%
Industrial 22%
Electric Power 40%

Petroleum 36%
Natural Gas 28%
Coal 18%
Renewable Energy 9%
Nuclear Electric Power 9%

71% 5% 23% 1%
Introduction

Highway Network

Riverside Grade

Transportation 28%
Residential & Commercial 10%
Industrial 22%
Electric Power 40%

Current Funding 46%
Funding Gap 54%

Petroleum 36%

2013 ASCE Infrastructure Report Card
Introduction

Examples of Current Funding Allocation Practices

- Traffic Congestions
- Pavement Conditions

What about Energy Performance of Rehabilitation Plans?
Can the current practice be improved?

<table>
<thead>
<tr>
<th>Road Section</th>
<th>Traffic Volume (vehicle/day)</th>
<th>Pavement Roughness (m/km)</th>
<th>Length (km)</th>
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Case 1: Traffic Volume

Case 2: Pavement Conditions

Case 3: Fuel Consumption
Optimization in Highway Rehabilitation

**Background**

**Single-Objective Optimization**

- Chan et al. 1994 – minimize cost
- Ferreira et al. 2002 – minimize cost
- Wang and Lui 1997 – maximize overall network performance

**Multi-Objective Optimization**

- Zhang et al. 2012 – energy consumption + GHG emissions + construction costs
- Mathew and Issac 2013 – minimize construction cost + maximize pavement performance
- Orabi and El-Rayes 2011 – maximize net benefits + minimize network service disruption
- Lidicker et al. 2012 – minimize construction costs and GHG emissions
Research Questions

- What is the impact of decision making in highway rehabilitation efforts on total network fuel consumption and the expected public benefits?

- How can the total fuel consumption and expected public benefits for the entire network be modeled?

- How can rehabilitation decisions be optimized in order to maximize public benefits and minimize energy consumption under budget constraints?
Research Objectives

- **Model** Fuel consumption in transportation networks
- **Estimate** Cost of travel delays due to highway construction operations
- **Estimate** Expected savings in road user costs due to completed rehabilitation projects
- **Analyze** Public costs and benefits of highway rehabilitation efforts over time
- **Optimize** Limited funding allocation to rehabilitation projects
Multi-Objective Optimization Problem

(1) Energy Consumption Estimating Module

(2) Travel-Delay Cost Estimating Module

(3) Road User Cost Savings Estimating Module

(4) Public Cost and Benefit Estimating Module

(5) Multi-Objective Optimization Module

**Decision Variables**
- Project Selection

**Planning Objectives**
- Max. Net Public Benefits
- Min. Energy Consumption

**Constraints**
- Limited Funding
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Methodology

**Travel-Delay Cost**
- Traffic Volume
- Vehicle Speed
- Unit Time Value
- Length of road
- Construction Duration

**Fuel Consumption**
- Traffic Volume
- Construction Duration
- Length of road
- Fuel Consumption Rate

**Road User Cost Savings**
- Traffic Volume
- Tire Depreciation Cost Rate
- Length of road
- Repair and Maintenance Cost Rate

**Lifecycle Public Cost and Benefits**
- Total Road User Cost Savings
- Travel-Delay Cost
- Discount Rate
### Application Example

#### Miami-Dade County
(District no.6)

<table>
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<tr>
<th>Project</th>
<th>IRI (m/km)</th>
<th>Traffic volume (veh/day)</th>
<th>Length (mile)</th>
<th>Free-flow speed (mph)</th>
<th>Work zone speed (mph)</th>
<th>Construction cost (million dollars)</th>
<th>Duration (week)</th>
<th>Number of lane</th>
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Application Example

- **Highway Programs based on Pavement Conditions**
- **Highway Programs based on Traffic Volume**

### Table: Alternative vs Project

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Conclusions

There is a trade-off between the expected public benefits and network energy consumption.

The model can provide decision makers with a wide range of optimal solutions that can be effectively selected to satisfy public expectations while minimizing energy consumption.
Future Work

Expand the optimization scope to be more practicable to transportation agencies’ decision making processes.

Expand the optimization module to include other types of decision variables

- Prioritizing the competing highway projects
- Identifying the impact of different rehabilitation methods on highway projects
Thank you for your attention