Transportation Research Forum 2005 Annual Meeting

Benefit / Cost Analysis of Spring Weight Restrictions In Lyon County, Minnesota

Presented by

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Outline

1. Introduction
2. Framework of Analysis
3. Freight Demand Model
4. Pavement Performance Model
5. Benefit/Cost Analysis
6. Conclusions

1. Introduction

Spring Weight Restrictions (SWR):

- A transportation policy which restricts the axle loading of heavy trucks during the spring thaw period.
- Widely enforced in cold regions in Canada, Finland, Sweden, Norway, France, northern states of US, and other countries.
- It aims to reduce pavement damage and extend the useful life of roads, but it also brings costs to some road users like trucking industry.

Does the benefit of SWR really exceed the cost?

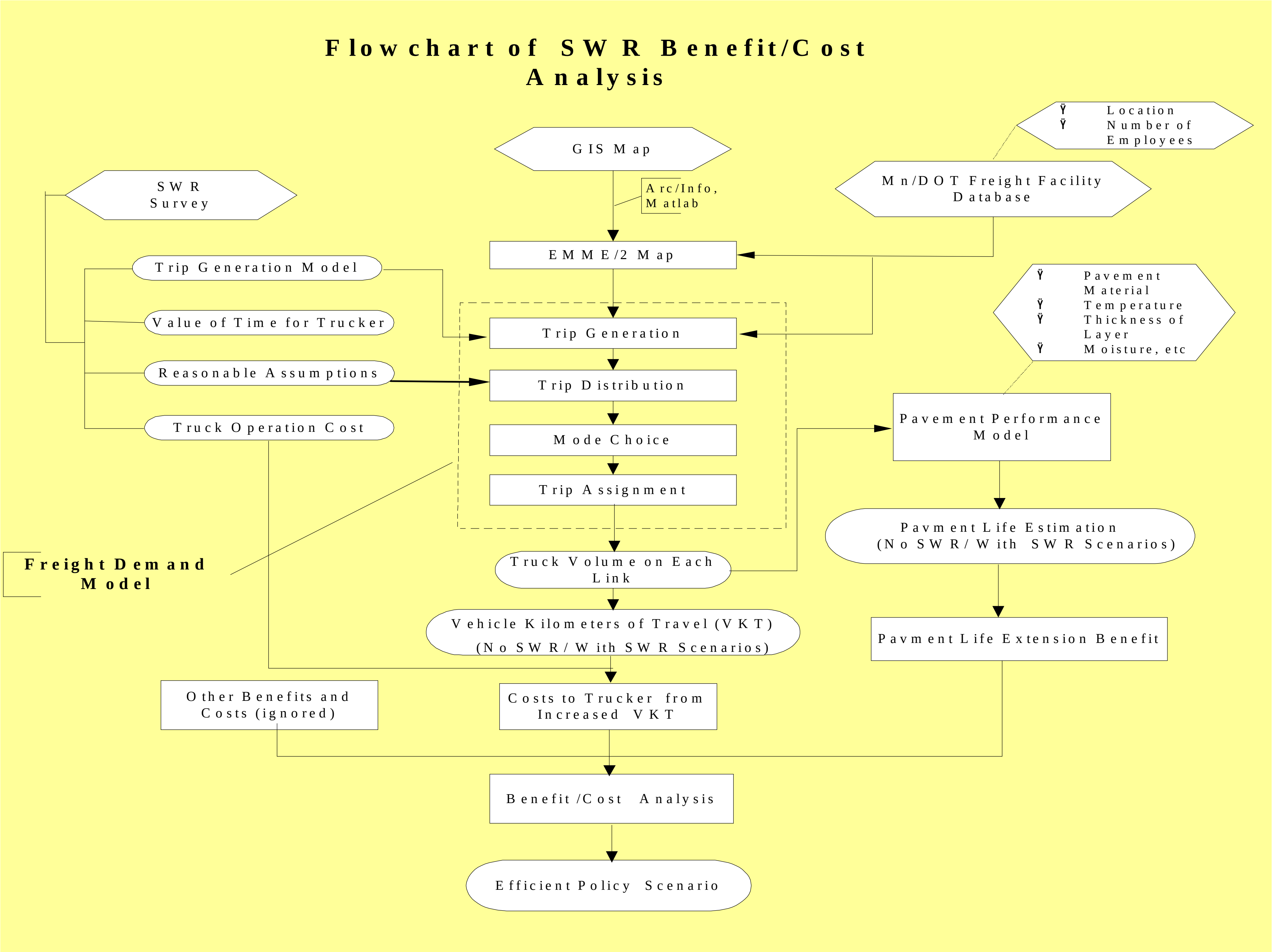
- Although the SWR policy has been implemented for many years, we are still unclear on this issue.
- The trucking industry complains that the SWR policy imposes costs and inconvenience due to increased number of truckloads or detouring.
- Road agencies strongly support this policy because they believe it reduces required pavement investment and maintenance.

Previous Studies

- A World Bank report indicated that the estimated cost savings associated with SWR during an extreme winter in Europe range from 40 percent up to 92 percent. (1993)
- The United States Federal Highway Administration (FHWA) found that SWR can significantly extend the useful pavement life. (1990)
- A study of Norwegian Public Roads Administration showed that the cost of SWR exceeded the benefit; therefore, the policy was lifted in 1995.
- The lifting of the load restrictions in Norway does not result in reduced road surfacing serviceability and the annual budgets for resurfacing actually have been reduced. (2004)

2. Framework of Analysis

- This paper quantifies the effects of Spring Weight Restrictions Policy for Lyon County, Minnesota.
- The basic idea of the analysis is:
  - To build a Freight Demand Model that can simulate truck flow under two scenarios: With and Without SWR.
  - To build a Pavement Performance Model which can estimate the pavement life under different traffic scenarios.



Flowchart of SWR Benefit/Cost Analysis
GIS Map
Arc/Info, Matlab
Location
Number of Employees
Mn/DOT Freight Facility Database
SWR Survey
EMME/2 Map
Trip Generation Model
Value of Time for Trucker
Reasonable Assumptions
Truck Operation Cost
Trip Generation
Trip Distribution
Mode Choice
Trip Assignment
Pavement Material
Temperature
Thickness of Layer
Moisture, etc
Pavement Performance Model
Pavment Life Estimation (No SWR / With SWR Scenarios)
Pavment Life Extension Benefit
Freight Demand Model
Truck Volume on Each Link
Vehicle Kilometers of Travel (VKT) (No SWR / With SWR Scenarios)
Other Benefits and Costs (ignored)
Costs to Trucker from Increased VKT
Benefit /Cost Analysis
Efficient Policy Scenario

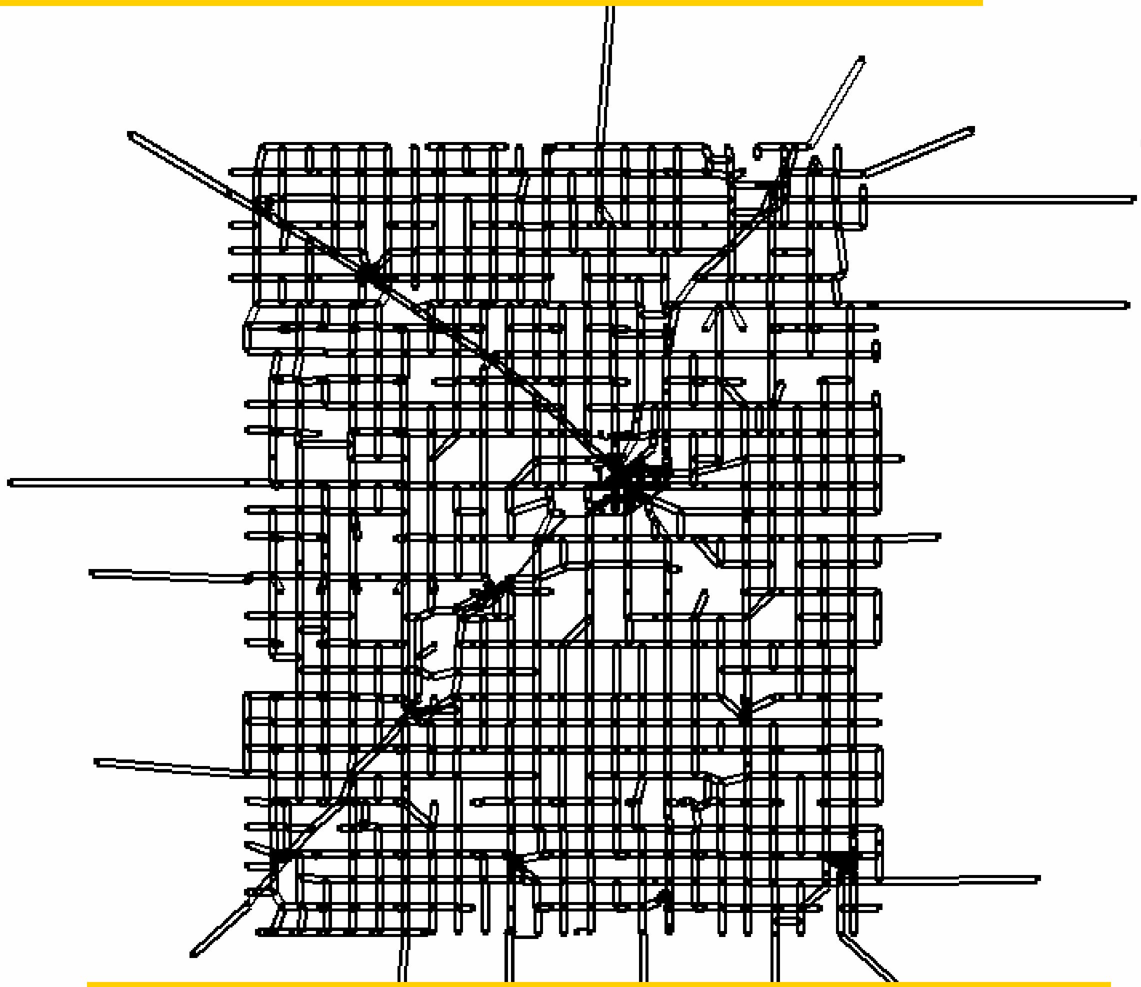
3. Freight demand model:

- **Modeling Area: Lyon County, MN**

  Roads in Lyon County are classified into 5, 7, 9 and 10 ton roads during the SWR period.
- **Methodology and tools:**
  - Four-step model
  - EMME/2 Software
  - Matlab,VBA programming
- **Comparison of truck volumes in two scenarios**
  - No SWR scenario
  - With SWR scenario

Lyon roads with a hierarchy of 5,7,9 and 10 ton axle limits

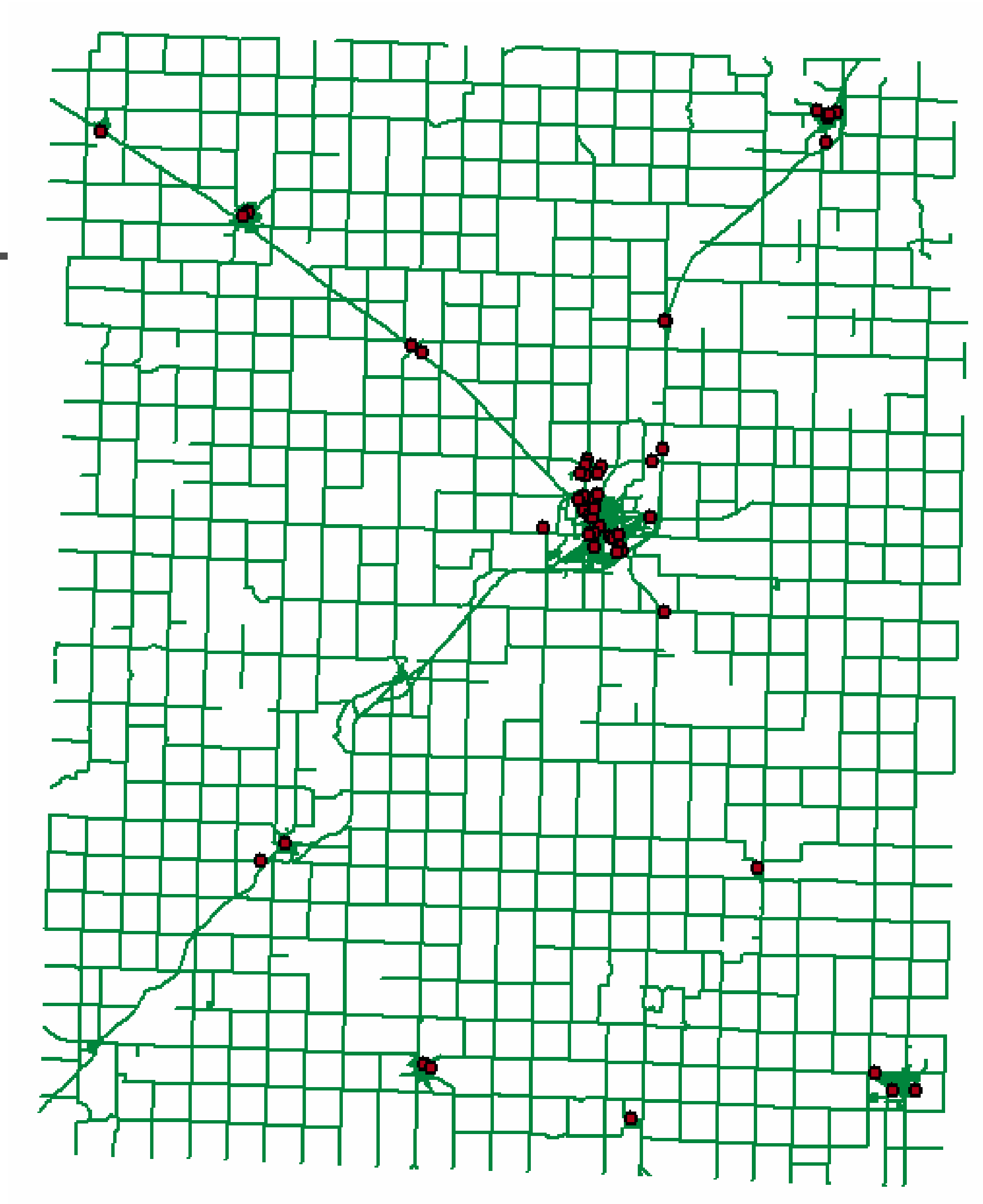
Build road network in EMME/2



Road network of Lyon County in EMME/2

Four-Step Planning Model

- ***Trip Generation***
  - 8 kinds freight facilities are located in Lyon County using Mn/DOT freight facility database:
    - Farm
    - Agriculture Chemical Center
    - Grain Elevator
    - Manufacturing Plant
    - Retail Outlet
    - Trucking Facility
    - Wholesale Distribution Center
    - Other Freight Facilities



Truck trip generated by farms:

- Total grain product of Lyon County (2001)

Corn:	558,911 tonnes
Soybean:	140,593 tonnes
All wheat:	4,515 tonnes
Oats:	2,465 tonnes
Total:	706,484 tonnes

Source: National Agriculture Statistics Service

Each farm has a daily truck trip rate of 0.67 in NoSWR scenario .

Truck trip rate of other freight facilities

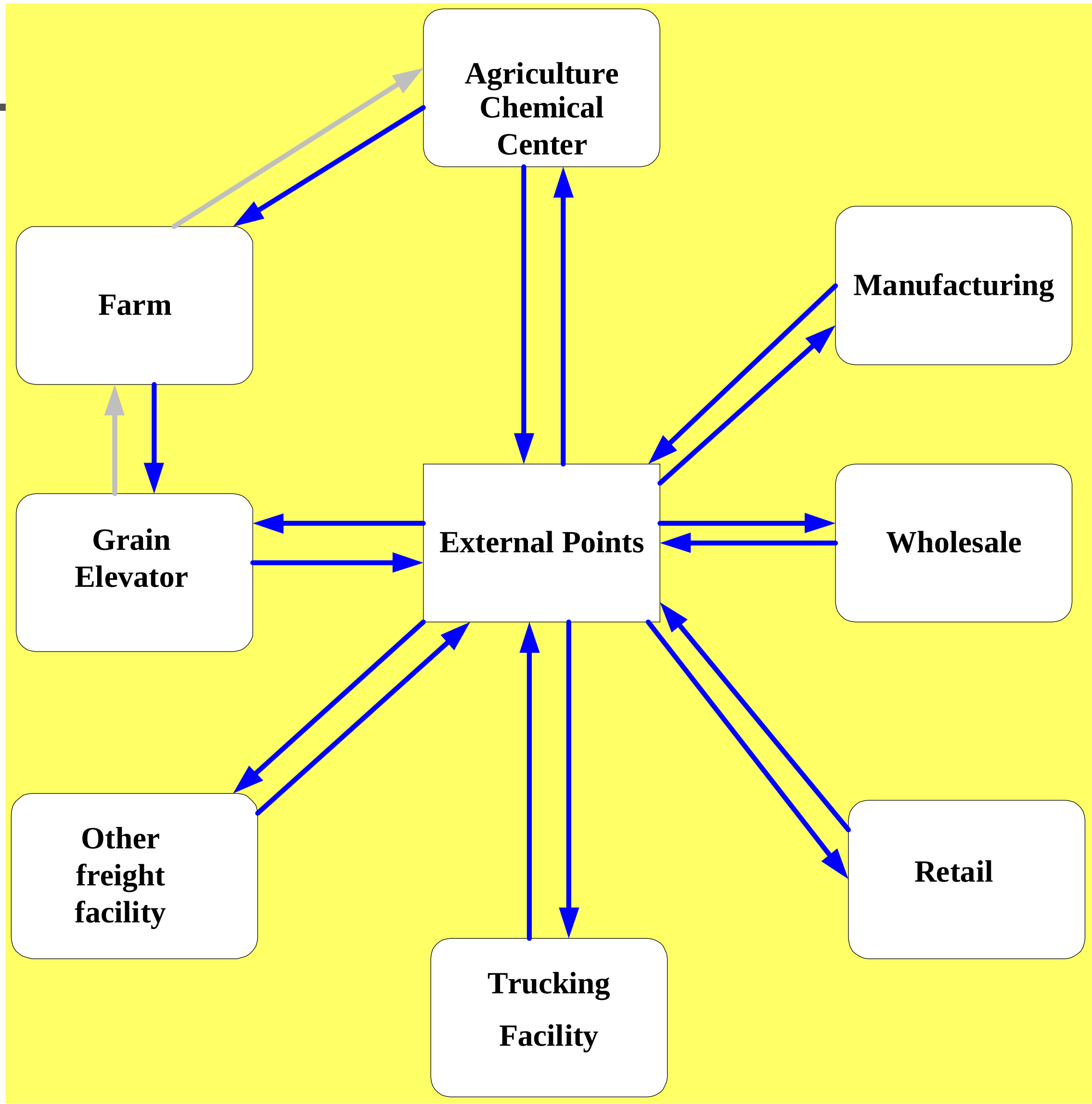
A truck trip generation model from SWR survey is adopted.

A Cobb-Douglas Model:

$$\text{Truck trip} = e^{\beta 1}(\text{Number of employee})^{\beta 2}$$

Freight Catalog	Total outbound trip
Agriculture chemical distribution center	101.44
Grain elevators	126.12
Manufacture plant	67.62
Retail outlet	128.7
Trucking facility	159.2
Whole sale outlet	61.12

Trip Distribution



Truck type choice

- To find the most economical type of trucks for truckers during SWR period, which costs them the least time.
- Assuming 30 minutes for loading and unloading cargo for each truckload, the total cost for a trip is:

$$TC = (TT + TL) * NT * c$$

- TC: Total cost
- TT: Travel time for each trip (hour)
- TL: Time for loading and unloading(hour)
- NT: Number of Truckloads
- c: Value of time (dollar per hour)

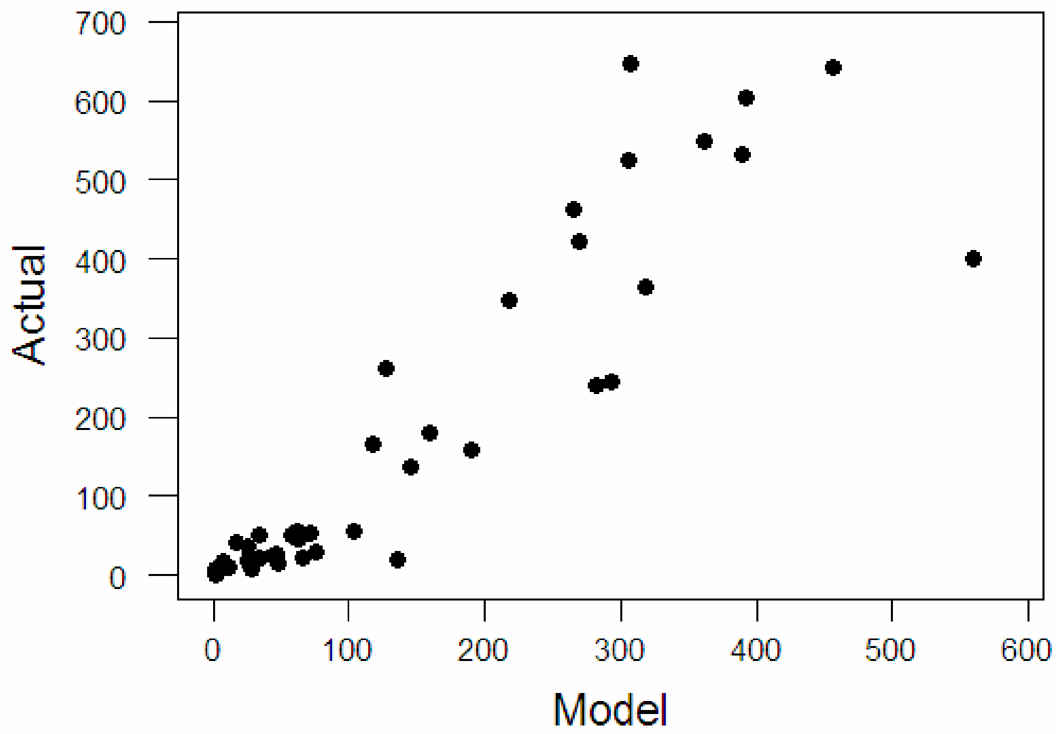
Trip Assignment

- Shortest time path assignment
- The volume-delay function is designed to exclude congestion effects

Model Validation and calibration

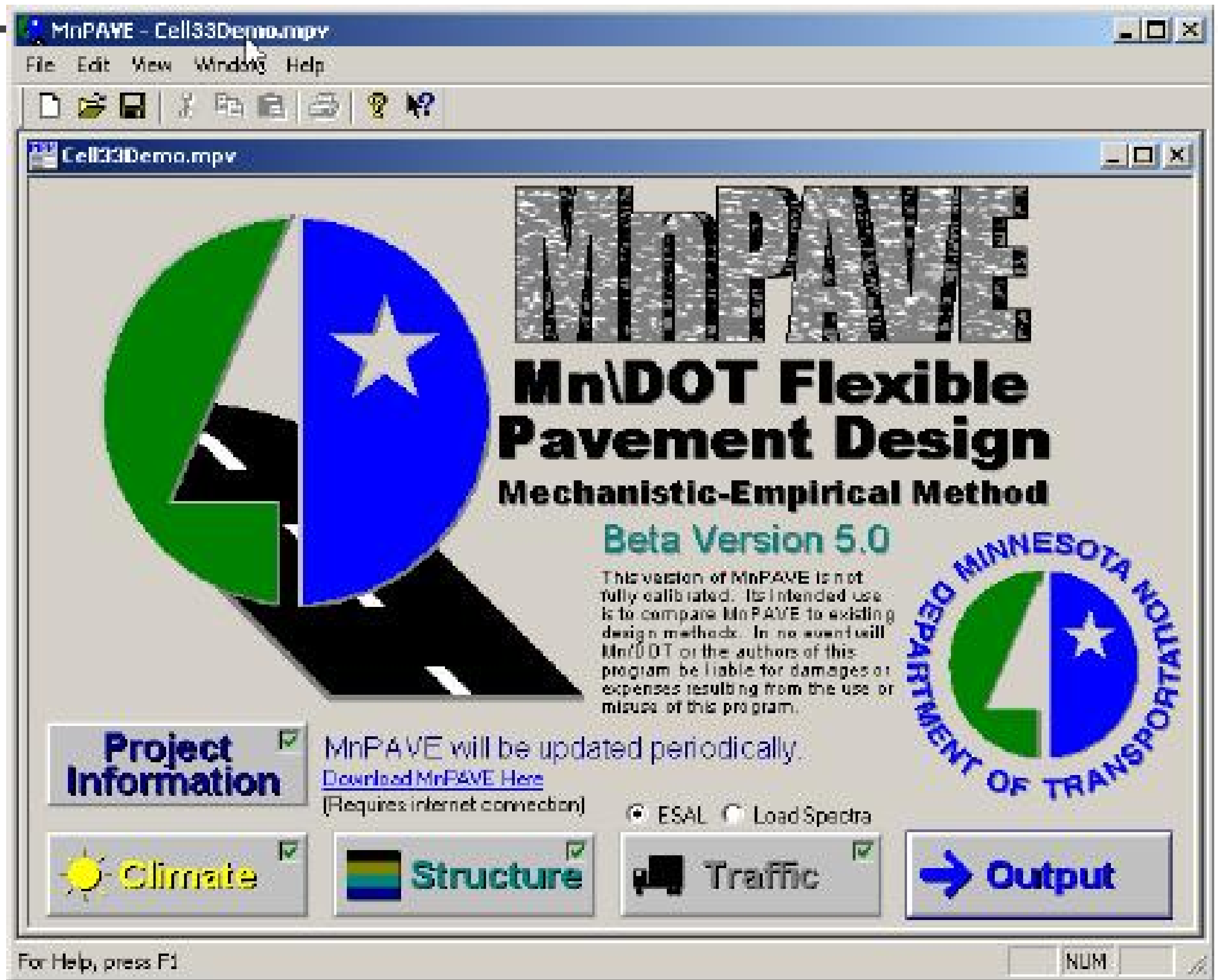
- Freight demand model was validated by comparing observed truck traffic on links in Lyon County outside the SWR period to their counterpart link counts in the model.
- The two data sets have a strong linear relationship.
- The R-squared value for the regression of this data is 0.836. This value shows a strong correlation between the model and the observation.
- A scaling factor of 1.21 was determined to transform the modeled truck rates to more realistic rates in the calibration process.

Relationship between model and observed results



R square=0.836

4.Pavement Performance Model



Pavement performance model

- It is worth noting that the pavement performance model only models the lifetime of pavements in terms of rutting failure.
- From engineering experience, pavement typically lasts 17 years before an overlay is needed in Minnesota. (Other assumptions are tested)
- Thus, when the estimated pavement life before rutting failure from the MnPave exceeds 17 years, we assume the pavement life is 17 years, as some other pavement failure mode is likely to have manifested itself beforehand.

5. Benefit/Cost Analysis of SWR Policy

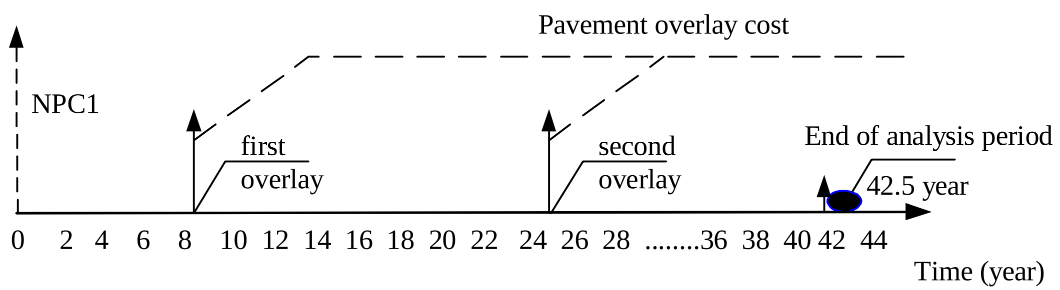
Cost estimates of different types of roads in Lyon County

Road Category	Structural overlay cost per center-line km ($)	Functional overlay cost per center-line km ($)	Length* (km)	Percentage
5 ton road (gravel)				
Average cost		18,750	1,437	
Annual cost (6 years)				
7 ton road				
CSAH 7-ton	72,813	40,625	179	89.60%
County road 7-ton	64,063	35,938	11.2	5.60%
MSA 7 ton	191,667	77,083	9.6	4.80%
Average cost	78,028	42,113		
9 ton road				
CSAH 9-ton	66,875	39,063	216.8	90.00%
County road 9-ton	64,583	34,375	0	0%
MSA 9 ton	233,125	77,083	24	10.00%
Average cost	83,450	42,853		

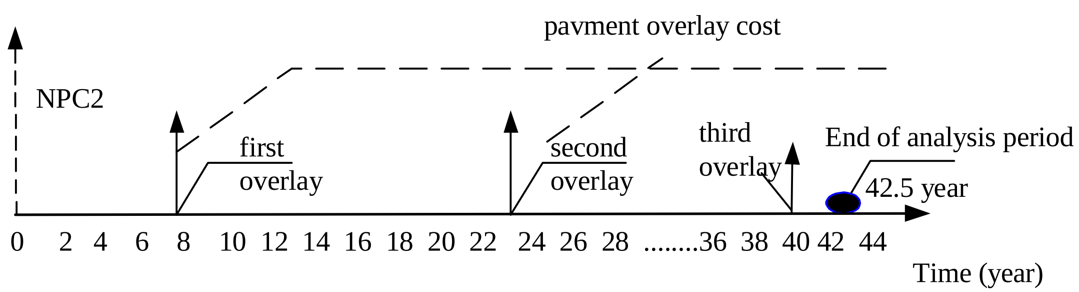
Pavement life extension benefit

- Pavement life extension benefits are calculated on a link-by-link basis.
- For each link, we have the estimated pavement life in the two scenarios. (with and without SWR)
- For most links, the pavement life in terms of rutting failure has a longer life in the scenario with SWR than in the scenario without.
- The overlay costs in both scenarios are discounted to the present value in an analysis period of 42.5 years
- The difference of overlay cost is the pavement life extension benefit due to SWR policy.

Cash flow diagrams of overlay in the two scenarios



With SWR Scenario



Without SWR Scenario

Pavement life extension benefit =NPC2-NPC1

Pavement life extension benefit on an example link

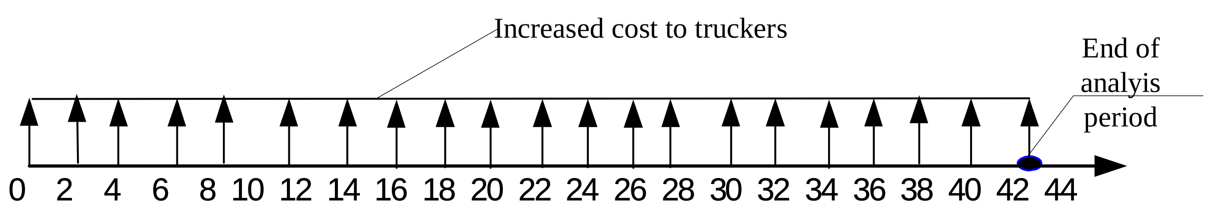
Link 1	From node id:	41		To node id :	9	
	Length (km)		1.584	Cost per km ($)		$42,112
	No SLR scenario			With SLR Scenario		
	Estimated life (year)		14.2	Estimated life (year)		14.5
Number of Overlay	Year	Cost($)	NPC($)	Year	Cost ($)	NPC ($)
1st overlay	7.1	66,706	52,248	7.3	66,706	51,962
2nd overlay	21.3	66,706	32,053	21.8	66,706	31,530
3rd overlay	35.5	32,839	9,680	36.3	28,455	8,161
Sum of NPC			93,981			91,652
Savings due to SLR						2,329

$$66{,}706 * \frac{1}{(1+i)^{7.1}} = \$\ 52{,}248$$

NPC2-NPC1=93,981-91,652=2,329

Cost to truckers

- The cost to the truckers due to SWR is calculated as the increased VKT multiplied by total truck operating cost per kilometer.
- SWR caused additional 30,628 km of truck VKT per day.
- Our SWR survey shows the total truck operating cost is $0.69 per km
- The total cost to all freight shippers and carriers is $21,133 per day.
- Assuming 8 weeks enforcement of SWR, the total annual cost is $1,183,447.
- The net present value of the cost to truckers in the following 42.5 years adds up to $25,977,572, assuming a 3.5% interest rate.



Benefit/Cost ratio from removing SWR on 7 and 9-ton roads only (retaining SWR on 5-ton roads) assuming different time before failure (Scenario 1 vs. Scenario 2')

Assumption (default life of road)	Cost (Increased pavement cost incurred by road agency) ($)	Benefit (Reduced cost to trucker) ($)	Benefit/Cost Ratio
15	278,446	6,057,602	21.76
17	*438,642*	*6,057,602*	*13.81*
20	500,782	6,057,602	12.10
25	644,082	6,057,602	9.41
30	763,415	6,057,602	7.93

6.Conclusions

- According to the above analysis, the benefit/cost ratio of lifting SWR on 7 and 9-ton roads in Lyon County is 13.81 in our base case, which supports lifting the SWR on those roads.
- The above result is based on our assumption of 100% compliance with SWR, which of course differs from reality.
- A reduction in compliance reduces both benefits (if roads are already “overloaded”, the SWR has less effect than shown here) and costs (if trucks are violating the SWR, they don’t save time by the elimination of SWR).

- The interests from both parties make this issue a political one.
- The cost of lifting SWR (increased pavement overlay cost) is borne solely by the road agencies.
- The benefit of SWR is apportioned among thousands of road users (trucking industry).
- If the trucking industry were to benefit from lifting SWR more than the costs imposed on road agencies, there are “gains from trade” to be had.
- A tax, toll, or user fee on trucks to pay for the additional road damage that would be caused without SWR is a win-win solution compared to the current situation with SWR.

- That is all.
- Thanks!
- Questions and Comments?