Assessing the Impact of Modal Diversion on Pavement Maintenance Costs and Asset Management Practices

R. Christopher Williams, Ph.D. (corresponding author)
Associate Professor
482A Town Engineering
Iowa State University
Department of Civil, Construction, and Environmental Engineering
Ames, Iowa 50011
Phone: 515-294-4419
Fax: 515-294-8216
Email: rwilliam@iastate.edu

Jason P. Bausano
Ph.D. Student
Iowa State University
Department of Civil, Construction, and Environmental Engineering
Ames, Iowa 50011

Richard Stewart, Ph.D.
Professor and Director
University of Wisconsin– Superior
Transportation and Logistics Research Center
P.O. Box 2000
Superior, Wisconsin 54880

Libby Ogard
Research Associate
Prime Focus LLC
918 Fox River Drive
DePere, WI 54115
920-217-7222
logard@new.rr.com

Anthony Pagano, Ph.D.
Department of Managerial Studies
University of Illinois at Chicago
601 S. Morgan Street
Chicago, Illinois 60607

ABSTRACT

This paper considers the impact of freight modal shifts on pavement life if short line railroads are no longer considered economically viable. The area selected for this case study considers a branch line connecting Ontonagon, Escanaba, and Rousseau, Michigan, which is currently served by the Escanaba Lake Superior Railroad (ELS), to the Green Bay, Wisconsin area. It is anticipated rail traffic will be diverted from Michigan to Green Bay, Wisconsin. The identification of current freight volumes on this rail segment and the corresponding trucking volumes, are estimated, if this rail traffic were diverted to nearby roads. A logistical flow analysis documents the increased truck movements by route if this rail line is lost. The current condition of the highway segments, which would be impacted by the potential line abandonment, is documented in terms of rutting, roughness, faulting, and cracking (alligator, transverse, and longitudinal). The pavement design method currently used by the Michigan Department of Transportation is the 1994 AASHTO Pavement Design Guide and the Wisconsin Department of Transportation uses "WisPave". These pavement design guides were used to measure the pavements' ability to handle the additional trucks on the highway in terms of structural number for flexible pavements and thickness for concrete pavements.

INTRODUCTION

Class 1 railroad carriers are optimizing methods to handle growing global trade volumes, and focus on taking full advantage of their network capacity by running high utilization trains moving end to end across their network. The changes the Class 1 carriers are implementing are having adverse impacts on short line and rural shippers; this group is seeing a reduction in services in many areas served by secondary railroads (short lines). Rural shippers, faced with limited options with declining rail service and limited car availability, and have taken their case to their local congressmen (Stewart, Wang, Sproule, Pasi, Ogard, 2006). These circumstances have resulted in the introduction of in new state truck size and weight legislation, throughout the Upper Midwest. On March 22nd 2006, Wisconsin passed into law AB 678 which raised truck gross vehicle weight (GVW) to 98,000 lbs for a number of products traditionally carried by short line railroads. This new legislation may have significant impact on highway pavement conditions.

This paper will assess the impact of modal conversion on pavement condition in Michigan and Wisconsin by quantifying rail carload volume which may be diverted to truck volume if rail service continues to decline for rural shippers. Freight volumes diverted to highway modes were analyzed and the resulting impacts on pavement design and condition were assessed.

BACKGROUND

Three Class 1 freight railroads in Michigan offer key transportation services to customers in agriculture, manufacturing and other industries. In the Upper Peninsula of Michigan, the Canadian National is the sole Class 1 railroad operator and the Escanaba Lake Superior Railway is the primary short line railroad. The state of Michigan recognizes the importance of preserving short line railroads. Without adequate investments in railroad infrastructure, a greater amount of freight moves by truck, taking a toll on pavements that were not designed to accommodate this traffic and weight. Additional costs beyond pavement damage occur from the increased truck traffic including: air pollution, increased congestion, additional hazardous cargo on highways, higher freight rates and adverse economic impacts to businesses and communities.

Short line and Regional railroads are defined by Federal Railway Administration guidelines. Regional railroads operate at least 350 miles and must generate a minimum of $40 million. Short line railroads fall into two categories, typically local carriers operate 350 miles or less. Short Line Switching or Terminal railroads typically shuttle or transfer cars between Class 1 connections and local shippers. Frequently, short line railroads are created when a Class 1 railroad puts up a segment of track for sale. This rationalization is often done because that rail line segment no longer meets the Class 1 carriers minimum volume threshold, business plan or network strategy. Today’s short segments can be tomorrow’s short-line railroads. Recent announcements concerning changes to certain short line routes and terminals make the question even more pressing. Additional rail freight demand, coupled with a decrease in line capacity could significantly impact pavements in many rural and urban settings. This paper identifies the impact on pavements that could be expected as a result of additional freight traffic moving over the highways in the states of Michigan and Wisconsin as a case study. This information is needed to help State Department of Transportation’s (DOT’s) evaluate how and where to support rail preservation.

RESEARCH OBJECTIVES

This research identifies current freight volumes on the rail segment(s) and the corresponding trucking volumes if this rail traffic were diverted to nearby roads. A logistical flow analysis was done and documents the increased truck movements by route if a rail line was lost. A comparison of the pavement structural design is included taking into account the increased traffic volumes.

CASE STUDY ROUTE SELECTION

The case study considers the closure of a short line railroad in northern Michigan's Upper Peninsula. A modal shift from rail to highway would occur thus resulting in an increase in truck traffic on the highways. Figures 1 through 3 represent three primary routes that were identified based on surveys of shippers. Figure 1 illustrates the route identified from surveying shippers from Menominee, Michigan to Green Bay, Wisconsin. Figure 2 shows the route from Ontonagon, Michigan to Green Bay, Wisconsin. Figure 3 shows the route from Rousseau, Michigan to Green Bay, Wisconsin.

DATA COLLECTION

Relevant traffic flow data for the selected carriers were gathered. Data from shippers, railroads, and DOT's were used, including but not limited to data on types of traffic (local, interline, overhead and/or international origins and destinations). Data related to pavements such as pavement thicknesses (hot mix asphalt (HMA), concrete, base, subbase), material characterization data, subgrade soil type, existing truck traffic, and the existing condition of the pavement was collected from the Michigan and Wisconsin Department of Transportation's (MDOT and WisDOT). Typical subgrade modulus values (subgrade support value or modulus of subgrade reaction) was selected based on the American Association of State Highway and Transportation Officials (AASHTO) classification of the subgrade soil type (Huang 1993, p 327 and 365). The subgrade soil support values used were from a previous WisDOT research project (Testing Wisconsin Asphalt Mixtures for the AASHTO 2002 Mechanistic Design Procedure) in which the AASHTO soil designation was known. The subgrade support value was used in the WisPave pavement design guide simulations for flexible pavements and the modulus of subgrade reaction was used for rigid pavement design. Resilient modulus and modulus of subgrade reaction was used in the 1993 AASHTO pavement design guide for flexible and rigid pavements.

LOGISTICAL FLOW OF NEW TRUCK FREIGHT

The least cost alternative highway routes for the logistical movement if a modal shift were to take place in each of the line segments were identified. Logistical decisions were based on origin destination pairs, travel time, truck operation parameters and other truck user costs. Data available from prior regional and national studies along with data gathered from on going research provided the benchmarks for logistical analysis. Modal conversion of freight and routing models were developed in another study for the Midwest Regional University Transportation Center (MRUTC) titled “Twin Ports Intermodal Terminal Study” (project 02-06) and elements of that methodology will be presented in this paper.

Freight modes may be influenced by a number of factors such as transportation cost, service, terms of payment, availability of trucks and drivers; quality, condition and availability of rail cars and trucks, and physical freight characteristics. Packaging requirements, physical plant/distribution center characteristics, origin and destination loading and unload characteristics are also often significant factors in mode selection.

PAVEMENT DESIGN

The objective was to assess the incremental pavement structural design due to modal shift from rail to truck in the selected case study. The design was based upon the flows generated in Figures 1 through 3. The diversion of freight is anticipated to occur over multiple routes and includes 48 pavement cross-sections (designs). One assumption inherent when using the WisPave pavement design software is that it does not take into account the current condition of the pavement structure; it assumes that it is a new pavement structure. The WisPave software does not take into account reliability and the change in present serviceability index, which is used to trigger rehabilitation and maintenance activities. However, the pavement sections in Michigan since they were designed using the 1993 AASHTO pavement design guide, use reliability and present serviceability index in the equations for structural number and concrete pavement thickness.

The total tonnage during the most recent year of shipping on the railroad was measured and then divided by 48,000 lbs to determine the additional number of trucks that would be on the highway routes. While gross vehicle weight is limited to 80,000 lbs, it is assumed that the tare weight of the truck and trailer equipment averages 32,000 lbs. The number of trucks was estimated based on a straight tonnage conversion methodology. Actual shipments may be somewhat higher based on specific order quantities or production limitations. It was calculated that there would be an annual increase of 25,678 trucks on the three routes listed above. However, the trucks will be distributed along the routes according to the conversations with the various shippers and some assumptions when needed. It was assumed that the additional trucks would be a 3S-2 truck (class 10 truck). Table 1 summarizes the traffic data in terms of average annual daily traffic (AADT), growth factor, AADT at design life, and percent trucks for each route and in some cases the county where the traffic level changed. Included in Table 1 is the new traffic if the short rail closes. Two simulations for each route were performed for the existing traffic and the new traffic if the short line railroad closes.

Typical (default) values for layer coefficients were selected when using the WisPave and AASHTO 1993 pavement design guide for the surface, base, subbase 1 and subbase 2. Tables 2 through 6 show the simulations for each route and pavement structure on that route. On the average the new structural number (SN) is 0.07 units greater than the existing SN for flexible and composite pavements. For rigid pavements the new pavement thickness is 0.17 inches greater than the existing pavement thickness. There is a tendency for the as built SN or pavement thickness to be over designed providing a much greater as built design versus the as designed. For the flexible and composite pavements, the average SN for the as built versus the required SN is 0.28 units greater than the required SN. For rigid pavements the average as built pavement thickness is 0.43 inches greater than required pavement thickness. Since the majority of the pavements are over designed, an increase in traffic may not affect the pavement in terms of rutting, cracking, or faulting. However, for those pavements that are under designed or designed at optimum, an increase in traffic may accelerate the damage to the pavements in terms of rutting and cracking for flexible pavements and cracking and faulting for rigid pavements. Nonetheless, 18 of the 48 pavement sections primarily on two of the five routes will experience a shorter life with the additional modal shift in freight than their as built life.

CONCLUSIONS

Rural shippers are being faced with limited options with declining rail service and limited car availability, and have taken their case to their local congressmen. These circumstances are resulting in new state truck size and weight legislation being introduced throughout the Upper Midwest. This new legislation may have significant impact on highway pavement conditions.

The pavement conditions considered in this paper are the changes in SN and concrete pavement thickness due to the increase of truck traffic in the highway system in the state of Michigan and Wisconsin. The results show that there is an increase in SN and concrete pavement thickness due to the increase in traffic on these routes. However, these pavements have as built SN's or concrete pavement thicknesses greater than the existing and potential future SN's or concrete pavement thicknesses. 18 of the 48 pavement sections primarily on two of the five routes will experience a shorter life with the additional modal shift freight than their as built life. Those pavements that are built at the optimum design, they should be monitored closely to determine if they will deteriorate quickly due to the increase in truck traffic. Furthermore, the greatest impact on reduced as built service life will occur on lower volume roadways.

REFERENCES

Huang, Yang H. Pavement Analysis and Design. Prentice Hall, New Jersey. 1993.

MapQuest, http://www.mapquest.com, MapQuest, online, 2006

Pavement Information Files (PIF). Wisconsin Department of Transportation, 2006.

Stewart, Richard, Wang, Xiubin, Sproule, William, Pasi, Lautala, Ogard, Libby, Evaluation of Shipper Requirements and Rail Service for Northern Wisconsin and the Upper Peninsula of Michigan, US Department of Transportation, University of Wisconsin-Superior, 2006.

Wisconsin Department of Transportation. Wisconsin Highway Traffic Volume Data. 2005.

Wisconsin Department of Transportation. Wisconsin Vehicle Classification Data. 2005.

WisPave Version 2.4.1, Wisconsin Department of Transportation Pavement Engineering

Software.

Soil Survey of Iron County, Michigan. United States Department of Agriculture. 1997.

Soil Survey of Houghton County, Michigan. United States Department of Agriculture. 1991.

Soil Survey of Baraga County, Michigan. United States Department of Agriculture. 1988.

Soil Survey of Dickinson County, Michigan. United States Department of Agriculture. 1989.

Soil Survey of Florence County, Wisconsin. United States Department of Agriculture. 2004.

Soil Survey of Marinette County, Wisconsin. United States Department of Agriculture. 1991.

Field Operations of the Bureau of Soils. Reconnaissance Soil Survey of Ontonagon County, Michigan. United States Department of Agriculture. 1921. pp. 73-100

Field Operations of the Bureau of Soils. Reconnaissance Soil Survey of Ontonagon County, Michigan. United States Department of Agriculture. 1921. pp. 73-100

Field Operations of the Bureau of Soils Maps. Reconnaissance Soil Survey of Ontonagon County, Michigan. United States Department of Agriculture. 1921.

LIST OF TABLES

Table 1 Summary of Traffic Data

			Current % Heavy Trucks									% Heavy Trucks with Closure of Short Rail Line										
Case Studies	**Route**	**County**	**$AADT_0$**	**$AADT_{20}$**	**Growth Factor**	**% Heavy**	**2D 6**	**3-SU 7**	**2S-1 + 2S-2 9**	**3S-2 10**	**2-S1-2 12**	**# of Truck Increase**	**$AADT_0$**	**$AADT_{20}$**	**% Increase**	**% Heavy Vehicles**	**Growth Factor**	**2D 6**	**3-SU 7**	**2S-1 + 2S-2 9**	**3S-2 10**	**2-S1-2 12**
ELS Route 1	Menominee to WI Border	Menominee	23500	34920	2%	3.6	47.2	8.3	13.9	30.6	0	256	23501	34921	0.003	3.6	2%	47.2	8.3	13.9	30.6	0
	In City of Marinette	Marinette	14300	21249	2%	13	25.4	4.6	12.3	56.2	1.5	256	14301	21250	0.005	13.0	2%	25.4	4.6	12.3	56.2	1.5
	US-41 SB to Green Bay	Marinette	8400	12482	2%	13	25.4	4.6	12.3	56.2	1.5	256	8401	12483	0.008	13.0	2%	25.4	4.6	12.3	56.2	1.5
	US-41/US-141 SB to Green Bay	Oconto	7600	11293	2%	13	25.4	4.6	12.3	56.2	1.5	25678	7670	11398	0.926	13.9	2%	23.7	4.3	11.5	59.1	1.4
	US-41/US-141 SB to Green Bay	Brown	16900	25113	2%	13	25.4	4.6	12.3	56.2	1.5	25678	16970	25217	0.416	13.4	2%	24.6	4.5	11.9	57.5	1.5
ELS Route 2	Ontonagon to Green Bay, US-45 SB	Ontonagon	1100	1635	2%	16	17.5	5.6	16.9	59.4	0.6	10056	1128	1675	2.505	18.5	2%	15.1	4.9	14.6	64.9	0.5
	US-45 SB	Gogebic	2900	4309	2%	13	25.4	4.6	12.3	56.2	1.5	10056	2928	4350	0.950	14.0	2%	23.7	4.3	11.4	59.1	1.4
	US-2 EB	Gogebic	3200	4755	2%	13	25.4	4.6	12.3	56.2	1.5	10056	3228	4796	0.861	13.9	2%	23.8	4.3	11.5	58.9	1.4
	US-2 EB	Iron	1400	2080	2%	16	17.5	5.6	16.9	59.4	0.6	10056	1428	2121	1.968	18.0	2%	15.6	5	15.1	63.8	0.6
	US-141 SB	Iron	1400	2080	2%	16	17.5	5.6	16.9	59.4	0.6	10056	1428	2121	1.968	18.0	2%	15.6	5	15.1	63.8	0.6
	US-2 EB	Florence	1400	2080	2%	16	17.5	5.6	16.9	59.4	0.6	10056	1428	2121	1.968	18.0	2%	15.6	5	15.1	63.8	0.6
	US-2/US-141 SB	Dickinson	8400	12482	2%	13	25.4	4.6	12.3	56.2	1.5	17739	8449	12554	0.579	13.6	2%	24.3	4.4	11.8	58	1.5
	US-141 SB	Marinette	4200	6241	2%	13	25.4	4.6	12.3	56.2	1.5	17739	4249	6313	1.157	14.2	2%	23.3	4.2	11.3	59.7	1.4
	US-141/US-41 SB	Oconto	7600	11293	2%	13	25.4	4.6	12.3	56.2	1.5	25678	7670	11398	0.926	13.9	2%	23.7	4.3	11.5	59.1	1.4
	US-141/US-41 SB	Brown	16900	25113	2%	13	25.4	4.6	12.3	56.2	1.5	25678	16970	25217	0.416	13.4	2%	24.6	4.5	11.9	57.5	1.5
ELS Route 3	Rousseau to Green Bay, M-38 EB	Houghton	590	877	2%	13	25.4	4.6	12.3	56.2	1.5	2393	597	886	1.111	14.1	2%	23.4	4.3	11.3	59.6	1.4
	NF-16 SB	Ontonagon	900	1337	2%	16	17.5	5.6	16.9	59.4	0.6	2751	908	1349	0.837	16.8	2%	16.6	5.3	16	61.4	0.6
	NF-16 SB	Houghton	900	1337	2%	16	17.5	5.6	16.9	59.4	0.6	2751	908	1349	0.837	16.8	2%	16.6	5.3	16	61.4	0.6
	M-28 EB	Houghton	1700	2526	2%	16	17.5	5.6	16.9	59.4	0.6	4951	1714	2546	0.798	16.8	2%	16.7	5.4	16.1	61.3	0.6
	M-28 EB	Baraga	1700	2526	2%	16	17.5	5.6	16.9	59.4	0.6	4951	1714	2546	0.798	16.8	2%	16.7	5.4	16.1	61.3	0.6
	US-141 SB	Baraga	1100	1635	2%	16	17.5	5.6	16.9	59.4	0.6	4951	1114	1655	1.233	17.2	2%	16.2	5.2	15.7	62.3	0.6
	US-141 SB	Iron	1100	1635	2%	16	17.5	5.6	16.9	59.4	0.6	4951	1114	1655	1.233	17.2	2%	16.2	5.2	15.7	62.3	0.6
	US-2 EB	Florence	1400	2080	2%	16	17.5	5.6	16.9	59.4	0.6	4951	1414	2100	0.969	17.0	2%	16.5	5.3	15.9	61.7	0.6
	US-2/US-141 SB	Dickinson	8400	12482	2%	13	25.4	4.6	12.3	56.2	1.5	17739	8449	12554	0.579	13.6	2%	24.3	4.4	11.8	58	1.5
	US-141 SB	Marinette	4200	6241	2%	13	25.4	4.6	12.3	56.2	1.5	17739	4249	6313	1.157	14.2	2%	23.3	4.2	11.3	59.7	1.4
	US-141/US-41 SB	Oconto	7600	11293	2%	13	25.4	4.6	12.3	56.2	1.5	25678	7670	11398	0.926	13.9	2%	23.7	4.3	11.5	59.1	1.4
	US-141/US-41 SB	Brown	16900	25113	2%	13	25.4	4.6	12.3	56.2	1.5	25678	16970	25217	0.416	13.4	2%	24.6	4.5	11.9	57.5	1.5

Table 2 Route 1 Simulations

Case Study	Route	Calculated ESAL's	County	Pavement Type	Simulation	Required SN	As Built SN
Route 1	US-41 SB	3,131,700	Menominee	HMA	Existing Traffic	4.77	5.88
	US-41 SB	3,131,700	Menominee	HMA	New Traffic	4.77	5.88
	US-41 SB	3,518,600	Marinette	HMA	Existing Traffic	4.37	4.44
	US-41 SB	3,525,900	Marinette	HMA	New Traffic	4.37	4.44
	US-41 SB	3,730,300	Oconto	HMA	Existing Traffic	5.06	4.94
	US-41 SB	3,730,300	Oconto	HMA	New Traffic	5.06	4.94
	US-41/US-141 SB	3,175,500	Oconto	HMA	Existing Traffic	4.94	6.08
	US-41/US-141 SB	3,511,300	Oconto	HMA	New Traffic	5.01	6.08
	US-41/US-141 SB	7,095,600	Brown	HMA	Existing Traffic	5.47	5.63
	US-41/US-141 SB	7,394,900	Brown	HMA	New Traffic	5.50	5.63

Table 3 Route 2 Simulations

Case Study	Route	Calculated ESAL's	County	Pavement Type	Simulation	Required SN	As Built SN
Route 2	US-45 SB	584,000	Ontonagon	HMA	Existing Traffic	4.03	10.62
	US-45 SB	722,700	Ontonagon	HMA	New Traffic	4.16	10.62
	US-45 SB	584,000	Ontonagon	HMA	Existing Traffic	4.51	5.26
	US-45 SB	722,700	Ontonagon	HMA	New Traffic	4.65	5.26
	US-45 SB	584,000	Ontonagon	HMA	Existing Traffic	4.03	5.02
	US-45 SB	722,700	Ontonagon	HMA	New Traffic	4.16	5.02
	US-45 SB	1,226,400	Gogebic	HMA	Existing Traffic	4.49	4.78
	US-45 SB	1,343,400	Gogebic	HMA	New Traffic	4.55	4.78
	US-2 EB	1,343,200	Gogebic	HMA	Existing Traffic	4.55	5.11
	US-2 EB	1,474,600	Gogebic	HMA	New Traffic	4.61	5.11
	US-2 EB	1,343,200	Gogebic	HMA	Existing Traffic	4.55	6.10
	US-2 EB	1,474,600	Gogebic	HMA	New Traffic	4.61	6.10
	US-2 EB	744,600	Iron	HMA	Existing Traffic	4.18	5.11
	US-2 EB	876,000	Iron	HMA	New Traffic	4.28	5.11
	US-2 EB	744,600	Iron	HMA	Existing Traffic	4.18	6.54
	US-2 EB	876,000	Iron	HMA	New Traffic	4.28	6.54
	US-141	744,600	Iron	HMA	Existing Traffic	4.18	4.36
	US-141	876,000	Iron	HMA	New Traffic	4.28	4.36
	US-2 EB	744,600	Florence	HMA	Existing Traffic	3.92	4.54
	US-2 EB	876,000	Florence	HMA	New Traffic	4.02	4.54
	US-2/US-141	3,518,600	Dickinson	HMA	Existing Traffic	5.20	4.88
	US-2/US-141	3,759,500	Dickinson	HMA	New Traffic	5.25	4.88
	US-2/US-141	3,518,600	Dickinson	HMA	Existing Traffic	5.20	4.33
	US-2/US-141	3,759,500	Dickinson	HMA	New Traffic	5.25	4.33
	US-2/US-141	3,518,600	Dickinson	HMA	Existing Traffic	5.20	1.98
	US-2/US-141	3,759,500	Dickinson	HMA	New Traffic	5.25	1.98
	US-8 SB	1,766,600	Marinette	JRCP	Existing Traffic	N/A	N/A
	US-8 SB	3,197,400	Marinette	JRCP	New Traffic	N/A	N/A
	US-141 SB	1,766,600	Marinette	HMA	Existing Traffic	3.92	4.55
	US-141 SB	1,985,600	Marinette	HMA	New Traffic	4.00	4.55
	US-141 SB	1,766,600	Marinette	HMA	Existing Traffic	3.92	3.08
	US-141 SB	1,985,600	Marinette	HMA	New Traffic	4.00	3.08
	US-141 SB	1,766,600	Marinette	HMA	Existing Traffic	3.92	3.14
	US-141 SB	1,985,600	Marinette	HMA	New Traffic	4.00	3.14
	US-141 SB	1,766,600	Marinette	HMA	Existing Traffic	3.92	3.20
	US-141 SB	1,985,600	Marinette	HMA	New Traffic	4.00	3.20
	US-141 SB	1,766,600	Marinette	JPCP w/dowels	Existing Traffic	N/A	N/A
	US-141 SB	3,197,400	Marinette	JPCP w/dowels	New Traffic	N/A	N/A
	US-141 SB	5,095,400	Oconto	JPCP w/dowels	Existing Traffic	N/A	N/A
	US-141 SB	5,664,600	Oconto	JPCP w/dowels	New Traffic	N/A	N/A
	US-41/US-141 SB	3,175,500	Oconto	HMA	Existing Traffic	4.94	6.08
	US-41/US-141 SB	3,511,300	Oconto	HMA	New Traffic	5.01	6.08
	US-41/US-141 SB	7,095,600	Brown	HMA	Existing Traffic	5.47	5.63
	US-41/US-141 SB	7,394,900	Brown	HMA	New Traffic	5.50	5.63

Table 4 Route 3 Simulations

Case Study	Route	Calculated ESAL's	County	Pavement Type	Simulation	Required SN	As Built SN
Route 3	M-38 EB	255,500	Houghton	HMA	Existing Traffic	3.56	4.71
	M-38 EB	292,000	Houghton	HMA	New Traffic	3.64	4.71
	NF-16 SB	489,100	Ontonagon	HMA	Existing Traffic	3.41	4.45
	NF-16 SB	518,300	Ontonagon	HMA	New Traffic	3.44	4.45
	NF-16 SB	489,100	Houghton	HMA	Existing Traffic	3.41	4.45
	NF-16 SB	518,300	Houghton	HMA	New Traffic	3.44	4.45
	M-28 EB	897,900	Houghton	HMA	Existing Traffic	4.79	3.91
	M-28 EB	934,400	Houghton	HMA	New Traffic	4.82	3.91
	M-28 EB	897,900	Baraga	HMA	Existing Traffic	4.79	4.30
	M-28 EB	934,400	Baraga	HMA	New Traffic	4.82	4.30
	US-141 SB	584,000	Baraga	HMA	Existing Traffic	3.74	5.54
	US-141 SB	657,000	Baraga	HMA	New Traffic	3.80	5.54
	US-141 SB	584,000	Iron	HMA	Existing Traffic	4.03	3.56
	US-141 SB	657,000	Iron	HMA	New Traffic	4.11	3.56
	US-141 SB	584,000	Iron	HMA	Existing Traffic	4.03	4.62
	US-141 SB	657,000	Iron	HMA	New Traffic	4.11	4.62
	US-2 EB	744600	Florence	HMA	Existing Traffic	3.92	4.54
	US-2 EB	876000	Florence	HMA	New Traffic	4.02	4.54
	US-2/US-141	3,518,600	Dickinson	HMA	Existing Traffic	5.20	4.88
	US-2/US-141	3,759,500	Dickinson	HMA	New Traffic	5.25	4.88
	US-2/US-141	3,518,600	Dickinson	HMA	Existing Traffic	5.20	4.33
	US-2/US-141	3,759,500	Dickinson	HMA	New Traffic	5.25	4.33
	US-2/US-141	3,518,600	Dickinson	HMA	Existing Traffic	5.20	1.98
	US-2/US-141	3,759,500	Dickinson	HMA	New Traffic	5.25	1.98
	US-8 SB	1,766,600	Marinette	JRCP	Existing Traffic	N/A	N/A
	US-8 SB	3,197,400	Marinette	JRCP	New Traffic	N/A	N/A
	US-141 SB	1,766,600	Marinette	HMA	Existing Traffic	3.92	4.55
	US-141 SB	1,985,600	Marinette	HMA	New Traffic	4.00	4.55
	US-141 SB	1,766,600	Marinette	HMA	Existing Traffic	3.92	3.08
	US-141 SB	1,985,600	Marinette	HMA	New Traffic	4.00	3.08
	US-141 SB	1,766,600	Marinette	HMA	Existing Traffic	3.92	3.14
	US-141 SB	1,985,600	Marinette	HMA	New Traffic	4.00	3.14
	US-141 SB	1,766,600	Marinette	HMA	Existing Traffic	3.92	3.20
	US-141 SB	1,985,600	Marinette	HMA	New Traffic	4.00	3.20
	US-141 SB	1,766,600	Marinette	JPCP w/dowels	Existing Traffic	N/A	N/A
	US-141 SB	3,197,400	Marinette	JPCP w/dowels	New Traffic	N/A	N/A
	US-141 SB	5,095,400	Oconto	JPCP w/dowels	Existing Traffic	N/A	N/A
	US-141 SB	5,664,600	Oconto	JPCP w/dowels	New Traffic	N/A	N/A
	US-41/US-141 SB	3,175,500	Oconto	HMA	Existing Traffic	4.94	6.08
	US-41/US-141 SB	3,511,300	Oconto	HMA	New Traffic	5.01	6.08
	US-41/US-141 SB	7,095,600	Brown	HMA	Existing Traffic	5.47	5.63
	US-41/US-141 SB	7,394,900	Brown	HMA	New Traffic	5.50	5.63

LIST OF FIGURES

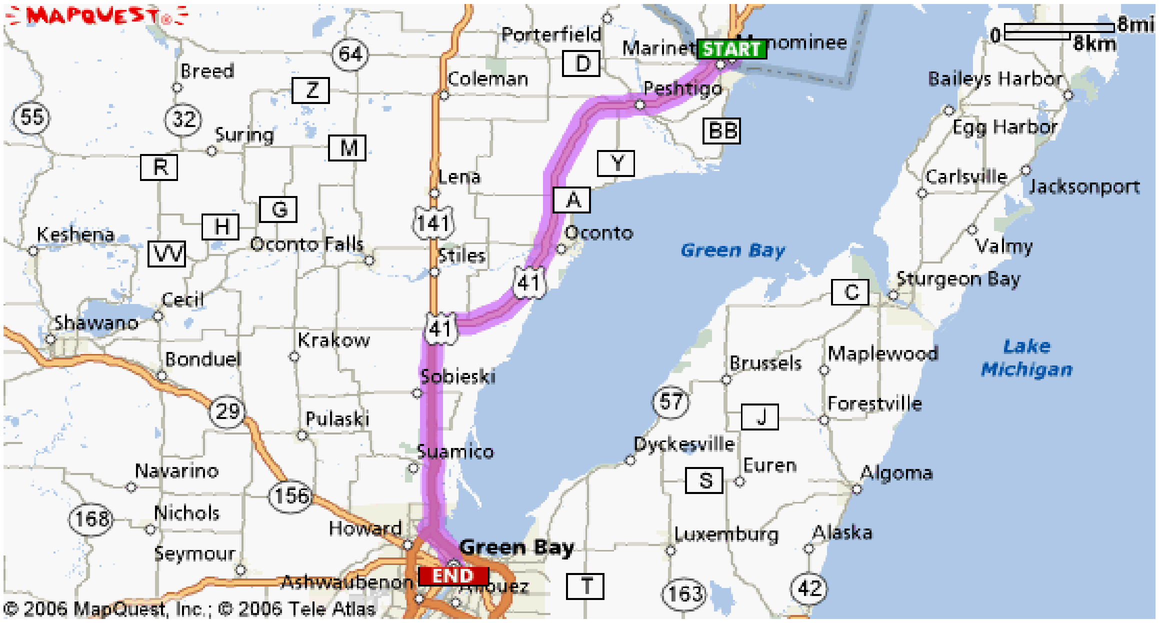


Figure 1 Route 1, Menominee, MI to Green Bay WI

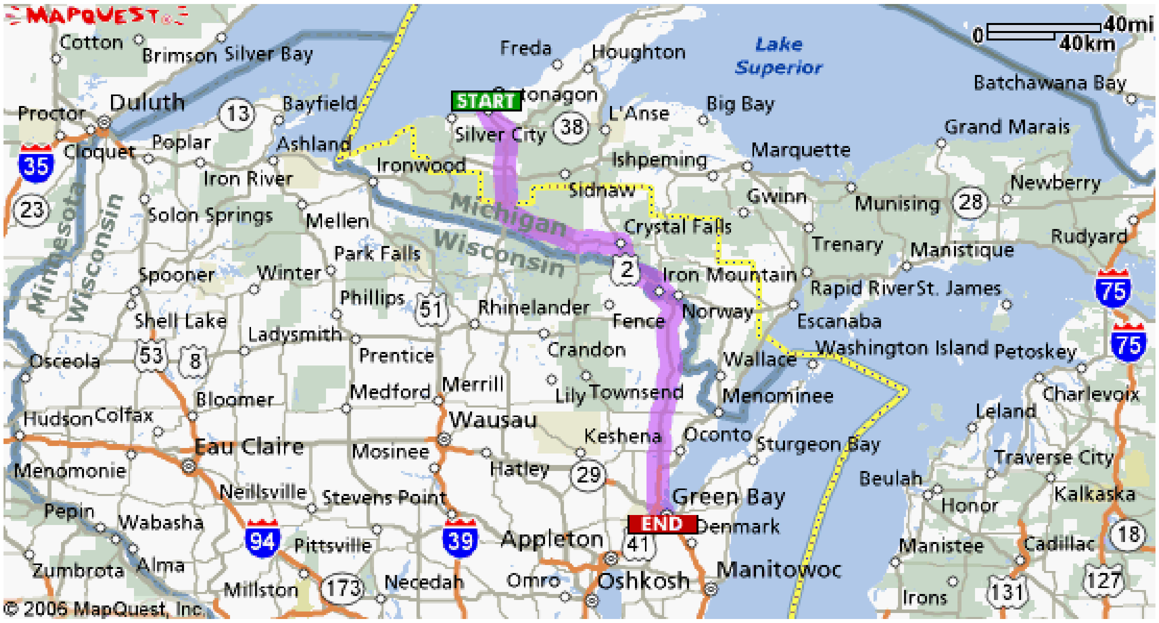


Figure 2 Route 2, Ontonagon, MI to Green Bay WI

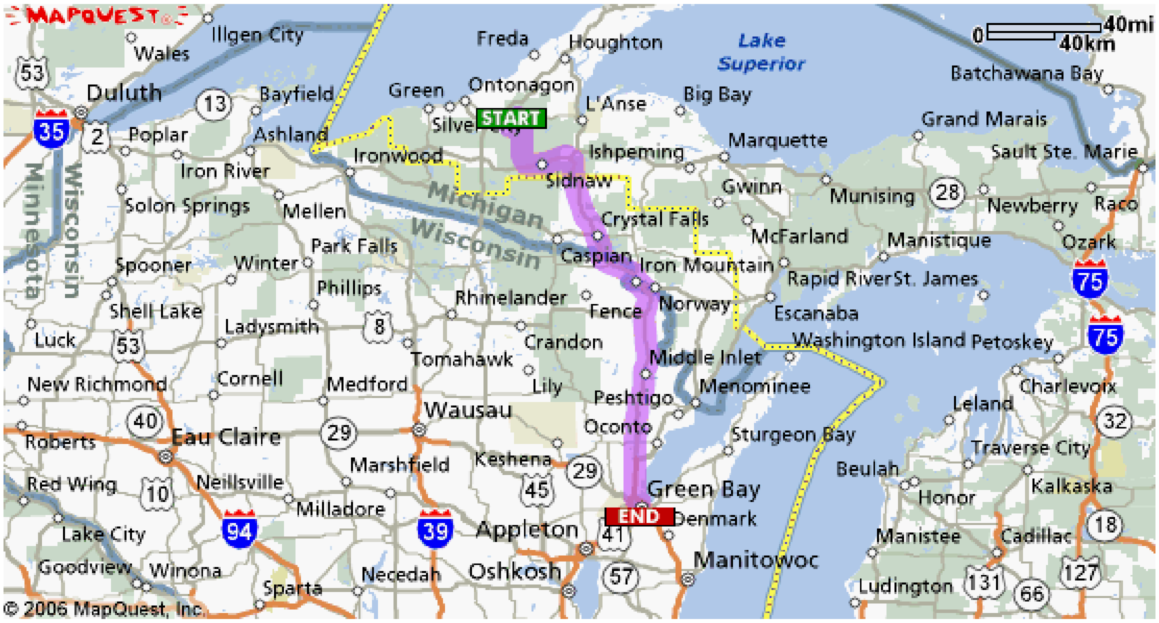


Figure 3 Route 3, Rousseau, MI to Green Bay WI


MICHIGAN'S RAILROAD SYSTEM
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
RAILROADS OPERATING IN MICHIGAN
DETROIT AREA INSET
ONTARIO
LAKE ERIE
MRA
MDOT
January 2007
0 10 20 30 40 50
Miles

Wisconsin Railroads 2006

NOTE:

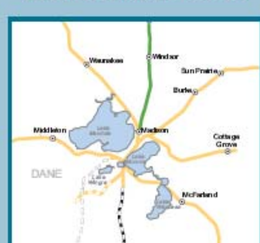
1 Canadian National is the parent company of Duluth, Missabe & Iron Range, Wisconsin Central Limited and the Sault St. Marie Railroad.

Duluth, Winnipeg & Pacific (switching and terminal operations in Superior) not shown.

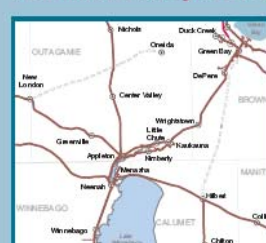
Map displays rail lines and corridors owned by operating freight railroads and government agencies. Other privately owned facilities (examples: industrial lead, utility company spurs, museum tracks) not shown. Line Color represents principal operator, may not be owner.

Superior Area Detail

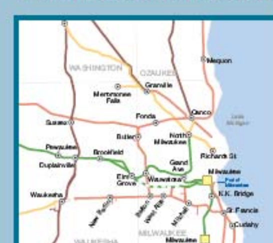
Madison Area Detail



Fox River Valley Detail



Milwaukee Area Detail



Produced by the Bureau of Planning, Wisconsin Department of Transportation, September 2006