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Log Movement in the Superior Region - Rate and Capacity Based Analysis of Modal Shares

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TECHNICAL SUMMARY

Title

Log Movement in the Superior Region - Rate and Capacity Based Analysis of Modal Shares

Introduction

For the last two decades, the rail system in the Superior (Project) region (Upper Peninsula of Michigan and northern parts of Wisconsin and Minnesota) has witnessed declining freight volumes. This has specifically impacted forest products industry, one of the largest users of freight rail transportation in the region. Log movements by rail from aggregation points to the mills has been a cost effective and safe method for obtaining raw materials and many outbound forest products have moved to final destination from the mills by rail. Unfortunately, forest products movements (logs or final products) aren't necessarily a perfect match with the current business model of larger railroads and as a result, changes in the rail rate and service structures have shifted increasing tonnage of forest products movements (especially logs) off the rails and onto trucks.

Retaining and improving the transportation infrastructure and freight rail operations is vital to the efforts to increase the opportunities for economic growth and new job creation in the region. Retaining or expanding the forest products industry in this region is challenging without rail and the potential for any other natural resource/heavy manufacturing industry developments, whose prerequisite for a new development is rail access, is limited.

Approach and Methodology

This project, conducted by the Michigan Technological University (Michigan Tech) in collaboration with the Lake State Shipper Association (LSSA), CN Railway, Escanaba & Lake Superior Railroad, and the funding organizations, is part of an effort to develop a strategy for continuing freight movement by forest industry on railroads in the Project region. More specifically, it concentrated on the following five objectives and related research questions:

- **Objective 1** – *Create a model for, and recover, shipper data at the "actionable shipper data" level of detail*
- **Objective 2** – *Develop spatial model for the modal splits of log movements by truck versus by truck and rail for existing infrastructure (incorporating capacity and operational limitations)*
- **Objective 3** – *Investigate a number of rail cars needed for log movements in the project area*
- **Objective 4** – *Explore the value and impact of increased log movements by rail on the log truckers*

• **Objective 5** – *Identify inbound and outbound "non-log" movements by forest products and other industries*

Conclusions

The analysis and results of this project are based on actual data and models validated by comparing their results with actual data. The results provide foundation for forest products industry and transportation providers, as they ponder future business development and transportation logistics. However, that's all it is – a foundation. Turning the results into tangible actions requires additional work that is likely to require co-operation by various stakeholders.

Recommendations

Based on our analysis, we offer the following recommendations. A more detailed description of recommendations is provided in Chapter 8 below.

• *Expand log analysis to include two more years of data*;

• *Investigate the benefits from re-opening rail segments*

• *Establish benchmarks from other regions for rail rates and service*

• *Develop extension and replacement strategy for log cars, including prioritization of high-efficiency cars, merits of rail car pools and justifications for public investment*

• *Initiate direct shipper/rail service provider discussions for line-specific strategies toward volume increases/rate reductions*

• *Expand case studies to evaluate log trucker benefits from rail movements*

• *Combine Wisconsin and Michigan Transearch data for regional analysis*

• *Investigate four-county region for transload facility in the Upper Peninsula (UP) of Michigan*

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Table of Contents

0. EXECUTIVE SUMMARY

For the last two decades, the rail system in the Superior (Project) region (Upper Peninsula of Michigan and northern parts of Wisconsin and Minnesota) has witnessed declining freight volumes. This has specifically impacted forest products industry, one of the largest users of freight rail transportation in the region. Log movements by rail from aggregation points to the mills has been a cost effective and safe method for obtaining raw materials and many outbound forest products have moved to final destination from the mills by rail. Unfortunately, forest products movements (logs or final products) aren't necessarily a perfect match with the current business model of larger railroads and as a result, changes in the rail rate and service structures have shifted increasing tonnage of forest products movements (especially logs) off the rails and onto trucks.

Retaining and improving the transportation infrastructure and freight rail operations is vital to the efforts to increase the opportunities for economic growth and new job creation in the region. Retaining or expanding the forest products industry in this region is challenging without rail and the potential for any other natural resource/heavy manufacturing industry developments, whose prerequisite for a new development is rail access, is limited.

This project, conducted by the Michigan Technological University (Michigan Tech) in collaboration with the Lake State Shipper Association (LSSA), CN Railway, Escanaba & Lake Superior Railroad, and the funding organizations, is part of an effort to develop a strategy for continuing freight movement by forest industry on railroads in the Project region. More specifically, it concentrated on the following five objectives and related research questions:

- **Objective 1 –** *Create a model for, and recover, shipper data at the "actionable shipper data" level of detail*
- **Objective 2 –** *Develop spatial model for the modal splits of log movements by truck versus by truck and rail for existing infrastructure (incorporating capacity and operational limitations)*
- **Objective 3 –** *Investigate a number of rail cars needed for log movements in the project area*
- **Objective 4 –** *Explore the value and impact of increased log movements by rail on the log truckers*
- **Objective 5 –** *Identify inbound and outbound "non-log" movements by forest products and other industries*

The project used detailed train operations data from CN Railway and log movement data provided by the members of the LSSA to develop the spatial model for log movement analysis (Chapter 3). In addition to the analysis results from this project, the developed database and models offer opportunities for the industry and public to perform further analysis, or to use them for other purposes, such as freight lane modifications, discussions on future rates and services, and infrastructure investment decisions.

The data included almost ten million tons of logs transported within a single calendar year (2017) by five participating companies and fourteen mills. Approximately 85 percent of logs moved directly to mills by truck, while the remaining tonnage moved by rail from the sidings and yards. The project team developed rate formulas for truck and rail movements and validated the accuracy of the model by comparing the simulated modal shares with the actual movement data. For the non-log movements, three separate datasets were used for identifying the main freight lanes and commodities for the region.

The following sections briefly discuss the project results related to each one of the objectives identified above. The methodology and results or log analysis are presented in more detail in Chapter 4 and for non-log analysis in Chapter 5. A detailed discussion of the results is provided in Chapter 6.

Objective 1 – *Create a methodology to obtain and securely store freight data at the "Actionable Shipper Data" Level of Detail.* "Actionable Shipper Data" means shipment data at a level of detail sufficient to investigate individual shipments. Database that included almost ten million tons of log shipment data in the Project region from project partners was developed and organized. We also developed a detailed model of the rail transportation network and operations in collaboration with the Project region's principal rail service provider (CN Railway). Michigan Tech and LSSA Data Co-op Committee entered into a joint multi-shipper confidentiality agreement, subject to LSSA's Antitrust Compliance Guidelines and data security protocols that satisfied shipper concerns and obligations for limiting disclosure of individual shipper proprietary and "sensitive competitive" information used in the Project.

Objective 2 – *Develop spatial model for the modal splits of log movements by truck versus by truck and rail for existing infrastructure (incorporating capacity and operational limitations).* Analysis under the second objective concentrated mainly on investigating the impacts of operational and rate changes on truck and rail modal shares. Based on the results, we observed only minimal impact on rail modal share from increased sharing and/or re-opening of sidings. We believe this is mainly due to forest industry's efficiency in minimizing the log transportation distances in 2017 (almost 75% within 100 miles). Rail rate discounts created meaningful increases in rail share, but would have to be justifiable for the rail service providers. Any negotiations for rate adjustments should take place between major shippers and railroads and are likely to concentrate on specific origin-destination pairs.

Objective 3 – *Investigate a number of rail cars needed for log movements in the project area.* Log car availability and challenges with the seasonality of movements have received growing attention in the region, as great portion of log car fleet is close to reaching its maximum service life. The analysis revealed that moving the log volumes in the region in ideal conditions and without modal shift would require approximately 400-600 dedicated log cars shared between all shippers, depending on the service and storage requirements. The higher fleet size could move the logs immediately as they arrive to the siding, while the lower end would nearly eliminate the idling of rail cars during slower months and enable stable rail volumes throughout the year. However, smaller fleet size would require short-term storage (and additional handling) of logs at the siding, both elements that increase costs for shippers. We also found that the reduction of a single day in loading/unloading process (2.5 to 1.5 days) would eliminate almost 100 cars (20 %) of the fleet without reduction in throughput. This highlights the importance of fast asset rotation, a finding that was also supported by our case study of log movements in Finland. Our quantitative analysis did not investigate the details of replacement or ownership strategy, nor the known differences in efficiency among current car types. However, we found examples of successful public and private car pools to support commodity movements by rail and had discussions with stakeholders on priorities and potential funding sources for the replacement. Our analysis can form foundation for investigating alternative car ownership, operation, and replacement options for the log movements in the region. In addition, results can be used to evaluate, if potential public benefits warrant public investment as part of the solution.

Objective 4 – *Explore the value and impact of increased log movements by rail on the log truckers.* To the best of our knowledge, our case studies were the first attempts to quantify the potential benefits and disadvantages of log truckers due to increased use of rail transportation. We found that in three out of four case studies, concentrating log movements in rail yard/siding provided benefits to truckers, both in terms of time efficiency (percentage of daily hours of service used efficiently) and of value efficiency (average loaded ton-miles per day). In addition, we found that while the loaded ton-miles per day increased (increasing revenue), the total miles per day decreased, a factor that would reduce both total fuel consumption and equipment wear (reduced expenses). The ensuing sensitivity analysis found that multimodal transportation (truck and rail) was more reactive to the increase of average truck speed and to the changes in maximum hours or service than truck-only system. As trucks are a necessity for transporting logs from the forest siding before any rail movement can take place, any improvements to truckers' health must be a high priority. Since our analysis had some data limitations, a more thorough analysis are warranted to better define potential benefits to log truckers, producers and public from the increased use of multimodal system. Such analysis, together with market basket analysis for other potential rail traffic, would be especially beneficial on determining the appropriateness of public investment on supporting light-density lines that currently have insufficient freight for continuing operations (such as ones to L'Anse and Munising).

Objective 5 – *Identify "non-log" movements into/out of the region by forest products/other industries.* The "non-log" movements (defined as any other freight besides logs) were the only part of the project not utilizing the spatial model developed. These analysis were hindered by their national (instead of regional) scale and the lack of comprehensive data. Since the most comprehensive dataset (Transearch) only included the Upper Peninsula (UP) of Michigan, the analysis concentrated heavily on the UP counties. We found that the UP generates significant volumes of freight (almost 18 million tons annually). More than half of that is transported by trucks and 77 percent of truck traffic originates/terminates in four counties that fit within a 70-mile radius (Delta, Marquette, Dickinson, and Menominee). The high concentration of freight in these counties, their proximity of each other, and their central location in relation to remaining UP counties lead us to believe that one of these counties would be a prime location for potential transload/intermodal terminal. However, the case study conducted on Duluth Intermodal Terminal offers a clear indication that despite the volumes, establishing transload/intermodal facility in the region would involve many challenges, in part due to container/volume/location issues. It would also require a detailed analysis on the likelihood that truck freight could be converted to multimodal option (truck/rail).

While there were certainly limitations in our project (Chapter 7), such as the reliance of a single year of data (2017) and shortcomings of certain performance and parametric data, we believe the analysis and results provide a solid foundation for continuing efforts to develop a strategy toward increased rail movements by forest products industry in the Project region. Based on our analysis, we offer the following recommendations. A more detailed description of recommendations is provided in Chapter 8

- *Expand log analysis to include two more years of data*;
- *Investigate the benefits from re-opening rail segments*
- *Establish benchmarks from other regions for rail rates and service*
- *Develop extension and replacement strategy for log cars, including prioritization of high-efficiency cars, merits of rail car pools and justifications for public investment*
- *Initiate direct shipper/rail service provider discussions for line-specific strategies toward volume increases/rate reductions*
- *Expand case studies to evaluate log trucker benefits from rail movements*
- *Combine Wisconsin and Michigan Transearch data for regional analysis*
- *Investigate four-county region for transload facility in the Upper Peninsula (UP) of Michigan*

1. INTRODUCTION

For the last two decades, the rail system throughout the Upper Peninsula (UP) of Michigan (MI), Northern Wisconsin, and Northern Minnesota has seen reduced business. Starting in 2012, the Northwoods Rail Transit Commission (NRTC) that consists of the thirteen counties of Northern Wisconsin, as well as nine of the fifteen counties in the Upper Peninsula (UP) of Michigan, has been leading an effort to not only put a spotlight on the decline, but to seek solutions for the situation. However, the tangible results to date have been limited.

One of the industries that have been particularly hard hit is the forest products industry. Moving logs by rail from aggregation points to the mills has been a very cost effective and safe method of moving raw material. Unfortunately, most of these movements start or end on branch lines and move fairly short distances (as compared to national rail shipment averages) to reach the mills. These types of movements don't align well with the current business model for large railroads that is based on moving large blocks of cars (generally anywhere from 20-100) for fairly long distances (national average is over 1,000 miles). As a result, the prices considered profitable by larger railways tend to push logs off their rails and onto trucks. The situation is also challenging in the final product transportation, as there tends to be high number of destinations within and outside the region, limiting the opportunities for large blocks or rail cars at once.

Retaining and improving the transportation infrastructure is vital to efforts to increase the opportunities for economic growth and to create new jobs in the Project region. If rail service issue is not solved, it will be difficult to expand the forest products industry and a valuable natural resource will remain underutilized in the forests, because it is not cost competitive to move it to market. It will also limit the potential for any other natural resource/heavy manufacturing industry developments, whose prerequisite for a new site includes rail access. Finally, and probably most importantly, without solutions railways will cease operating on branch lines and operators will seek their abandonment, eliminating all opportunities for any new industry, forest based or otherwise, that might be attracted to the region because of rail availability, eliminating all new jobs that come with them.

Recent discussions by the Michigan Forest Products Council (MFPC), an industry group that includes representatives of the largest mills in the Project region focused on the need to develop a strategy to either get operating railroads back into moving logs ,or to make a case for investigating potential for other operators to take over the service on the branch lines. The NRTC, who participated in the MFPC discussions, has also endorsed this strategy. Two specific steps to advance the strategy are an effort funded by the Wisconsin Department of Transportation (WisDOT) to update a previous shipper survey in Northern Wisconsin and this Project, conducted by the Michigan Technological University (Michigan Tech) in collaboration with the Lake State Shipper Association (LSSA), CN Railway and E&LS Railroad, and funding agencies.

Michigan Tech's project used actual train movement data from CN and log movement data provided by the members of the Lake State Shipper Association (LSSA) to create a detailed spatial simulation model of the log movements by rail and truck in the region. This model was used to analyze the movements and investigate whether operational modifications related to where, when and how logs enter the system have potential to improve the business case for rail movements. It also investigated the challenges related to final product transportation (all freight but logs), although those movements occur nationwide and as such could not be included in the regional spatial model.

2. PROJECT OBJECTIVES

The research was concentrating on the following five objectives:

- **Objective 1 –** *Create a methodology to obtain and securely store freight data at the "Actionable Shipper Data" Level of Detail.* This objective concentrates in development of a comprehensive data base of region's forest products shipment data at a level of detail sufficient to investigate individual shipments.
- **Objective 2 –** *Develop spatial model for the modal splits of log movements by truck and versus truck and rail for existing infrastructure (incorporating capacity and operational limitations)*: This entails using data-driven optimization modeling studies for identifying possibilities to increase the rail share and potential other benefits, if infrastructure/operations are modified.
- **Objective 3 –** *Investigate a number of rail cars for log movements in the project area*: This provides information on the number of dedicated rail cars in the region that would be needed to move the logs. This also includes investigating opportunities to use consistent rail shipments to alleviate spring breakup limitations and rail car idling.

- **Objective 4 –** *Explore the value and impact of increased log movements by rail on the log truckers*: This includes studying impact of increased shipments by rail on the productivity on log truckers.
- **Objective 5 –** *Identify inbound and outbound "non-log" movements by forest products/other industries*: This includes mapping main freight lanes for outbound/final forest products (and other freight shipments) and exploring the opportunities for potential modal shift (truck to rail) or multimodal options (truck and rail).

As part of the analysis toward the objectives mentioned above, the research attempted to answer to following five questions:

1) Are there opportunities for creating economies of scale in rail, if log movements in the region are considered a single commodity pool (rate sensitivity)?
2) What number of rail cars dedicated to the region would be needed to move the product while minimizing rail car idling?
3) Are there opportunities to use consistent rail shipments to alleviate spring breakup limitations?
4) Would increase in consolidated shipments by rail create productivity improvements for log truckers?
5) Are there strategic locations for larger rail sidings that could accommodate larger blocks of log cars, thus better supporting the current rail business model?

3. DATA

3.1. Log Data

3.1.1. Data Sources

Log transportation analysis required a comprehensive database of log movements in the project region. The project utilized a confidential dataset of log truck scale tickets and rail shipment records obtained from the participating LSSA companies. The data was collected in standard format (see Appendix A for the data form). Key data fields included:

- Unique identifier for the trip
- Purchaser and seller company information

- Date/Month/Year that ticket issued
- Shipping information such as origin/destination locations, distance, and mode of transport
- Product type and rate information
- Weight information

3.1.2. Companies participating in the project

Five forest products companies and fourteen of their mills in our project area provided a comprehensive data on their truck and rail shipments for the 2017 calendar year. In addition, one major landowner provided data. Data was processed to remove inconsistencies and to modify the existing data into a unified geographical coordination format (latitude and longitude). In addition, for companies who provided only consolidated county/city level origin, an "alternative origin" location was developed to replace the centroid of county or city. A more detailed description of the data cleaning process and "alternative origin" determination are provided in Appendix B.

3.1.3. Summary of Log Movement Data

Table 1 provides the characteristics of our log movement data used in the project. The raw data included 118,709 records of truck and rail shipment data (104,746 truck records and 13,936 rail records). Total tonnage of log movement collected from 14 mills was 9,282,305 tons. Approximately 85% of total tonnage was moved by trucks directly from forest landings (or yards) to the mills, while multimodal transportation system with truck and rail accounted for the remaining 15% of log movements in our database. As mentioned, data preprocessing was conducted to synchronize the common coordinate system and the level of detail of shipment origins. The road infrastructure used in our research included all road types from national highways to the regional forest roads. Actual road and rail network provided by US Department of Transportation (US DOT) was used for the analysis. For the local forest roads, we integrated forest road data from the three state government's GIS database in our project area: WI, MN, and UP MI.

Table 1. Summary of log movement data used in this project

	Category	Summary of log movement data
1	**Data Size: Number of participating companies and mills**	5 companies and their 14 mills ***Total tons = 9,282,305** *Truck = 7,936,027; Rail = 1,346,278
2	**Number of Data**	In total 118,709 records of truck and rail shipment data (104,746 truck records and 13,936 rail records)
3	**Number of Origin/Destination**	Number of origins (log landings/yards): 8,206 Number of destinations (mills): 14
4	**Data Year**	2017 (January ~ December)
5	**Project Area**	WI, MN, and UP of MI
6	**Geographic coordinates system**	Latitude and Longitude (Preprocessing: “Modification” of PLSS data to Lat/Long)
7	**Level of detail (logging origins)**	Preprocessing: “Dispersement” of county centroids
8	**Infrastructure**	Actual road/rail network provided by US DOT

All geographical preprocessing and spatial analysis were conducted by ESRI ArcMap 10.3. Figure 1 shows the locations of all origins (logging sites) and destinations (mills) in this project. Total number of origins was 8,206 and number of final destinations was 14.

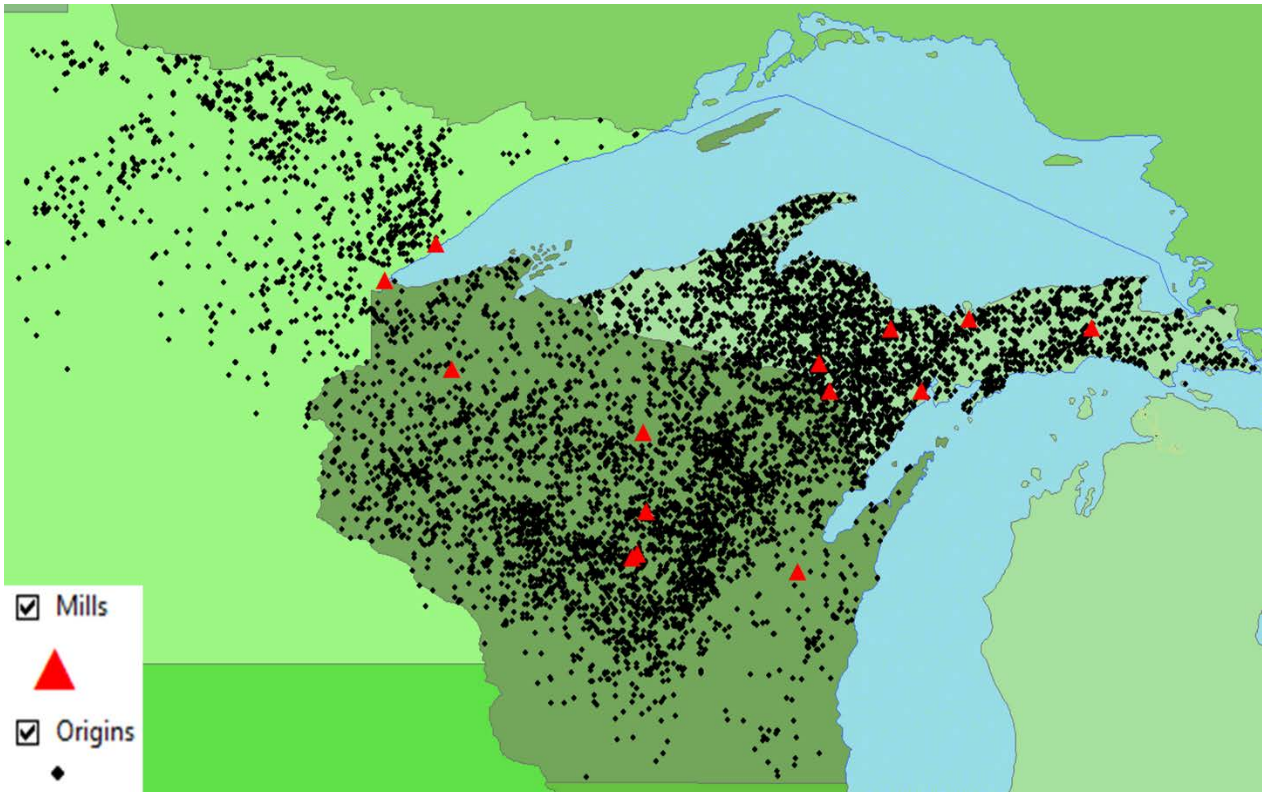


Figure 1. Origin/Destination Map for Log Movements

3.2. "Non-log" Data

The "non-log" data analysis included all other freight to and from the region, excluding the logs. Mapping such movements requires utilization of freight data beyond forest industry. We used the following three data sources for the analysis:

1) Non-log products movement data from the LSSA companies participating in the project
2) Rail freight survey results provided by the Northwoods Rail Transit Commission (NRTC)
3) Transearch 2015 Data provided by the Michigan Department of Transportation (MDOT) (for Upper Peninsula of Michigan only)

The LSSA "non-log" product data collection followed similar format as log data. Twenty individual locations by six companies provided their truck and rail shipments for 2017. The second non-log movement data source was the rail freight survey conducted by NRTC in November 2017 via email/mail. 74 businesses (including several forest products companies) in Northern Wisconsin and in the UP Michigan responded to the survey. The third data source was the Transearch 2015 database shared by the MDOT. Transearch is a planning tool to analyze current and future freight flows by origin, destination, commodity, and transport mode. It is based on more than 100 data sources from third -party entities, such as railway waybills and the Commodity Flow Survey (CFS). The commodities of Transearch database are classified by “4-digit Standard Transportation Commodity Code” (STCC4).

The inbound and outbound local/interstate commodity flows by truck and rail in the UP were utilized for this project and we excluded STCC 2411 (Logs, Piling, Posts, Pulpwood, Wood Chips, etc.) as those were considered “log” products. Table 2 summarize aggregated truck and rail tonnage collected from the three databases. It can be seen that while shipping volumes collected by LSSA participants or by NRTC provided more detail, they accounted for fairly low percentage when compared with the overall volume from Transearch. This limited completeness of the more detailed data hindered their usefulness for the analysis. Since we only received inbound rail data from a single LSSA company we could not aggregate the volume data and have hidden the inbound rail data in Table 2.

Table 2. Summary of Non-Log Movement Data

Source	Total tonnage of data by mode of transportation				
LSSA Non-log data		Regional	Inbound	Outbound	Total
	Truck	1,160,707	83,392	1,344,439	2,588,538
	Rail	407,368		1,103,845	
	Total	1,568,076		2,448,283	
	Rail %	26%		45%	
NRTC Survey (2018) Non-log data		Regional	Inbound	Outbound	Total
	Truck	1,401,747	n/a	n/a	1,401,747
	Rail	202,348	n/a	n/a	202,348
	Total	1,604,095	n/a	n/a	1,604,095
	Rail %	13%	n/a	n/a	13%
Transearch (2015) Non-log data		Regional	Inbound	Outbound	Total
	Truck	5,400,471	1,890,686	1,845,007	9,136,164
	Rail	5,489,890	985,200	2,260,649	8,735,739
	Total	10,890,361	2,875,886	4,105,656	17,871,903
	Rail %	50%	34%	55%	49%

3.3. Rail Operational Data

3.3.1. Data Sources

Railway operations data in the project area was collected directly from the main rail carriers in the region, CN Railway (CN) and Escanaba & Lake Superior Railroad (E&LS). Detailed rail operation data is not commonly publicly available, but CN graciously shared their data with the research team. A detailed understanding of train movements was critical for our spatial model, as without such knowledge, building realistic route plans that meet the train's actual paths would be impossible. Many of the past studies have not accounted for such specific train schedules and operations, but rather assumed rail as "shortest path" movements and trains stopping at each siding top pick up/drop off cars. The GIS map in Figure 2 depicts all current rail tracks and the rail sidings in project area, although some of the segments/sidings have been out of service for extended period of time. The figure also shows the main rail routes of log movements, created based on the rail shipment data collected for this project.

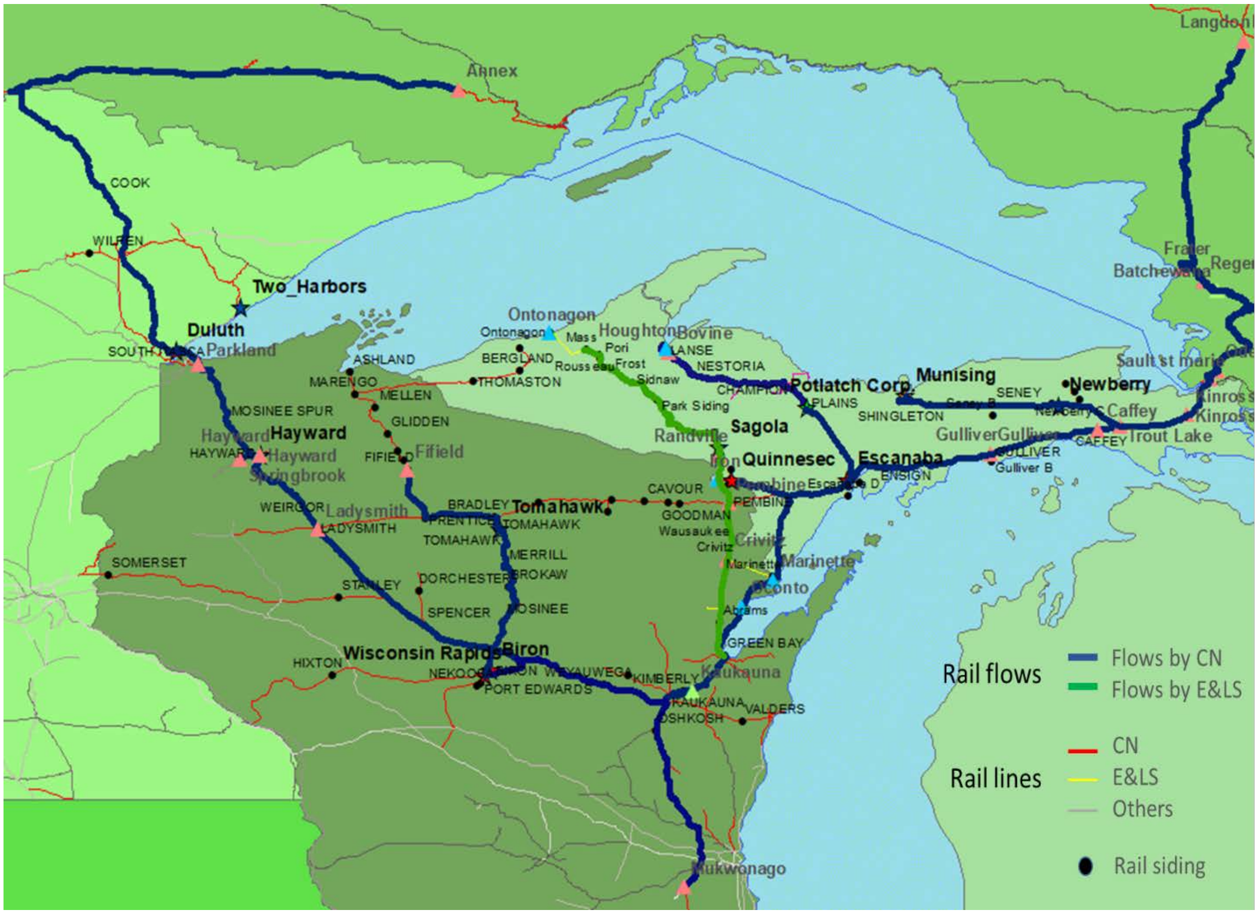


Figure 2. Main Rail Routes for Log Movements in the Project Region

3.3.2. Summary of Rail Operational Data

The rail operation data used in the project included current track in operation, rail sidings available (including some that were currently closed), route information for each scheduled train (departure/arrival time per each stop), and basic crew schedule information. We were provided schedules for 35 trains operating between 72 O-D pairs from CN. For the E&LS, the operational snapshot from the operations and train delay reports (TDR'S) during the last quarter of 2018 was provided. The most important data included each origin/destination, functions at each siding (drop/pickup/pass), schedules at each location, days of operation and connecting trains at yards. Since rail operations data, such as train routings and schedules, are confidential, they are not included in the report.

4. LOG MOVEMENT ANALYSIS

Table 3 presents the five types of analyses we conducted to answer the project questions related to moving logs, based on 2017 log movement data: 1) Shared siding/volume discount analysis, 2) Fuel price sensitivity analysis, 3) Railcar peaking analysis, and 4) Trucker value analysis. In this section, we briefly introduce each analysis.

- **Shared siding/volume discount analysis:** This analysis builds the foundation for the analysis. It explores the actual log movements by rail and truck in 2017 and compares them with results from our spatial model. It provides a control group by replicating the actual movements in the model and investigates potential modal shifts from sharing sidings, discounted rail rates, and volume based discounts.
- **Fuel price sensitivity analysis:** This examined the impact of fuel price change on the modal shift from shared siding/volume discount analysis.
- **Rail car peaking analysis:** This analysis explores the number of rail cars needed in the region to move the product. It also provides scenarios to evaluate how the number of cars impacts the seasonal variations, storage needs at the sidings, and the amount of rail car idling.
- **Trucker value analysis**: This analysis conducts a series of case studies that attempt to quantify the impact on truckers from shift to multimodal truck/rail operational model.

Table 3. Analysis to Address Project Questions/Objectives

Project Questions	Analysis
Are there opportunities for creating economies of scale in rail, if log movements in the region are considered as a single pool (rate sensitivity)?	**Shared Siding/Volume Discount Analysis + Non-log Movement Analysis**
Are there strategic locations for larger rail sidings that could accommodate larger blocks of cars, providing better alignment with the current rail business model?	
What number of rail cars dedicated to the region would be needed to move the product?	**Rail Car Peaking Analysis**
Are there opportunities to use consistent rail shipment to alleviate spring breakup limitations	
Would increase in consolidated shipments by rail create productivity improvements for log truckers?	**Trucker Value Analysis**
Are there any impacts on log movement modal share by various fuel prices?	**Fuel Price Sensitivity Analysis**

4.1. Preliminary Analysis: Truck and Rail Rate Estimation Models

The calculation of accurate transportation rates in the US is a challenging task [1]. This is especially true for rail rates, as they are often line, commodity, volume, and company specific and divided between publicly available tariffs and confidential contract rates. Even greater complexity is generated by movements that require interchanges between different rail service providers. At the same time, having an accurate rate estimates is an absolute necessity, as our objective functions rely heavily on truck and rail transportation rates. This section summarizes the methodology we used to develop truck and rail rate estimates.

The truck rates are based on actual log truck price obtained from the LSSA participants for the 4,831 OD pairs in the project. A regression model (Figure 3) where X indicates a one-way distance between OD pair and Y means the trucking price per tons shipped was used to develop the rate equation. All distances between OD pairs are calculated by Network Analyst of ArcGIS for Desktop 10.3.1 based on actual road network provided by US DOT. The truck rate formula proved to have a close correlation with the actual rates (R^2 value of over 0.95).

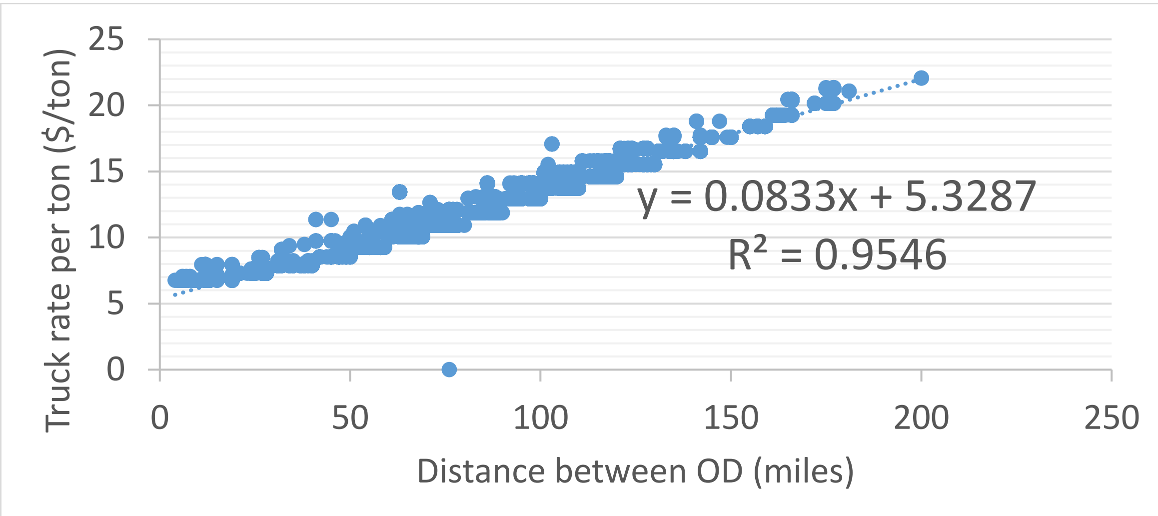


Figure 3. Regression model for log truck rates

There have been past attempts by the researchers to establish rail rates from publicly available databases [2, 3], but those cases are typically applicable only to the specific regions/movements. Referencing the official tariffs of rail carrier is an alternative option to estimate a rail rate, but it does not provide any potential contractual volume discounts. We developed our own rail rate estimation formula through multiple regression analysis that was based on actual rate data obtained from the LSSA participants. The rail rates were collected for 528 rail OD pairs. Since the cost for one loading/unloading of a truck is normally included in the trucking price, no additional cost was included in the rail rates for such activities. The model considers all rail cars to be provided by the operating railroad, so special rates for privately owned fleets are excluded. The total number of data records (rail tickets) was 9,750 and 50% of records were used to develop the model. The remaining 4,875 records were used to model validation. Along with the basic process of stepwise multiple regression analysis, we selected six highly correlating decision variables to estimate rail rate per tons shipped in the project area, as follows:

$$Y = 8.204 + 0.007X_1 - 6.364X_2 + 0.057X_3 + 6.81X_4 - 0.294X_5 - 0.738X_6$$

- Y: Rail rate per ton
- X1: Rail distance between each OD
- X2: Annual volume (tons) of each OD
- X3: Hauling hours
- X4: Is origin in Ontario, CA? (Yes=1 or No=0)
- X5: Is another rail carrier (not CN) included in OD? (Yes=1 or No=0)
- X6: Is origin in Wisconsin? (Yes=1 or No=0)

The advanced R^2 of our regression model was 0.87. Figure 4 shows the comparative result of real rate and estimated rate from our regression model. The results showed a reasonable correlation between the model and actual rates, validating its use in the project.

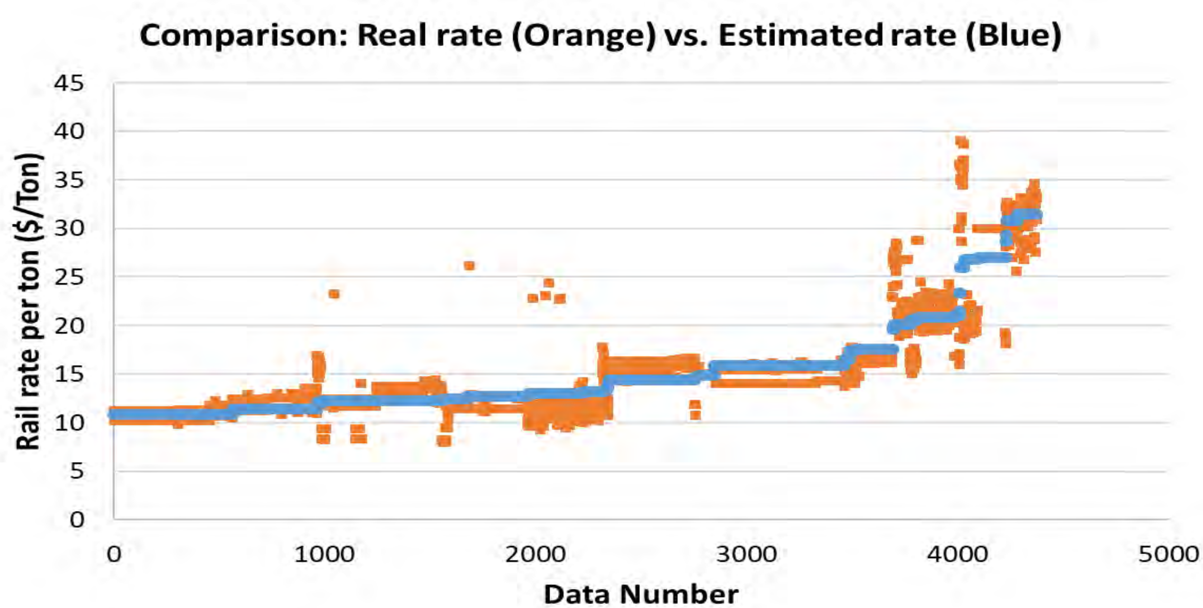


Figure 4. Rail Rate Regression Model Validation Results

4.2. Shared siding/volume discount analysis

4.2.1. Research Scenarios and Model Development

The main objective of the first model was to explore the impact of 1) allowing shared use of rail sidings across the companies, 2) re-opening rail sidings, combined with rate discounts, and 3) siding-specific volume discounts. Our mathematical model was applied in four different scenarios (Table 4) and compared against the current (benchmark) situation. A more detailed explanation of the mathematical model used for each scenario is provided in Appendix C.

Table 4. Scenarios for shared siding/volume discount analysis

Scenario #:	Sharing/Discount Options	Main Goal of Analysis
Scenario 1.	- No sharing (benchmark or current scenario)	- Validating model vs. actual shipments
Scenario 2.	- Each existing siding can be used by all mills of a specific (owning) company	- Impact of improved access on modal shares
Scenario 3.	- Each existing siding can be used by all mills of all companies	- Impact of shared access on modal shares
Scenario 4.	- All existing and currently closed sidings can be used by all mills of all companies - Volume discounts from specific sidings available	- Impact of re-opened sidings and open access on modal shares - Impact of rail rate reductions on modal shares - Determining sidings benefitting from volume discounts

We consider rail transportation network from two perspectives – shippers and carriers/operators. To reflect the rail carrier-perceived network in Scenarios 1~3, we needed to know the actual train routes rather than using the shortest rail distance between origin and destination, as has been commonly done in past research.

We developed the actual link-node map for the rail routes in our project area(Figure 5 (a)), based on the log movement data collected from the forest companies and the actual rail operation data from the regional rail carriers (operation schedule by each train number and rail trip plan of each individual O-D pair). The rail route map includes the nodes (rail sidings) and the links (rail track segments). The 28 nodes colored in black circle indicates the rail sidings that are currently used by the forest companies participating in the project. Note that the link between two nodes has a direction that describes the origin and destination of each segment. For example, while there were log movements from Bovine to Plains, no log shipments were recorded from Plains to Bovine, according to the rail movements data from the forest companies. This rail route map (Figure 5 (a)) was utilized for Scenarios 1~3.

Figure 5 (b) shows another route map created by hypothetically re-opening rail sidings that are currently closed or not used. The 28 re-opened/re-used rail sidings (nodes) are expressed by hollow green and blue circles. This rail route map (Figure 5 (b)) was utilized for Scenario 4.

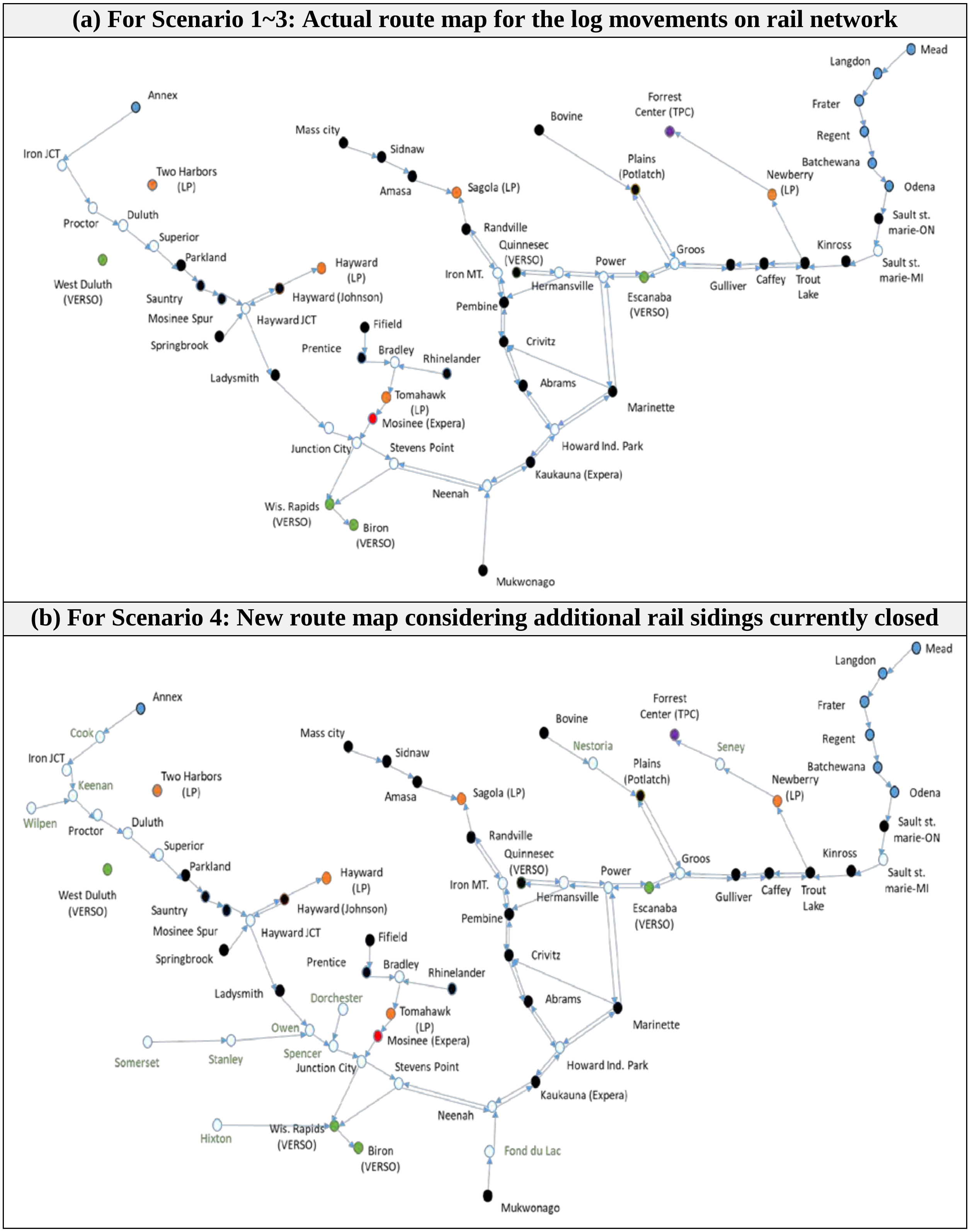


Figure 5. Actual route map for the log movements on rail network (a) and route map including currently closed or not used rail sidings (b)

4.2.2. Results of Shared siding/volume discount analysis

4.2.2.1. Result by each Scenario

Table 5 presents the rail modal share percentage (of total tonnage) for Scenarios 1~3. The column (a) in the table (Current mode share), indicates the actual 2017 mode share of LSSA log shipments by rail in our project region. As seen in column (b), the results from the benchmarking model (Scenario 1) are almost identical with the actual shipments (14.51% vs. 14.50%, respectively), providing an excellent validation of our model. Columns (c) and (d) show the shares when rail sidings are more openly shared, first within a company (c), and then by all companies in the project (d). Based on the analysis, the impact of "shared rail sidings" on rail share increase was limited. It was found that the share of rail tons was increased by only 0.47% even when all rail siding were shared among all participating forest companies (Scenario 3 – Column (d)).

Table 5. Results – Rail Modal Share for Scenarios 1~3

			(a) Current rail share (%)	(b) Scenario 1 No shared rail sidings	(c) Scenario 2 Shared Rail sidings within company	(d) Scenario 3 Shared rail sidings with all companies
	Company	Mill	**Rail %**	**Rail %**	**Rail %**	**Rail %**
1	Company 1	Mill 1	38.3%	38.3%	38.3%	38.3%
2	Company 2	Mill 2	0.0%	0.0%	0.7%	0.8%
3	Company 3	Mill 3	1.5%	1.5%	1.5%	1.6%
4	Company 4	Mill 4	19.0%	18.9%	18.9%	18.9%
5	Company 5	Mill 5	31.4%	31.4%	31.4%	31.4%
6	Company 6	Mill 6	3.4%	3.9%	3.9%	4.5%
7	Company 7	Mill 7	2.2%	2.2%	2.2%	2.2%
8	Company 8	Mill 8	31.6%	31.5%	31.5%	31.5%
9	Company 9	Mill 9	14.7%	14.6%	14.6%	14.6%
10	Company 10	Mill 10	0.0%	0.0%	0.0%	0.0%
11	Company 11	Mill 11	0.0%	0.0%	0.0%	0.0%
12	Company 12	Mill 12	1.9%	1.9%	1.9%	1.9%
13	Company 13	Mill 13	27.0%	27.0%	27.0%	27.0%
14	Company 14	Mill 14	3.3%	3.3%	3.3%	3.3%
Change in Rail Tonnage				**(0.06%↑)**	**(0.20%↑)**	**(0.47%↑)**
Total Rail Share			**14.50%**	**14.51%**	**14.53%**	**14.57%**

Various reasons may explain the small impact of the shared rail sidings on modal share.We believe one of the reasons to be the relatively short-distance of truck movements between most OD pairs in the project area. Figure 6 illustrates the log tons shipped by truck for five OD distance categories: 1) 0~50 miles, 2) 50~100 miles, 3) 100~150 miles, 4) 150~200 miles, and 5) 200~250 miles. More than 96.2% of log tonnage was shipped for less than 150 miles, making the transfer to rail economically challenging.

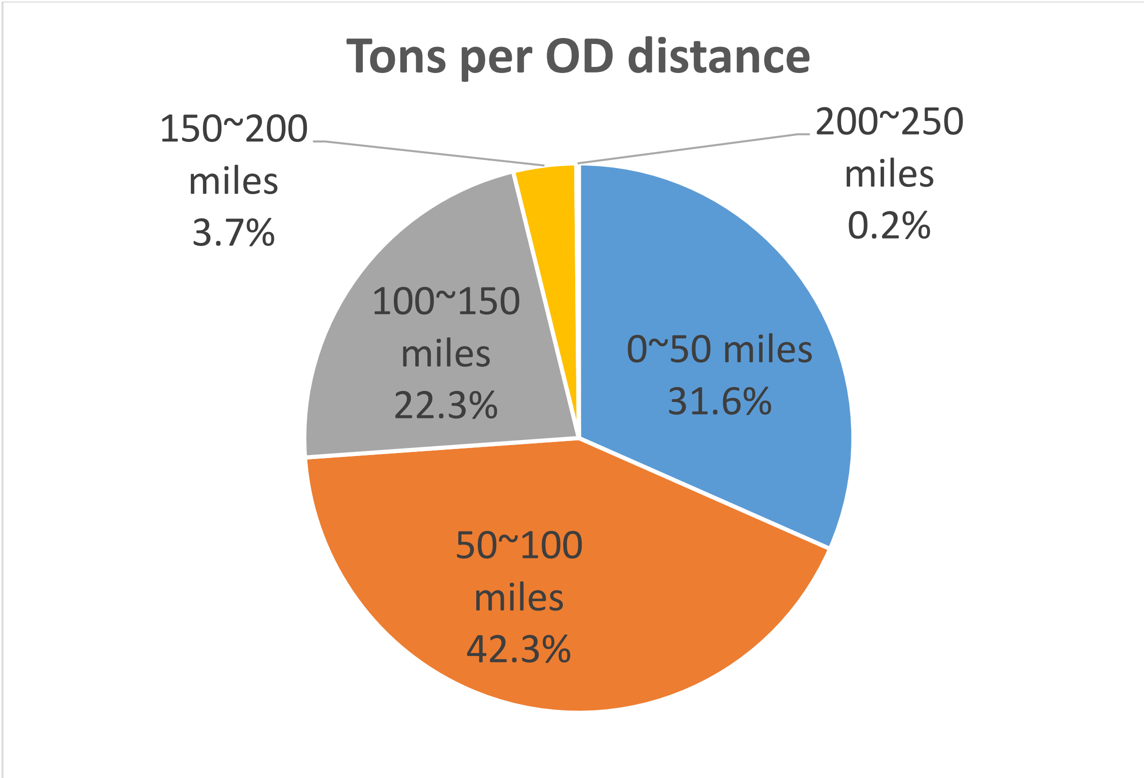


Figure 6. Log Truck Shipping Distance Breakdown

Table 6 presents rail modal shares for Scenario 4 that included fully shared sidings and re-opening of currently closed sidings. Column (a) is the current mode share of log transportation in project area and column (b) shows the result of new mode share occurred by assuming 28 rail sidings are re-opened. The results show that the re-opening of sidings increased rail tonnage by 2.3%, or from 14.5% to 14.8% of total tonnage. This would equal approximately 800+ new rail carloads into the system.

Columns (c)~(e) in Table 6 show the results on the10 to 30% rail rate discount scenarios, respectively. As shown, rate discounts (10~30%) would increase rail tonnage between 6.7-19.1% (or modal share by 1-3.5%). However, there would have to be justification for rail carriers to provide such reductions, an aspect that was not investigated in the project.

Table 6. Modal Shares for Scenario 4 with and without rail rate discounts

	Company	Mill	(a) Current rail share (%)	(b) Scenario 4 + No rail discount	(c) Scenario 4 + 10% Rail rate discount	(d) Scenario 4 + 20% Rail rate discount	(e) Scenario 4 + 30% Rail rate discount
			Rail %	**Rail %**	**Rail %**	**Rail %**	**Rail %**
1	Company 1	Mill 1	38.3%	38.8%	38.9%	39.9%	41.7%
2	Company 2	Mill 2	0.0%	0.8%	1.3%	2.5%	5.2%
3	Company 3	Mill 3	1.5%	1.6%	1.8%	1.9%	2.0%
4	Company 4	Mill 4	19.0%	18.9%	19.0%	19.5%	20.2%
5	Company 5	Mill 5	31.4%	32.3%	33.4%	34.6%	38.5%
6	Company 6	Mill 6	3.4%	4.5%	5.4%	10.0%	13.1%
7	Company 7	Mill 7	2.2%	2.2%	2.2%	2.4%	2.6%
8	Company 8	Mill 8	31.6%	31.5%	31.5%	31.5%	31.6%
9	Company 9	Mill 9	14.7%	14.7%	14.7%	14.9%	14.9%
10	Company 10	Mill 10	0.0%	0.0%	0.0%	0.0%	0.5%
11	Company 11	Mill 11	0.0%	0.0%	1.7%	1.7%	1.8%
12	Company 12	Mill 12	1.9%	1.9%	1.9%	1.9%	1.9%
13	Company 13	Mill 13	27.0%	27.9%	32.4%	39.2%	39.4%
14	Company 14	Mill 14	3.3%	4.1%	5.0%	5.6%	7.1%
Change in Rail Tonnage				**(2.3% ↑)**	**(6.7% ↑)**	**(13.1% ↑)**	**(19.1% ↑)**
Total Rail Share			**14.50%**	**14.8%**	**15.5%**	**16.7%**	**17.9%**

4.2.2.2. Scenario 4 with volume based discounts

While general rail rate discounts may be challenging to justify, discounts based on guaranteed shipment volumes have been used in the past. We examined three volume-based rate discount cases (10%, 20%, and 30%) from specific sidings for four minimum volumes (50,000, 100,000, 200,000, and 300,000 rail tons), respectively. For example, if more than 200,000 tons was shipped from a specific siding to one or multiple destinations within a year, the rail rate discount (10, 20 or 30%) would be applied to all shipments from that siding.

Table 7 provides the modal share for Scenario 4 with volume-based rail rate discounts. Columns a, c and e show the total shipping cost compared to base case for each rate reduction and columns b, d, and f show the rail share of total tonnage . As shown, log tonnage shipped by rail would increase the most (Table 7-(3)(f): 22.5%) when the volume discount threshold is 50,000 tons per siding and rate reduction 30%. Rail tonnage would also increase significantly with 30% discount and 200,000 tons volume limit (Table 7-(3)(f): 21.7%), but the total shipping cost savings would be reduced by almost half (from 4.0% to 2.1%). Overall, potential exists to increase rail modal share through volume discounts from specific sidings, but it may require sacrificing the rates for some individual shipments to achieve the volume threshold. In addition, the savings from shipments would be unequally divided between mills/companies.

Table 7. Impact of Volume Based Rail Discounts on Rail Modal Share and Total Shipping Cost

		Total log shipment costs and the percentage of rail shipments					
Minimum Aggregation Tons		**(1) Scenario 4 + 10% Rail rate discount per**		**(2) Scenario 4 + 20% Rail rate discount per**		**(3) Scenario 4 + 30% Rail rate discount per**	
		(a) Total Cost (Cost change %)	**(b) Rail Share (Rail ton change %)**	**(c) Total Cost (Cost change %)**	**(d) Rail Share (Rail ton change %)**	**(e) Total Cost (Cost change %)**	**(f) Rail Share (Rail ton change %)**
1	50,000	$105,368,334 (1.2% ↓)	14.9% (2.7% ↑)	$103,990,239 (2.5% ↓)	16.3% (11.2% ↑)	$102,349,034 (4.0% ↓)	18.7% (22.5% ↑)
2	100,000	$105,679,365 (0.9% ↓)	15.4% (6.0% ↑)	$104,406,878 (2.1% ↓)	16.9% (14.3% ↑)	$102,934,746 (3.5% ↓)	17.5% (17.0% ↑)
3	200,000	$106,220,340 (0.4% ↓)	15.5% (6.7% ↑)	$ 105,582,520 (1.0% ↓)	15.5% (6.7% ↑)	$104,399,448 (2.1% ↓)	18.5% (21.7% ↑)
4	300,000	$106,667,639 (0.0%)	14.8% (2.3% ↑)	$106,328,354 (0.3% ↓)	17.5% (17.2% ↑)	$105,478,076 (1.1% ↓)	17.5% (17.2% ↑)

As part of the volume discount analysis, we identified rail sidings that attracted highest volumes of logs through them. Table 8 shows three existing and re-opened sidings with highest volumes for current situation (actual 2017 volumes), for Scenario 4, and for 50,000 ton and 200,000 ton volume discount scenarios. Current volumes are shown for all existing sidings while re-opened sidings have volumes only for the hypothetical scenarios (naturally there's no current traffic, as they are closed). Gulliver, Plains, and Caffey in the Upper Peninsula of Michigan were the Top 3 existing rail sidings based on annual volumes. The ranking was the same for Scenario 4 results, with and without volume discounts. For the re-opened rail sidings, Stevens Point, Bradley, Dorchester, and Spencer (all in Wisconsin) had the highest volumes. It was noted that when the rail rate discount was 50,000 annual tons (Table 8 (c)), a total of approximately 170,000 tons of rail shipments were shipped through re-opened Top three rail sidings. However, when the volume limit was set to 200,000 annual tons (Table 8 (d)), only 15,000 tons were shipped through the same sidings. It is evident that up to 50,000 tons of logs were available nearby the sidings, but once this threshold was raised to 200,000, it became too difficult to route sufficient volume to receive the discount and without discount, even some of the logs from the 50,000-ton threshold scenario moved back to truck transportation.

Table 8. Top 3 Existing and Re-Opened Rail sidings by Volume

Rank		(a) Current 2017 (Bench marking)		(b) Scenario 4 + No rail discount		(c) Scenario 4 + 30% Rail discount by 50,000 aggregation		(d) Scenario 4 + 30% Rail discount by 200,000 aggregation	
TOP 3 Existing Rail sidings (Tons)	1	Gulliver, MI	214,581	Gulliver, MI	214,657	Gulliver, MI	214,784	Gulliver, MI	217,784
	2	Plains, MI	131,015	Plains, MI	135,335	Plains, MI	164,765	Plains, MI	200,000
	3	Caffey, MI	116,522	Caffey, MI	116,596	Caffey, MI	116,522	Caffey, MI	200,000
TOP 3 New Rail sidings (Tons)	1	-		Stevens Point, WI	6,114	Stevens Point, WI	69,153	Stevens Point, WI	6,114
	2	-		Bradley, WI	5,083	Dorchester, WI	50,000	Bradley, WI	5,138
	3	-		Spencer, WI	4,167	Spencer, WI	50,000	Spencer, WI	4,167

4.2. Fuel Price Sensitivity Analysis for the Log Movement

All analysis used a single year of data (2017). Since truck/rail rates are partially (and unequally) impacted by fluctuations in fuel price, we conducted sensitivity analysis to investigate the impact of such fluctuations in modal choice. Per LSSA guidance, it was determined that the average miles per gallon (MPG) of log trucks in Wisconsin project area was 3.8 miles per gallon (average between loaded and unloaded miles) and average net freight tonnage of log truck was 29 tons. Similar data was not available for heavier Michigan trucks. Based on the data, we assumed 1/(29*3.8) = 0.009 gallons are needed to move a ton of freight one mile by log truck (ton-mile). To estimate the trucking rate for different fuel prices, we broke down the rate to fuel cost and non-fuel cost components. The new trucking rate for different fuel prices can be calculated by changing the fuel portion of the rate and adding it to the non-fuel cost as follows:

- *Current trucking rate per ticket (base year) = current fuel cost + current non-fuel cost*
    - *New trucking rate per ticket =* <u>*new fuel cost*</u> *+ current non-fuel cost*

New fuel cost in the equation indicates the fuel cost calculated by updating the current fuel price per gallon to new values ($3 to $5 per gallon). Non-fuel cost is kept fixed in all scenarios .

We selected $2.596 per gallon as a representative price of 2017 truck fuel price based on the EIA weekly retail diesel price at Midwest area [4]. Figure 7 compares the truck rate model based on 2017 data with new regression model developed to estimate the truck rate when fuel price increases from $3 to $5 per gallon. For the rail rates, the impact of fuel was calculated based on the formula provide by the CN Railway on their website [5]. According to the CN's fuel surcharge policy, the surcharge of all carload commodities except bulk commodities varies by $0.0060 for each $0.03 change in the price of diesel fuel when it deviates from the EIA weekly diesel price at Midwest area (same as above for truck rates) The fuel price fluctuation is incorporated automatically to rail rates through this formula.

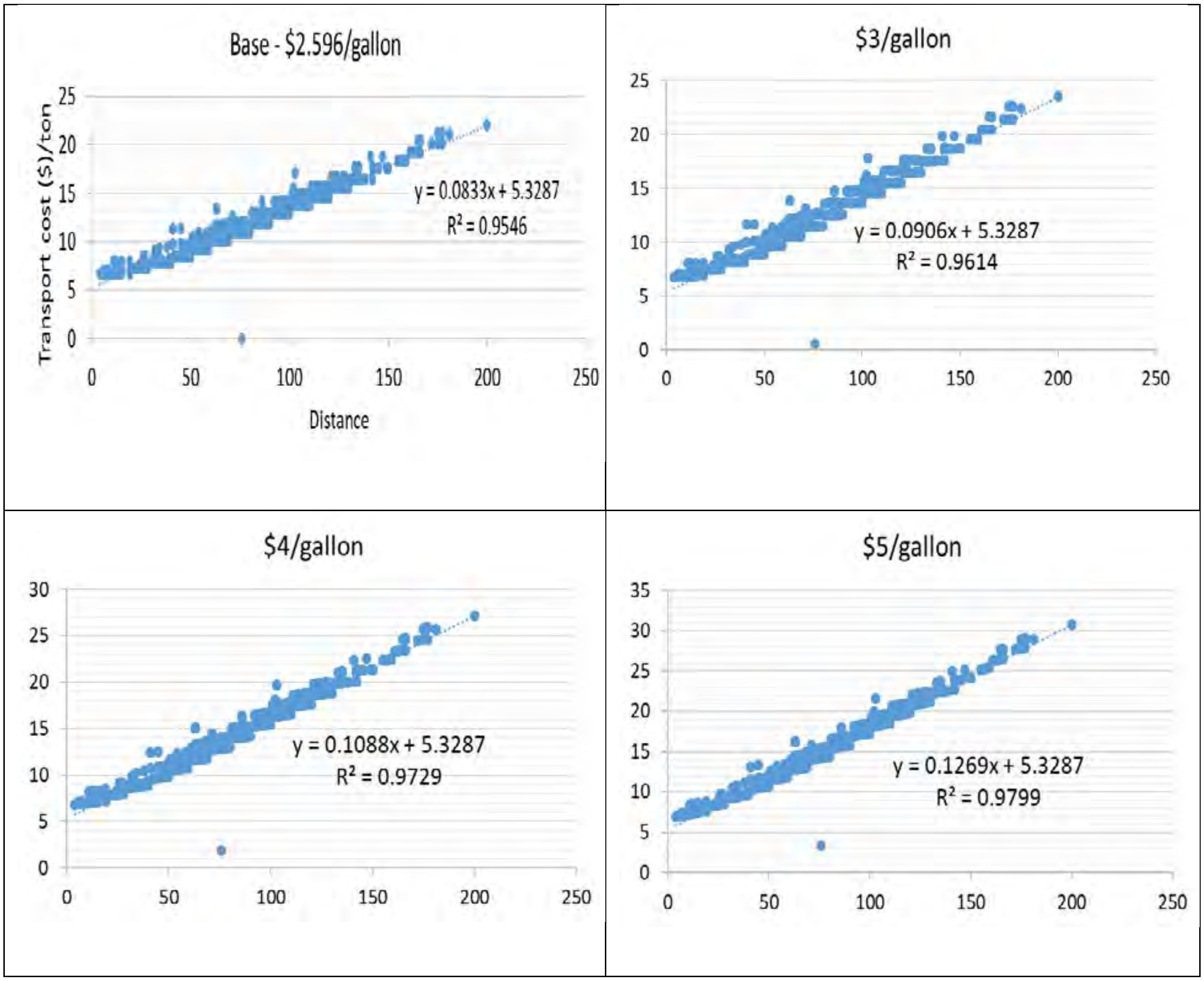


Figure 7. Impact of Fuel Surcharges on Log Truck Rate Regression Model

4.2.1. Results of Fuel Price Sensitivity Analysis for the Log Movement

Once the rates were determined, we used three different fuel prices ($3, $3, and $5 per gallon) t conduct the sensitivity analysis for Scenario 1 and Scenario 3 of the shared siding/volume discount analysis introduced earlier. The total tonnage shipped by rail and the total transportation cost of log movements were calculated for each fuel price. Table 9 provides the results of the analysis. In Scenario 1, the total transportation cost was increased by approximately 4% to 24% when fuel price increased from $3 to $5 per gallon, respectively. The increases were similar in Scenario 3, but rail modal share gains were much higher (2.36% vs. 17.12%, respectively). We believe the greater transfer percentage is due to the shorter distance to rail sidings under Scenario 3.

Table 9. Results - Fuel Price Sensitivity Analysis for the Log Movement

	Total transport cost			**Rail volume (tons increased)**		
	$3/gal	$4/gal	$5/gal	$3/gal	$4/gal	$5/gal
Scenario 1 (Benchmark – **Partially shared rail sidings**)	4.1% ↑	14.4% ↑	24.6% ↑	0.23% ↑	0.65% ↑	2.36% ↑
Scenario 3 (**Fully shared rail sidings**)	4.1% ↑	14.3% ↑	24.2% ↑	1.41% ↑	8.51% ↑	17.12% ↑

4.3. Rail Fleet Analysis

Freight rail uses fleets of rail cars that typically circulate either within specific service area or throughout the rail system. In addition to service schedules, operational patterns, and loading/unloading efficiencies, the capacity of rail transport is directly related to the number of available rail cars that are owned by a variety of different stakeholders. Different objectives by rail car owners and shippers may create conflicts when optimal number of cars to be utilized is determined. From railroadperspective, the objective is to always keep the cars moving, as they only provide revenue when transporting a load. Any idling of a car removes or reduces (demurrage) the revenue stream. From shipper's perspective, the objective is to have a rail car available when it's needed to avoid any unplanned loss of productivity and related freight storage costs. If the rail car owner is someone else that railroad or shipper, there expectations are determined based on the agreement for using the cars.

We developed a large-scale MILP model to estimate the number of rail cars needed in the project area concentrating on the impact of the fleet size on 1) rail car idling and 2) log storage needs at yards prior to rail transportation. The basic set and decision variables of the large-scale MILP models for each case (MODEL 5 and MODEL 6) are attached in the Appendix D. We applied the model to two project cases:

- Case 1: Logs moved by rail as soon as they arrive (prevent storage)

- Case 2: Logs either temporarily stored or moved as they arrive (storage available as alternative)

For both cases, we assumed the total time to ship the logs from rail siding/yard consisted of loading time at the site, hauling time, and unloading time at the destination (mill) (Figure 8).

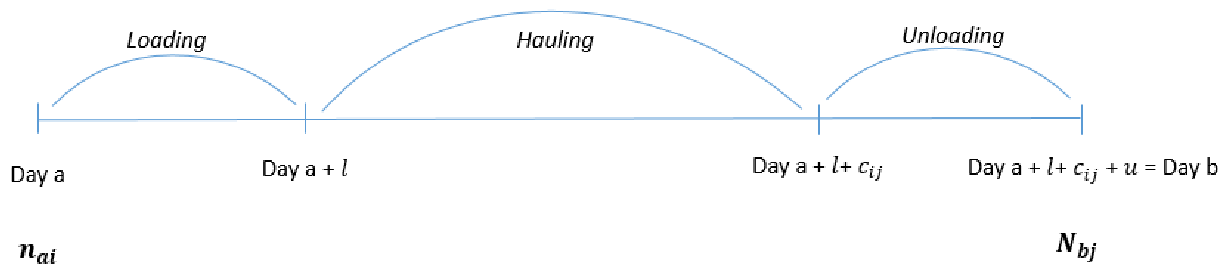


Figure 8. Shipping Formula

In Figure 8, c_{ij} indicates the rail hauling days to move from rail siding/yard ***i*** to mill ***j*** (same as ***j*** to ***i***) and the loading/unloading days are expressed by ***l*** and ***u***, respectively. n_{ai} means the number of rail cars that is about to be loaded at the origin ***i*** at day ***a***, and N_{bj} indicates the number of rail cars that finish their unloading at the mill ***j*** at day ***b***. Since we already know the day ***b*** based on the log movement data collected from the forest companies, we could calculate day ***a*** if we know the rail hauling days. Since there is little information on the actual rail hauling days (c_{ij} in Figure 8) between all OD pairs, we used multiple regression analysis to estimate the hauling days from siding to siding, based on the sample data of actual timetable collected from regional rail carriers. Two highly correlating decision variables, distance and number of rail carriers responsible for total move, were used to estimate rail hauling days in the project area (equation below). , The advanced $R^2$of our regression model was 0.74.

$$Y = 1.24 + 0.01X_1 + 0.76X_2$$

- Y: Rail freight hauling days between OD pair
- X1: Rail distance between each OD pair
- X2: Rail Carrier at Origin and Destination (If two are a same carrier = 1, otherwise = 0)

We used the 15,740 log tickets that shipped over 1,346,278 tonnage of logs by rail (we assumed one ticket indicates one rail car) for estimating the need for rail cars. Figure 9 provides the monthly averages for the log tickets/cars moved by rail and for the average rail hauling days per shipment from our multiple regression model. As shown in the Figure, September had the highest number of tickets and April the lowest. Average hauling days were highest in December and lowest in May.

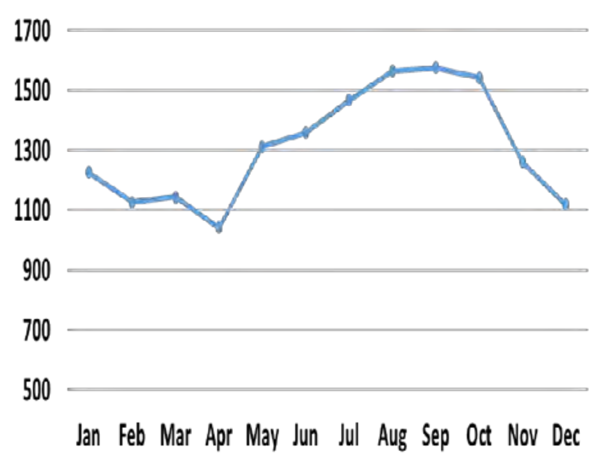
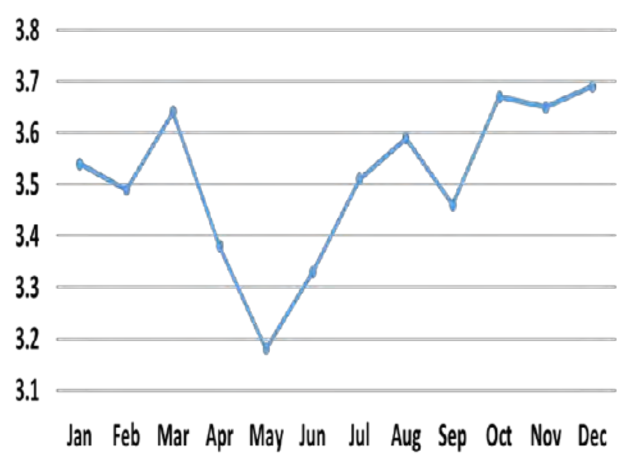
Number of Rail Log Tickets/Cars by Month	Average Rail Hauling Days per Shipment by Month
	

Figure 9. Monthly breakdown of log tickets moved by rail and the average rail hauling days

4.3.1. Results of Rail Car Peaking Analysis

4.3.1.1. Result of Case 1: Prevent storage in Rail Yards/Sidings

In our first case, we considered that all logs loads should have rail car available at the rail siding at the time of their arrival in trucks. to maximize the utilization efficiency, we considered all rail cars to be dedicated to the project region and available for shipments by any of the companies participating in the project. We first conducted the analysis for the months with lowest and highest volumes (April and September). Then we applied the same model to the log movements for the whole year of 2017. Figure 10 shows that minimum of 405 and 580 rail cars would be needed to deliver rail tons on April and September, respectively. If we consider a whole year, minimum number of rail cars to satisfy the annual rail tons in the project area is 593. We felt the actual number of log cars in the region (provided by CN) validated our results, as it was in between our low and high numbers.

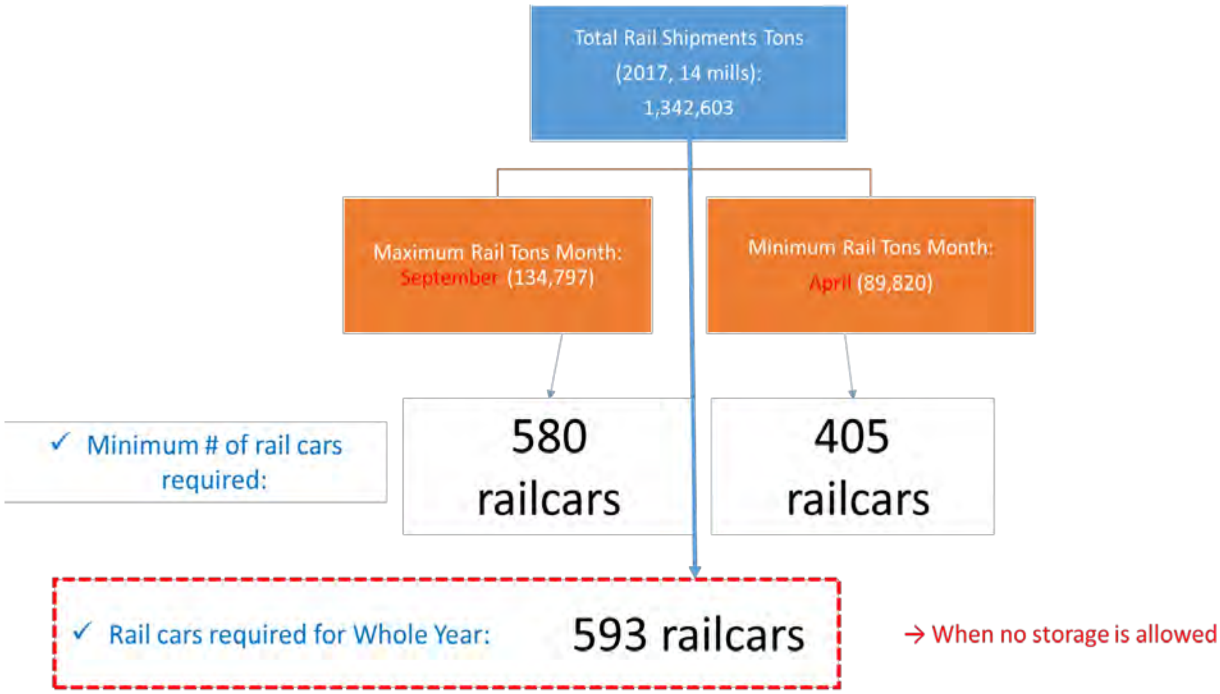


Figure 10. Results of Case 1: No Storage at Rail Sidings/Yards

Figure 11 shows a graphical representation of the rail car usage throughout the year analyzed. New-added car means that none of the cars from the current fleet (we started with 0 in day one) is available for the shipment, so new car is added to the model. Once we reach a surplus of cars for a specific day, a rail car not utilized for the freight shipment on any specific day is labeled as “idle”. As expected, new cars were added daily over the first month, until the fleet reached its full size of 593 in early February. Once full fleet size was achieved, some cars were idled due to demand fluctuations. For most of the year, the idling rate was fairly stable 25 cars per day (5% of the fleet), suggesting minor impact from seasonal variation.

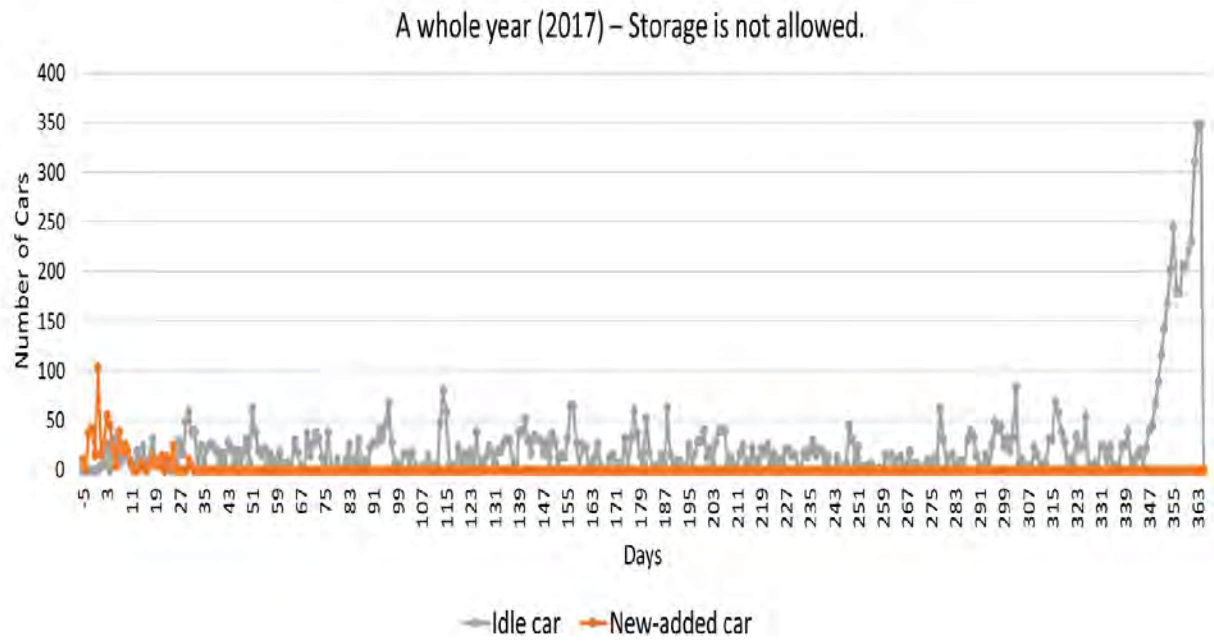


Figure 11. Number of Added and Idled Rail Log Cars Per Day (Fleet Size of 593)

4.3.1.2. Result of Case 2: Temporary Storage Allowed

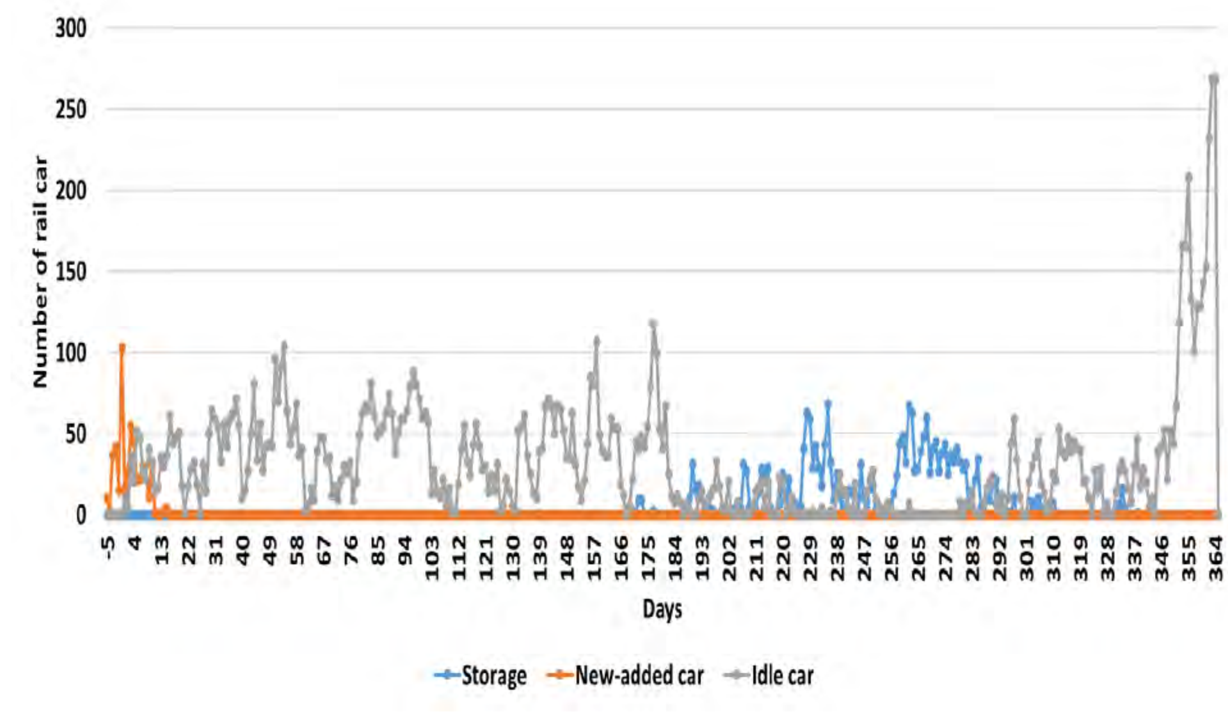
The objective of Case 1 was to move the logs to their final destination as fast as possible, preventing storage at the rail siding/yard. In Case 2, we varied the size of log car fleet size and loading/unloading times to examine their impact on storage and idled car needs (Table 10). The values were either derived from Case 1 analysis (fleet size) or from discussions with forest product companies (loading/unloading days). For example, the Alternative 1 means there is 493 rail cars available for the log movements in the project region and loading/unloading takes 1.5 days in all origin and destination sites. In the Alternative 4, there is only 400 rail cars available and it takes 2.5 days for both loading and unloading.

Table 10. Case 2 Alternatives (Storage Available)

Loading + Unloading days / **Available cars**	1.5 days + 1.5 days	2.5 days + 2.5 days
493	Alternative (1)	Alternative (2)
400	Alternative (3)	Alternative (4)

Figure 12 and Figure 13 show the graphical results on the four Case 2 alternatives. The figures show the amount of logs that require storage (in carloads), as well as the number of added and/or idled rail cars per day. All alternatives require some idling of cars (mainly in the spring) and some intermediate storage of logs (summer/fall). The Figures also reveal the trade-off between storing log products and the number of rail cars idled. In other words, the periods that there are lots of idled cars (grey lines in the Figure) shows low need for log products storage (blue lines in the figure) and vice versa. As expected, Alternative 1 (Figure 12 (a)) with larger car fleet and quicker loading/unloading see much less storage and more idling than other alternatives, especially Alternative 4 (Figure 13 (b)) that has smaller fleet and longer loading/unloading times.

(a) Alternative 1: 493 cars - Loading (1.5days)/Unloading (1.5days)



(b) Alternative 2: 493 cars - Loading (2.5days)/Unloading (2.5days)

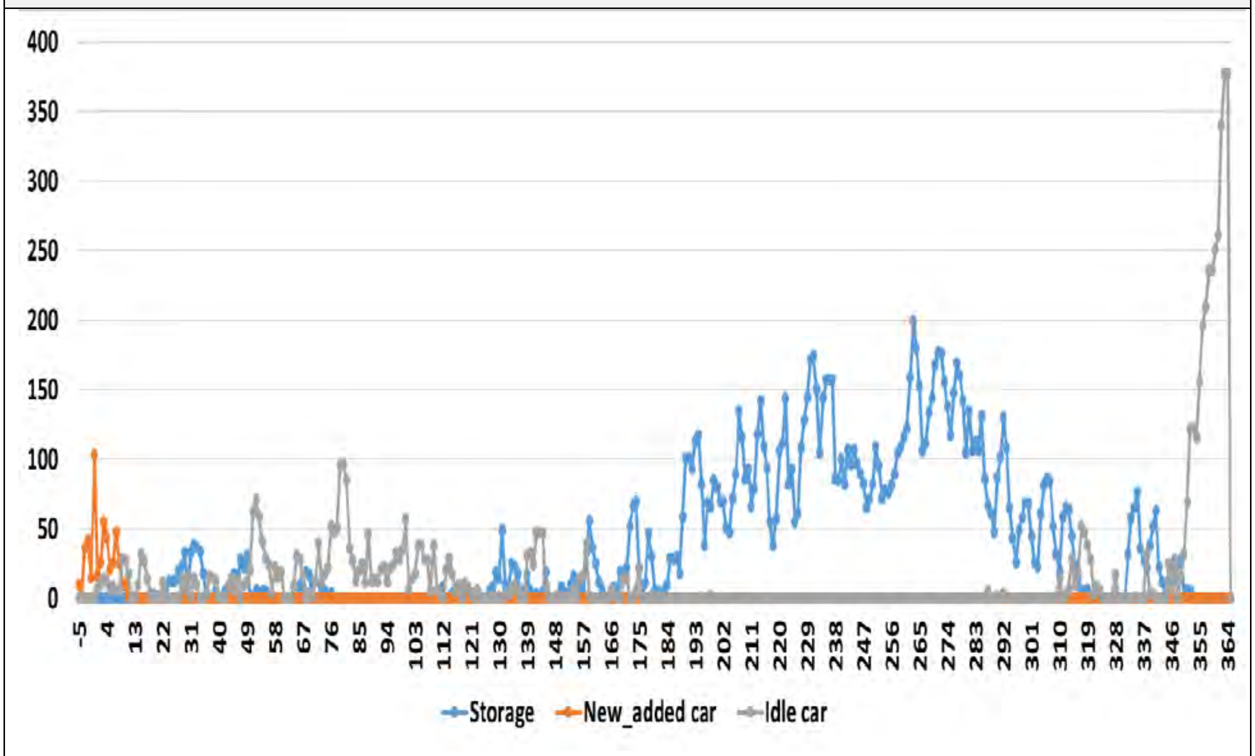


Figure 12. Results on Alternative 1 and 2 of rail car peaking analysis when log storage is allowed

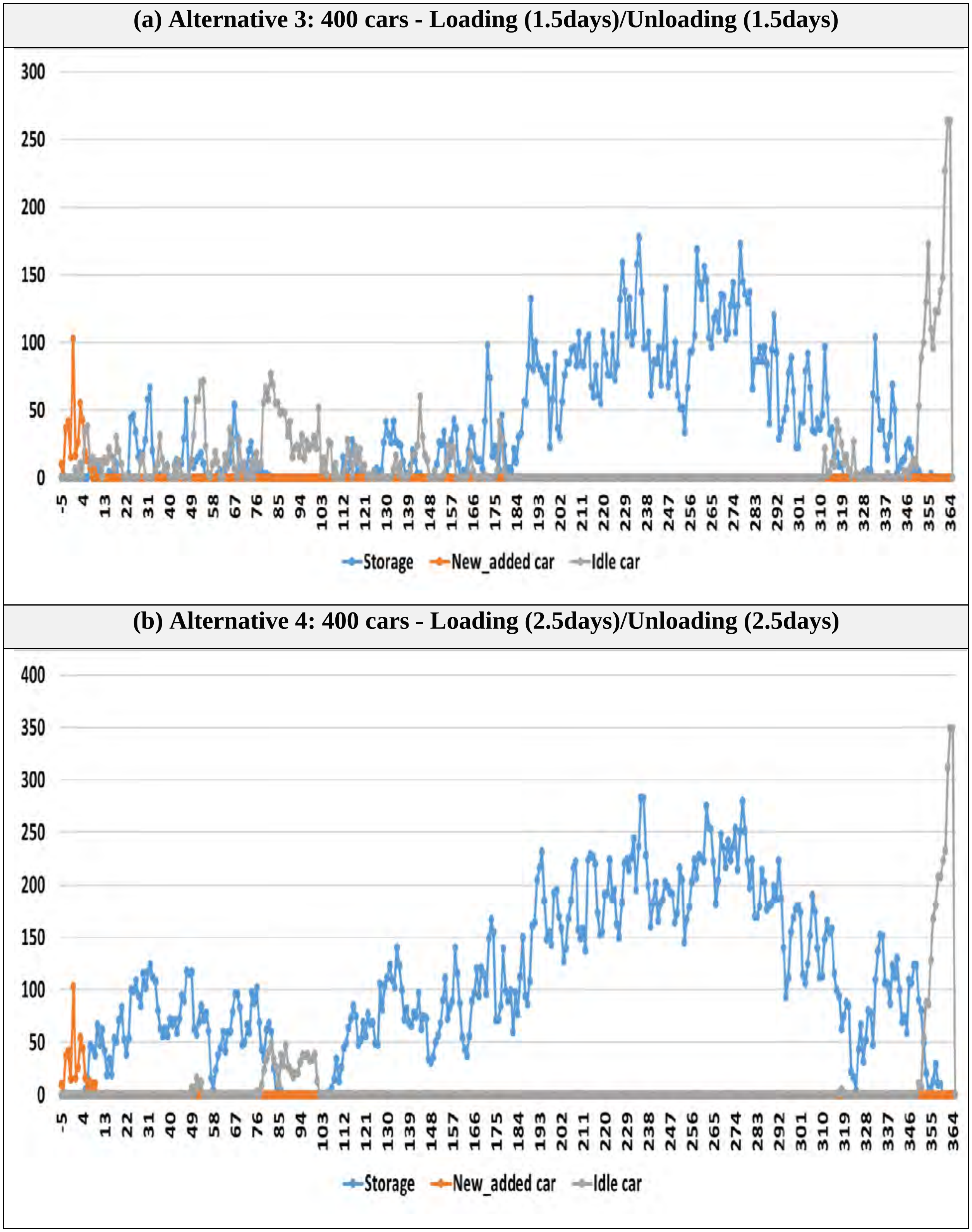


Figure 13. Results on Alternative 3 and 4 of rail car peaking analysis when log storage is allowed

Table 11 presents the percentage of carloads stored, as well as the average storage days at the origin sites. The table shows that increase of unloading/loading process by one day leads to a double-digit increase in stored loads and almost doubles the average days spent in storage. We can also see that the impact of one added day in loading/unloading has almost same impact on increased storage, as removing almost 100 cars from the rotation (alternative 2 vs. 3). It was found that 400 car rotation would almost eliminate car idling, but 31-47% of logs would be stored for 3-5 days (Alternatives 3 and 4). We also found that there was the great variation of storage days between individual sidings. For example, the storage days under Alternative 4 ranged from 2.8 days (Gulliver) up to 25.1 days (Crivitz). The average storage duration was 5.3 days.

Table 11. Percentage of Carloads Stored and the Average Storage Days at Origins

	Percentage of carloads stored at origin	Average storage days at origin
Alternative (1) – 493 cars, 1.5/1.5 days	8%	1.7 days
Alternative (2) – 493 cars, 2.5/2.5 days	30%	3.0 days
Alternative (3) – 400 cars, 1.5/1.5 days	31%	2.9 days
Alternative (4) – 400 cars, 2.5/2.5 days	47%	5.3 days

4.4. Trucker Value Analysis

The LSSA data showed that in 2017, truck transportation moved 85% of all log volumes in the region. Some industry experts have expressed the concern on the high reliance by the industry on truck transportation, as attracting new transportation professionals to the industry (or even maintain existing ones) has become more challenging. The main question of our “trucker value analysis” was whether increased use of rail transportation would hinder or help truckers in their operations. There are several past studies that have looked into the benefits of multimodal transportation from various perspectives; strategic planning problems [6-8], tactical planning problems [9-11] and operational planning problems [12-14]. Most studies used mathematical/simulation methodologies to figure out the strategic/tactics planning problems of multimodal transportation, but none have investigated the benefits for truck driver from the multimodal transportation using rail.

There are several ways to measure efficiency/productivity [15]. In our project, log truck efficiency used two core parameters; average loaded ton-miles per day and total ton-miles per day. Since most log trucks are owned by their operators and they get paid only for miles when loaded, an individual trucker's ultimate gains (salary) are heavily dependent on the loaded ton-miles. Based on the basic units of measurement (Weight, distance, and time), time efficiency and value efficiency were calculated and compared between truck-only (current) scenario and multimodal (with rail), as follows:

- **Time efficiency:**

$$\text{Productive time per day (considering maximum 12 hours of service)} = \frac{Actual\ operated\ hours\ by\ truck}{Maximum\ hours\ or\ service}$$

- **Value efficiency:**

$$\text{Actual loaded ton} - \text{miles for all shipments} = \text{Shipped tons per day} \times \text{Loaded miles per day}$$

To evaluate trucker's time and value efficiencies, we needed to calculate total days of operation and total time trucks operated per day. The detail explanation on the method to calculate both parameters is in Appendix E. Since investigating all truck movements would be labor some, we selected four specific rail sidings for the analysis. Figure 14 shows the locations of the sidings and origins of logs that were routed through each siding. As shown, each origin area was formed as 50 × 50 miles square, extending from the rail siding. In the analysis, all logs from within the section were trucked to rail siding instead of the final destination (mill). The results were compared against the actual data (truck only system). It should be noted that all experimental sections were designed to avoid a 30 miles' buffer zone from the destination sites (mills), as it would be unrealistic for the shippers to use rail transportation in replacement of extremely short-distance truck shipments.

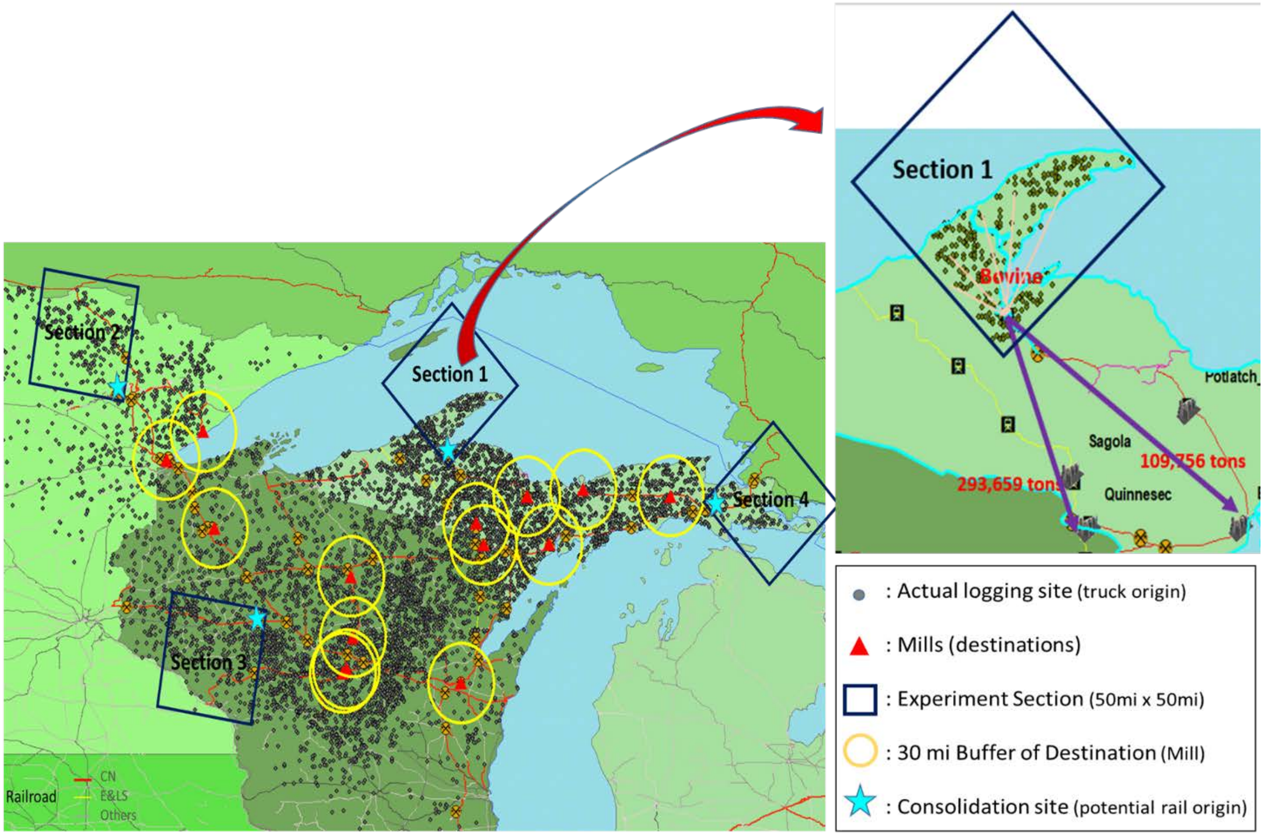


Figure 14. Locations of four experimental sections for trucker value analysis

For the analysis, we needed to understand how log trucks spend their daily hours of service. We obtained the breakdown from an earlier study that used GPS receivers for tracking several log trucks in the UP, MI region [16]. The information included the average stop times of log trucks per activity as shown in Table 12. These values were used together with the truck hauling hours based on average truck speed and OD distance to estimate the total daily operational hours of truck drivers.

Table 12. Average stop time (in hours) of log truck per each activity [16]

Activity	Administration	Technical	Gas	Other	Loading	Unloading	Unknown
Avg. stop time (hours)	0.07	0.36	0.12	0.04	1.35	0.65	0.22

4.4.1. Results of Trucker Value Analysis

As explained earlier, four rail sidings and related sections of feedstock were selected for the case studies. First, we identified the characteristics of each project section, calculating the number of truck origins, total tons shipped, the average distance between truck origins and mills as well as the average distance between truck origins and the rail siding selected for investigation. Table 13 summarizes the characteristics of all four case studies. As shown, each section had different average distance between truck origins and destinations (mill or rail siding). For example, Section 4 shows the shortest average distance between truck origins and selected rail siding (33 miles) while average distance to mills was relatively long (141 miles).

Table 13. Summary of Sections for Trucker Value Analysis

	Rail siding	# of truck origins	Avg. Distance between truck origins and mills (Destinations)	Avg. Distance between truck origins and rail siding	Total shipping tons
Section 1	Bovine, MI	207	134 miles	37 miles	247,896 tons
Section 2	Wilpen, MN	212	129 miles	65 miles	83,685 tons
Section 3	Stanley, WI	320	102 miles	47 miles	114,402 tons
Section 4	Trout Lake, MI	121	141 miles	33 miles	93,509 tons

We calculated time efficiency (the actual time log trucks operated divided by maximum hours of service per day) and the value efficiency (shipped ton-miles per day) for each section and then compared truck only scenario and multimodal (truck/rail) scenario. Table 14 shows the time efficiency and value efficiency for Rail Siding 1 (Bovine, MI).

Table 14. Example of time efficiency and value efficiency for the Rail Siding 1 (Bovine, MI)

(A) Time efficiency

	Route	Total Tons	Days	Available time for operations (12h*Days)	Actual time taken for operations	**Time Efficiency** (Actual time /Available time
(1) Truck + Rail Scenario	**Forest to Bovine siding**	247,896	2,580	30,957	23,866	**77.1%**
V.S						**V.S**
(2) Truck only Scenario	**Forest to Mill**	247,896	5,130	61,560	45,847	**74.5%**

(B) Value efficiency

	Route	Total Tons	Days	Shipped tons/day	Loaded miles	Loaded miles/day	Total miles/day	**Avg. Loaded ton-miles per day** (Shipped tons per day * Loaded miles per day)
(1) Truck + Rail Scenario	**From Forest to Bovine**	247,896	2,580	96.1	195,723	75.9	151.7	**7,290 ton-miles**
V.S								**V.S**
(2) Truck only Scenario	**From Forest to Mill**	247,896	5,130	48.3	550,207	107.3	214.5	**5,182 tons-miles**

Table 14 reveals that if all log trucks movements were shipped by a combination of truck and rail through Bovine, the time efficiency would slightly increase from 74.5% to 77.1%. The value efficiency, on the other hand, would increase from 5,182 ton-miles to 7,290 ton-miles, equivalent increase of 41% on average loaded ton-miles per day for each log truck. Table 15 summarizes the results of time efficiency and value efficiency for all four rail sidings investigated. The efficiencies increased in all locations, except Wilpen, MN (Rail Sidng 2). It can be seen that the average distance to Wilpen rail siding from the log origins was much longer than in other locations (65 miles) which may explain the efficiency reduction.

Table 15. Results of time efficiency and value efficiency comparing truck only and multimodal scenarios

		Time efficiency (Avg. ton-miles per day)			**Value efficiency (Avg. ton-miles per day)**		
Sec-tion	**Rail siding**	**Before: Truck Only**	**After: Truck & Rail**	**Change (After-Before)**	**Before: Truck Only**	**After: Truck & Rail**	**Change (Before/After)**
1	**Bovine, MI**	74.5%	77.1%	**2.6%p ↑**	5,182 tons-miles	7,290 ton-miles	**41% ↑**
2	**Wilpen, MN**	82.1%	65.7%	**16.4%p ↓**	3,029 tons-miles	2,281 ton-miles	**25% ↓**
3	**Stanley, WI**	64.8%	81.3%	**16.5%p ↑**	2,898 tons-miles	4,758 ton-miles	**64% ↑**
4	**Trout Lake, MI**	78.4%	87.5%	**9.1%p ↑**	6,496 tons-miles	8,117 ton-miles	**25% ↑**

4.4.2. Sensitivity analysis

We conducted sensitivity analysis on two key parameters of log truck movements to investigate their impact on results; 1) average truck speed variation between 30-50 mph (41 mph was used in the analysis) and 2) maximum hours of service per day limitations for truck drivers between 11-13 hours (12 hours was used in original analysis).

Figure 15 provides the comparative results for various log truck speeds. As expected, the ton miles per day (productivity) increased along with the increase of truck speed. However, the productivity increases are higher in multimodal scenario (Figure 15 (b)). We hypothesize that with closer destination, the higher speed allows truckers to get additional loads per day, due to faster round trips.

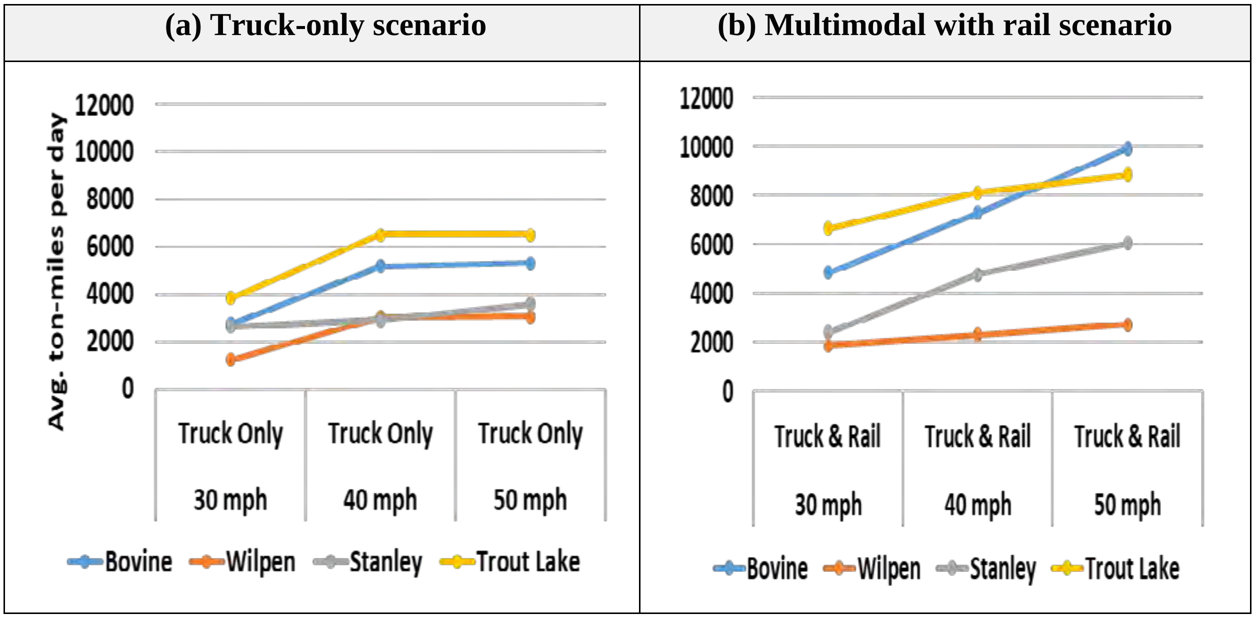


Figure 15. Results of sensitivity analysis for various log truck speeds

Figure 16 provides the comparative results on the sensitivity analysis for the hours of service. Similar to speed, ton-miles per day increase with higher hours of service, but the impact was higher in the multimodal scenario (Figure 16 (b)). We believe the same hypothesis to be true in this case as well; shorter trips to rail sidings allow more easily an addition of a trip to a daily schedule when hours are increased.

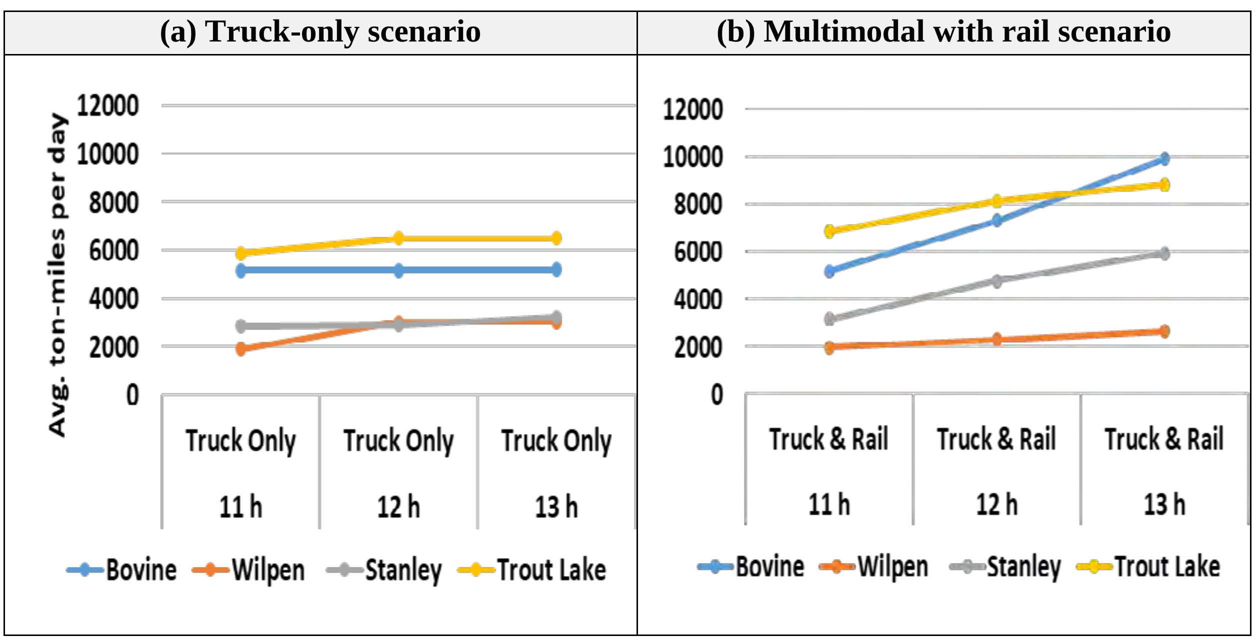


Figure 16. Results of sensitivity analysis for maximum hours of service

5. NON-LOG MOVEMENT ANALYSIS

The main objective of "non-log" movement analysis was to identify and collect information on all freight shipments to/from the region, regardless the industry, and use the information to identify potential opportunities for rail shipments. Transport of logs was excluded from the analysis, as they mainly move within the region and were covered in the other parts of the study. The spatial model did not cover the "non-log" freight movements, as building a detailed model for those movements would require extensive amount of currently unavailable data, such as pricing arrangements for shipments with interchanges between operators.

Since detailed analysis/modeling was not possible, we concentrated on quantitative evaluation and mapping of the main lanes for inbound/outbound freight. This section provides the outcomes of non-log movement data and analysis.

5.1. Data Summary and Shortcomings

As mentioned in Chapter 3, three databases were utilized to conduct non-log movement analysis: LSSA data collected directly from the forest companies, Transearch 2015 data, and NRTC survey data. The compilation of three sets of data that were each more or less incomplete created some challenges for the analysis. For example, each data set had geographical limitations, as presented in Table 16. The data collected from LSSA companies had very limited information on inbound flows that didn't come from the project region. For NRTC survey data, only flows within the region could be extracted, as inbound/outbound flows outside the region were lacking even state-level accuracy.

Table 16. Data Sources and Type of Data Included in the Source

	Location Accuracy	NRTC	Transearch	LSSA
REGIONAL Flows (Within the Lake Superior States: MI, MN, WI)	County-base	O	O	O
Non-Regional Flows (**Inbound** from States excluding MI, MN, WI)	State-base	X	O	X
Non-Regional Flows (**Outbound** to States excluding MI, MN, WI)	State-base	X	O	O

* O = Included; X = Not included

Table 17 summarizes the total inbound/outbound freight volumes by data source. The table reveals the other challenge with the data, namely great discrepancies in total volumes between the data sets. The total tonnage obtained from the LSSA or NRTC data accounts only for a small percentage of the volumes from Transearch (14% and 9%, respectively). This is despite the fact that Transearch data covered only the Upper Peninsula of Michigan while LSSA and NRTC data covered the whole project area. Since data from LSSA and NRTC was so limited, most analysis rely heavily on Transearch data (and the Upper Peninsula), as there's little benefit on trying to generate detailed analysis on freight lanes for other project areas when only small percentage of shipments is accounted for.

Table 17. Freight Tonnage by Data Source

Source	Total tonnage of freight movements in database
LSSA Non-log data	4,016,359
NRTC Survey (2018) Non-log data	1,604,095
Transearch (2015) Non-log data	17,871,903

5.2. Freight Flow Maps

Due to shortcomings offreight data that originated/terminated outside the project region in LSSA and NRTC database, only the regional flow maps/tables used data from all three databases, while non-regional maps/tables relied on mainly Transearch 2015 database (and hence covered only the UP of Michigan). Figures 17 and 18 show two examples of the maps developed, regional freight flows by truck (Figure 17) and non-regional inbound freight by truck (Figure 18). For regional shipments, the mapping was done on a county level accuracy, while for non-regional freight, the origin/destination outside the region were only available at state level. The thickness of the lines expresses the overall volume in the freight lane, the thicker the line, the more freight volume moves on the lane. The specific freight tonnage per lane is not provided, as some lanes present freight flows from a single company and revealing the tonnage would be against our confidentiality agreement. The remaining freight flow maps are provided in Appendix F.

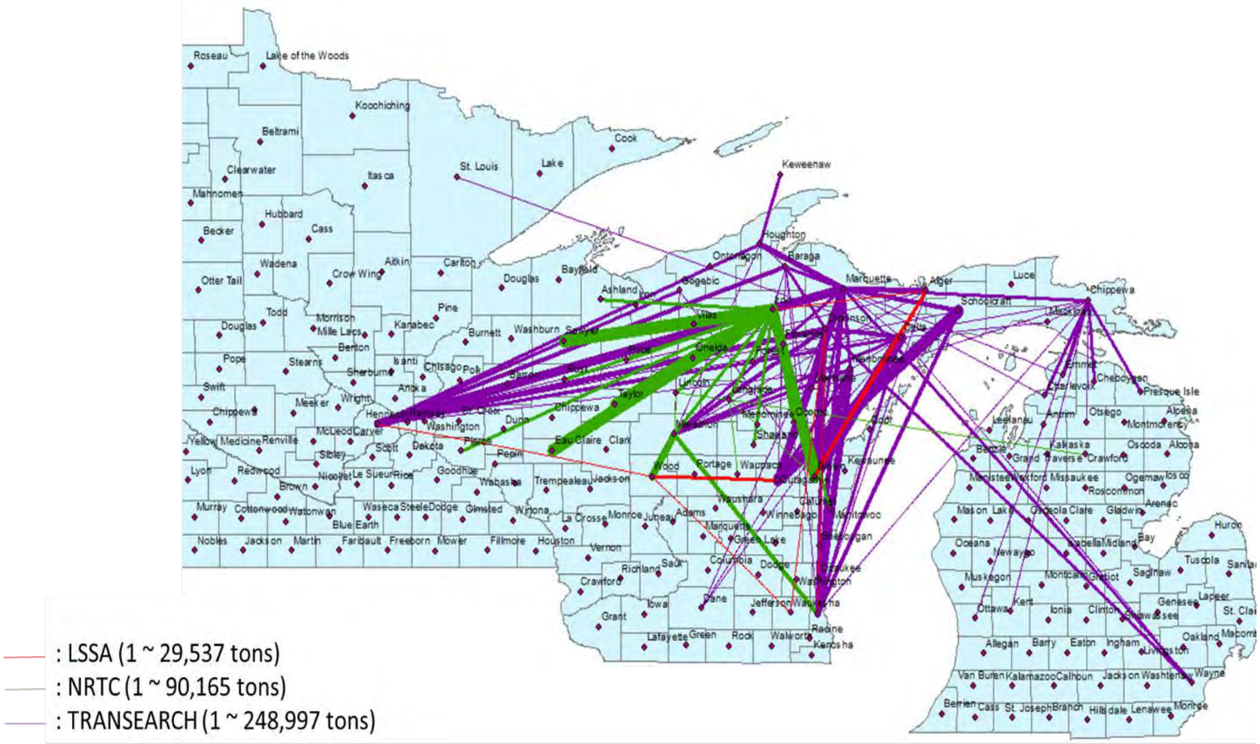


Figure 17. Map: Regional Freight flows by truck (minimum 10,000 tons)

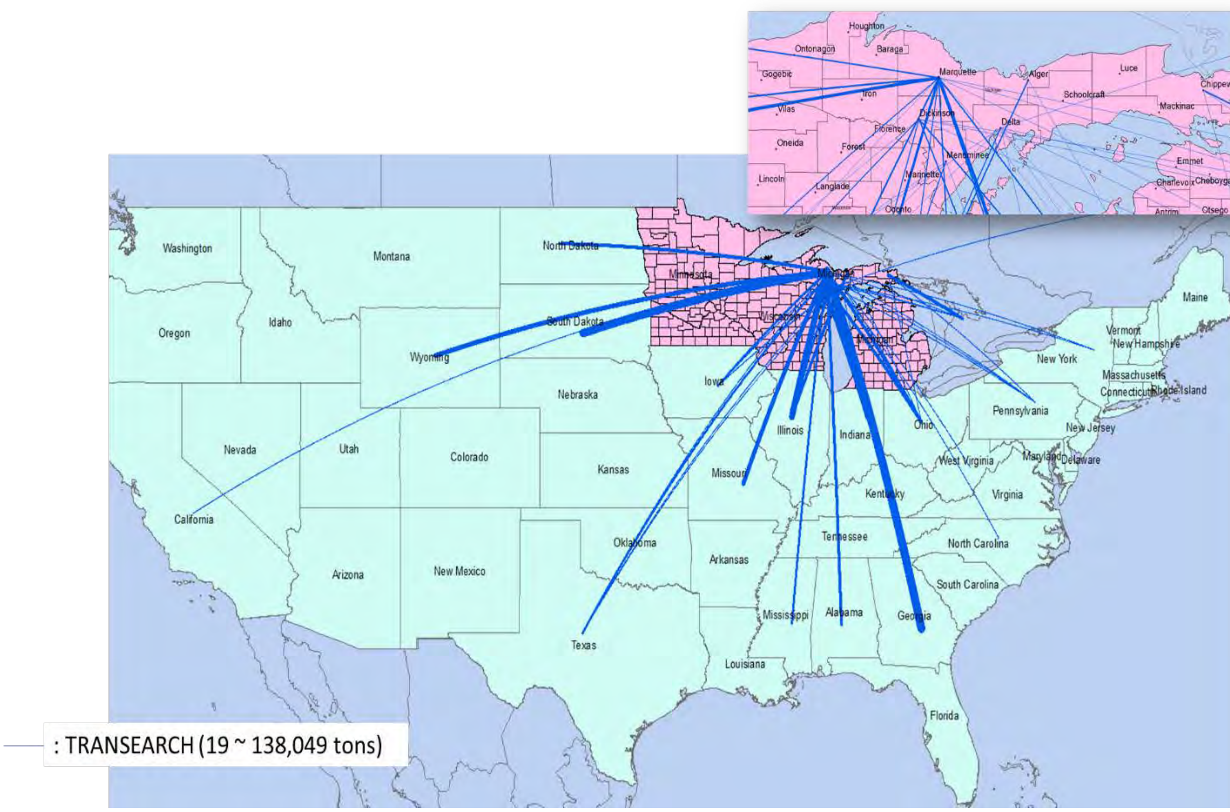


Figure 18. Map: Non-Regional Inbound freight flows by truck (Over 10,000 tons)

5.3. County Freight profiles

The Northwoods Rail Transit Commission (NRTC), in collaboration with the Wisconsin Department of Transportation released a local freight survey report in 2018, *the Wisconsin Northwoods Freight Rail Study* [17]. In this report, they provided the county freight profiles that contain information about major industries and employment activities, freight flows, and major shippers/receivers of freight for each county in their study area. As the scope of study region was limited to the counties at Northern Wisconsin area, we expanded the freight profiles to include the 15 counties in the UP of Michigan. Our county profiles include data on:

- Basic freight information: Labor force, number of employers and industries
- Major Commodities in Each County by Mode
- Tonnage of Freight Movements by Flow Direction
- Major Trading Partners by Mode – States/Provinces
- Major Trading Partners by Mode – Counties

While data can be collected from many sources, the data provided in our county freight profiles is derived from Transearch 2015 database and the center for rural community and economic development of Northern Michigan University [18]. Figure 19 shows an example part of freight information of Marquette county describing the tonnage of freight movements by flow direction. Complete freight profiles for each county are provided in Appendix G of this report.

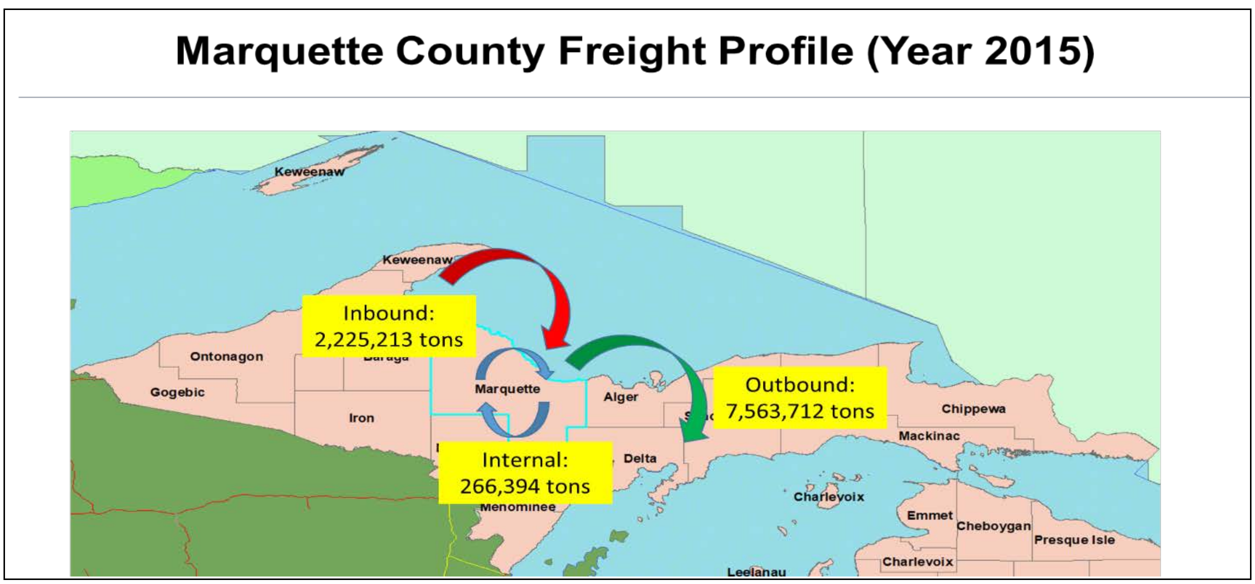


Figure 19. Example of tonnage of freight movements by flow direction (Marquette county)

5.4. Main Origin/Destination Counties

Tables 18 (truck) and 19 (rail) present the top counties for inbound/outbound tonnage, organized by data source (again, concentration is on the UP Michigan counties). From county perspective Marquette, MI and Iron, MI were the main origins for outbound freight shipments in the UP, while Dickinson, MI and Delta, MI were the main destinations for inbound shipments by truck (Table 18 (a) and (b)). Marquette, MI has high volumes for both inbound/outbound truck shipments.

Table 18. Top five origins and destinations in the project region for truck movements by data source

	Truck											
	(a) Top 5 Origins						**(b) Top 5 Destination**					
Data	**LSSA**		**Transearch**		**NRTC**		**LSSA**		**Transearch**		**NRTC**	
Rank / Tons	**1,160,707**		**5,400,471**		**1,401,747**		**1,160,707**		**5,400,471**		**1,401,747**	
1	Marquette, MI	20%	Marquette, MI	27%	Iron, MI	33%	Delta, MI	12%	Dickinson, MI	12%	Iron, MI	32%
2	Wood, WI	11%	Chippewa, MI	9%	Marathon, WI	19%	Marathon, WI	10%	Marquette, MI	11%	Marathon, WI	10%
3	Marathon, WI	11%	Delta, MI	7%	Brown, WI	8%	Outagamie, WI	9%	Marathon, WI	10%	Langlade, WI	7%
4	Oneida, WI	10%	Schoolcraft, MI	7%	Lincoln, WI	7%	Lincoln, WI	7%	Delta, MI	10%	Wood, WI	4%
5	Dickinson, MI	10%	Baraga, MI	6%	Eau Claire, WI	7%	Brown, WI	6%	Chippewa, MI	7%	Lincoln, WI	4%

For rail transportation, Marquette, MI and Dickinson, MI were main origins, while Delta, MI and Portage, WI were main destinations (Table 19 (a) and (b)). Similar to truck movements, Marquette, MI was critical location for both inbound/outbound rail movements. It should be noted that while LSSA and NRTC data accounted for only small percentage of overall shipments in Transearch, the top counties correlated fairly closely between the various data sources.

Table 19. Top five origins and destinations in the project region for rail movements by data source

	Rail											
	(a) Top 5 Origins						**(b) Top 5 Destination**					
Data	**LSSA**		**Transearch**		**NRTC**		**LSSA**		**Transearch**		**NRTC**	
Tons / Rank	**407,368**		**5,489,890**		**202,348**		**407,368**		**5,489,890**		**202,348**	
1	Dickinson, MI	55%	Marquette, MI	74%	Lincoln, WI	66%	Portage, WI	24%	Delta, MI	81%	Marathon, WI	15%
2	Delta, MI	23%	Delta, MI	13%	Marathon, WI	17%	Brown, WI	11%	Marquette, MI	8%	Milwaukee, WI	11%
3	Brown, WI	7%	St. Louis, MN	7%	Barron, WI	13%	Waukesha, WI	8%	Brown, WI	3%	Barron, WI	6%
4	Wood, WI	5%	Dickinson, MI	4%	Brown, WI	3%	Anoka, MN	5%	Dickinson, MI	2%	Wood, WI	5%
5	Midland, MI	3%	Outagamie, WI	1%	Waupaca, WI	0%	Carlton, MN	4%	Marathon, WI	2%	Lincoln, WI	5%

5.5. Preliminary Analysis for Freight Consolidation Location(s)

One of the objectives was to investigate potential locations where freight could be consolidated (transloaded) for larger-scale rail movements in the project region. To start, we broke down the freight movements between regional and non-regional flows, as non-regional flows tend to move for longer distances and as such are more suitable for rail transportation. Table 20 presents the breakdown. Based on the table, almost two thirds of the Upper Peninsula’s truck freight (inbound and outbound) are moving within neighboring states, making them less attractive for rail transportation. However, the remaining 30% accounts for over 2,000,000 tons of interstate truck traffic that go beyond neighboring states. Somewhat surprisingly, even higher percentages of inbound/outbound rail freight are regional movements, mainly iron ore movements on a few dedicated lanes.

We also calculated inbound/outbound tonnage for each Upper Peninsula county and ranked them for regional/non-regional flows (Tables 21 and 22). The top four critical counties in the Upper Peninsula were Delta, Dickinson, Marquette, and Menominee counties. As can be seen from the Tables, these counties were in top five for both inbound and outbound tonnage, only Chippewa broke the ranks for non-regional flows.

Table 20. UP Freight (in Tons) by County - Neighboring States vs. Rest of Country

	Inbound				**Outbound**			
	Truck		**Rail**		**Truck**		**Rail**	
UP County	**MI, WI, MN**	**Beyond MI, WI, MN**	**MI, WI, MN**	**Beyond MI, WI, MN**	**MI, WI, MN**	**Beyond MI, WI, MN**	**MI, WI, MN**	**Beyond MI, WI, MN**
Alger	195,083	109,342	6,440	29,960	62,556	304,141		6,760
Baraga	82,556	15,920		18,840	319,374	116,274		
Chippewa	371,033	191,370		36,280	490,631	307,386		
Delta	518,914	231,339	4,443,954	447,760	366,544	264,951	714,896	274,120
Dickinson	671,063	319,190	93,280	208,800	152,892	196,472	201,360	251,640
Gogebic	90,996	12,864			76,520	38,343		
Houghton	206,057	55,519			84,204	43,472		7,880
Iron	76,171	12,891			44,320	51,012		
Keweenaw	2,533	1,562			48,653	785		
Luce	30,358	9,451			11,746	13,858		
Mackinac	51,443	11,832	1,200	7,600	87,839	42,391		33,920
Marquette	574,515	747,477	425,536	172,480	1,451,730	201,985	4,045,404	1,624,889
Menominee	233,545	144,583		63,480	274,799	223,374	23,320	81,040
Ontonagon	13,437	11,508			8,347	2,791		
Schoolcraft	50,390	15,839			359,826	57,212	26,600	
Total tons	**3,168,094 (63%)**	**1,890,686 (37%)**	**4,970,410 (83%)**	**985,200 (17%)**	**3,839,980 (67%)**	**1,864,448 (33%)**	**5,011,580 (69%)**	**2,280,249 (31%)**

Table 21. Summary of UP freight by county (regional)

COUNTY	RAIL			TRUCK			Grand Total	Rail Rank	Truck Rank	Total Rank
	Inbound	Outbound	TOTAL	Inbound	Outbound	TOTAL				
Alger	36,400	6,760	43,160	195,083	62,556	666,540	709,700	5	6	6
Baraga	18,840	-	18,840	82,556	319,374	514,000	532,840	9	7	7
Chippewa	36,280	-	36,280	371,033	490,631	969,316	1,005,596	7	**4**	5
Delta	**4,867,874**	**965,176**	**5,833,050**	**518,914**	**366,544**	**1,286,015**	**7,119,065**	**2**	**2**	**2**
Dickinson	**302,080**	**453,000**	**755,080**	**671,063**	**152,892**	**1,267,259**	**2,022,339**	**3**	**3**	**3**
Gogebic	-	-	0	90,996	76,520	208,839	208,839	11	10	10
Houghton	-	7,880	7,880	206,057	84,204	357,440	365,320	10	9	9
Iron	-	-	0	76,171	44,320	182,011	182,011	11	12	12
Keweenaw		-	0	2,533	48,653	51,293	51,293	11	14	14
Luce	8,800	33,920	42,720	30,358	11,746	64,182	106,902	6	13	13
Mackinac	-	-	0	51,443	87,839	188,962	188,962	11	11	11
Marquette	**598,016**	**5,670,293**	**6,268,309**	**574,515**	**1,451,730**	**2,498,905**	**8,767,214**	**1**	**1**	**1**
Menominee	**63,480**	**104,360**	**167,840**	**233,545**	**274,799**	**853,618**	**1,021,458**	**4**	5	**4**
Ontonagon		-	0	13,437	8,347	36,013	36,013	11	15	15
Schoolcraft		26,600	26,600	50,390	359,826	483,217	509,817	8	8	8
TOTAL	**5,931,770**	**7,267,989**	**13,199,759**	**3,168,094**	**3,839,980**	**7,008,074**	**22,827,369**			

Table 22. Summary of UP freight by county (Non-regional)

COUNTY	RAIL			TRUCK			Grand Total	Rail Rank	Truck Rank	Total Rank
	Inbound	Outbound	TOTAL	Inbound	Outbound	TOTAL				
Alger	29,960	6,760	36,720	109,342	304,141	413,483	450,203	6	5	6
Baraga	18840	0	18,840	15,920	116,274	132,194	151,034	7	7	7
Chippewa	36280	0	36,280	191,370	307,386	498,756	535,036	5	3	4
Delta	**447,760**	**274,120**	**721,880**	**231,339**	**264,951**	**496,290**	**1,218,170**	**1**	**4**	**2**
Dickinson	**208,800**	**251,640**	**460,440**	**319,190**	**196,472**	**515,662**	**976,102**	**2**	**2**	**3**
Gogebic	0	0	0	12,864	38,343	51,207	51,207	9	12	12
Houghton	0	7,880	7,880	55,519	43,472	98,991	106,871	9	8	8
Iron	0	0	0	12,891	51,012	63,903	63,903	9	10	11
Keweenaw	0	0	0	1,562	785	2,347	2,347	9	15	15
Luce	0	0	0	9,451	13,858	23,309	23,309	9	13	13
Mackinac	7,600	33,920	41,520	11,832	42,391	54,223	95,743	8	11	9
Marquette	**172,480**	**1,624,889**	**1,797,369**	**747,477**	**201,985**	**949,462**	**2,746,831**	**3**	**1**	**1**
Menominee	**63,480**	**81,040**	**144,520**	**144,583**	**223,374**	**367,957**	**512,477**	**4**	**6**	**5**
Ontonagon	0	0	0	11,508	2,791	14,299	14,299	9	14	14
Schoolcraft	0	0	0	15,839	57,212	73,051	73,051	9	9	10
TOTAL	**985,200**	**2,280,249**	**3,265,449**	**1,890,687**	**1,864,447**	**3,755,134**	**7,020,583**			

We also identified the origin/destination states for truck movements into/from these top four UP counties. In total, they account for:

- Over 8,200,000 tons of truck freight (77% of all UP truck tonnage)
    - Over 5,900,000 regional tons (55% of all UP truck tonnage)
    - Over 2,300,000 non-regional tons (22% of all UP truck tonnage)
- 83% of total tonnage (rail + truck)

Figure 20 shows a breakdown of inbound truck tonnage based on commodity and origin states. Figure 21 provides same information for outbound from the top four UP counties. A small number of commodities account for most truck shipments. For the inbound movements, nonmetallic minerals and ores account for 38% of total (330,507 tons out of 862,093 total tons), and 88% of them are coming from the origins beyond neighboring states of Michigan, Minnesota or Wisconsin. For the outbound truck movements, lumber and wood products, as well as nonmetallic minerals and ores account for 38% of total (197,651 tons out of 523,396 total tons), and 53% of them are moving to the destinations beyond neighboring states. Overall, more than 2,000,000 tons of truck traffic (inbound and outbound combined) moves beyond neighboring states, all considered candidates for multimodal truck/rail movements.

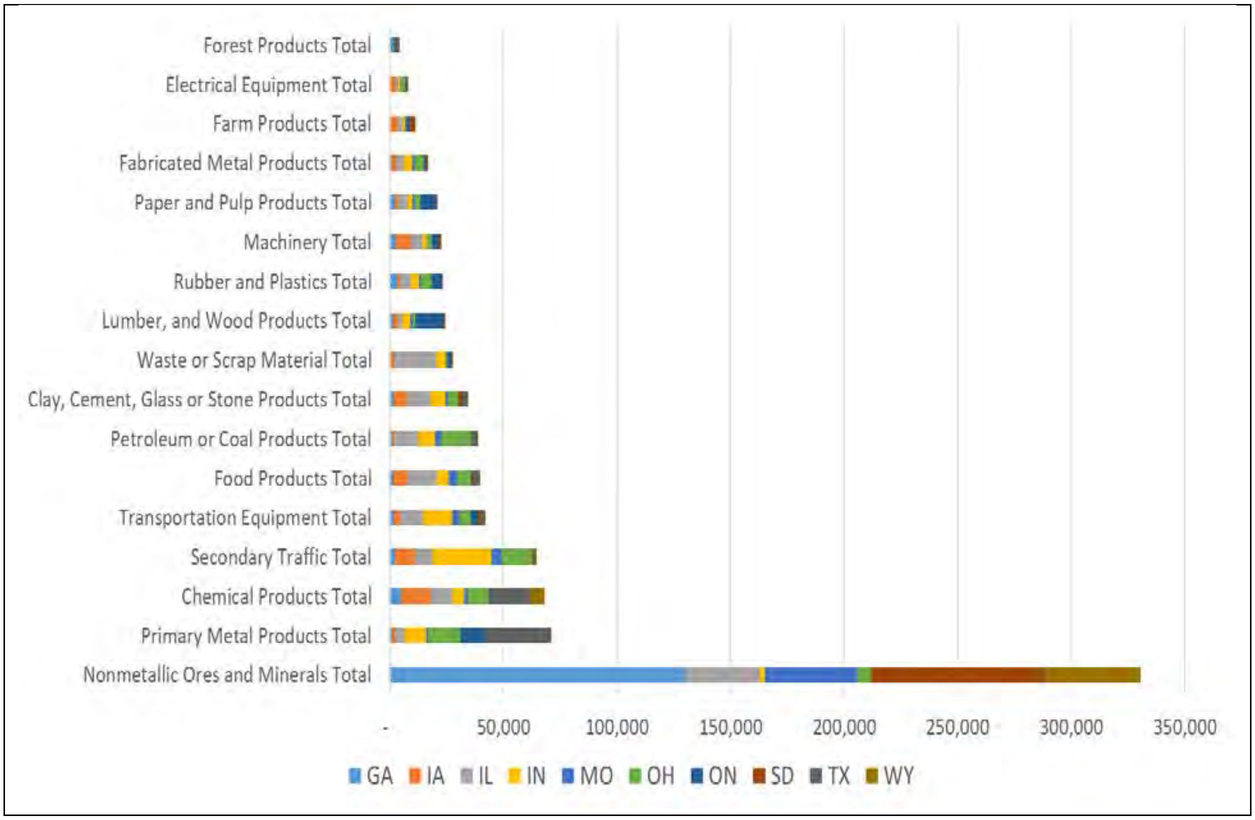


Figure 20. Origin and freight tons of non-regional inbound non-log truck movements for 4 top UP counties

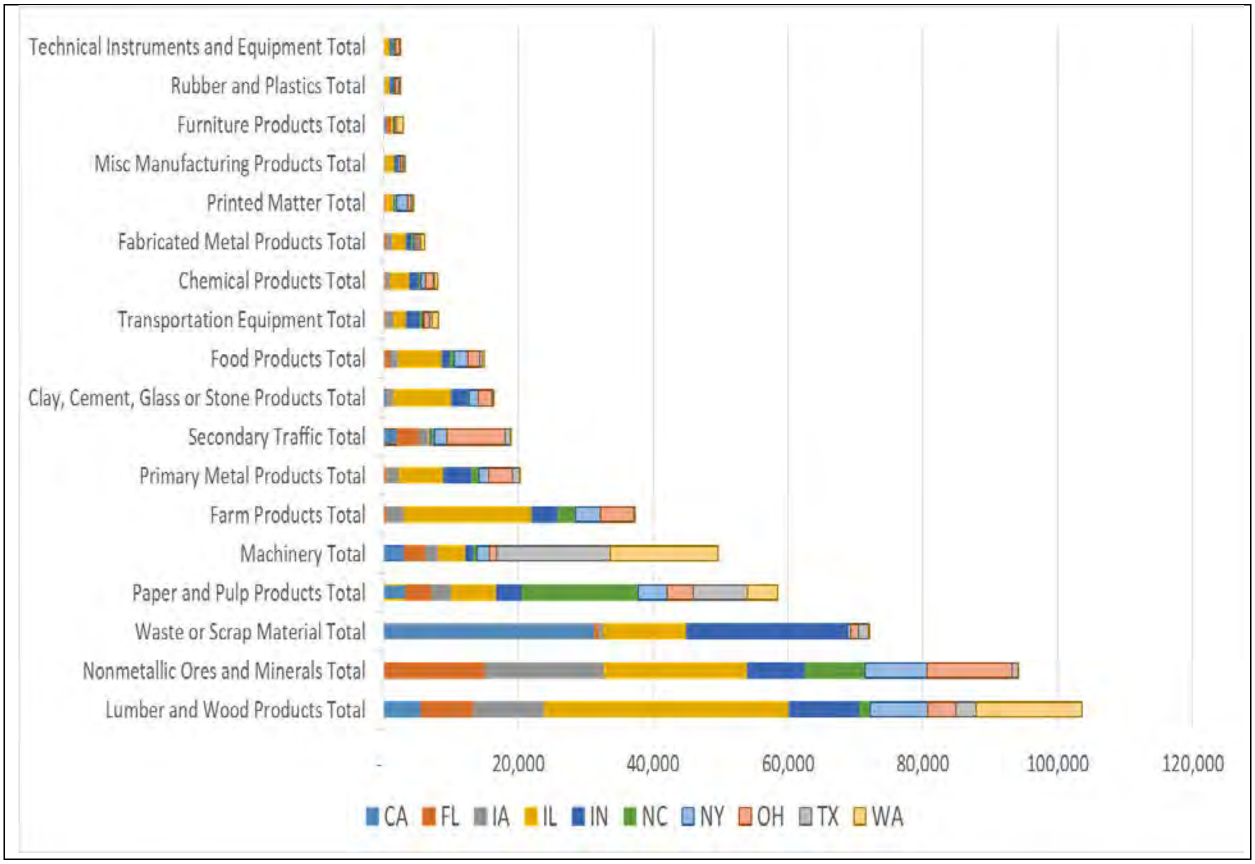


Figure 21. Destination and freight tons of non-regional outbound non-log truck for 4 top UP counties

From geographical perspective, the four top counties are not only closely located from each other (within 70 miles' radius), but they are also centrally located in the UP (Figure 22).

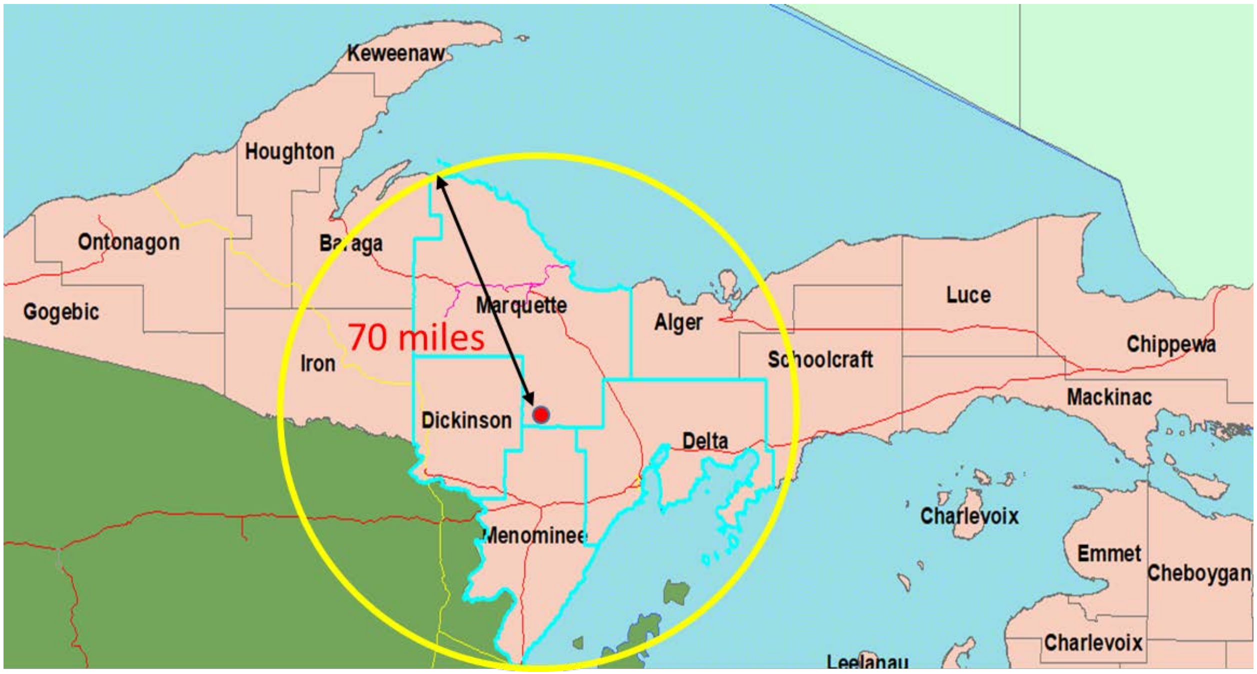


Figure 22. Four top counties of non-log shipments in UP, MI area

While the level of detail and comprehensiveness of data used for this project is not sufficient to make any recommendations on establishment or location of a transload/intermodal facility, it seems evident from the data that the four counties discussed above form perhaps the most attractive area for such development. Not only they account for the majority of the existing traffic, but they are located centrally in the region, making it possible for other counties to use the facility for their purposes. On the other hand, establishing intermodal/transload facility is a complicated endeavor. The following case study of Duluth Terminal discusses some of the challenges.

5.5. Duluth Terminal Case Study

We were graciously hosted by the CEO of the Lake Superior Warehousing, Jonathan Lamb, to discuss the experiences of Duluth Terminal located in Duluth, MN, and especially the establishment of an intermodal ramp at the facility. Figure 23 provides photos of the terminal and related facilities/equipment.

Figure 23. Complete view of Duluth Intermodal Terminal and the main facilities/equipment

The terminal includes 7.5 total acres for ramp operations, three warehouses and one equipment repair shop. The main equipment includes two 81-ton gantry cranes and one reach stacker. Other key information obtained during the visit include:

1) Overview

- Terminal has been in operation since 1991. It is a joint operation by Seaway Port Authority & Lake Superior Warehousing.
- Three businesses are included: maritime terminal, warehousing and CN intermodal terminal.

2) CN Intermodal Terminal

- This intermodal terminal has enabled expansion to new customers with no past experience with intermodal. Terminal is mainly used for international movements (including some to/from Canada).
- Before the establishment of intermodal ramp, terminal already had strong carload (transload) business with CN (6,000 annually), tightly connected with warehousing and foreign trade zone. Thus, creation of intermodal ramp required only limited capital investment and business practices were already established.
- This terminal is in unique location along CN intermodal mainline capable for providing access to three coasts and six ports.
- Main “attraction” has been use of overloaded containers through transloading. Shippers can ship containers with higher total weight by train (for the same price) and reduce the load through transloading for drayage by truck. In general, shippers are shipping three containers (on trucks) for the price of two (on train).
- Steamship lines are satisfied, as transloading in terminal reduces circulation time for international containers. Containers don’t need to leave the terminal for final drayage, but can be shipped back immediately (preferably after reloading).
- Intermodal containers move on daily blocks in existing trains (no special container trains). The terminal started as small operation, but ultimate goal is 45,000 TEUs annually.
- 50% of freight at the terminal is forest products with up to 200 miles’ drayage or even beyond.

- Unlike most small yards, there is no single anchor customer. This is mainly credited on the warehousing function.

3) Challenges for "new" regional terminal

- Steamship lines are reluctant to send containers to new terminals, especially if they are new and not along mainlines. Even existing terminals struggle to receive sufficient numbers of containers.
- Unless the infrastructure is already built, high capital investment is required. This would be difficult to justify without public funding source.
- There must be need for international movements due to very low levels of domestic volumes.

A more detailed technical memorandum of the Duluth case study is included in Appendix H.

6. DISCUSSION OF RESULTS

The following sections provide a brief discussion of the various analysis and related results conducted as part of the project. The conclusions are developed solely by the research team's independent interpretation and evaluation of data and results. We have tried to concentrate the discussion on topics that are backed by the data used for the analysis and exclude topics that may be of importance, but cannot be analyzed with our data (such as service quality). The findings have been reviewed by the industry stakeholders (LSSA and railway operators) and project sponsors, but the conclusions are solely based on interpretations by the research team.

As stated earlier, we believe this to be the first large-scale and detailed modeling analysis of log movements in the region at the level of actionable shipper data. While earlier research has been conducted, neither the freight (log) data, nor the rail operational data have been as comprehensive and detailed, as the nearly ten million tons of movements obtained for the project. We believe that having such data set is essential for the analysis. Based on the validation conducted in Scenario 1, we also have a high confidence level on the accuracy of our spatial model and (mainly rate) formulas developed for the project. Analysis for Scenarios 2~4 are "hypothetical", so freedoms have been taken by the researchers, such as the expectation that a single siding can be shared by multiple companies. Those scenarios concentrated on using the data to identify potential inefficiencies and other opportunities that would facilitate increased use of rail transportation for log movements in the project region. While we did not find specific inefficiencies, we believe that our results provide accurate and data-based foundation for the stakeholders to build on when addressing other pertinent issues. In addition, the database and models constructed as part of the project offer opportunities for either continuing analysis or for the stakeholders to use them for other aspects not directly evaluated in the project, such as perceived shortcomings in rail service, access, or cost (beyond shipping rates), identification of both high potential and high-risk segments, and tradeoffs between volumes and rail rates. They could also be used to entice new rail service providers when evaluating perceived opportunities in the region.

Based on the results, it seems evident that *additional flexibility through shared rail sidings* have limited potential to increase rail modal share for log movements. The same is true for re-opening unused/closed sidings and for establishing a single log super-yard where high volumes of logs could be concentrated. The main reason for lack of benefits from additional flexibility was the efficiency of forest industry in minimizing transportation distance (almost 75% of log movements were less than 100 miles in 2017). For a single log super-yard, the origins seemed to be too widely dispersed throughout the region.

The only scenarios that created significant increase in rail share were through rail rate discounts. However, whether 15-20% increase in annual log shipments by itself is sufficient for current rail transportation providers to consider such reductions is questionable, unless operational efficiencies can be obtained as well. Tying the rate discounts to guaranteed volumes from specific sidings might be more attractive, as it would create consistently and continuously larger blocks of cars, but the actual implementation would be more challenging, especially if multiple mills/companies are needed to meet the volume threshold. A case study we conducted in Finland (Appendix I) revealed success in this type of shift to a fewer, but larger log sidings/yards (in some cases with multiple companies) with annually fixed volumes/operating schedule and very tight loading/unloading windows. We are unaware of similar examples in the US, but our data could be used for such evaluations.

Another extensively discussed strategy toward rate reductions is the potential shift of some lines to shortline operations in the region. While there is recognition that shortlines possess certain cost advantage over Class 1 railroads (in some cases 25% or more) and may provide improved customer service [24], the incorporation of shortline in the transportation\ chain would also introduce an interchange between railroads, potentially reducing or eliminating the cost and time benefits. On the other hand, shortline railroads have demonstrated success in being profitable on lines with low carload densities and in securing development and rehabilitation capital through state and local community development programs. These are both noteworthy aspects to our region, especially on the low-density branch lines.

While added flexibility didn't seem to have much of an effect on the modal share, the *sensitivity analysis on fuel price* showed that increasing fuel price could contribute to increased modal share by rail. Especially in cases where shared rail sidings improved the accessibility to rail by shortening the distance to nearest siding, the impact grew to double digits. However, it should be remembered that there were some uncertainties in the truck data used for the analysis.

Log car availability and challenges with the seasonality of movements have received growing attention in the region, as increasing portion of the current log car fleet is close to reaching its service life. Considering the high replacement cost of rail cars, it is essential that each car is constantly in full utilization and all inefficiencies are removed from the system. One alternative to improve the car utilization would be a centrally managed and dedicated car pool for the region. Such pool would eliminate company boundaries and if combined with data analytics, could maximize the efficiency of car circulation. There are examples of such pools, such as the Washington State Grain Train Program that has been active since 1994 [23]. The total fleet of 116 cars offers a fair and equitable allocation of WSDOT owned cars to Washington grain shippers by providing cost-effective grain hopper cars to move Washington grain to market. In addition to the economic justification by supporting local businesses, Washington justifies their investment in the program through various metrics, such as reduction of trucks, vehicle miles traveled and greenhouse gas emissions, all desirable impacts of increased rail usage. Another example of carpooling is CN grain fleet where both private and railroad-owned rail cars are pooled together to a CN managed fleet for grain movements. The current status of that operation is unclear.

Equally important is to develop a replacement strategy for the log car fleet, whether it is through extending the life of current cars, or acquisition of new ones. The potential for public funding for such activities is ideal, as there is unprecedented attention being paid to rural development by federal transportation funding programs. Our data analysis and data provides foundation for any funding proposals to replace the fleet, but there is still insufficient understanding on the condition of current fleet and impacts of alternative ownerships on rail rates. Based on our understanding of the current fleet, there seems to be potential for extending the life of the fleet, but there are differences in the efficiency of different car types. Any fleet life extension should concentrate only on those car types that offer greatest efficiencies and hence lowest unit cost for log movements. In addition, potential public (or private) investments in log car fleet are only warranted, if the removal of car replacement cost from rail service provider costs enables truck-competitive rail rates. These issues should be immediately clarified with the rail service providers to avoid any lost opportunity under current programs.

Our *rail car peaking analysis* supports fleet replacement strategy, as it attempted to define the necessary size of such pool for moving logs in the project region. Our analysis revealed that moving the current log volumes in the region would require approximately 400-600 dedicated log cars in ideal conditions, depending on the expectations. This would require that each car of the fleet immediately moves to the nearest location needing a car after unloading (independent of the company in need of service). This would remove inefficiencies by reducing excess empty miles by cars and by providing the fastest circulation possible. The lower end of the fleet size (400 cars) would nearly eliminate the idling of rail cars which is a desired situation from the rail operator (and car owner) perspective, as the cars only provide revenue when moving with logs. On the other hand, it would require temporary storage (and additional handling) of logs at the siding, both elements that increase the costs for shippers. If the high end of fleet size was available (600 cars), logs could always move forward in timely fashion, but some cars would be idled during slower months. Attention should also be paid to loading/unloading processes, as the reduction of a single day in loading/unloading process (2.5 to 1.5 days), would allow elimination of almost 100 cars (20 %) of the fleet without reduction in throughput, a significant improvement in car utilization. While our fleet analysis were hypothetical, they were based on true data and provide a solid foundation for more detailed analysis, whether they relate to fleet replacement, improved efficiencies of car circulation, or alternative rail car ownership options.

Trucker value analysis was the first attempt to quantify the potential benefits/disadvantages of log truckers caused by increased role of rail transportation. While our data for conducting the analysis had shortcomings, the outcomes were mainly positive. In three out of four of our case studies, routing all log movements from certain region through rail yard/siding provided benefits to truckers, both in terms of time efficiency (amount of daily service time used efficiently) and of value efficiency (loaded ton-miles per day). In addition, we found that while the loaded ton-miles (revenue) per day increased, the total miles per day decreased, a factor that would reduce both trucks' fuel consumption and equipment wear (costs). The potential of rail transportation to improve the bottom line of truckers is an important finding, as recruiting and keeping trucks and drivers is a well-known challenge for the forest industry. Any opportunity to improve truckers' potential to sustain a sufficient income is of utmost importance, as trucks are essential for initial transportation from forest landings, whether their destination is rail siding or a mill. Without a healthy fleet of trucks and drivers, any other actions taken to improve forest products transportation become irrelevant. Our analysis showed that use of rail has potential to improve the economic health of truckers and the sensitivity analysis suggested that any improvements for average truck speeds or maximum hours or service would create greater benefits under multimodal system.

The concentration of the modeling effort and analysis of this project were on the regional log movements. We did also conduct analysis on other freight movements (called *non-log movements*), but the level of detail was hindered by their national scale and the lack of quality and comprehensiveness of the data from large shipper/receivers in the project region (within or outside the forest industry). Since the most comprehensive dataset only included the Upper Peninsula (UP) of Michigan, the analysis concentrated heavily on the UP counties. We found that the project region generates significant volumes of freight (almost 18 million tons annually). While rail transportation of specific iron ore movements within the region already accounts for majority of the tonnage, there are almost two million annual tons of both inbound and outbound truck movements that move beyond the states of Wisconsin, Michigan and Minnesota. Shift of this traffic to truck/rail would mean over 20,000 annual car loads to the region (both inbound and outbound). We identified four central counties that fit within approximately 70-mile radius (Delta, Marquette, Dickinson, and Menominee) and account for more than 70% of the total truck traffic in the UP. The high concentration of freight in these counties, their proximity of each other, and their central location in relation to remaining UP counties lead us to believe that one of these counties would be a prime location for potential multi-user transload/intermodal terminal. We also found, that there is a recent initiative in Escanaba region that investigates the establishment of such facility. However, the case study conducted on Duluth Intermodal Terminal indicates that despite the volumes, establishing transload/intermodal facility in the region would involve many challenges, in part due to container/volume/location issues.

7. PROJECT LIMITATIONS

While the project received unprecedented support from the members of LSSA and the operating railways, there were certainly shortcomings and limitations that should be recognized when interpreting the analysis results. The following highlights the ones considered most critical to the outcomes:

- The project concentrated on identification of opportunities from data-based analysis only. In reality, there are many other important aspects for successful rail system, such as shipper/rail service provider relationships and reliability of service, but they are more challenging to quantify and were largely excluded from the project. Even then, we believe that our data analysis can form foundation for discussions on other important, but non-quantitative topics.
- All analysis relied on a single year (2017) of log movement data. According to industry representatives, 2017 was an excellent year for mills when it comes to wood inventory. This allowed for optimized procurement and transportation logistics, potentially reducing the average transportation distance of logs. Relying on a single year of data also reduces the reliability of locational analysis, such as identification of sidings with highest volumes, as there may be significant annual variations in harvesting locations.
- Capacity limitations at individual rail sidings (or mills) were not considered in analysis. In reality, adding significant log volumes at a siding, or to the mill, might create capacity challenges, if available track is limited.
- Car peaking and fleet size analysis consider ideal conditions with no consideration for foul weather, or equipment related delays. In reality, both are likely to create some uncertainty in the results and should be accounted for when determining the actual fleet size. In addition, our analysis considered all cars to belong to a single equipment pool shared by all the companies and mills. This would require across the board agreement between all stakeholders and establishment of a new management structure for the fleet. In reality, some cars today are privately owned and their routes are limited to the controlling company, limiting the potential for region-wide optimization of fleet circulation. .
- There were several limitations in the data and process used for trucker value analysis. The breakdown how log trucks spend their hours of service relied on operational data of a small sample of trucks (five in total). The analysis also excluded the time it takes the trucks to

arrive to first loading locations from their residences. Finally, when analyzing the maximum number of trips per day for each truck, the model only allowed drivers to pick up the second (or third) load from the same location as the first one for the day. It also didn't allow drivers to complete "partial trips", where truck gets loaded before night and is taken to final destination in the morning.

8. RECOMMENDATIONS

The analysis and results of this project are based on actual data and models validated by comparing their results with actual data. The results provide foundation for forest products industry and transportation providers, as they ponder future business development and transportation logistics. However, that's all it is – a foundation. Turning the results into tangible actions requires additional work that is likely to require co-operation by various stakeholders. In the following, we provide suggestions and recommendations for future development related to *log movements* in the project region:

- *Expand log analysis to include two more years of data*; As noted earlier, all analysis in our project were based on a single year of data (2017). For an industry to make strategic decisions, it would be essential that at least two more years of data were added to the analysis to account for fluctuations in freight (locations and volume). Since the perception was that 2017 was a fairly good year for wood supply, we would recommend that at least one of the added years would come from a year when wood supply was scarce. This would reveal the level of impact wood supply has on transportation distances and modal shares, as well as reveal locational deviations between different years.
- *Investigate the impact from re-opening rail segments*; Our project concentrated on finding cost savings by identifying potential shortcomings of the current log transportation modal selection, or by pooling the resources across companies. In addition, we investigated the impacts of re-opening sidings for use. All such scenarios provided limited benefits. However, we did not look into the impact of re-opening closed rail segments in the region (such as Highway 8 Rail Corridor) to provide a more direct routing for logs, as we would have had to develop "hypothetical" train routings. Such analysis could be done, but defining potential benefits would require close collaboration with the rail operator to understand the operational arrangements for the re-opened segments.

- *Establish benchmarks for rail rates and service*; We investigated the impact of rail rate reductions on modal share and found that they have to be fairly steep for a meaningful increase in rail tonnage (20-30%). It would be beneficial to have some benchmarking values from other forest regions in the US to understand, how our rate structure compares with them and whether the size of a rail carrier seems to make a difference in rates. Alternate strategy would be to look into potential for rail rate reductions through shortline involvement. As mentioned earlier, they tend to hold cost advantage over Class 1 railroads, but whether such advantage would be eliminated by interchange requirements is unclear. Our project developed the volumes and other detailed data necessary for benchmarking, as well as for shortlines to evaluate their level of interest to the business opportunities in the region.
- *Evaluate merits of alternative rail log car extension/replacement strategies and establish justification for public investment*; Since availability of rail cars for logs in the region is such a critical issue, more attention should be paid to the current state of the fleet. It was challenging to get a detailed inventory of the fleet and even more the condition of it, but it is clear that replacement needs are immediate. State of Washington provides a great example of publicly owned rail car pool that has been successfully operated for two decades. Various business and public benefits have been utilized to justify the public investment on such pool. Our project provided some early benchmarking values for the openly accessible fleet size and the impact of loading and unloading efficiencies, but did not specify a strategy for replacement efforts. Industry/rail providers and the public sector needs to investigate the alternative strategies for replacing the rail car fleet in the region, including 1) opportunities on extending the life of current fleet with concentration on most efficient log cars, 2) potential for local manufacture of new log cars, 3) alternative ownership and operational strategies, and 4) potential justification for the use of public funding. Regardless the preferred strategy, the success of any fleet would ultimately be dependent on whether the impact of ownership and operational changes on rail rates would be sufficient make rail economical for log movements. In another words, would 1) reduction of rail car idling, 2) tightly capped loading/unloading times (and/or trade-offs involving value/impacts on log truckers), 3) static volumes throughout the year, 4) elimination of rail car replacement cost, 5) increased efficiency of cars, enable truck-

competitive rail rates, acceptable for both railroads and shippers. Without long-term commitments from both parties to move logs by rail, fleet investments would be unjustified.

- *Initiate direct shipper/rail service provider discussions for line-specific strategies toward volume increases/rate reductions.* Higher and consistent volumes, elimination of rail car ownership and improved rail equipment utilization all impact rail rates. Potential adjustments in these parameters have potential to lead into competitive rail rates, at least on selected lanes. These analysis should be initiated by main shipper(s) and rail providers and concentrate on specific line segments. We would recommend that the first two lines would be light-density lines to L'Anse and Munising that currently have insufficient freight for continuing operations. Due to their underutilization, they are also prime candidates for potential public investment, if a strong case can be built for increased shipments.
- *Expand case studies to evaluate log trucker benefits from rail movements;* Trucker value benefits from increased use of a specific rail siding may provide additional justification for lane-specific strategies discussed in previous recommendation. Our case studies suggested benefits for truckers when rail sidings replaced mills as the final destination. This type of operation (log trucks running nearby logs to large rail concentration yard) is already taking place in the region (Odena yard by Longyear) and in Finland (Appendix I). While there is additional cost related to the extra handling created by rail movement, it should be analyzed, if that cost can be recovered by a combination of reduced unit rates by truckers due to higher ratio of loaded miles versus total miles, and rail rates due to increased and consistent volumes from specific locations. While the non-log freight movements received less attention in this project, they are by no means less important. The following discussion provides recommendations for future consideration, concentrating on *non-log movements*:
- *Combine Wisconsin and Michigan Transearch data for regional analysis*; This research attempted to utilize three incomplete sets of data for analyzing freight movements in the region. The most comprehensive database was Transearch, but it only covered the Upper Peninsula (UP) of Michigan. Based on our past experience, we believe that the accuracy of Transearch database on such rural areas may not be as robust as in some urban/metropolitan areas. We believe that Wisconsin DOT also has access to Transearch data. While it won't remove the potential inaccuracies, a more complete picture of the

project region's freight could be completed, if both data sets could be used together for the analysis, along with additional shipper-provided actionable shipper data from more extensive group of large shippers. It would also provide guidance how to narrow the region down to more detailed data collection and analysis, as described below.

- *Investigate four-county region for transload facility in the Upper Peninsula (UP) of Michigan*; We believe that UP has sufficient volume of freight to investigate potential transload, but it would likely require collaboration by multiple shippers. The Duluth Terminal case study (Appendix H) highlighted the difficulties in establishing new terminal, especially for intermodal movements. It also suggested that partnership between private and public entity might be a proper pathway for development, as it enables the use of public resources in the development process. We recommend a detailed market analysis for the centrally located four-county region identified in the study (Delta, Marquette, Menominee and Dickinson). Transearch data can function as foundation for the analysis, but a much more detailed understanding would be needed, before considering such endeavor. As a potential alternative for a new terminal, attention should also be paid for any possibilities for increased use of Duluth Terminal to benefit the UP region.

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Appendix A

A Standard Data Collection Format – Log Movement Data

Table A-1. A Standard Data Collection Format – Log Movement Data

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< The List of Data Col

Purchase _Company	Purchase _Address	Purchase _City	Purchase _State	Purchase _Zip_Code	Sold _Company	Sold _Address	Sold _City	Sold _State	Sold _Zip_Code	Ship _Name	Ship _Facility_State	Ship _Zip_Code	Ship _County	Ship _State	Ship _Coordinates Latitude	Ship _Coordinates Longitude	Mileage (One-way)
ex) Michigan Tech	1400 Townsend D	Houghton	MI	49931	Nothern Michiga	1401 Presque I	Marquette	MI	49855	"Macho Man	MI	49931	Houghton	MI	46.547583	-87.395595	99

Table A-1. A Standard Data Collection Format – Log Movement Data (continued)

ENTIAL

on for Log Movement >

Scale_Date_In	Scale_Ticket	LoadID	Shipping_Mode	Rail_Car_Type (Leased or Nonleased)	Gross_Weight	Tare_Weight	Net_Weight	Weight_UOM	Activity_Type (HAUL/HAULING or HAUL/INCENTIVE)	Purchase_Type	Species_Purchased	Product_Purchased	Total_Dollars
2017-10-02 00:00:01	007047	36837	TRUCK	N/A	174160	62040	112120	LB	HAUL/HAULING	FEE	MH	PLPWD	

Appendix B

Data Cleaning Process

The origin locations of log shipments were provided in two formats: the geographic coordinate system of longitudes and latitudes and the Public Land Survey System (PLSS). Since using geographic coordinates in a Geographical Information System (GIS) program is simpler than importing PLSS, all the PLSS system data was modified to the latitude and longitude system. Most states publish their own PLSS data. In this project, the shape files on the PLSS from Michigan, Wisconsin, and Minnesota were utilized. Each PLSS data includes the township, section and quarter section. The process for generating the lookup table has done using the centroid of the section. Figure B-1, as an example, shows the centroid of each section in the PLSS of Upper Peninsula (UP) of Michigan. A search was done in ESRI ArcMap to select the section information, which was then exported to a spreadsheet file.

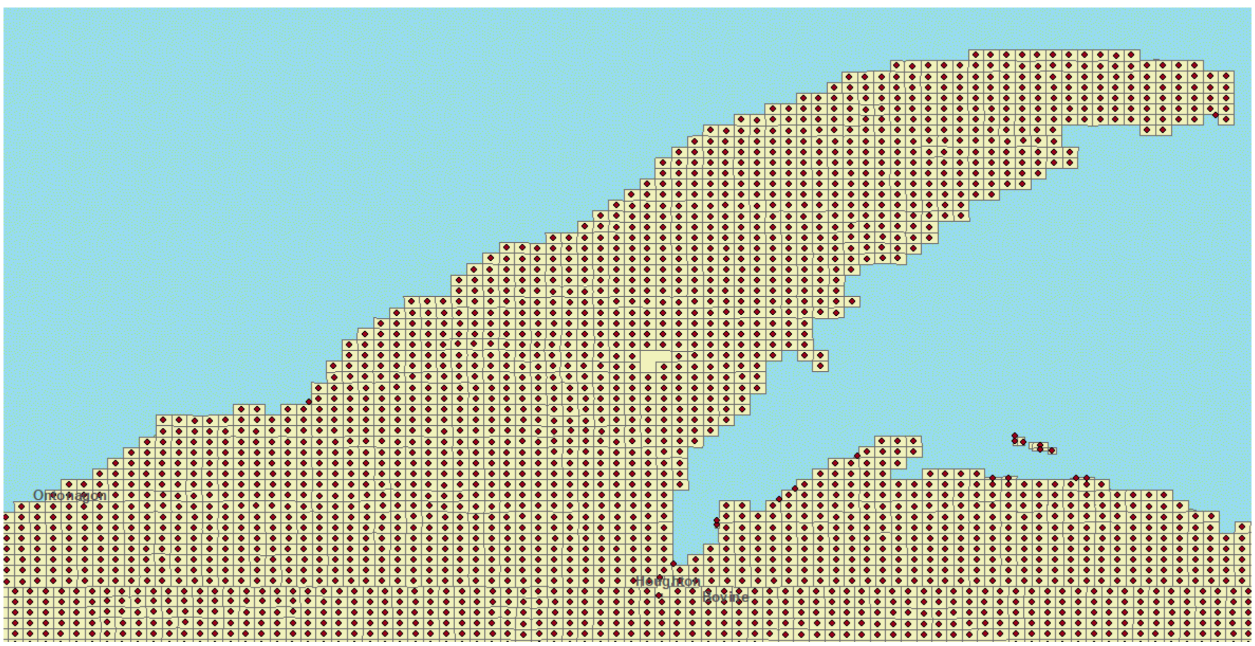


Figure B-1. Centroid of each section in the PLSS of Houghton at UP, MI

Another data cleaning process is related to detailed information of truck origin locations. Level of detail information on the site locations is critical to achieve meaningful analytical results. In this project, approximately 80% of the shipments were defined using exact location of truck origins while remaining 20% came with locations defined by centroid of county and city. A single (a centroid of county) is not representable of all forest landings within the county. The main goal of this preprocessing was to systematically distribute the loads from the centroid to alternative locations, based on the inventory of forest within the corresponding county.

The biomass inventory data from the US Department of Agriculture (USDA) Forest [19] was utilized as a basic reference data. The four-step process used for creating alternative location is outlined in Figure B-2. To determine the final origin replacing the country centroid, a data-driven origin selection rule (in tons) was developed with following decision algorithm:

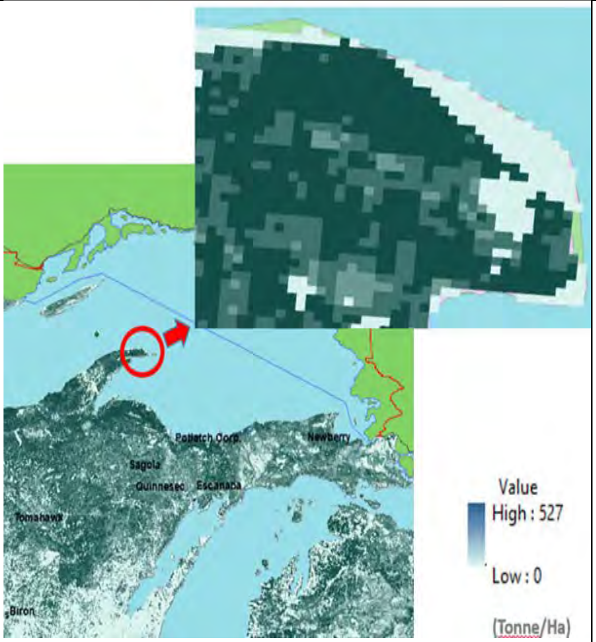
1) If **0 < volume of logs in centroid < 1,000**
    - ➢ Number of New Origins in a county = 1 (the highest biomass inventory location)

2) If **1,000 < volume of logs in centroid < 10,000**
    - ➢ Number of New Origins in a county = 3 (three highest biomass inventory locations)

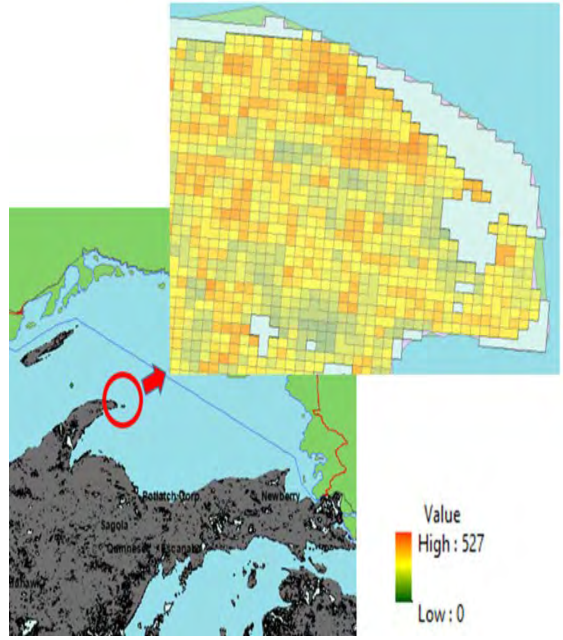
- If **10,000 < volume of logs in centroid < 50,000**
    - ➢ Number of New Origins in a county = 5 (five highest biomass inventory locations)

4) If **50,000 < volume of logs in centroid**
    - ➢ Number of New Origins in a county = 10 (ten highest biomass inventory locations)

"Volume of logs in centroid" indicates the annual log tonnage that ships from the county. For example, if there is a centroid in a county where the annual log tonnage is 20,000 tons based on our database, the log tonnage for the county was evenly distributed to top five highest biomass inventory locations in the county. As a result of this preprocessing, the total number of truck origins were increased by 674.

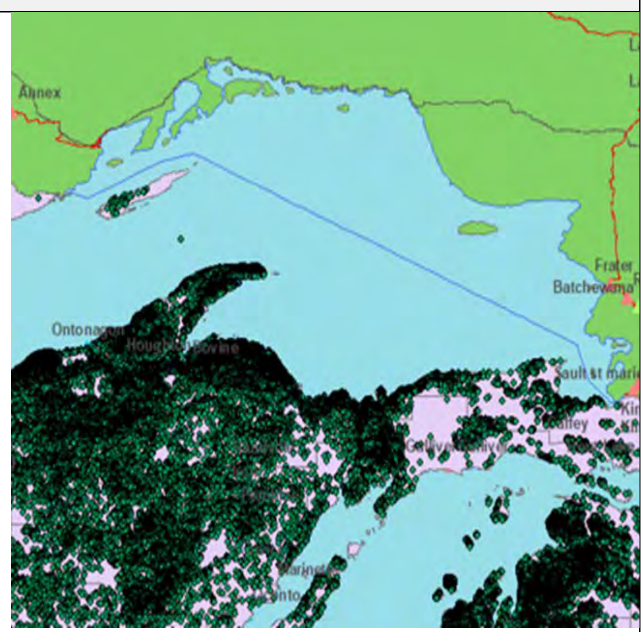


Step 1. Download a raster data (30m resolution) of forest biomass inventory from USDA Forest Service



Step 2. Change a data format from raster to shapefile (Polygon) data

Step 3. Select polygons where there is over 100 tons/ha of forest biomass



Step 4. Change polygons into points and find top-ranked alternative origins based on high biomass inventory (tons/ha) area in each county.

Figure B-2. 4-step process used for creating alternative location in UP, MI

Appendix C

Shared Siding/Volume Discount Analysis:

Explanation of the optimization model used for each scenario

Set, Decision Variables, and Input Parameters for Optimization models

For shared siding/volume discount analysis, four optimization programming models were developed to estimate optimal mode share of log movements under each scenario. In this Appendix, the explanation of basic notations and the main concept of each model will be addressed. First of all, following Table C-1 provides the sets, decision variables, and input parameters that were used in the mathematical models.

Table C-1. Notations for Set, Decision Variables, and Input Parameters

Sets
▪ I = Set of logging sites, $i \in I$ ▪ J = Set of mills, $j \in J$ ▪ H = Set of forest companies, $h \in H$ ▪ K = Set of consolidation sites (rail sidings) on the shipper perceived rail network, $k \in K$ ▪ K' = Set of new consolidation sites (new rail sidings) on the shipper perceived rail network, $k' \in K'$ ▪ L = Set of rail link between rail siding k and mill j on the shipper perceived rail network, $l \in L$ ▪ L' = Set of rail link between new rail siding k' and mill j on the shipper perceived rail network, $l' \in L'$ ▪ B = Set of rail node (station) on the carrier perceived rail network, $b \in B$ ▪ B' = Set of new rail node (station that currently closed) on the carrier perceived rail network, $b' \in B'$ ▪ A = Set of rail link between rail nodes on the carrier perceived rail network, $a \in A$ ▪ V = Rail OD pair on the carrier perceived rail network, $v \in V$ ▪ V'= Rail OD pair on the carrier perceived rail network for new rail siding k', $v' \in V'$
Decision Variables
▪ X_{ijh} = Flow of logs shipped by truck from logging site i to mill j of forest company h ▪ Y_{kjh} = Flow of logs shipped by rail from rail siding k to mill j of forest company h ▪ $Y_{k'jh}$ = Flow of logs shipped by rail from new rail siding k' to mill j of forest company h ▪ Z_{ikjh} = Flow of logs (collected at site i) shipped by truck from logging site i to rail siding k that supposed to move to mill j of forest company h ▪ $Z_{ik'jh}$ = Flow of logs (collected at site i) shipped by truck from logging site i to new rail siding k' that supposed to move to mill j of forest company h ▪ $W_{kk'jh}$ = Flow of logs shipped by truck from siding k to new siding k' that supposed to move to mill j of forest company h ▪ μ_{kjh} = Dummy variable for log flow shipped by rail from siding k to mill j of forest company h ▪ $\mu_{k'jh}$ = Dummy variable for log flow shipped by rail from new siding k to mill j of forest company h ▪ t_{kjh} = Dummy variable for log flow shipped by rail from siding k to mill j of forest company h ▪ $t_{k'jh}$ = Dummy variable for log flow shipped by rail from new siding k to mill j of forest company h
Input Parameters
- Cost Parameters (C)
▪ C^{T_1} = Unit cost of truck shipment from logging site to mill ($/ton) ▪ C^{T_2} = Unit cost of truck shipment from logging site to rail siding ($/ton) ▪ C^{T_3} = Unit cost of truck shipment from rail siding k to new rail siding k' ($/ton) ▪ C_l^R = Unit cost of rail shipment for rail link l ($/ton) ▪ $C'^R_{l'}$ = Unit cost of rail shipment for new rail link l' for new rail siding k' ($/ton) ▪ C_k^L = Unit cost of trans-loading in a rail siding k ($/ton)

- $C_{k'}^{L}$ = Unit cost of trans-loading in a new rail siding k' ($/ton)
- α, β = Fixed cost ($/ton) and variable cost ($/ton-mile) of truck shipment, respectively
- C_{v}^{R} = Unit cost of rail shipment between rail OD pair v ($/ton)
- ${C'}_{v'}^{R}$ = Unit cost of rail shipment between new rail OD pair v' for new rail siding k' ($/ton)
- γ_v: Constants of rail rate model
- $\delta_v, \varepsilon_v, \zeta_v, \eta_v, \lambda_v$: Coefficients of rail rate model
- F_1, F_2, F_3, F_4: Factors of rail rate model
- π = Threshold of rail volume aggregation to get rail rate discount (tons)
- σ = Ratio of rail rate discount when threshold of rail volume is satisfied (%)

- Distance Parameters (d)

- $d_{ij},\ d_{ik},\ d_{kk'}$: Road distance between i - j, i – k, and k-k', respectively (miles)
- d_v: Rail distance of rail OD pair v (miles)
- $d_{v'}$: Rail distance of new rail OD pair v' (miles)

- Supply and Demand Quantity Parameters (D, S)

- D_j: Log demand of a mill j (tons)
- S_{ijh}^{I}: Log supply from the logging site I that supposed to move to mill j of forest company h (tons)
- S_{kjh}^{k}: Log supply from the rail siding k that supposed to move to mill j of forest company h (tons)

- Incidence Matrix

- $[\varphi_{[i][j]}]$: Incidence matrix between logging site i and mill j,

$$\varphi_{[i][j]} = \begin{cases} 1 & if\ logging\ site\ i\ is\ used\ by\ mill\ j \\ 0 & otherwise \end{cases}$$

- $[\omega_{[k][j]}]$: Incidence matrix between rail siding k and mill j,

$$\omega_{[k][j]} = \begin{cases} 1 & if\ rail\ siding\ k\ is\ used\ by\ mill\ j \\ 0 & otherwise \end{cases}$$

- $[\chi_{[a][b]}]$: Incidence matrix between link a and node b,

$$\chi_{[a][b]} = \begin{cases} 1 & if\ link\ a\ starts\ from\ node\ b \\ -1 & if\ link\ a\ ends\ at\ node\ b \\ 0 & otherwise \end{cases}$$

- $[\tau_{[v][b]}]$: Incidence matrix between OD pair v and node b,

$$\tau_{[v][b]} = \begin{cases} 1 & if\ OD\ pair\ v\ starts\ at\ node\ b \\ -1 & if\ OD\ pair\ v\ ends\ at\ node\ b \\ 0 & otherwise \end{cases}$$

- $[{\tau'}_{[v'][b']}]$: Incidence matrix between new OD pair v' and new node b',

$$\tau_{[v'][b']} = \begin{cases} 1 & if\ new\ OD\ pair\ v'\ starts\ at\ node\ b' \\ -1 & if\ OD\ pair\ v'\ ends\ at\ node\ b' \\ 0 & otherwise \end{cases}$$

- $[\vartheta_{[kj][v]}]$: Incidence matrix between path kj and OD pair v,

$$\vartheta_{[kj][v]} = \begin{cases} 1 & if\ path\ kj\ connects\ v \\ 0 & otherwise \end{cases}$$

- $[{\vartheta'}_{[k'j][v']}]$: Incidence matrix between path kj and new OD pair v',

$$\vartheta_{[k'j][v']} = \begin{cases} 1 & if\ path\ k'j\ connects\ v' \\ 0 & otherwise \end{cases}$$

<u>*Scenario 1: Benchmarking the mode share status of 2017 shipment*</u>

Figure C-1 describes the first scenario of shared siding/volume discount analysis which combines two differently perceived rail networks. As shown, log products can be shipped by direct trucking flow (Xij) or by combining truck (Zik) and rail shipment (Ykj). While the rail link (l) is represented by simple route at shipper-perceived network, it moves through more complicated route which is expressed by rail OD pair (v) at carrier-perceived network. To represent the benchmark scenario, integer linear programming (ILP) model was developed. This first mathematical model (MODEL 1) includes objective function to minimize truck and rail transportation costs, and assigns the optimal volumes to each mode of transportation.

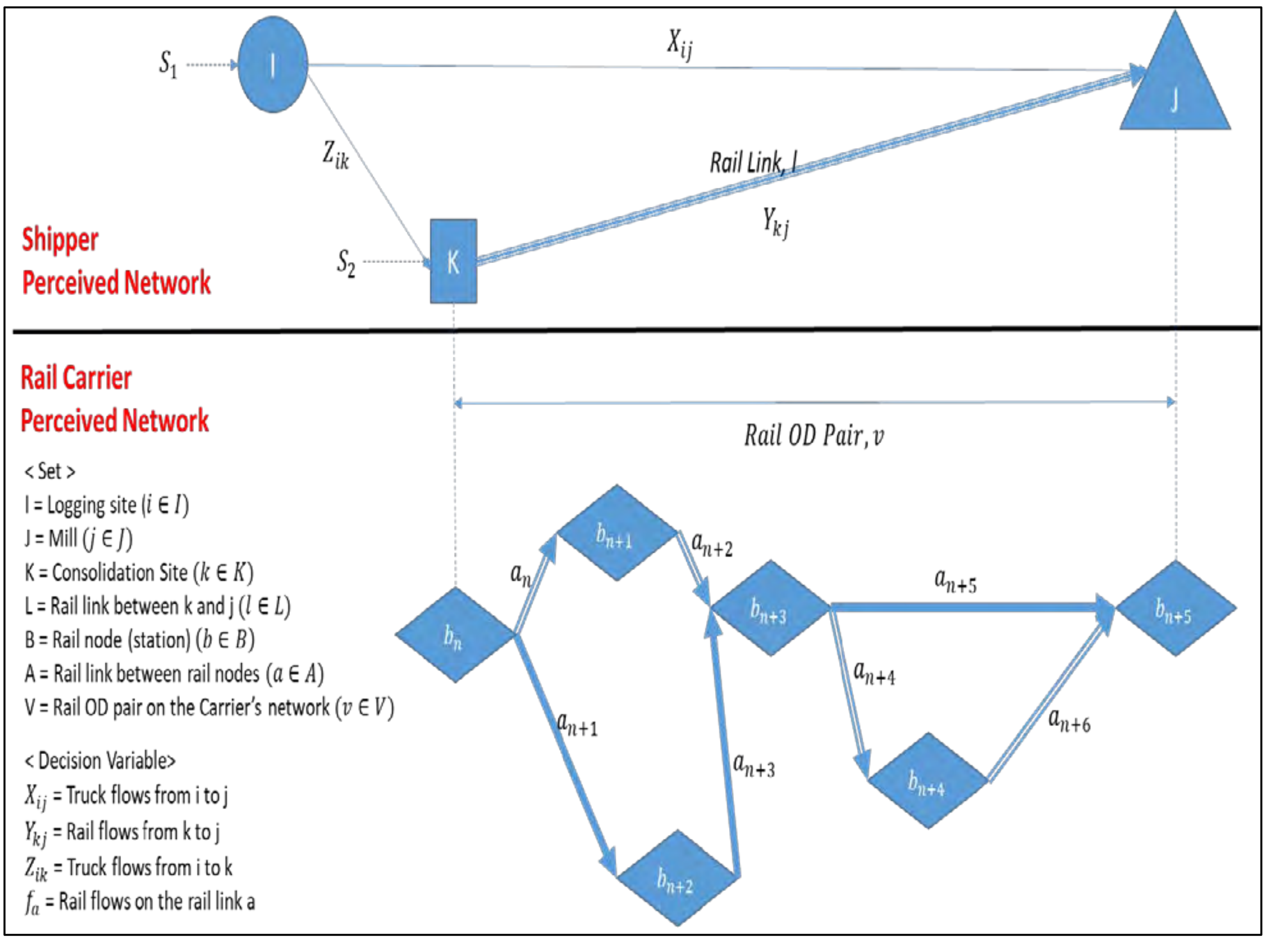


Figure C-1. Scenario 1: Partially shared rail consolidation

Whole mathematical model of scenario 1 is as follow:

MODEL 1

$$Min \sum_i \sum_j \sum_h C^{T_1} \cdot X_{ijh} + \sum_k \sum_j \sum_h (C_l^R + C_k^L) \cdot Y_{kjh} + \sum_i \sum_k \sum_j \sum_h C^{T_2} \cdot Z_{ikjh} \;\ldots\ldots (1)$$

$$s.t. \sum_i \sum_h \varphi_{[i][j]} \cdot X_{ijh} + \sum_k \sum_h \omega_{[k][j]} \cdot Y_{kjh} = D_j \quad \forall\, j \in J \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$X_{ijh} + \sum_k Z_{ikjh} = S_{ijh}^I \quad \forall\, i \in I, h \in H, j \in J \;\ldots\ldots\ldots\ldots (3)$$

$$Y_{kjh} - \sum_i Z_{ikjh} = S_{kjh}^K \quad \forall\, k \in K, h \in H, j \in J \;\ldots\ldots\ldots (4)$$

$$\sum_{a \in A} f_a \cdot \chi_{[a][b]} = \sum_k \sum_j \sum_h \sum_v \vartheta_{[kj][v]} \cdot Y_{kjh} \cdot \tau_{[v][b]} \quad \forall\, b \in B \;\ldots\ldots\ldots (5)$$

$$X_{ij}, Y_{kjh}, Z_{ik}, f_a \geq 0 \quad \forall i \in I, j \in J, k \in K, h \in H, a \in A$$

$$where,$$

$$C^{T_1} = \alpha + \beta \cdot d_{ij}$$

$$C^{T_2} = \alpha + \beta \cdot d_{ik}$$

$$C_l^R = \sum_{v \in V} (\xi_{[l],[v]} \cdot C_v^R) \quad \forall\, l \in L$$

$$C_v^R = \gamma_v + \delta_v \cdot d_v + \varepsilon_v \cdot F_1 + \zeta_v \cdot F_2 + \eta_v \cdot F_3 + \lambda_v \cdot F_4 \quad \forall\, v \in V$$

$$d_v = \vartheta_{[kj][v]} \cdot d_{kj} \quad \forall\, j \in J, k \in K$$

Line (1) indicates the objective function which minimizes sum of direct truck cost, indirect truck cost, and rail costs. Line (2) means demand constraint. Demand of each mill is equal to sum of tonnage shipped by direct truck and rail using current rail sidings. Line (3) is a constraint of supply at truck origins. Supply of each truck origin is equal to sum of tonnage shipped by direct truck and indirect truck to current rail sidings. Line (4) is also a constraint of supply at rail origins Supply of each rail origin is equal to sum of tonnage shipped by rail minus indirect truck to current rails sidings. Finally, line (5) indicates flow balance on rail networks. Rail flows of shipper perceived network is equal to rail flows of carrier perceived network.

Scenario 2: Assumed that companies share their sidings with their own mills, and Scenario 3: Assumed that companies share sidings with all mills in the project area

For Scenario 2 and 3, the similar approaches were utilized but each model was based on different assumption on the sharing of rail consolidation sites. In Scenario 2, it was assumed that every mills of same forest company can share their rail sidings to consolidate their log shipments. This means it was not allowed to share the rail sidings between different companies' mills. We removed this limitation in Scenario 3 allowing any rail sidings can be shared between all mills in the project area. Figure C-2 depicts the different assumptions of two scenarios in a perspective of shipper's rail network. Two ILP models were developed to represent the Scenario 2 and Scenario 3, respectively. They include same objective functions, but constraints were modified along with the different assumptions on sharing facilities. Each mathematical model also includes different set of incidence matrices.

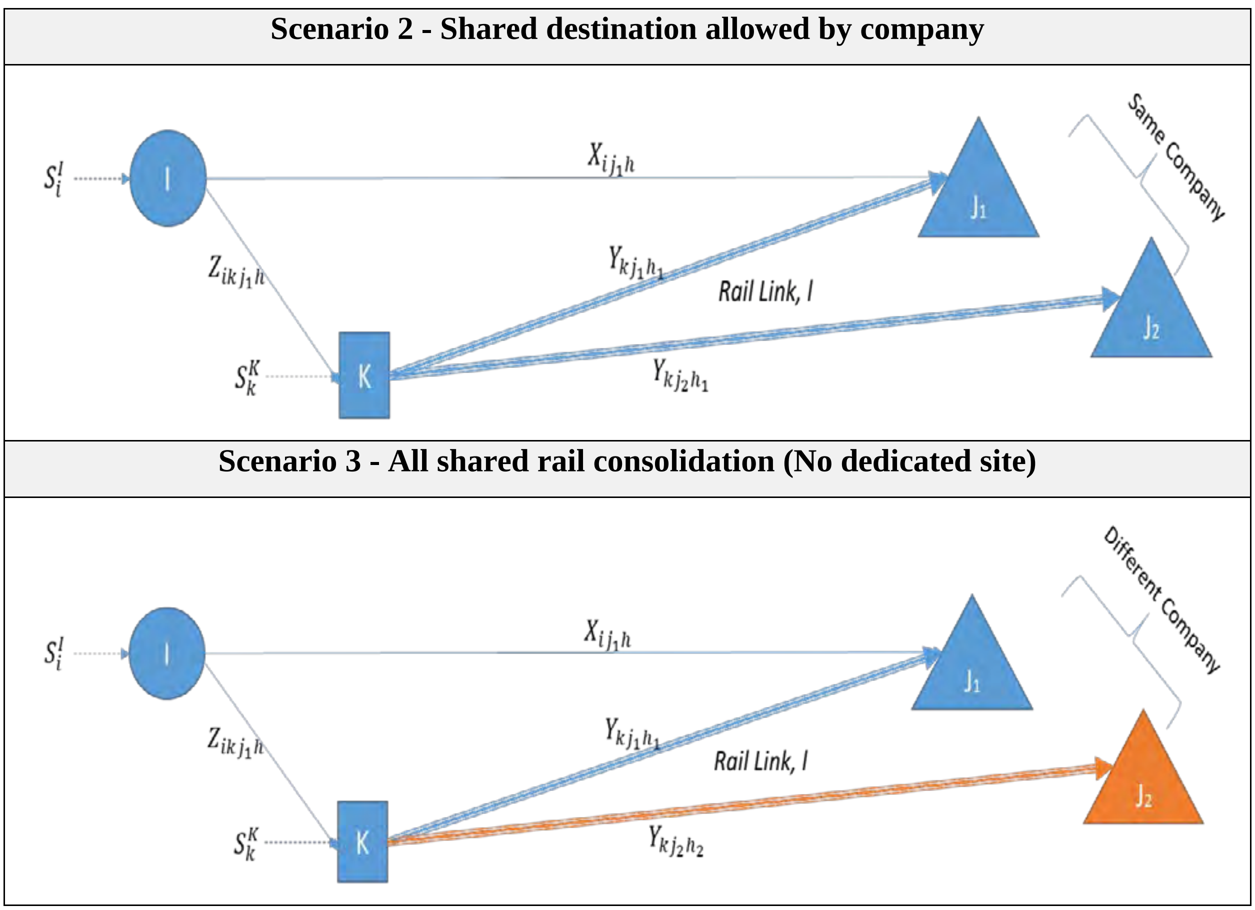


Figure C-2. Shipper-perceived rail network for Scenario 2 and Scenario 3

The whole mathematical models (MODEL 2 and MODEL 3) for Scenario 2 and 3 are as follows:

MODEL 2

$$Min \sum_i \sum_j \sum_h C^{T_1} \cdot X_{ijh} + \sum_k \sum_j \sum_h C_l^R \cdot Y_{kjh} + \sum_i \sum_k \sum_j \sum_h (C^{T_2} + C_k^L) \cdot Z_{ikjh} \;\; \dots \dots (1)$$

$$s.t. \sum_i \sum_h \varphi_{[i][j]} \cdot X_{ijh} + \sum_k \sum_h \omega_{[k][j]} \cdot Y_{kjh} \cdot \omega'_{[j][h]} = D_j \quad \forall\, j \in J \;\; \dots \dots (2)$$

$$X_{ijh} + \sum_k Z_{ikjh} = S_{ijh}^I \quad \forall\, i \in I, h \in H, j \in J \;\; \dots \dots (3)$$

$$Y_{kjh} - \sum_i Z_{ikjh} = S_{kjh}^K \quad \forall\, k \in K, h \in H, j \in J \;\; \dots \dots (4)$$

$$\sum_{a \in A} f_a \cdot \chi_{[a][b]} = \sum_k \sum_j \sum_h \sum_v \vartheta_{[kjh][v]} \cdot Y_{kjh} \cdot \tau_{[v][b]} \quad \forall\, b \in B \;\; \dots \dots (5)$$

$$X_{ij}, Y_{kjh}, Z_{ik}, f_a \geq 0 \quad \forall i \in I, j \in J, k \in K, h \in H, a \in A$$

MODEL 3

$$Min \sum_i \sum_j \sum_h C^{T_1} \cdot X_{ijh} + \sum_k \sum_j \sum_h C_l^R \cdot Y_{kjh} + \sum_i \sum_k \sum_j \sum_h (C^{T_2} + C_k^L) \cdot Z_{ikjh} \;\; \dots \dots (1)$$

$$s.t. \sum_i \sum_h \varphi_{[i][j]} \cdot X_{ijh} + \sum_k \sum_h Y_{kjh} = D_j \quad \forall\, j \in J \;\; \dots \dots (2)$$

$$X_{ijh} + \sum_k Z_{ikjh} = S_{ijh}^I \quad \forall\, i \in I, h \in H, j \in J \;\; \dots \dots (3)$$

$$Y_{kjh} - \sum_i Z_{ikjh} = S_{kjh}^K \quad \forall\, k \in K, h \in H, j \in J \;\; \dots \dots (4)$$

$$\sum_{a \in A} f_a \cdot \chi_{[a][b]} = \sum_k \sum_j \sum_h \sum_v \vartheta_{[kjh][v]} \cdot Y_{kjh} \cdot \tau_{[v][b]} \quad \forall\, b \in B \;\; \dots \dots (5)$$

$$X_{ij}, Y_{kjh}, Z_{ik}, f_a \geq 0 \quad \forall i \in I, j \in J, k \in K, h \in H, a \in A$$

As shown, Model 2 and Model 3 were modified from Model 1 in that incidence matrices in line (2) and line (5) were added or removed to reflect the conditions of scenario 2 and scenario 3.

Scenario 4: Assumed re-opening of closed sidings in addition to a condition of Scenario 3

The final scenario for the shared siding/volume discount analysis considers two assumptions in addition to the Scenario 3. Firstly, we integrated new rail sidings that currently not used into the existing rail network to investigate the impact on new locations of rail consolidation sites for the log movements. Figure C-3 describes the shipper-perceived rail network for Scenario 4 considering the re-opened rail sidings. As shown in the Figure, we added the link between new rail sidings and truck origin ($Z_{ik'jh}$) as well as the link between new rail siding and exising rail siding ($W_{kk'jh}$). The alternative locations of rail siding were selected from the regional carrier's data on the possible consolidation sites that used before but currently closed. We did not take into account the construction of new rail siding, as it requires additional investments to purchase land and build rail tracks and turnouts.

The second assumptions for the final scenario is that rail rate discounts can be offered when rail volume could meet a certain quota on a rail siding. For example, 10% rail rate discount for the O-D pair is available, if annual rail tonnage is more than 100,000 tons in the rail siding. Unlike the ILP models for Scenario 1~3, two mixed integer linear program (MILP) models were developed to integrate new assumptions.

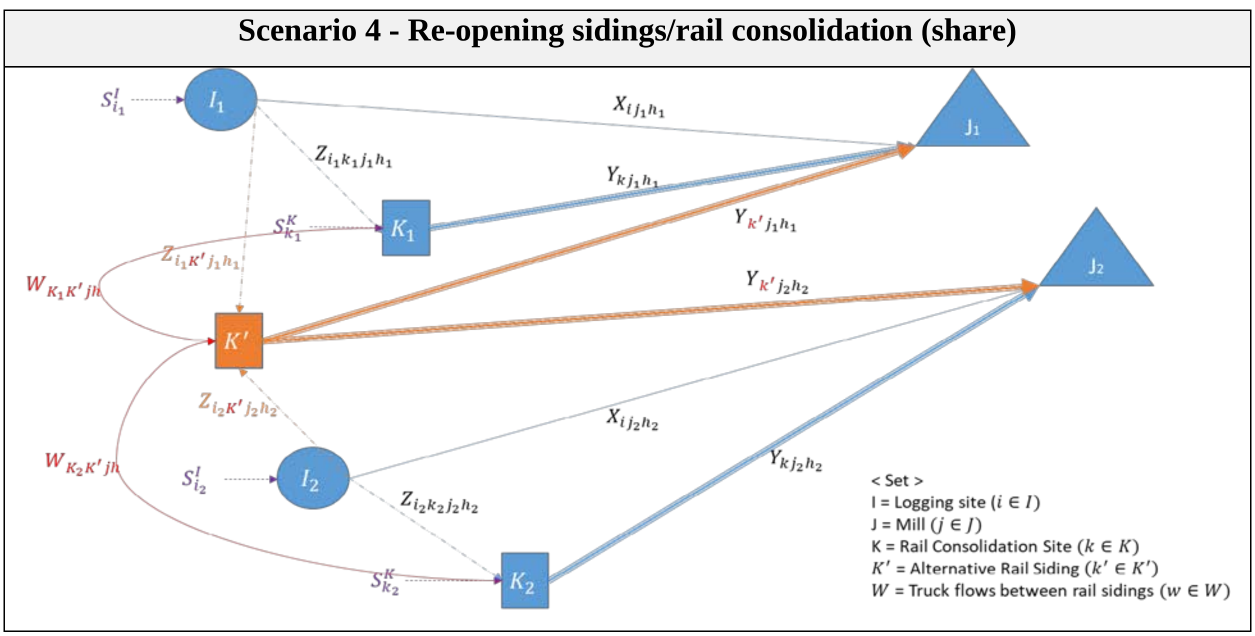


Figure C-3. Shipper-perceived rail network for Scenario 4

The detail explanation about the first mathematical model (MODEL 4-1) of Scenario 4 that assumes re-opening of closed sidings in addition to a condition of Scenario 3 is as follows:

MODEL 4-1

$$Min \sum_{i}\sum_{j}\sum_{h} C^{T_1} \cdot X_{ijh} + \sum_{k}\sum_{j}\sum_{h} C_l^R \cdot Y_{kjh} + \sum_{k'}\sum_{j}\sum_{h} C_l^R \cdot Y_{k'jh}$$
$$+ \sum_{i}\sum_{k}\sum_{j}\sum_{h} (C^{T_2} + C_k^L) \cdot Z_{ikjh} + \sum_{i}\sum_{k'}\sum_{j}\sum_{h} (C^{T_2} + C_{k'}^L) \cdot Z_{ik'jh}$$
$$+ \sum_{k}\sum_{k'}\sum_{j}\sum_{h} (C^{T_3} + C_{k'}^L) \cdot W_{kk'jh} \; \ldots\ldots (1)$$

$$s.t. \sum_{i}\sum_{h} \varphi_{[i][j]} \cdot X_{ijh} + \sum_{k}\sum_{h} Y_{kjh} + \sum_{k'}\sum_{h} Y_{k'jh} = D_j \quad \forall\ j \in J \; \ldots\ldots\ldots (2)$$

$$X_{ijh} + \sum_{k} Z_{ikjh} + \sum_{k'} Z_{ik'jh} = S_{ijh}^I \quad \forall\ i \in I, h \in H, j \in J \; \ldots\ldots (3)$$

$$\sum_{k'} W_{kk'jh} + Y_{kjh} - \sum_{i} Z_{ikjh} = S_{kjh}^K \quad \forall\ k \in K\ , h \in H, j \in J \; \ldots (4)$$

$$\sum_{a \in A} f_a \cdot \chi_{[a][b]} = \sum_{k}\sum_{j}\sum_{h}\sum_{v} \vartheta_{[kj][v]} \cdot Y_{kjh} \cdot \tau_{[v][b]}$$
$$+ \sum_{k'}\sum_{j}\sum_{h}\sum_{v'} \vartheta'_{[k'j][v']} \cdot Y_{k'jh} \cdot \tau'_{[v'][b']} \quad \forall\ b, b' \in B \quad \ldots\ldots (5)$$

$$\sum_{i} Z_{ik'jh} + \sum_{k} W_{kk'jh} = Y_{k'jh} \quad k' \in K', h \in H, j \in J \; \ldots\ldots\ldots (6)$$

$$X_{ijh}, Y_{kjh}, Z_{ikjh}, W_{kk'jh}, f_a \geq 0 \;\; \forall i \in I, j \in J, k \in K, k' \in K', h \in H, a \in A$$

Line (1) indicates the objective function which minimizes sum of direct truck cost, indirect truck cost, and rail costs. Line (2) means demand constraint. Demand of each mill is equal to sum of tonnage shipped by direct truck, rail with current rail sidings, and rail with new rail siding. Line (3) is a constraint of supply at truck origins. Supply of each truck origin is equal to sum of tonnage shipped by direct truck, indirect truck to current rail sidings, and indirect truck to new rail siding. Line (4) is also a constraint of supply at rail origins Supply of each rail origin is equal to sum of tonnage shipped by rail and indirect truck to new rail siding extracted by indirect truck to current rails sidings. Line (5) indicates flow balance on rail networks. Rail flows of shipper perceived network is equal to all rail flows of carrier perceived network considering not only current rail sidings but new rail sidings. Finally, Line (6) means rail tons shipped from new rail siding is equal to sum of indirect truck tons from truck origins and indirect truck tons from current rail sidings.

The detail explanation about the second mathematical model (MODEL 4-2) of Scenario 4 that assumes re-opening of closed sidings and rail rate discounts for the volume aggregation in the rail siding is as follows:

MODEL 4-2

$$Min \sum_i \sum_j \sum_h C^{T_1} \cdot X_{ijh} + \sum_k \sum_j \sum_h C_l^R \cdot Y_{kjh} + \sum_{k'} \sum_j \sum_h C_l^R \cdot Y_{k'jh}$$
$$+ \sum_i \sum_k \sum_j \sum_h (C^{T_2} + C_k^L) \cdot Z_{ikjh} + \sum_i \sum_{k'} \sum_j \sum_h (C^{T_2} + C_{k'}^L) \cdot Z_{ik'jh}$$
$$+ \sum_k \sum_{k'} \sum_j \sum_h (C^{T_3} + C_{k'}^L) \cdot W_{kk'jh} + \sum_k \sum_j \sum_h C_l^R \cdot \mu_{kjh}$$
$$+ \sum_{k'} \sum_j \sum_h C_l^R \cdot \mu_{k'jh} \dots\dots (1)$$

$$s.t. \sum_i \sum_h \varphi_{[i][j]} \cdot X_{ijh} + \sum_k \sum_h Y_{kjh} + \sum_{k'} \sum_h Y_{k'jh} = D_j \quad \forall\ j \in J \ \dots\dots\dots (2)$$

$$X_{ijh} + \sum_k Z_{ikjh} + \sum_{k'} Z_{ik'jh} = S_{ijh}^I \quad \forall\ i \in I, h \in H, j \in J \ \dots\dots (3)$$

$$\sum_{k'} W_{kk'jh} + Y_{kjh} - \sum_i Z_{ikjh} = S_{kjh}^K \quad \forall\ k \in K\ , h \in H, j \in J \ \dots (4)$$

$$\sum_{a \in A} f_a \cdot \chi_{[a][b]} = \sum_k \sum_j \sum_h \sum_v \vartheta_{[kj][v]} \cdot Y_{kjh} \cdot \tau_{[v][b]}$$
$$+ \sum_{k'} \sum_j \sum_h \sum_{v'} \vartheta'_{[k'j][v']} \cdot Y_{k'jh} \cdot \tau'_{[v'][b']} \quad \forall\ b, b' \in B \quad \dots\dots (5)$$

$$\sum_j \sum_h Y_{kjh} \geq 100000 - M(1 - t_{kjh}) \qquad \forall\ k \in K, h \in H, j \in J \dots\dots\dots (6)$$

$$\sum_j \sum_h Y_{kjh} < 100000 + M \cdot t_{kjh} \qquad \forall\ k \in K, h \in H, j \in J \ \dots\dots\dots (7)$$

$$-0.1Y_{kjh} - M(1 - t_{kjh}) \le \mu_{kjh} \le -0.1Y_{kjh} + M(1 - t_{kjh}) \qquad \forall\, k \in K, h \in H, j \in J \;\; \dots\dots (8)$$

$$-M \cdot t_{kjh} \le \mu_{kjh} \le M \cdot t_{kjh} \qquad \forall\, k \in K, h \in H, j \in J \;\; \dots\dots\dots (9)$$

$$\sum_{j}\sum_{h} Y_{k'jh} \ge 100000 - M(1 - t_{k'jh}) \qquad \forall\, k' \in K', h \in H, j \in J \;\; \dots\dots\dots (10)$$

$$\sum_{j}\sum_{h} Y_{k'jh} < 100000 + M \cdot t_{k'jh} \qquad \forall\, k' \in K', h \in H, j \in J \;\; \dots\dots\dots (11)$$

$$-0.1Y_{k'jh} - M(1 - t_{k'jh}) \le \mu_{k'jh} \le -0.1Y_{k'jh} + M(1 - t_{k'jh}) \qquad \forall\, k' \in K', h \in H, j \in J \;\; \dots\dots (12)$$

$$-M \cdot t_{k'jh} \le \mu_{k'jh} \le M \cdot t_{k'jh} \qquad \forall\, k' \in K', h \in H, j \in J \;\; \dots\dots\dots (13)$$

$$\sum_{i} Z_{ik'jh} + \sum_{k} W_{kk'jh} = Y_{k'jh} \qquad k' \in K', h \in H, j \in J \;\; \dots\dots\dots (14)$$

$$X_{ijh}, Y_{kjh}, Z_{ikjh}, W_{kk'jh}, f_a \ge 0\,, \mu_{kjh} \le 0, t_{kjh} \in \{0,1\}\,, \mu_{k'jh} \le 0, t_{k'jh} \in \{0,1\}$$

$$\forall i \in I, j \in J, k \in K, k' \in K', h \in H, a \in A$$

where,

$$C^{T_1} = \alpha + \beta \cdot d_{ij}$$

$$C^{T_2} = \alpha + \beta \cdot d_{ik}$$

$$C^{T_3} = \alpha + \beta \cdot d_{kk'}$$

$$C_l^R = \sum_{v \in V} (\xi_{[l],[v]} \cdot C_v^R) \qquad \forall\, l \in L$$

$$C'^R_l = \sum_{v' \in V'} (\xi_{[l],[v']} \cdot C'^R_{v'}) \qquad \forall\, l \in L$$

$$C_v^R = \gamma_v + \delta_v \cdot d_v + \varepsilon_v \cdot F_1 + \zeta_v \cdot F_2 + \eta_v \cdot F_3 + \lambda_v \cdot F_4 \qquad \forall\, v \in V$$

$$C'^R_{v'} = \gamma_{v'} + \delta_{v'} \cdot d_{v'} + \varepsilon_{v'} \cdot F_1 + \zeta_{v'} \cdot F_2 + \eta_{v'} \cdot F_3 + \lambda_{v'} \cdot F_4 \qquad \forall\, v' \in V'$$

$$d_v = \vartheta_{[kj][v]} \cdot d_{kj} \quad \forall\; j \in J, k \in K$$

$$d_{v'} = \vartheta'_{[k'j][v']} \cdot d_{k'j} \quad \forall\; j \in J, k' \in K'$$

The main difference between MODEL 4-1 and MODEL 4-2 is in line (6)~(13) which indicate the newly added constraints relating to rail rate discounts from volume aggregation. Line (6)~(9) show if-then constraint to add rail discount condition per aggregation for current rail sidings. For example, we can assume that if annual rail tons is more than 100,000 tons in a OD pair, there would be 10% rail rate discount for the OD pair. Line (10)~(13) indicate if-then constraint to add rail discount condition per aggregation for new rail sidings. Note that this model includes four dummy variables (μ_{kjh}, $\mu_{k'jh}$, t_{kjh}, $t_{k'jh}$) to support the if-then constraint.

The Solution Approach

In this project, we used the ILP/MILP solver of IBM ILOG CPLEX Optimization Studio 12.7 with Python API (Application Programming Interfaces), which is based on the dynamic search algorithm. The dynamic search algorithm in CPLEX basically consists of four blocks to solve large scale MILP problem: pre-processing, LP relaxation, branch and cuts, and heuristics [20]. Pre-processing step reduces the size of the problem and improves the formulation through a probing technique that analyses the logical implications of fixing each binary variable to 0 or 1. For heuristics, the relaxation induced neighborhood search (RINS) algorithm is selected in this project. RINS algorithm is based on the fact that the solution of the continuous relaxation at the current node is most often not integral, but its objective value is always better than that of the incumbent [21]. RINS sets an objective cut-off based on the variables that have the same values in the incumbent and in the current continuous relaxation, and then solves a sub-MILP on the remaining variables. The details of this built-in CPLEX algorithm is shown in an IBM document [22]. All experiments were run on a 3.6 GHz Core i7 processor with 16 Gbytes of RAM.

Appendix D

Rail Car Peaking Analysis:

Explanation of the optimization model used for each project case

<u>Set, Decision Variables, and Input Parameters for Optimization models</u>

For Rail Car Peaking Analysis, two optimization programming models were developed to estimate optimal number of rail cars under each project case. In this Appendix, the explanation of basic notations and the main concept of each model will be addressed. Following Table D-1 provides the sets, decision variables, and input parameters that were used in the mathematical models.

Table D-1. Notations for Set, Decision Variables, and Input Parameters

Sets
▪ I = Set of logging sites, $i \in I$ ▪ J = Set of mills, $j \in J$ ▪ A = Set of day that loading a freight on a rail car is about to start, $a \in A$ ▪ B = Set of day that unloading a freight from a rail car is terminated, $b \in B$
Decision Variables
▪ x_{ai} = Number of rail cars added at origin i at day a ▪ w_{aibj} = Number of rail cars that re-assigned from mill j at day b to origin i at day a ▪ d_{bj} = Number of idle cars occurred at mill j at day b ▪ s_{ai} = Number of carloads (tickets) deferred at origin i at day a
Input Parameters
▪ n_{ai} = Number of rail cars that supposed to be loaded at the origin i at day a ▪ N_{bj} = Number of rail car that supposed to be ended its unloading at the mill j at day b ▪ c_{ij} = Hauling days that take to move from origin i to mill j (same as j to i) ▪ l = Days that needed to load a freight to a rail car at origin site ▪ u = Days that needed to unload a freight from a rail car at destination site ▪ $MAX\ x$ = Average number of rail cars between maximum tons' month and minimum tons' month

<u>Case 1: Logs move by rail as they arrive (eliminate storage)</u>

Whole mathematical model of case 1 is as follow:

MODEL 5

$$\text{Min} \quad \sum_a \sum_i x_{ai} \cdots\cdots (1)$$

$$\sum_a \sum_i w_{aibj} + d_{bj} = N_{bj} + d_{(b-1)j} \quad \forall b \in B,\ j \in J \cdots\cdots (2)$$

$$\sum_b \sum_j w_{aibj} + x_{ai} = n_{ai} \quad \forall a \in A,\ i \in I \cdots\cdots (3)$$

$$w_{aibj}\{c_{ij} - (a-b)\} \le 0 \quad \forall a \in A,\ i \in I, b \in B,\ j \in J \cdots\cdots (4)$$

$$w_{aibj},\ x_{ai}, d_{bj} = Positive\ Integer$$

Note that $N_{bj} = n_{ai} + l + c_{ij} + u$. The first line (1) of this model indicates the objective function which minimizes newly added rail car in this project area. The second line (2) means that following equation:

(Number of cars that ended its unloading) + (Number of cars that being idled car at the previous day) = (Number of cars that re-assigned) + (Number of cars that become to be idled)

The third line (3) indicates the number of cars loading at i at time a is same as the sum of new car and reassignments to i at time a from all j at all time b. The final line (4) of this model addresses if rail hauling days would be larger than difference between loading day (a) and unloading day (b), then rail car reassignment would not be made it as it would fail to arrive in time to the origin that needs a car.

Case 2: Logs can be moved or stored as they arrive (storage available as alternative)

Whole mathematical model of case 2 is as follow:

MODEL 6

$$\text{Min} \qquad \sum_{a}\sum_{i} s_{ai} \cdots\cdots (1)$$

$$\sum_{a}\sum_{i} w_{aibj} +\ d_{bj} = N_{bj} +\ d_{(b-1)j} \qquad \forall b \in B,\ j \in J \cdots\cdots (2)$$

$$\sum_{b}\sum_{j} w_{aibj} + x_{ai} + S_{ai} = n_{ai} + S_{(a-1)i} \qquad \forall a \in A,\ i \in I \cdots\cdots (3)$$

$$w_{aibj}\{c_{ij} - (a - b)\} \leq 0 \quad \forall a \in A,\ i \in I, b \in B,\ j \in J \cdots\cdots (4)$$

$$\sum_{a}\sum_{i} x_{ai} \leq MAX\ x \cdots\cdots (5)$$

$$w_{aibj},\ x_{ai}, d_{bj}, S_{ai} = Positive\ Integer$$

The main difference between MODEL 5 and MODEL 6 is in the objective function and line (3) and (5). The objective function (1) of this model minimizes number of carloads (tickets) deferred at origin i at day a, as minimized S_{ai} would lead to minimized x_{ai} by the equation in line (3). The line (3) is equivalent to following equation:

(Number of cars reassigned) + (Number of cars newly added) + (Number of carloads deferred at the day)

= (The number of cars that is about to be loaded) + (Number of carloads deferred at the previous day)

Finally, the line (5) makes sure that total number of rail cars newly added in the project area should not exceed the aaverage number of rail cars between max. and min. tons of months. In this analysis, we assumed the value of MAX x is 493 which is an average of rail cars in April and September.

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Appendix E

Trucker Value Analysis:

A method to calculate total shipping days and total actual times taken for shipping to evaluate trucker's time and value efficiencies from collaborating with rail

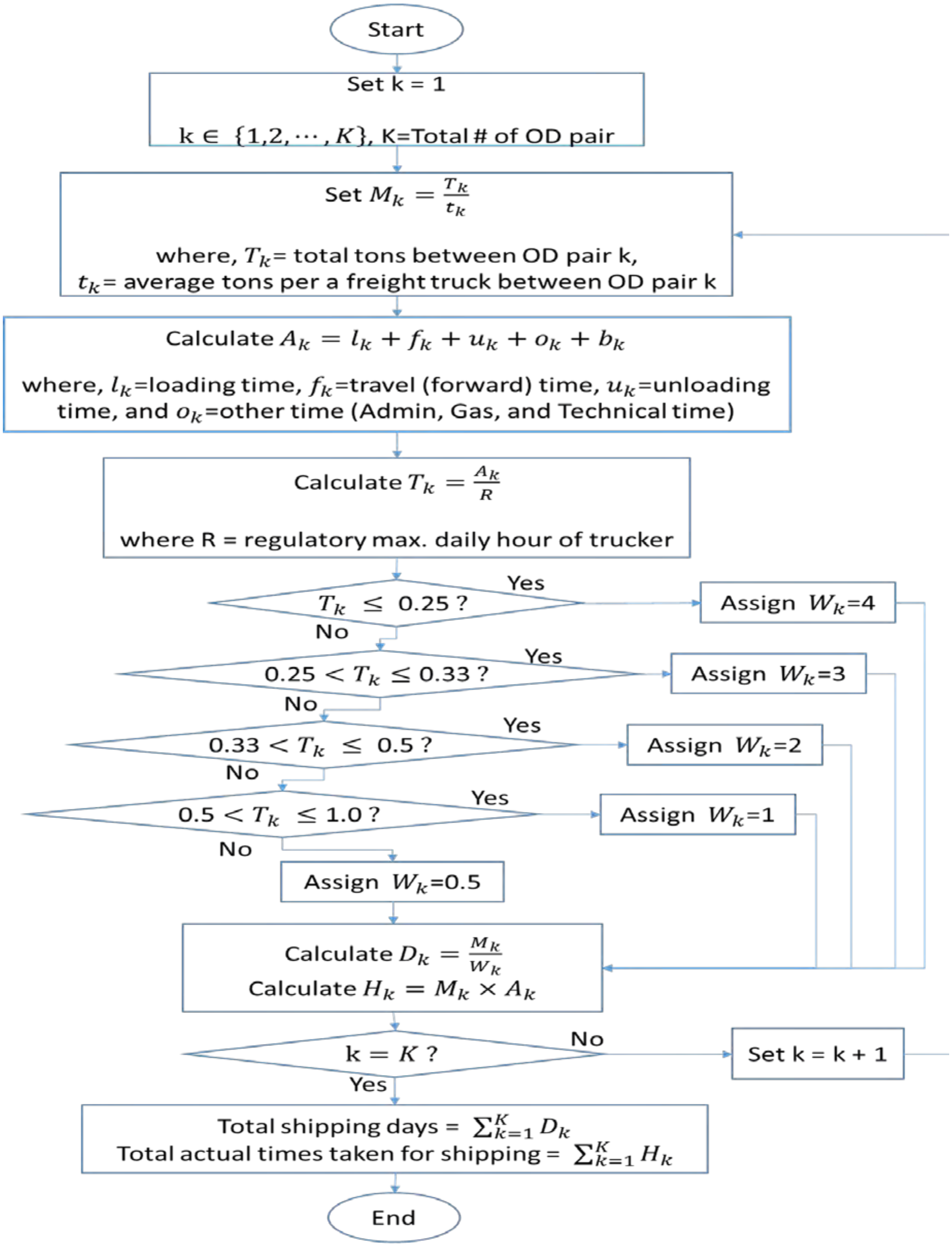


Figure E-1. Flow map 4 to calculate total shipping days and total actual times taken for shipping

Appendix F

Non-log Movement Analysis:

Non-log freight flow maps per mode of transportation

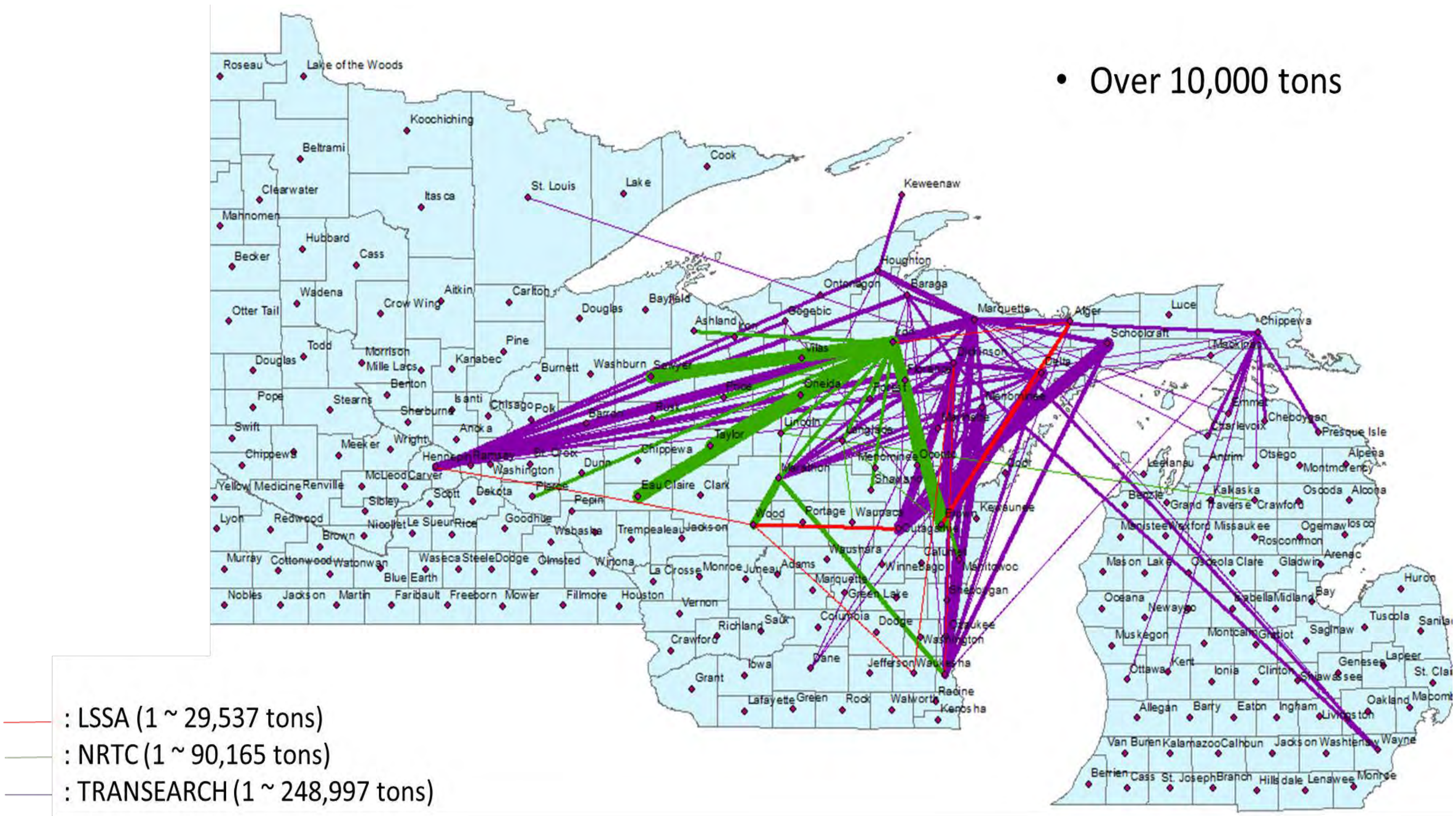


Figure F-1. Map: Non-log freight flows by truck for regional area

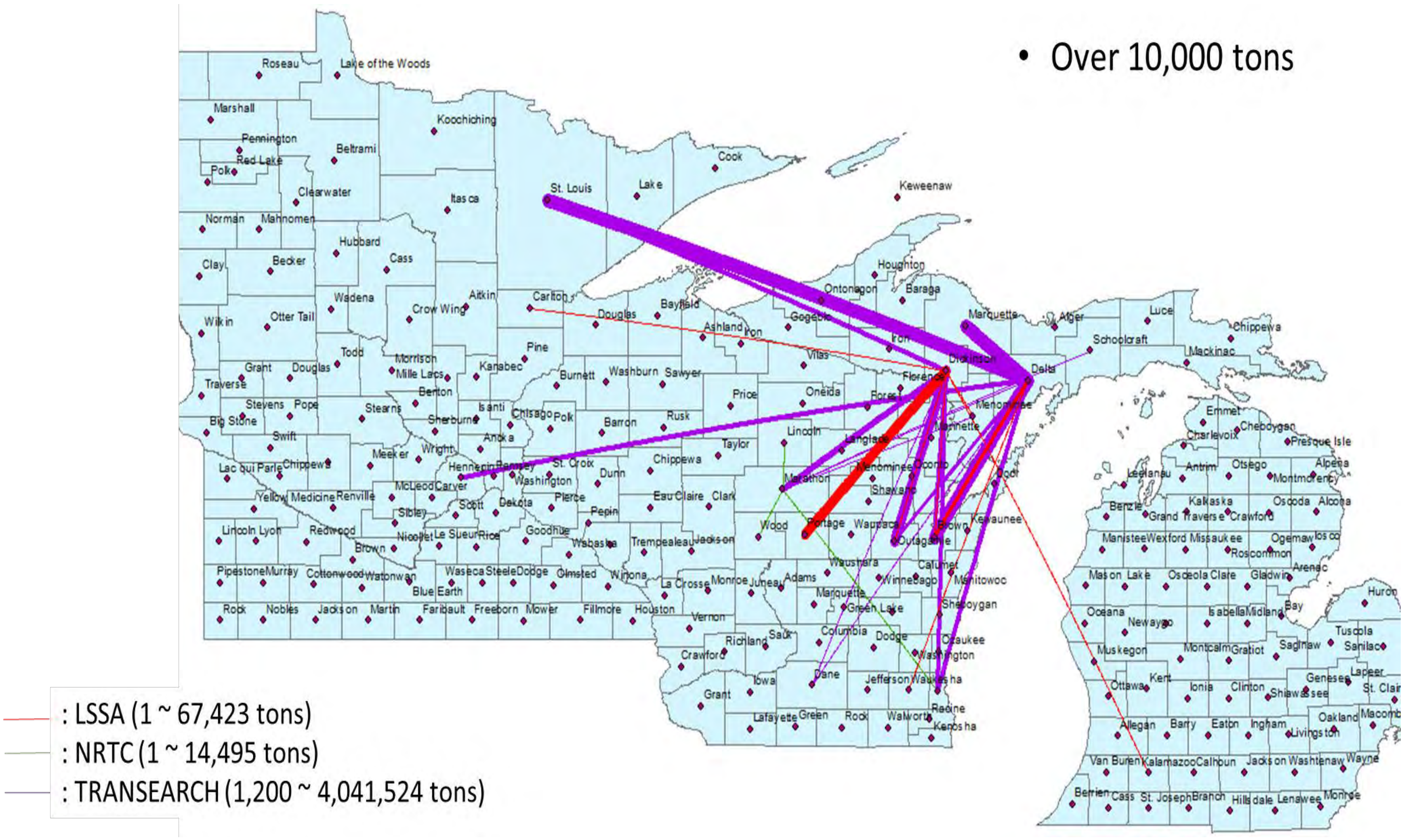


Figure F-2. Map: Non-log freight flows by rail for regional area

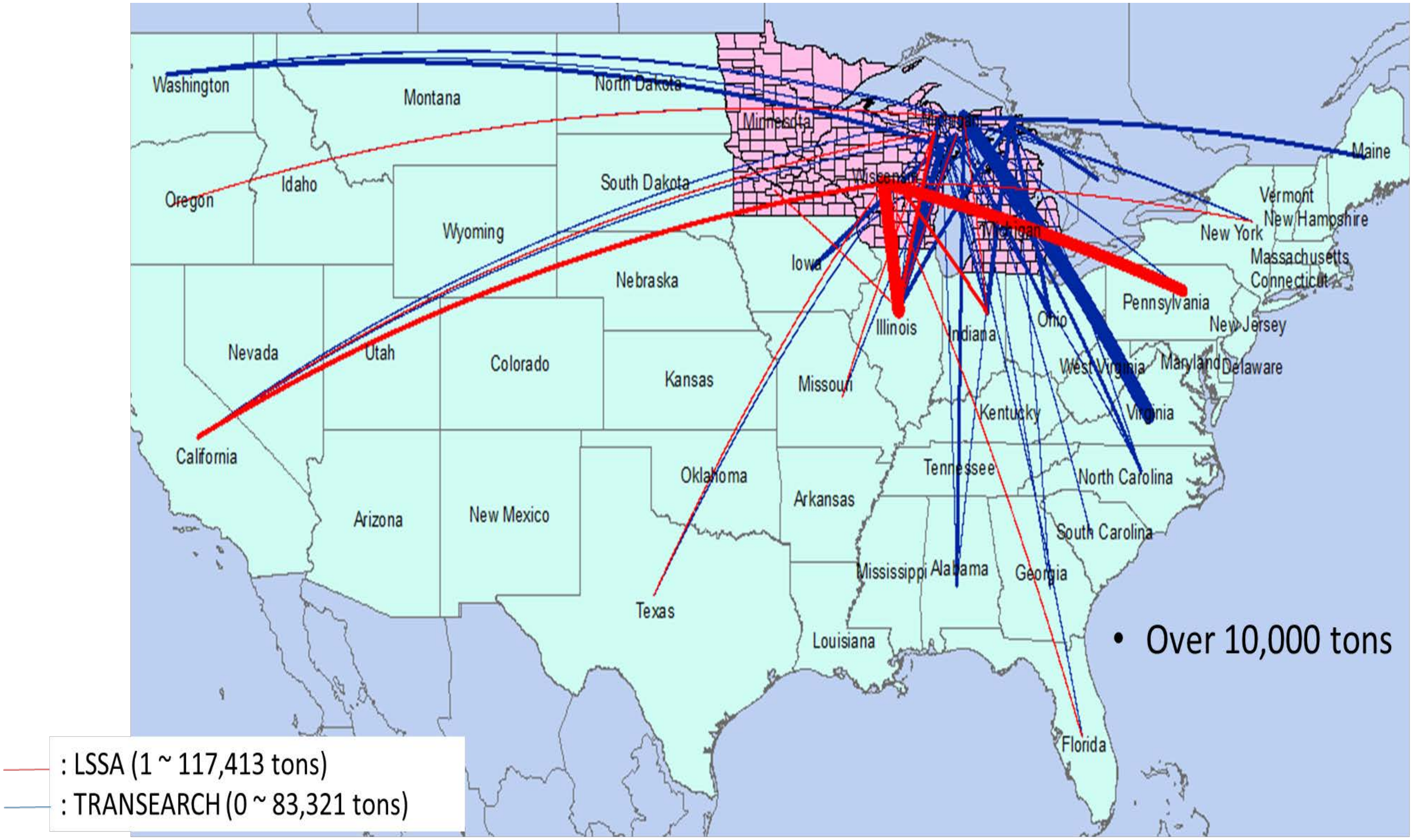


Figure F-3. Map: Non-log freight flows by non-regional outbound truck shipments

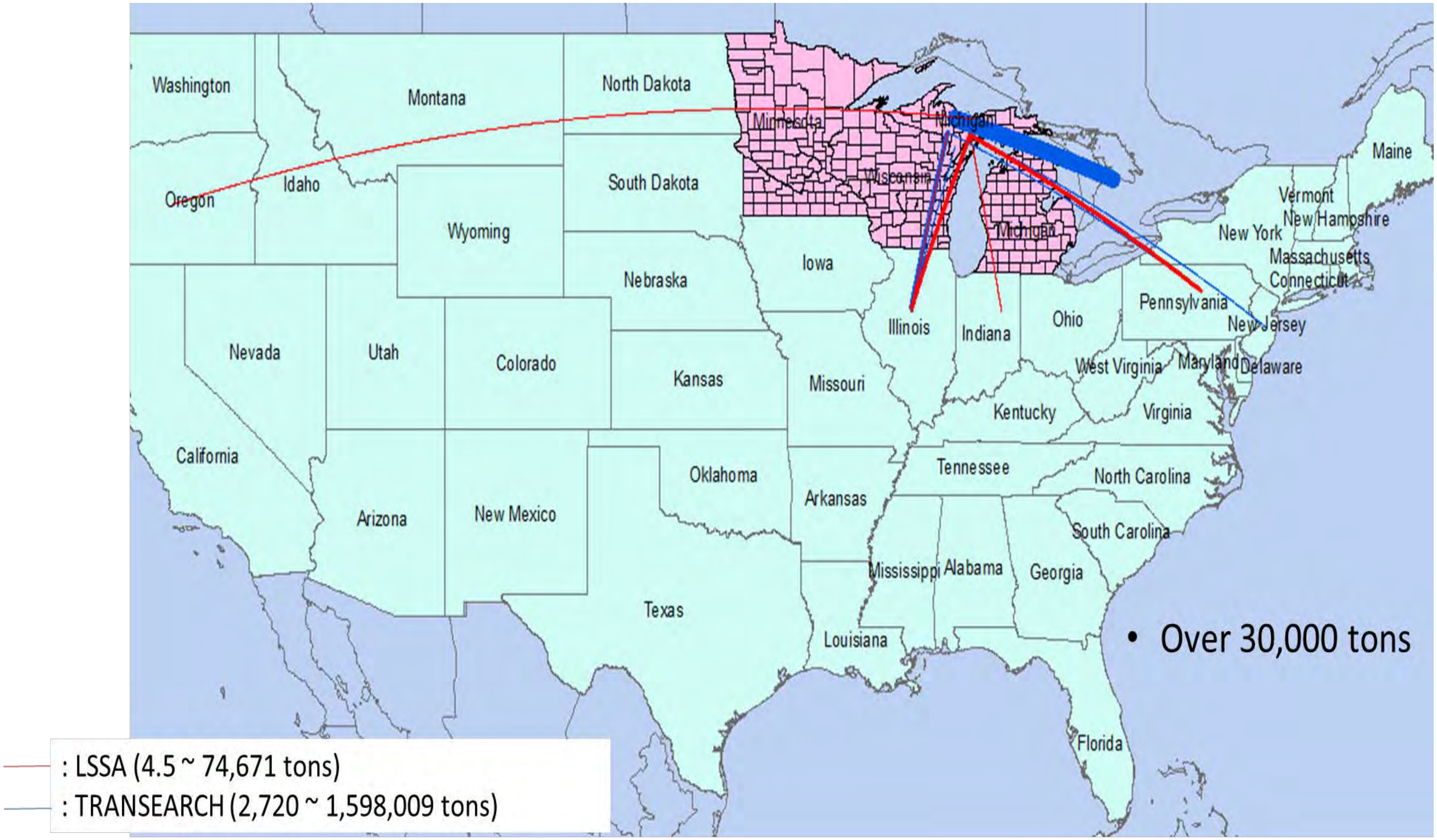


Figure F-4. Map: Non-log freight flows by non-regional outbound rail shipments

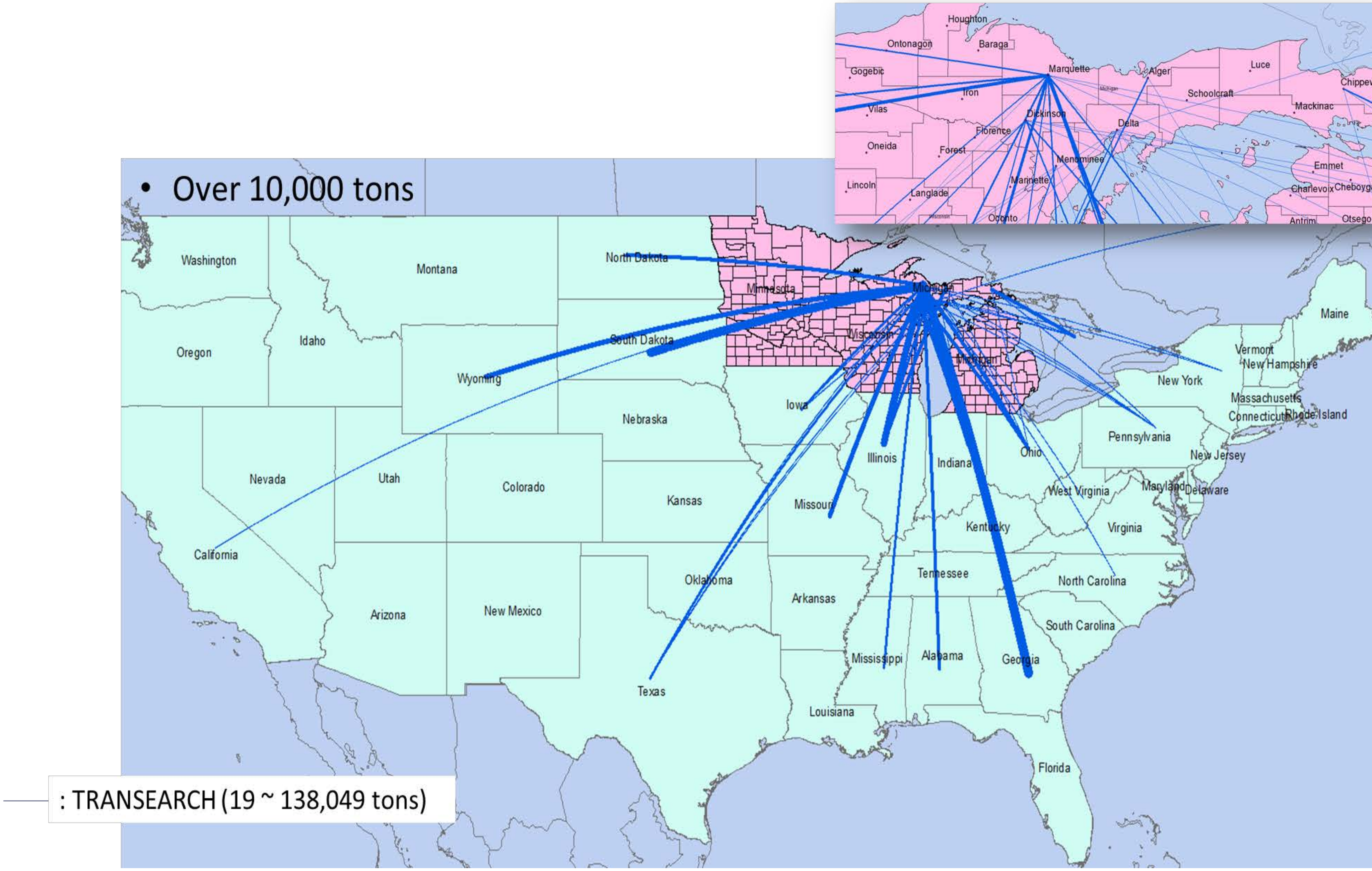


Figure F-5. Map: Non-log freight flows by non-regional inbound truck shipments

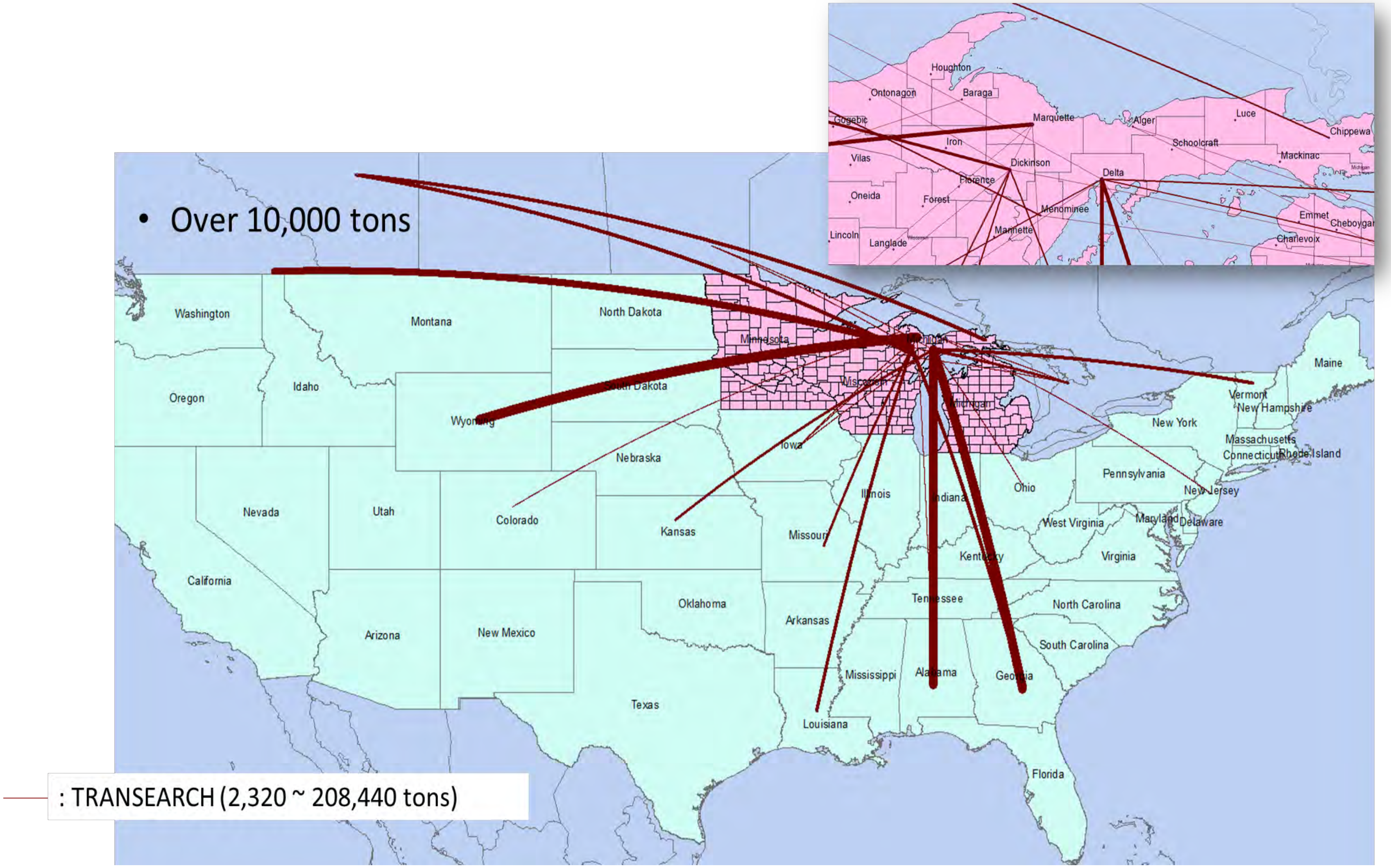


Figure F-6. Map: Non-log freight flows by non-regional inbound rail shipment

Appendix G

Non-log Moment Analysis:

Freight profiles for all counties in Upper MI

Appendix. G

Non-log Moment Analysis:
Freight profiles for all counties in Upper MI

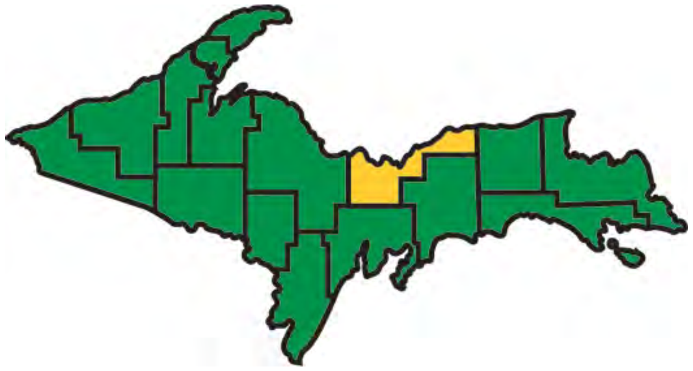
List of UP Counties, MI (pages)

List of UP Counties, MI

< Contents per each county profile >

- Basic freight information: Labor forces, number of employers and industries
- Major Commodities in Each County by Mode
- Tonnage of Freight Movements by Flow Direction
- Major Trading Partners by Mode – States/Provinces
- Major Trading Partners by Mode – Counties

Alger County Freight Profile (Year 2015)



At a Glance	
9,383	Population
3,242	Total Labor Force
2,975	Employed
8.24%	Unemployment

Employers (# Employed)

Major Employers that Export	
Neenah Paper, Inc. (Munising Mill)	266
Timber Products	159
Trenary Home Bakery	20

Other Main Employers	
Munising Public Schools	104
TenderCare	99
Christmas Kewadin Casino	89
County of Alger	58
Superior Central Schools	38
Glen's Market	35
People's State Bank	32
Pictured Rocks National Lakeshore	20

Industries (# of Establishments)		
Accommodations and food services	34	17%
Retail Trade	34	17%
Construction	29	14%
Transportation and warehousing	16	8%
Other services, excluding public administration	14	7%
Administrative and waste services	12	6%
Health care and social assistance	10	5%
Arts, entertainment, and recreation	9	4%
Agriculture, forestry, fishing, and hunting	9	4%
Manufacturing	9	4%
Finance and insurance	8	4%
Professional and technical services	7	3%
Information	4	2%
Wholesale trade	4	2%
Real estate, rental, and leasing	3	2%
Management of companies and enterprises	1	0.5%
Utilities	1	0.5%
TOTAL	**204**	**100%**

Alger County Freight Profile (Year 2015)

Major Commodities in Alger County by Mode

Internal		
Truck		Rail
Logs, Lumber, and Wood Products	11,604	None
Waste or Scrap Metal	767	
Clay, Cement, Glass or Stone Products	711	
Farm Products	88	
Paper and Pulp Products	56	
Shipping Containers	0	

Inbound		
Truck		Rail
Waste or Scrap Material	194,112	
Logs, Lumber, and Wood Products	173,003	
Nonmetallic Ores and Minerals	32,924	
Secondary Traffic	8,553	
Clay, Cement, Glass or Stone Products	8,400	
Petroleum or Coal Products	2,566	
Farm Products	2,464	
Chemical Products	1,672	6,440
Food Products	1,473	
Transportation Equipment	1,316	
Forest Products	1,315	
Miscellaneous or Mixed Shipments	555	
Paper and Pulp Products	213	29,960
Primary Metal Products	59	
Fabricated Metal Products	41	
Printed Matter	29	
Shipping Containers	0	

Outbound		
Truck		Rail
Paper and Pulp Products	289,550	
Logs, Lumber, and Wood Products	88,086	6,760
Food Products	9,944	
Farm Products	9,280	
Clay, Cement, Glass or Stone Products	7,283	
Waste or Scrap Material	2,368	
Secondary Traffic	521	
Printed Matter	31	
Shipping Containers	0	

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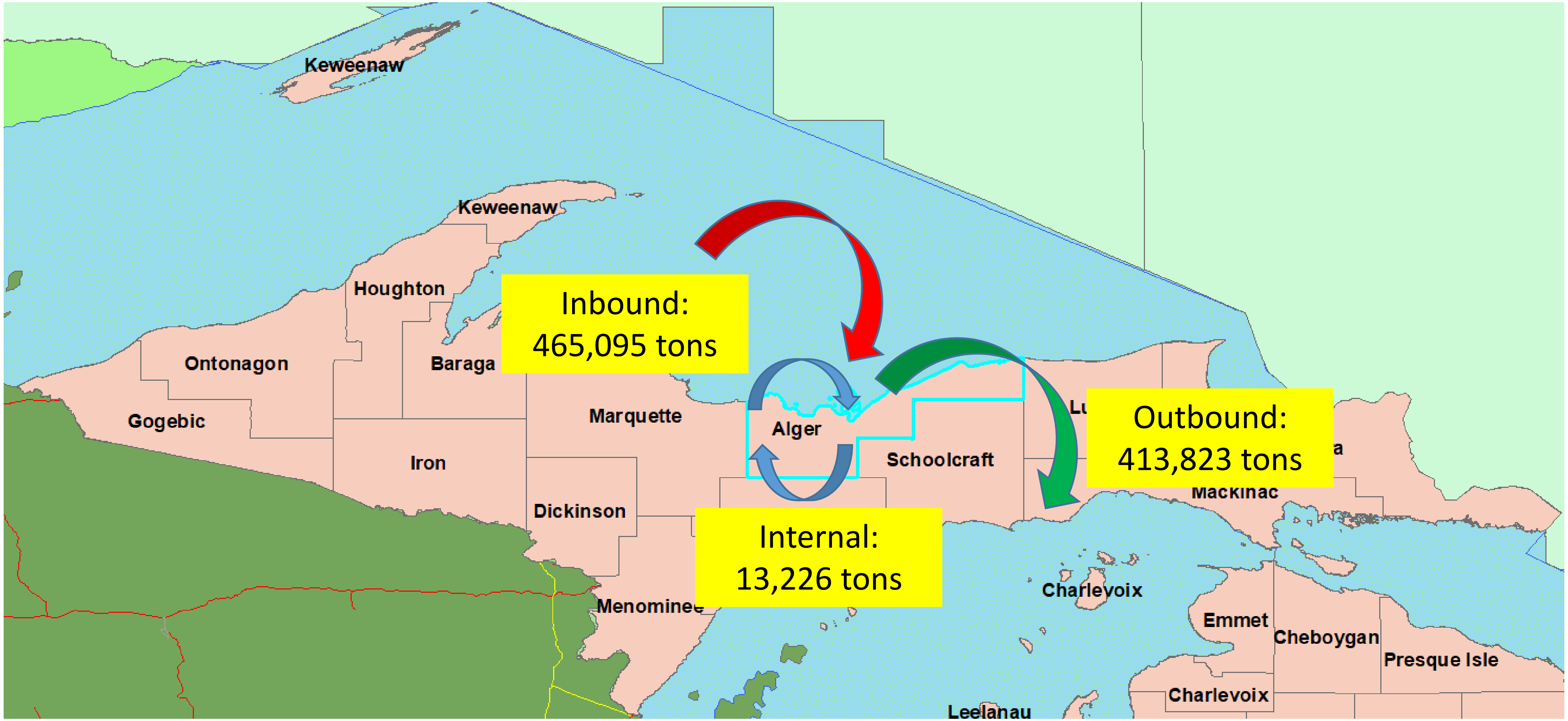
Alger County Freight Profile (Year 2015)



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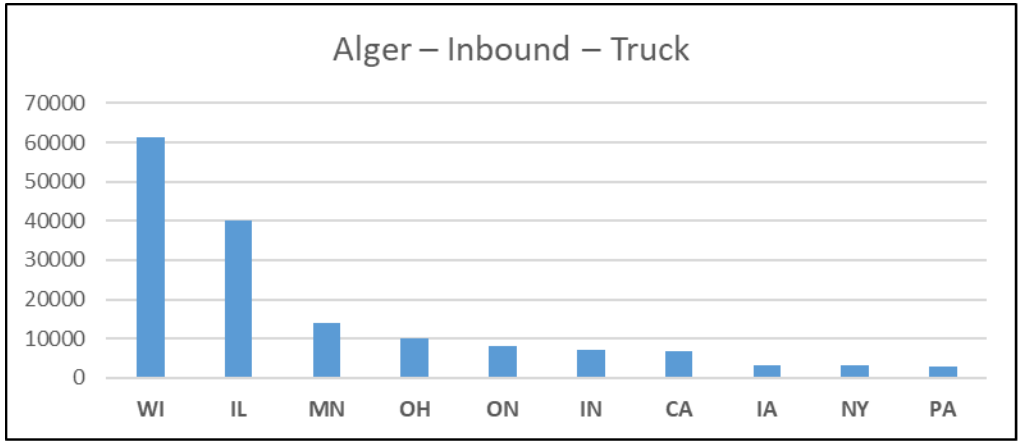
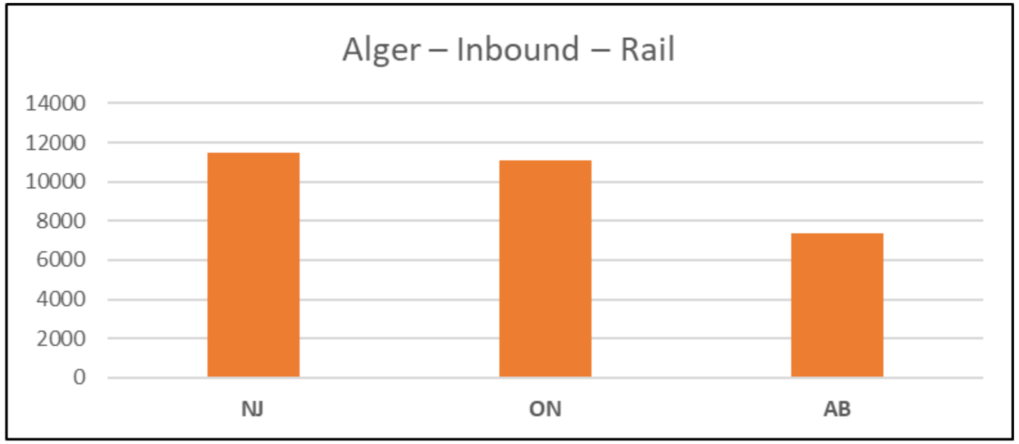
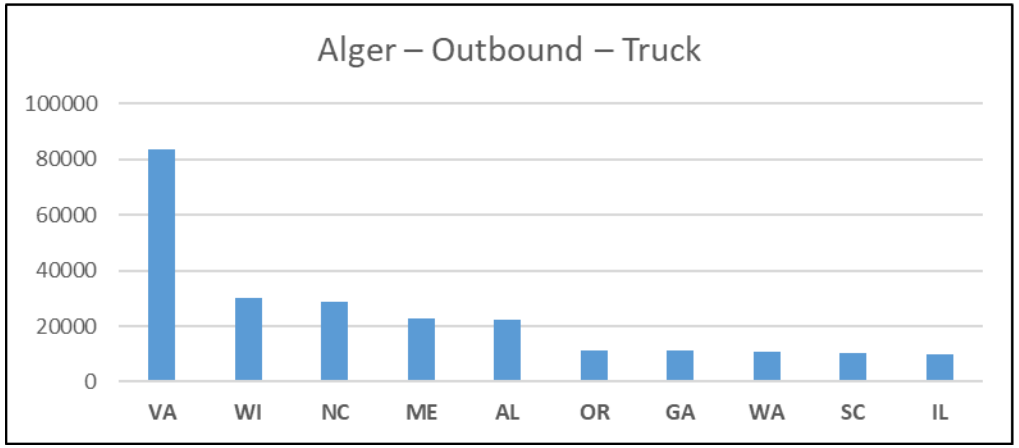
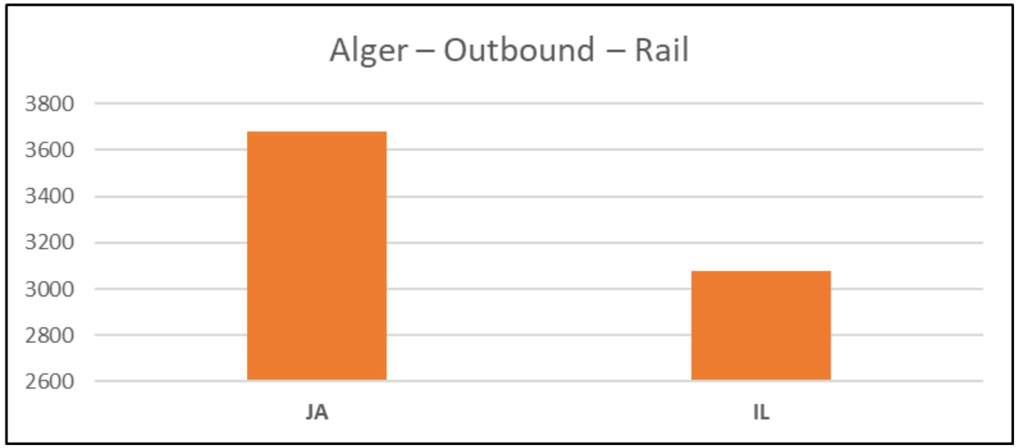
Alger County Freight Profile (Year 2015)

Major Trading Partners by Mode – States/Provinces









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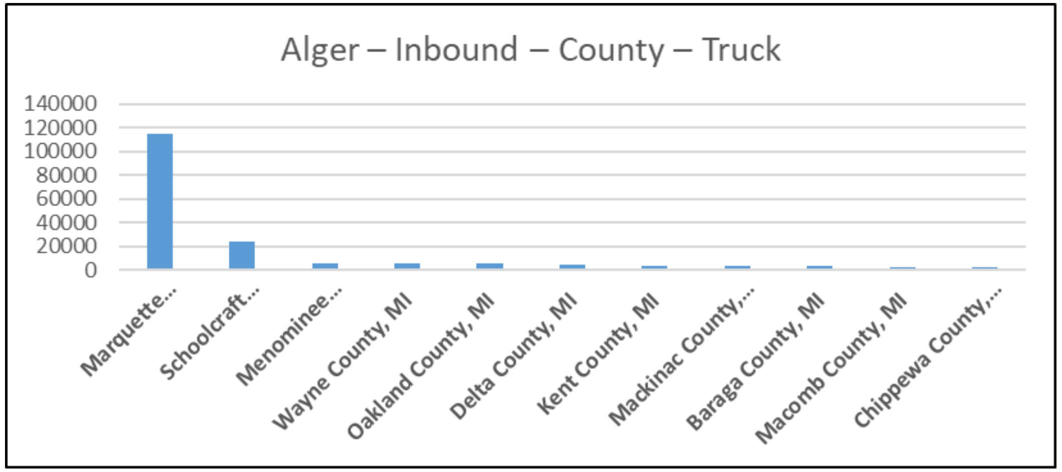
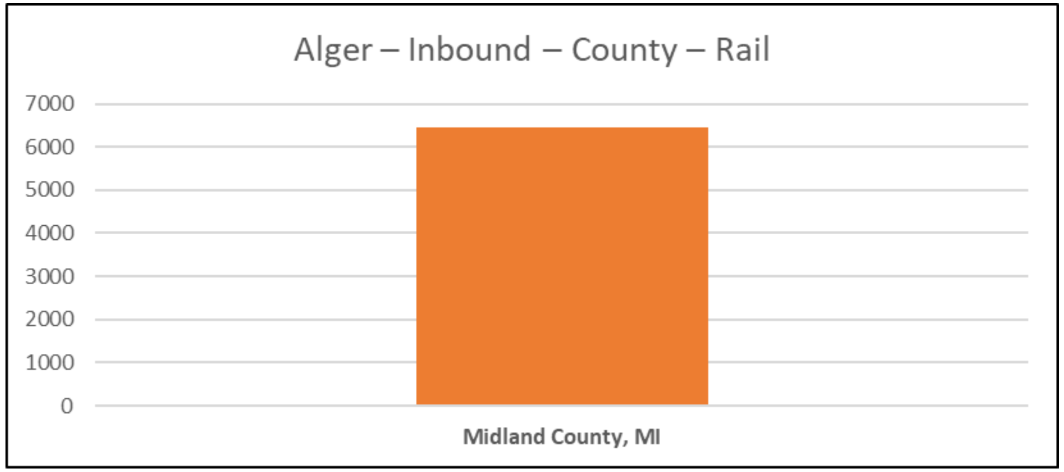
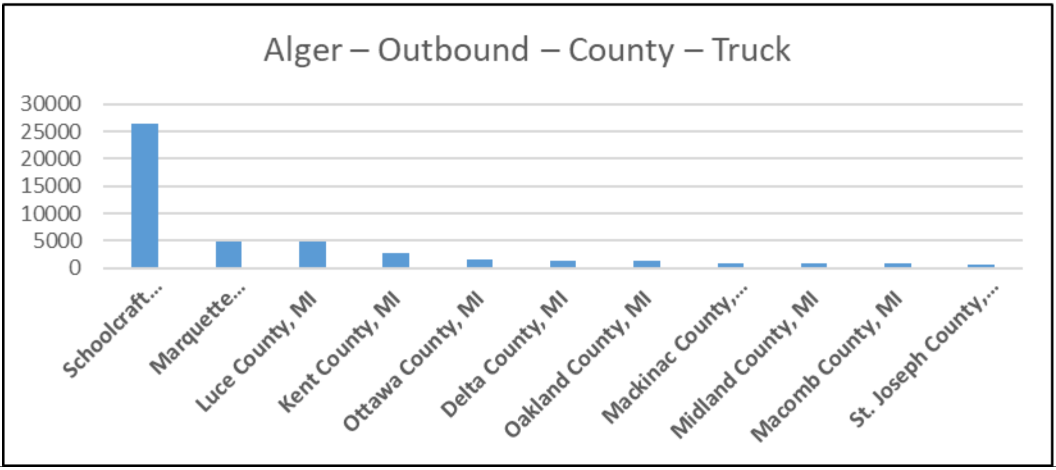
Alger County Freight Profile (Year 2015)

Major Trading Partners by Mode – Counties







Alger – Outbound – County – Rail

None

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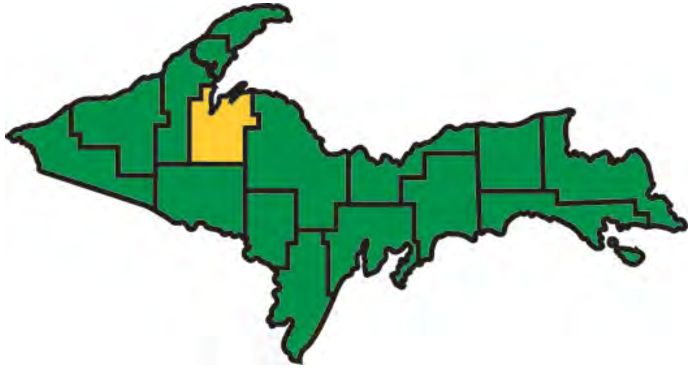
Baraga County Freight Profile (Year 2015)



At a Glance	
8,740	Population
3,306	Total Labor Force
3,016	Employed
8.8%	Unemployment

Employers (# Employed)	
Major Employers that Export	
Certainteed	152
Pettibone Traverse Lift, LLC.	75
Peninsula Powder Coating	31
Erickson Lumber & True Value	28
Selkey Manufacturing	12
Other Main Employers	
Michigan Department of Corrections	301
Baraga Co. Memorial Hospital	191
KBIC Casino	178
L'Anse Township Schools	119
Baraga County Extended Care	85
Baraga County	34
Keweenaw Bay Indian Community	N/A

Industries (# of Establishments)		
Retail trade	26	14%
Agriculture, forestry, fishing, and hunting	23	12%
Manufacturing	23	12%
Accommodations and food services	21	11%
Other services, except public administration	20	10%
Transportation and warehousing	15	8%
Construction	15	8%
Health care and social assistance	10	5%
Finance and insurance	8	4%
Wholesale trade	7	4%
Administrative and waste services	7	4%
Professional and technical services	5	3%
Information	3	2%
Mining, quarrying, oil and gas extraction	2	1%
Real estate, rental, and leasing	2	1%
Utilities	1	0.5%
Arts, entertainment, and recreation	1	0.5%
TOTAL	**189**	**100%**

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Baraga County Freight Profile (Year 2015)

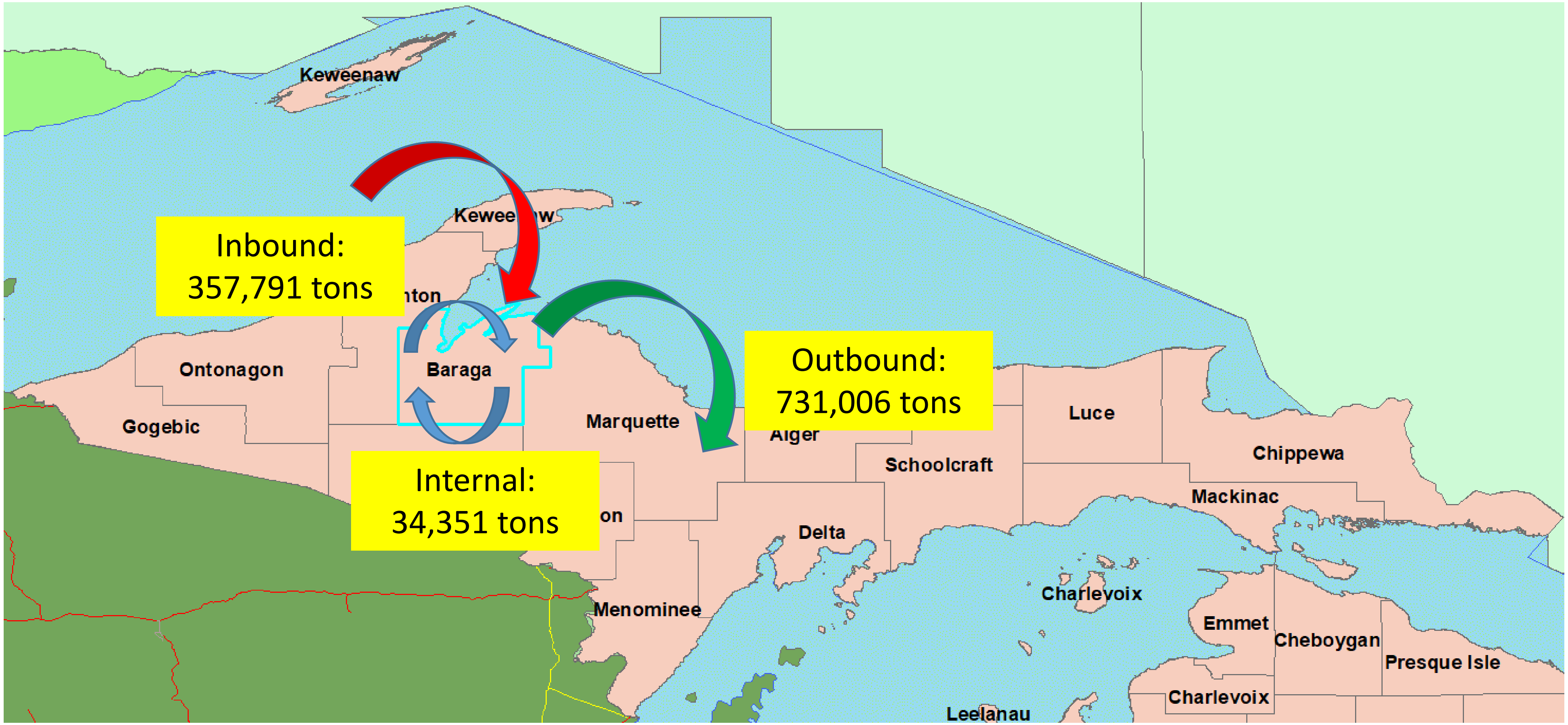
Major Commodities in Baraga County by Mode

Internal		
Truck		Rail
Logs, Lumber, and Wood Products	25,722	None
Nonmetallic Ores and Minerals	5,334	
Clay, Cement, Glass or Stone Products	2,715	
Primary Metal Products	383	
Waste or Scrap Material	115	
Machinery	52	
Fabricated Metal Products	30	
Shipping Containers	0	

Inbound		
Truck		Rail
Logs, Lumber, and Wood Products	245,485	
Nonmetallic Ores and Minerals	52,487	11,640
Secondary Traffic	10,114	
Primary Metal Products	6,991	
Clay, Cement, Glass or Stone Products	6,714	3,600
Waste or Scrap Material	4,915	3,600
Petroleum or Coal Products	4,619	
Transportation Equipment	3,448	
Chemical Products	1,429	
Food Products	704	
Machinery	465	
Forest Products	312	
Paper and Pulp Products	312	
Fabricated Metal Products	277	
Rubber and Plastics	206	
Farm Products	166	
Miscellaneous or Mixed Shipments	145	
Printed Matter	109	
Technical Instruments and Equipment	25	
Furniture Products	17	
Electrical Equipment	8	
Apparel or Finished Textiles	3	
Shipping Containers	0	

Outbound		
Truck		Rail
Logs, Lumber, and Wood Products	275,744	114,840
Nonmetallic Ores and Minerals	179,453	
Clay, Cement, Glass or Stone Products	134,667	
Primary Metal Products	7,044	
Chemical Products	6,389	
Machinery	4,497	
Farm Products	2,689	
Waste or Scrap Material	2,346	
Fabricated Metal Products	2,285	
Secondary Traffic	720	
Technical Instruments and Equipment	129	
Printed Matter	124	
Rubber and Plastics	79	
Shipping Containers	0	

Baraga County Freight Profile (Year 2015)



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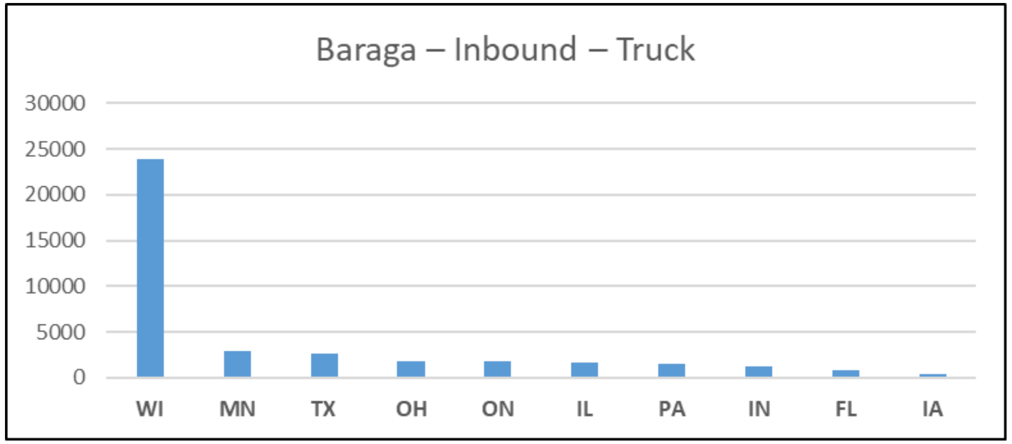
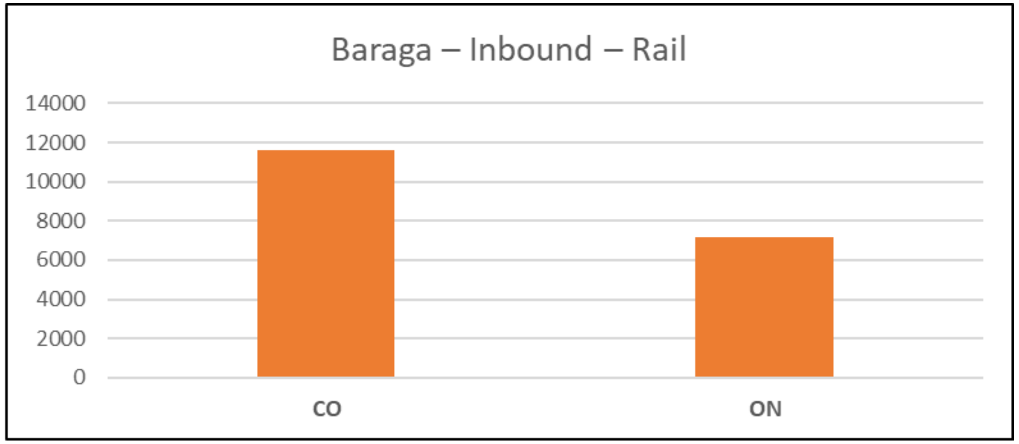
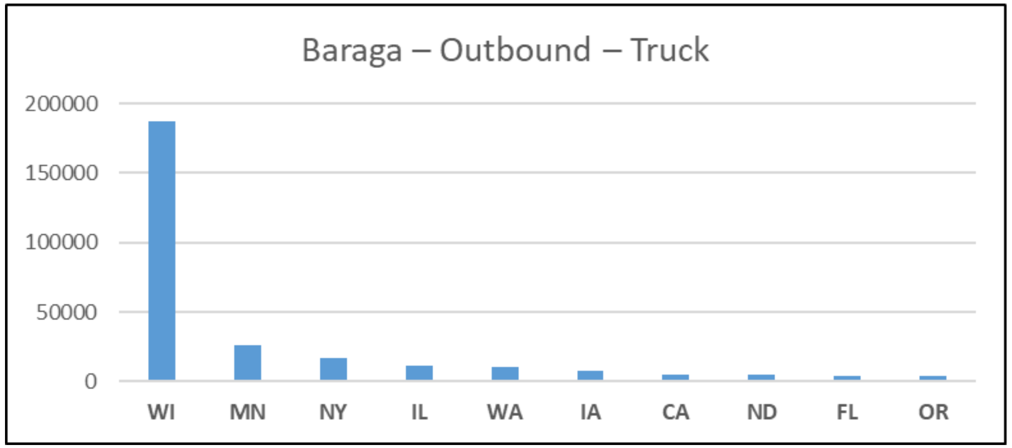
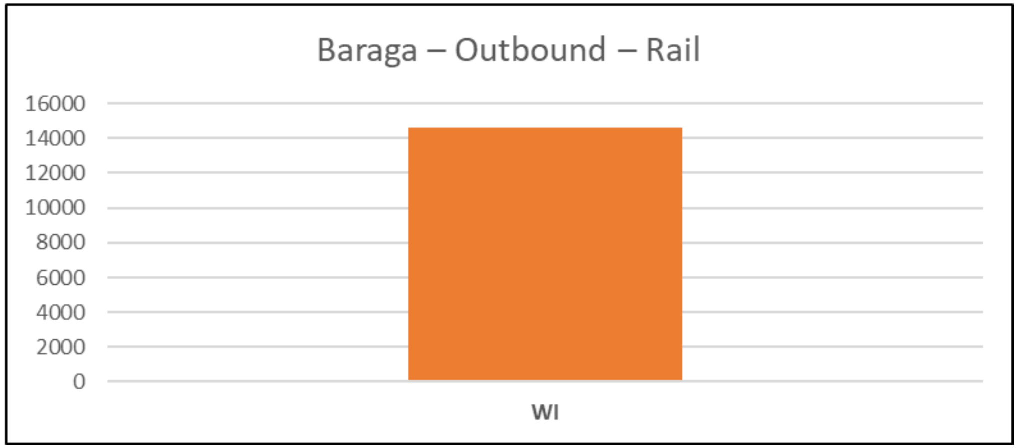
Baraga County Freight Profile (Year 2015)

Major Trading Partners by Mode – States/Provinces









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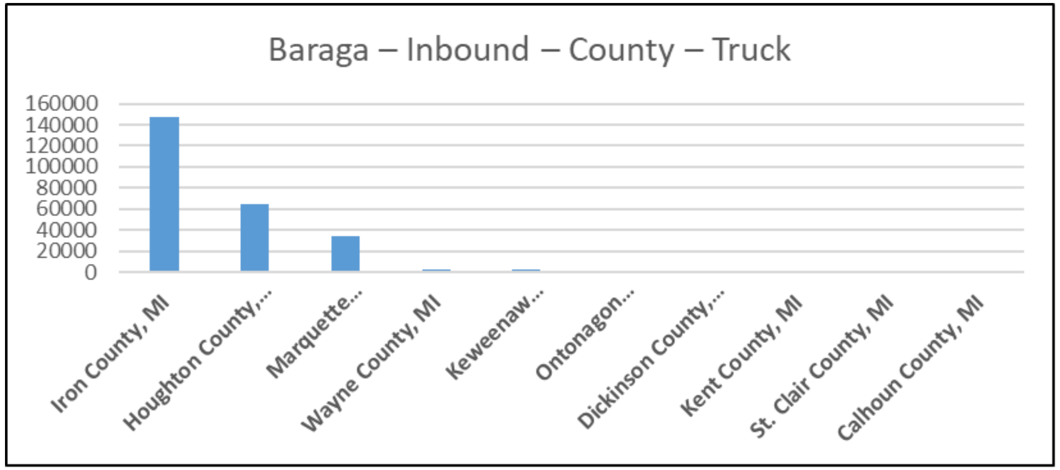
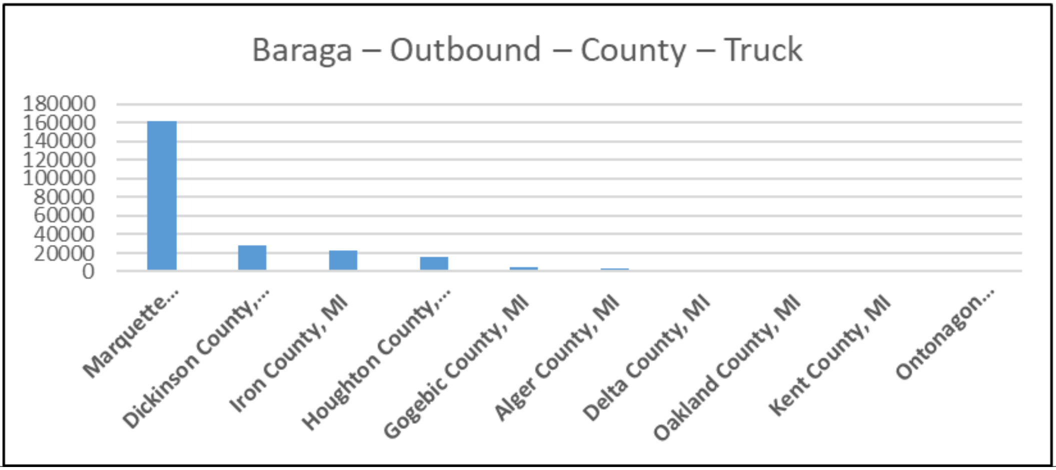
Baraga County Freight Profile (Year 2015)

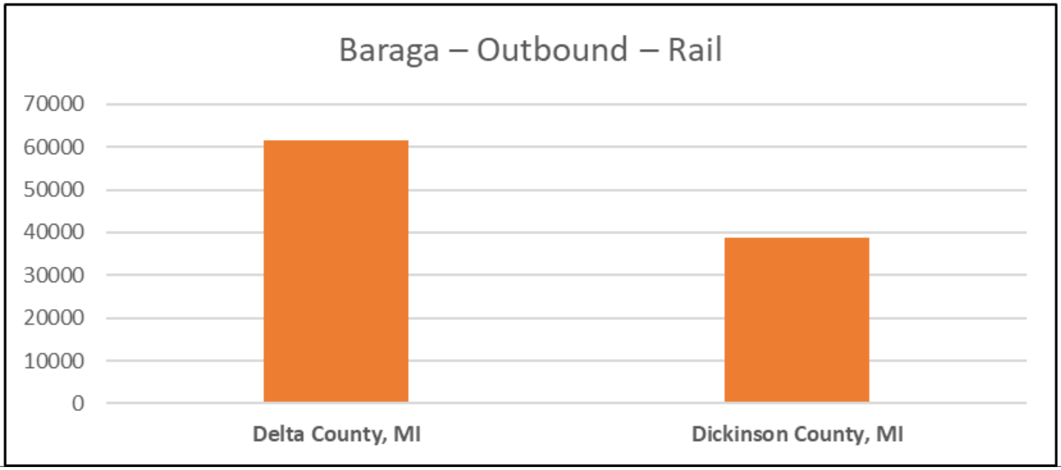
Major Trading Partners by Mode – Counties



Baraga – Inbound – Rail

None





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Chippewa County Freight Profile (Year 2015)

At a Glance	
38, 698	Population
16,880	Total Labor Force
15,623	Employed
7.4%	Unemployment

Employers (# Employed)	
Major Employers that Export	
Percision Edge Surgical Products	200
PCC Superior Fabrication	129
Hoover Percision Productions	57
R&B Electronics	51
Other Main Employers	
Bay Mills Resort	674
Lake Superior State University	500
Sault Ste. Marie Public Schools	292
U.S. Coast Guard	262
City of Sault Ste. Marie	160
Chippewa County	154
Chippewa–Luce–Mackinaw CAA	131
Hiawatha Behavioral Health	129
Cloverland Electric Co–Op	108

Industries (# of Establishments)		
Retail trade	131	18%
Accommodations and food services	110	15%
Construction	96	14%
Other services, except public administration	72	10%
Health care and social assistance	59	8.2%
Professional and technical services	43	6%
Finance and insurance	36	5%
Transportation and warehousing	28	3.9%
Administrative and waste services	26	3.6%
Wholesale trade	24	3.3%
Manufacturing	22	3%
Real estate, rental, and leasing	19	2.6%
Agriculture, forestry, fishing, and hunting	18	2.5%
Arts, entertainment, and recreation	16	2.2%
Information	10	1.4%
Utilities	5	0.7%
Mining, quarrying, oil, and gas extraction	4	0.6%
TOTAL	**719**	**100%**

Chippewa County Freight Profile (Year 2015)

Major Commodities in Chippewa County by Mode

Internal

Truck		Rail
Nonmetallic Ores and Minerals	147,838	None
Waste or Scrap Material	29,077	
Clay, Cement, Glass or Stone Products	16,121	
Logs, Lumber, and Wood Products	13,424	
Farm Products	1,550	
Food Products	408	
Secondary Traffic	198	
Technical Instruments and Equipment	175	
Machinery	128	
Printed Matter	45	
Misc Manufacturing Products	12	
Shipping Containers	0	

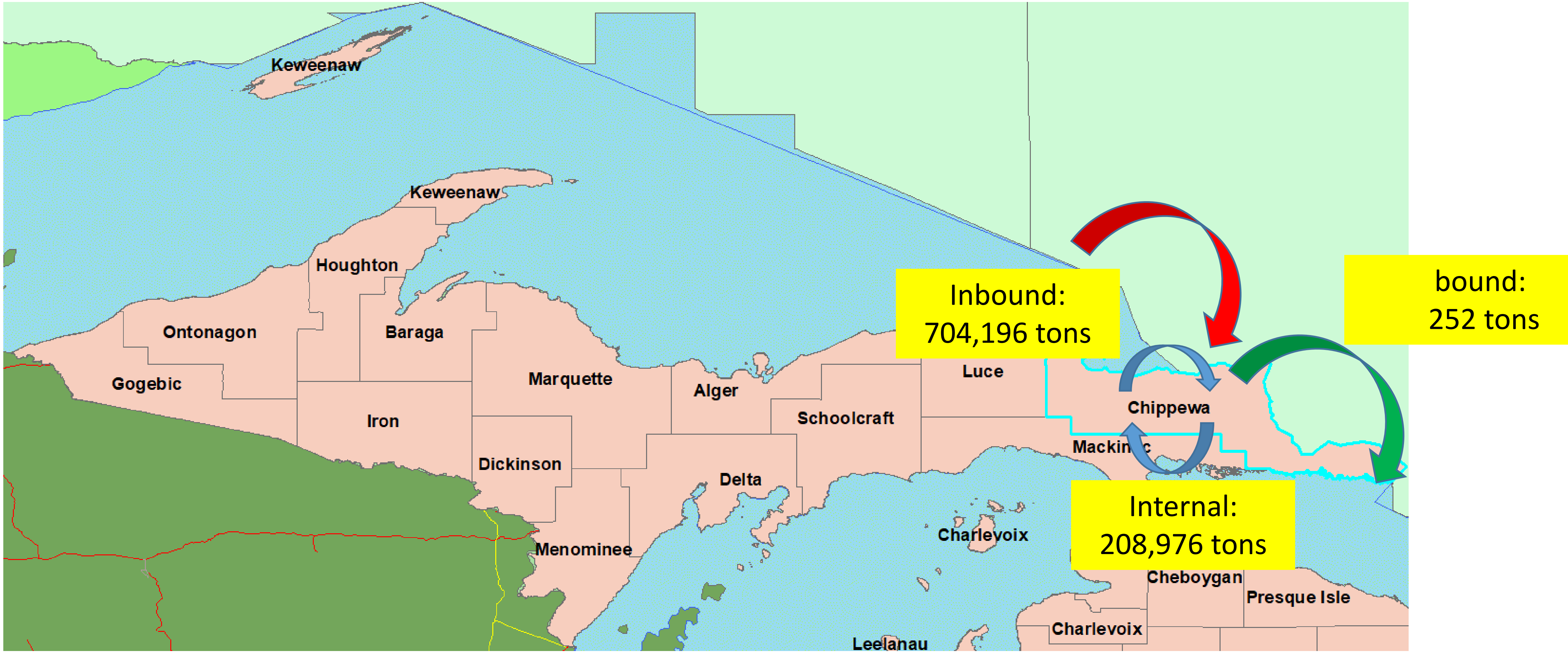
Inbound

Truck		Rail
Nonmetallic Ores and Minerals	238,700	
Logs, Lumber, and Wood Products	112,959	
Clay, Cement, Glass or Stone Products	73,571	
Waste or Scrap Material	59,285	
Secondary Traffic	50,283	
Food Products	32,462	
Petroleum or Coal Products	32,307	36,280
Chemical Products	18,430	
Farm Products	9,747	
Primary Metal Products	8,533	
Printed Matter	6,910	
Machinery	6,761	
Transportation Equipment	6,129	
Paper and Pulp Products	3,913	
Electrical Equipment	2,537	
Technical Instruments and Equipment	1,983	
Misc Manufacturing Products	1,008	
Furniture Products	694	
Miscellaneous or Mixed Shipments	671	
Rubber and Plastics	435	
Tobacco Products	251	
Fresh Fish	126	
Textile Mill Products	125	
Ordnance	52	
Apparel or Finished Textiles	32	
Fabricated Metal Products	7	
Misc Freight Shipments	5	
Shipping Containers	0	

Outbound

Truck		Rail
Nonmetallic Ores and Minerals	532,675	
Waste or Scrap Material	122,676	
Logs, Lumber, and Wood Products	117,123	45,880
Farm Products	54,597	
Clay, Cement, Glass or Stone Products	45,300	
Machinery	11,520	
Primary Metal Products	7,482	
Food Products	3,660	
Technical Instruments and Equipment	3,560	
Paper and Pulp Products	3,077	
Fabricated Metal Products	1,102	
Chemical Products	681	
Rubber and Plastics	501	
Furniture Products	465	
Transportation Equipment	443	
Misc Manufacturing Products	420	
Secondary Traffic	416	
Printed Matter	409	
Apparel or Finished Textiles	100	
Electrical Equipment	67	
Petroleum or Coal Products	56	
Metallic Ores	42	
Shipping Containers	0	

Chippewa County Freight Profile (Year 2015)



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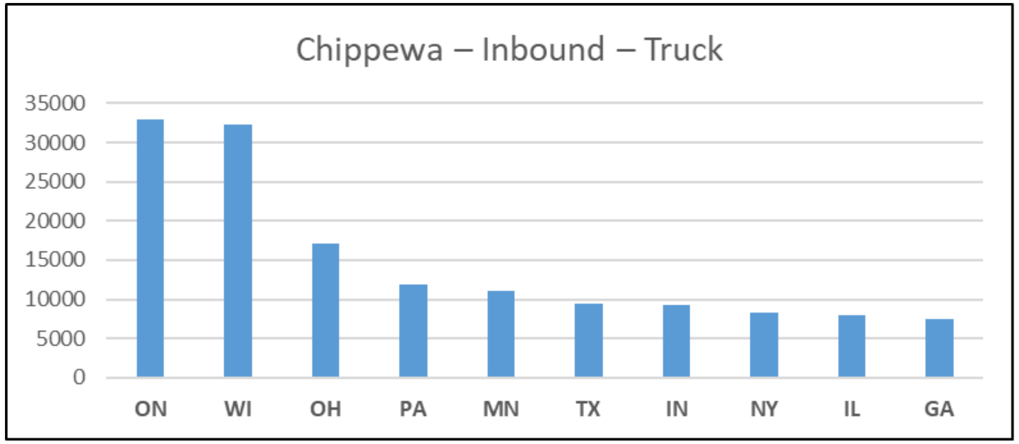
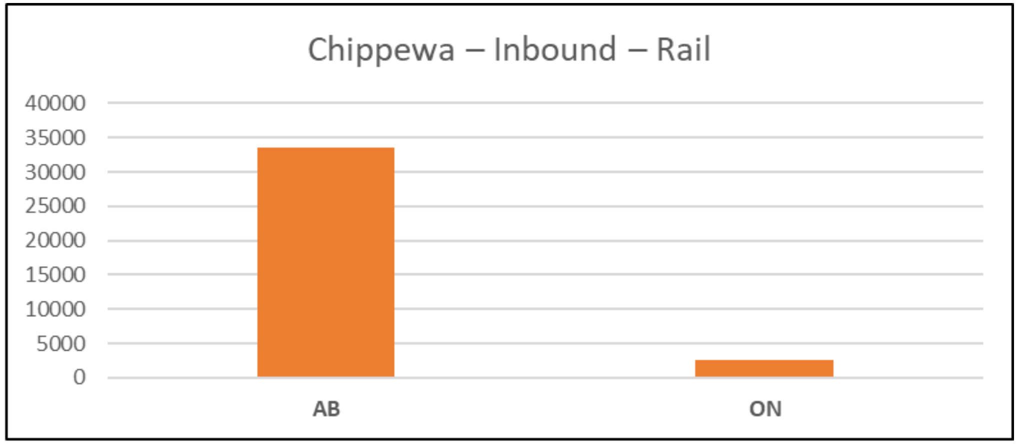
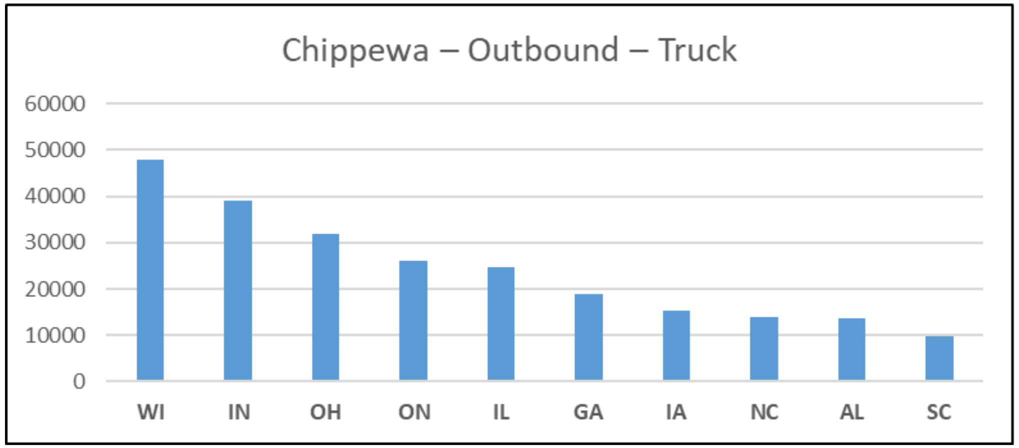
Chippewa County Freight Profile (Year 2015)

Major Trading Partners by Mode – States/Provinces







Chippewa – Outbound – Rail

None

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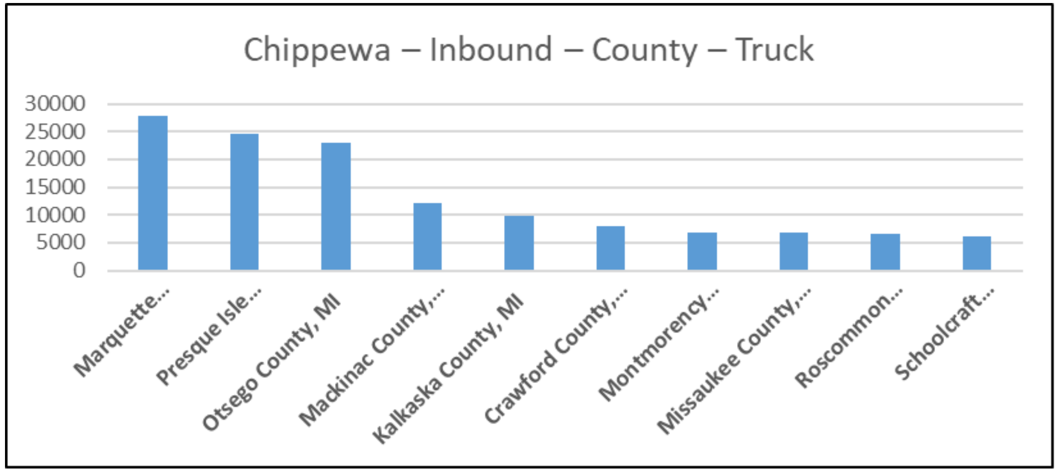
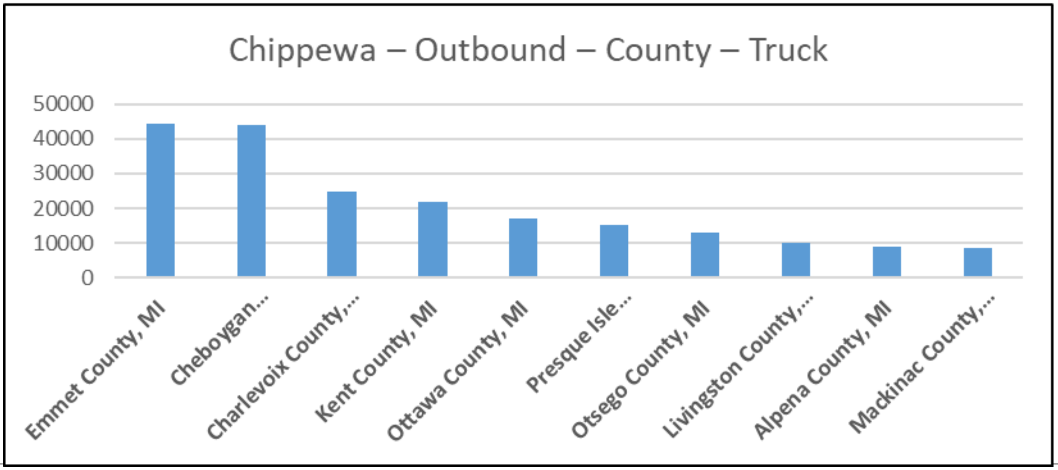
Chippewa County Freight Profile (Year 2015)

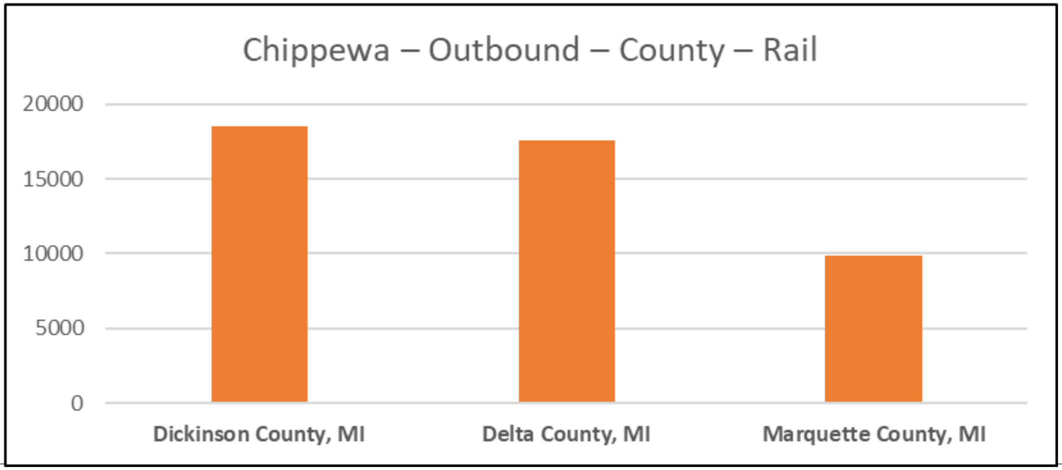
Major Trading Partners by Mode – Counties



Chippewa – Inbound – County – Rail

None





Delta County Freight Profile (Year 2015)

At a Glance	
36,841	Population
17,336	Total Labor Force
16,213	Employed
6.5%	Unemployment

Employers (# Employed)	
Major Employers that Export	
Verso	881
Engineered Machine Products	325
Andex Industries	86
VanAire	75
Pisces	21
Delta Manufacturing	21
Other Main Employers	
Hannahville Indian Community	1,084
OSF St. Francis Hospital and Medical	669
Wal–Mart	381
Escanaba Area Schools	370
Bay de Noc Community College	260
Bishop Noa Nursing Home	158
Elmer's County Market	153

Industries (# of Establishments)		
Retail trade	148	15%
Other services, except public administration	117	12%
Construction	117	12%
Accommodations and food services	91	9.3%
Health care and social assistance	80	8.1%
Manufacturing	64	6.5%
Professional and technical services	63	6.4%
Transportation and warehousing	61	6.2%
Administrative and waste services	46	4.7%
Finance and insurance	44	4.4%
Wholesale trade	39	4%
Agriculture, forestry, fishing, and hunting	32	3.3%
Real estate, rental, and leasing	25	2.5%
Arts, entertainment, and recreation	21	2.1%
Educational services	19	1.9%
Utilities	8	0.8%
Information	6	0.6%
Management of companies and enterprises	1	0.1%
Mining, quarrying, oil and gas extraction	1	0.1%
TOTAL	**983**	**100%**

Delta County Freight Profile (Year 2015)

Major Commodities in Delta County by Mode

Internal

Truck		Rail
Logs, Lumber, and Wood Products	43,529	
Nonmetallic Ores and Minerals	27,823	
Clay, Cement, Glass or Stone Products	14,097	
Farm Products	1,456	
Machinery	891	
Food Products	457	
Misc Manufacturing Products	266	
Paper and Pulp Products	220	23,840
Secondary Traffic	178	
Transportation Equipment	131	
Furniture Products	56	
Rubber and Plastics	46	
Printed Matter	25	
Technical Instruments and Equipment	17	
Shipping Containers	0	

Inbound

Truck		Rail
Metallic Ores		4,396,354
Logs, Lumber, and Wood Products	263,002	94,400
Nonmetallic Ores and Minerals	246,984	
Paper and Pulp Products	86,239	34,200
Chemical Products	67,181	96,040
Secondary Traffic	61,599	
Clay, Cement, Glass or Stone Products	53,826	332,560
Primary Metal Products	27,461	7,920
Farm Products	23,776	
Food Products	23,060	22,040
Transportation Equipment	18,270	
Petroleum or Coal Products	16,413	2,600
Electrical Equipment	8,258	
Fabricated Metal Products	7,875	
Machinery	7,161	
Rubber and Plastics	6,682	
Forest Products	4,571	
Textile Mill Products	3,749	
Printed Matter	2,574	
Furniture Products	2,323	
Waste or Scrap Material	1,490	
Misc Manufacturing Products	1,408	
Miscellaneous or Mixed Shipments	1,086	
Technical Instruments and Equipment	181	
Apparel or Finished Textiles	120	
Tobacco Products	94	
Leather Products	41	
Fresh Fish	8	
Ordnance	5	
Shipping Containers	0	

Outbound

Truck		Rail
Nonmetallic Ores and Minerals	257,289	425,536
Logs, Lumber, and Wood Products	113,518	18,080
Clay, Cement, Glass or Stone Products	102,619	4,000
Secondary Traffic	62,876	
Farm Products	59,003	
Paper and Pulp Products	40,790	552,280
Machinery	23,477	
Waste or Scrap Material	20,883	3,600
Food Products	10,742	
Primary Metal Products	9,468	
Rubber and Plastics	5,339	
Transportation Equipment	4,751	3,600
Misc Manufacturing Products	3,182	
Fabricated Metal Products	1,636	
Furniture Products	1,099	
Printed Matter	1,092	
Technical Instruments and Equipment	73	
Apparel or Finished Textiles	35	
Shipping Containers	0	

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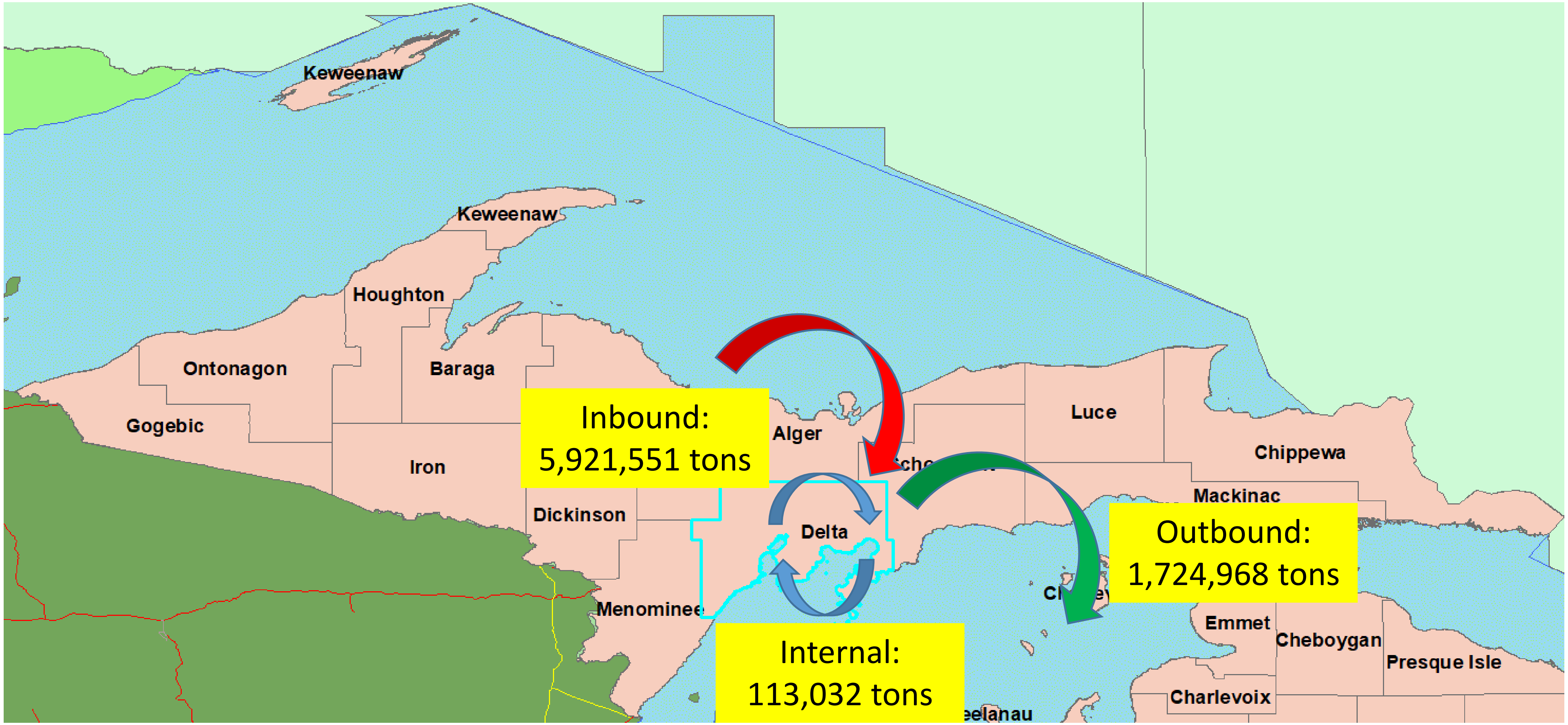
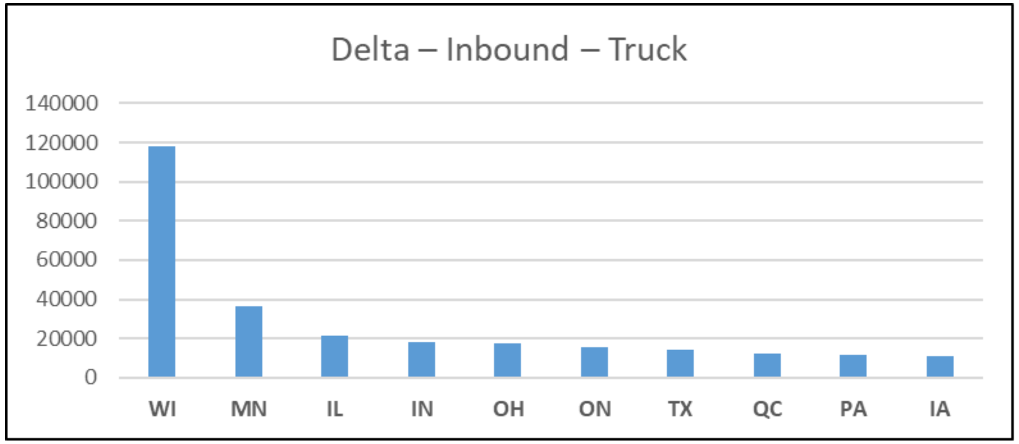
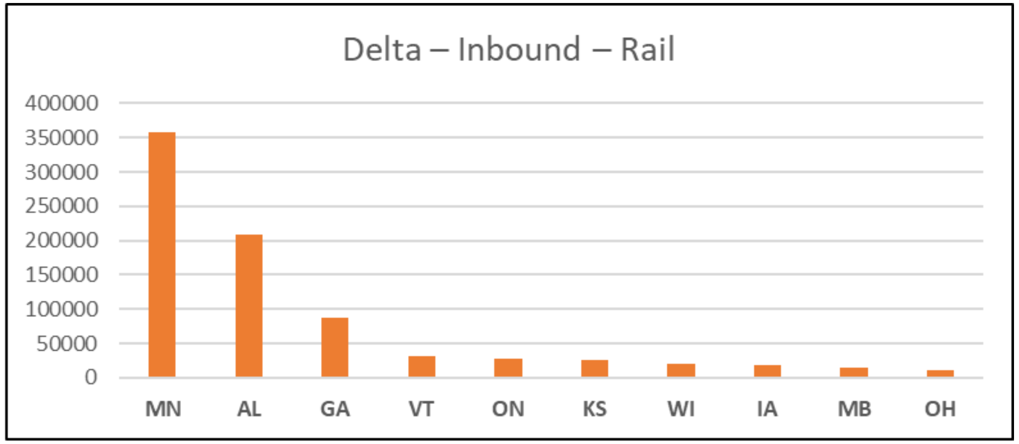
Delta County Freight Profile (Year 2015)

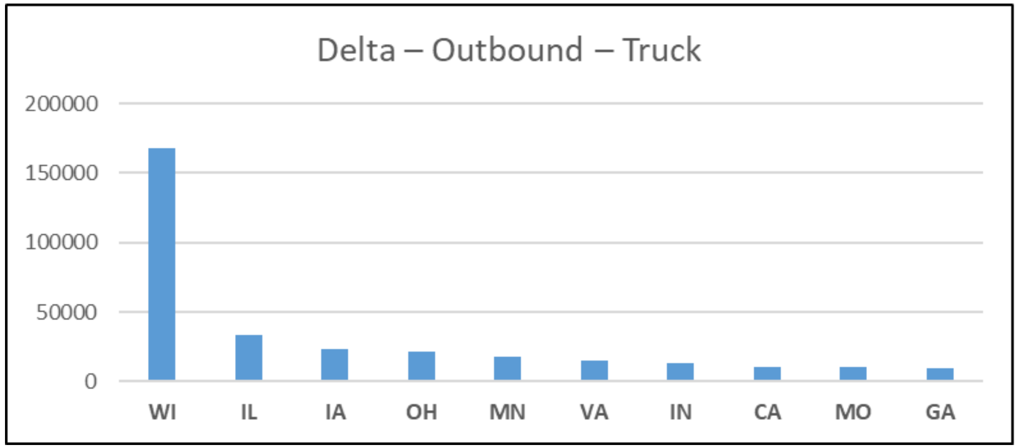


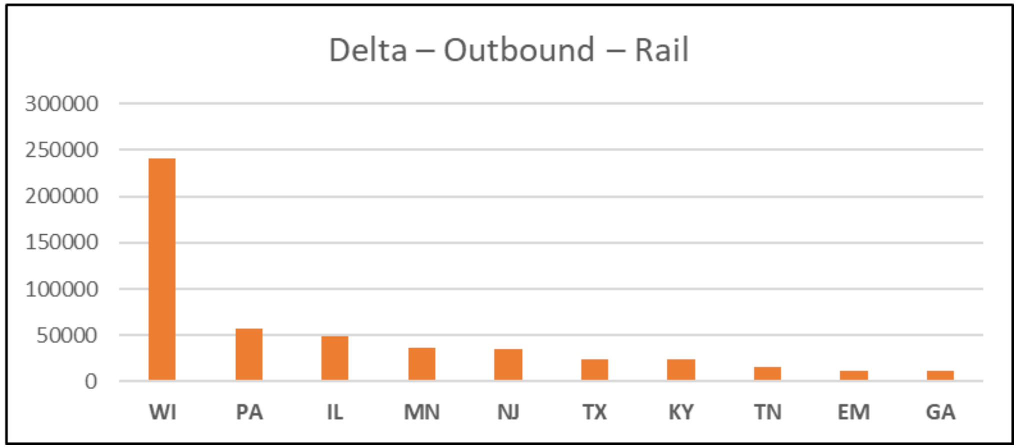
Delta County Freight Profile (Year 2015)

Major Trading Partners by Mode – States/Provinces









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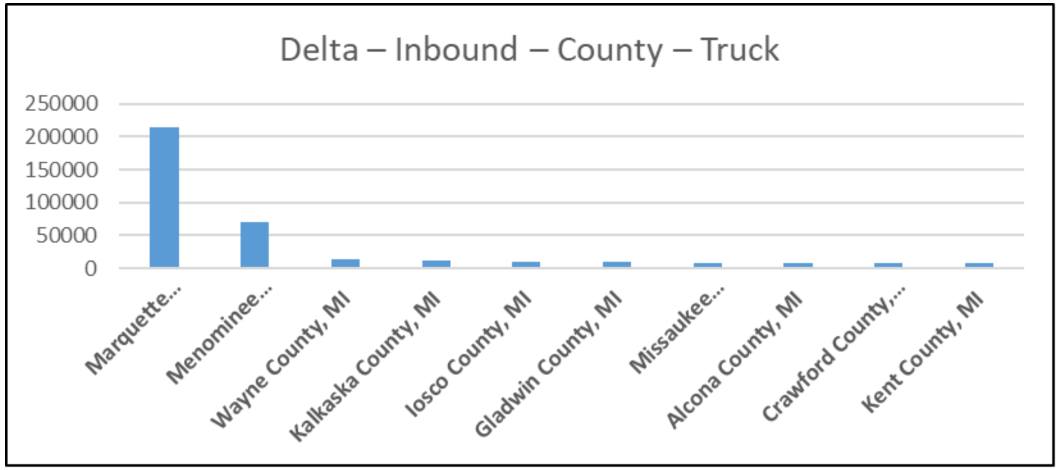
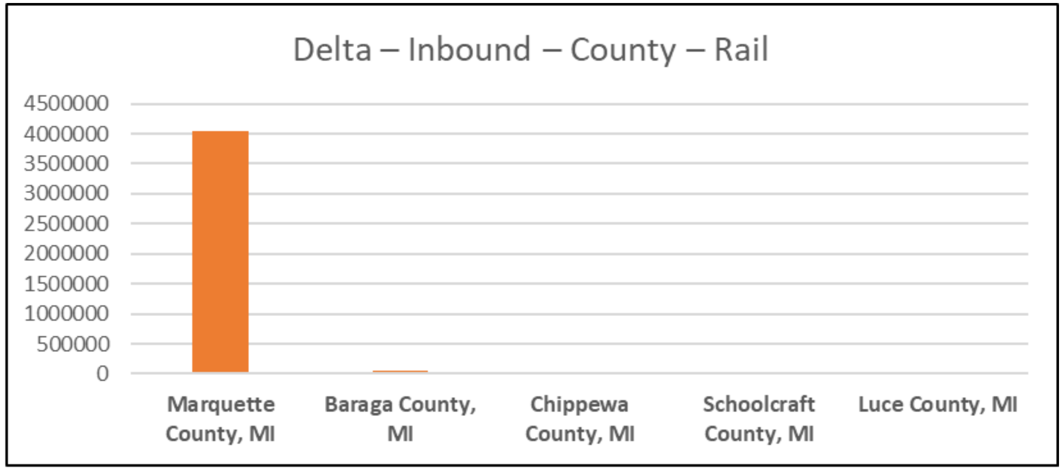
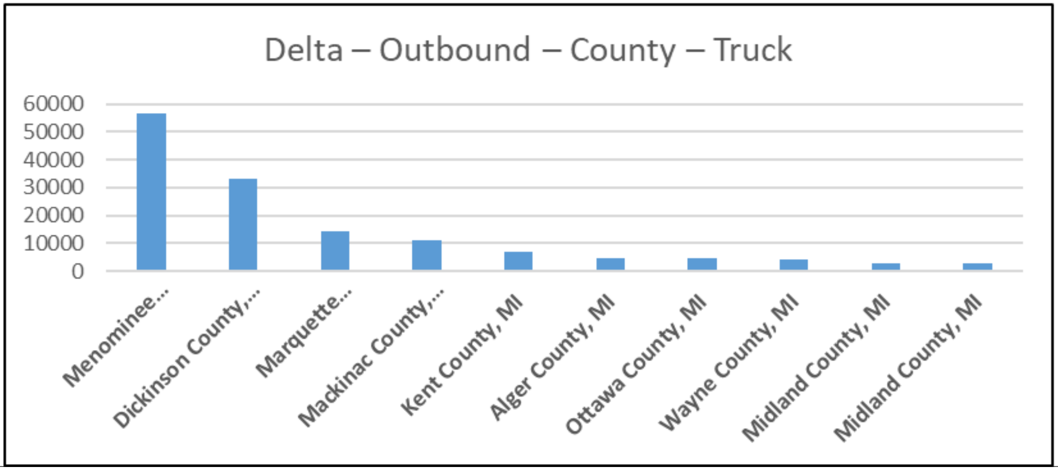
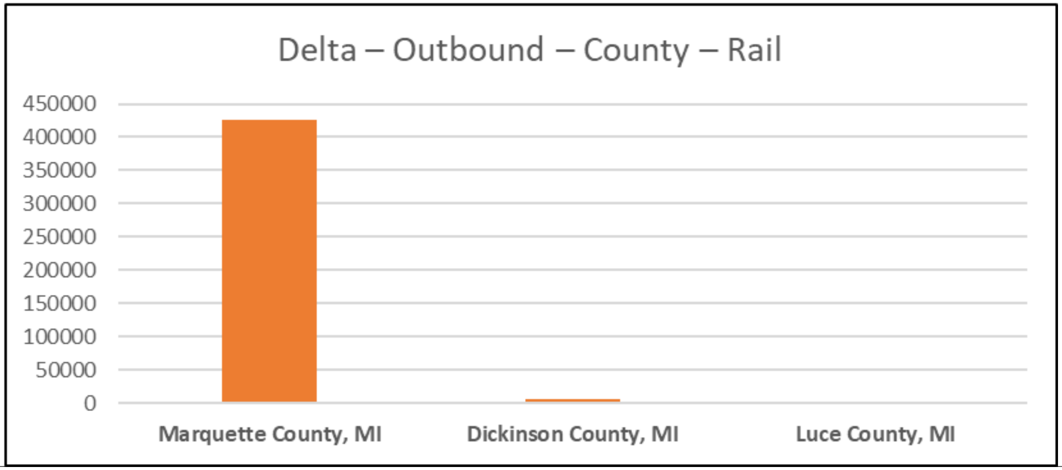
Delta County Freight Profile (Year 2015)

Major Trading Partners by Mode – Counties

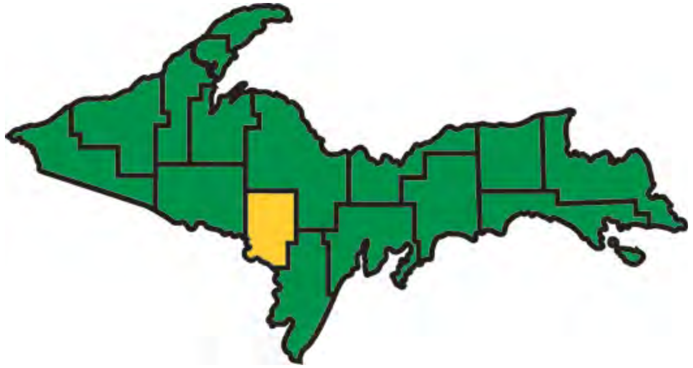








Dickinson County Freight Profile (Year 2015)



At a Glance	
26,097	Population
12,082	Total Labor Force
12,114	Employed
5.4%	Unemployment

Employers (# Employed)	
Major Employers that Export	
Verso	483
Northern Star Industries	474
Grede Foundries	383
MU Electric	277
Champion, Inc.	212
LP Corporation	152
Oldenburg Group, Inc.	77
Other Main Employers	
Dickinson Health Care System	912
Department of Veterans Affairs Hospital	686
CCI Systems, Inc.	306
Breitung Township Schools	177
US Special Delivery	87
Iron Mountain Schools	86

Industries (# of Establishments)		
Retail trade	125	16%
Health care and social assistance	104	13%
Construction	91	11%
Other services, except public administration	77	10%
Accommodations and food service	75	10%
Professional and technical service	58	7.2%
Wholesale trade	49	6.1%
Manufacturing	43	5.4%
Finance and insurance	36	4.5%
Transportation and warehousing	34	3.2%
Administrative and waste services	27	3.4%
Real estate and rental and leasing	26	3.2%
Agriculture, forestry, fishing and hunting	20	2.5%
Arts, entertainment, and recreation	13	1.6%
Educational services	10	1.2%
Information	10	1.2%
Utilities	4	0.5%
Management of companies and enterprises	1	0.1%
TOTAL	**803**	**100%**

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Dickinson County Freight Profile (Year 2015)

Major Commodities in Dickinson County by Mode

Internal

Truck		Rail
Clay, Cement, Glass or Stone Products	18,653	None
Transportation Equipment	8,345	
Logs, Lumber, and Wood Products	4,552	
Machinery	2,059	
Primary Metal Products	967	
Fabricated Metal Products	464	
Food Products	384	
Chemical Products	283	
Secondary Traffic	244	
Printed Matter	150	
Misc Manufacturing Products	75	
Electrical Equipment	2	
Shipping Containers	0	

Inbound

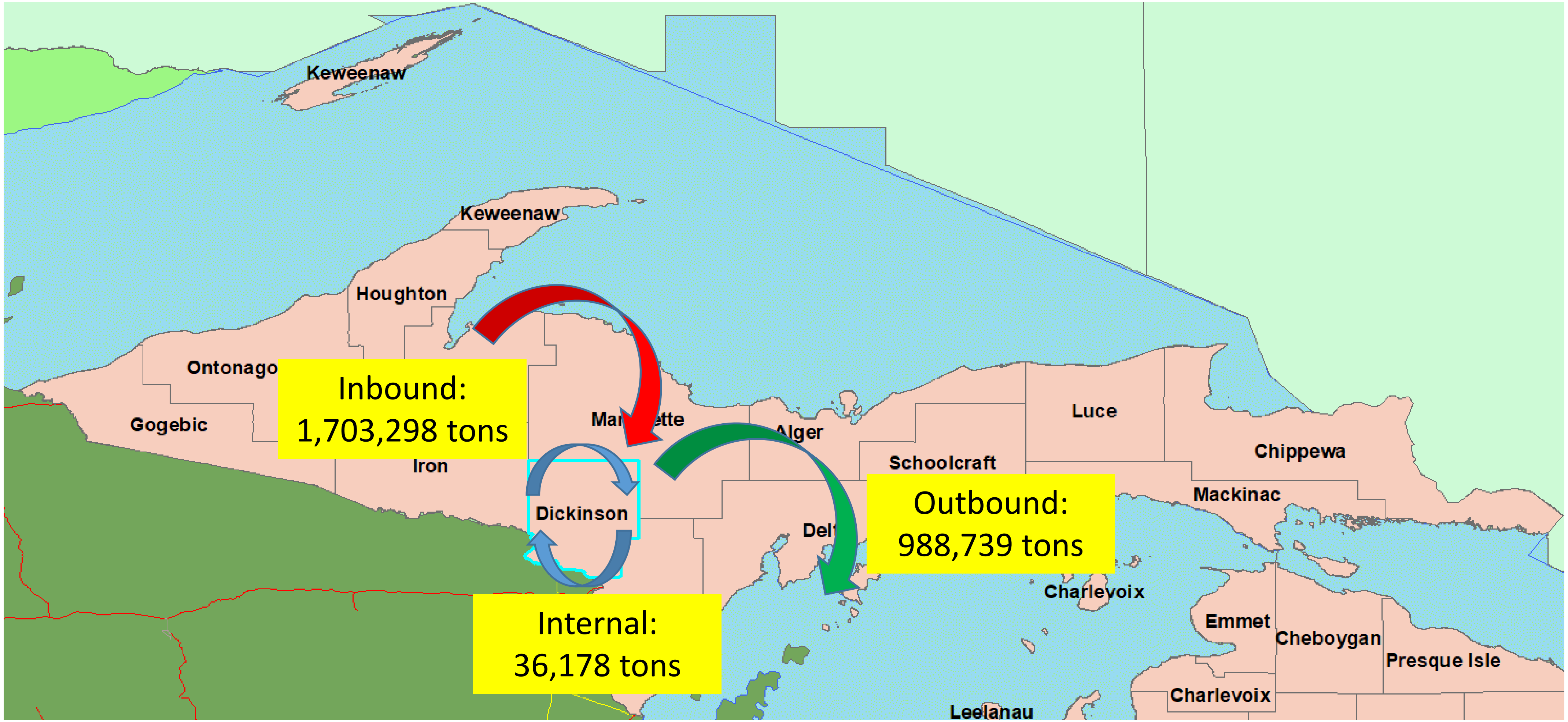
Truck		Rail
Nonmetallic Ores and Minerals	319,405	
Clay, Cement, Glass or Stone Products	122,918	152,640
Transportation Equipment	98,725	
Primary Metal Products	74,885	
Secondary Traffic	73,269	
Petroleum or Coal Products	69,104	
Fabricated Metal Products	56,270	
Logs, Lumber, and Wood Products	45,815	410,960
Chemical Products	40,260	75,080
Machinery	22,851	
Rubber and Plastics	21,219	
Food Products	16,171	10,760
Electrical Equipment	8,466	
Paper and Pulp Products	8,134	63,600
Farm Products	5,724	
Forest Products	1,628	
Furniture Products	1,565	
Printed Matter	1,400	
Miscellaneous or Mixed Shipments	1,093	
Misc Manufacturing Products	497	
Technical Instruments and Equipment	421	
Apparel or Finished Textiles	147	
Tobacco Products	134	
Textile Mill Products	116	
Leather Products	35	
Ordnance	6	
Shipping Containers	0	

Outbound

Truck		Rail
Logs, Lumber, and Wood Products	186,385	142,600
Metallic Ores		7,720
Machinery	64,452	
Waste or Scrap Material	39,054	7,440
Primary Metal Products	36,972	
Clay, Cement, Glass or Stone Products	26,835	
Transportation Equipment	25,038	
Food Products	10,399	
Farm Products	9,886	
Printed Matter	8,824	
Paper and Pulp Products	8,145	401,480
Chemical Products	7,469	
Fabricated Metal Products	3,594	
Misc Manufacturing Products	1,363	
Secondary Traffic	1,019	
Electrical Equipment	34	
Textile Mill Products	21	
Apparel or Finished Textiles	9	
Shipping Containers	0	

Michigan Tech

Dickinson County Freight Profile (Year 2015)



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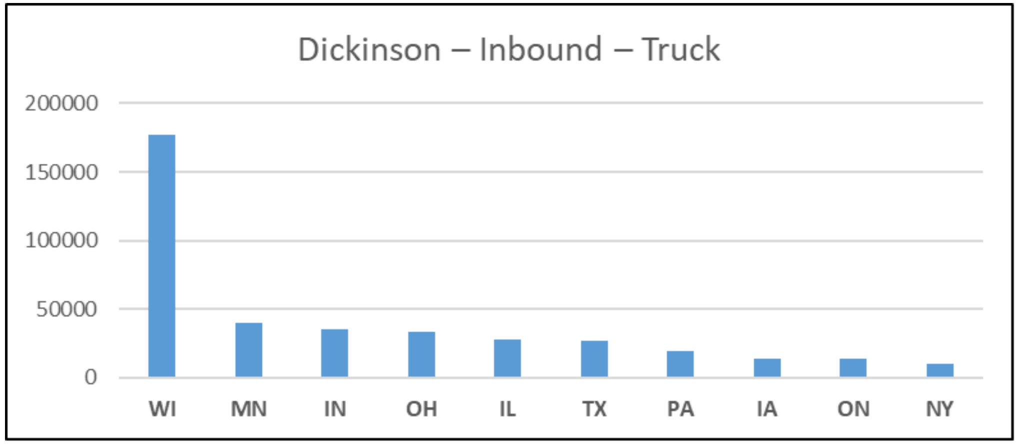
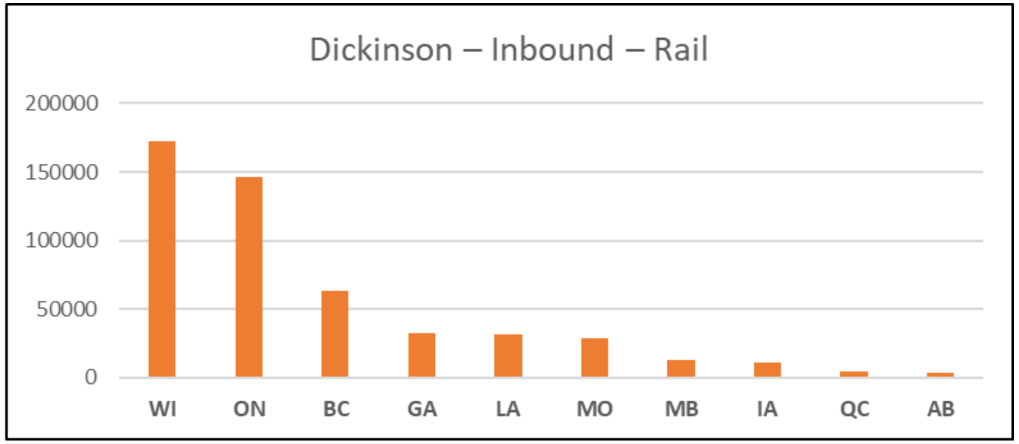
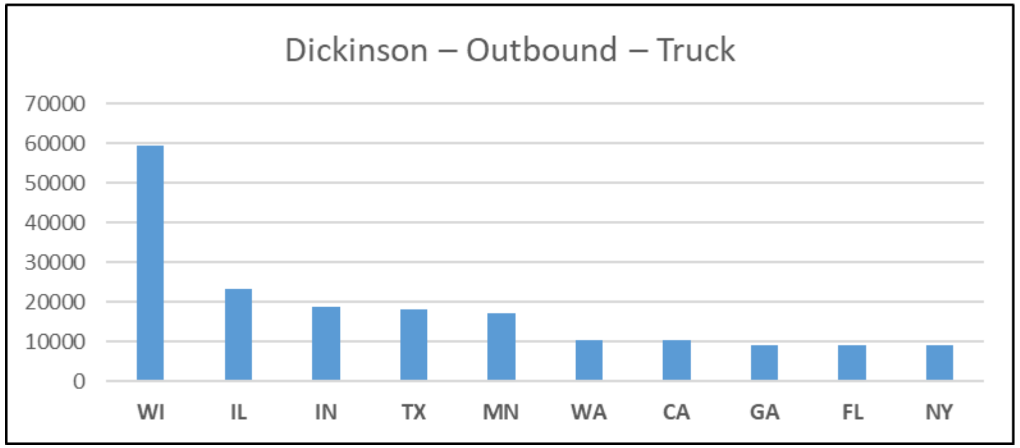
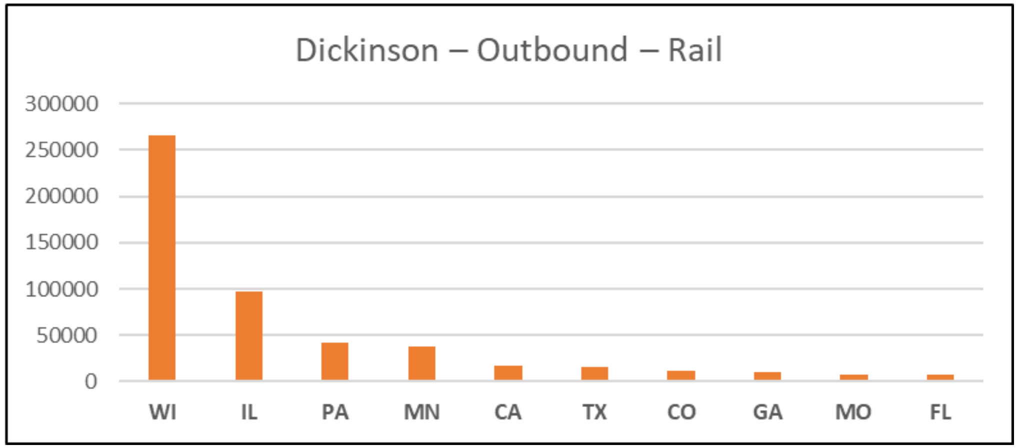
Dickinson County Freight Profile (Year 2015)

Major Trading Partners by Mode – States/Provinces









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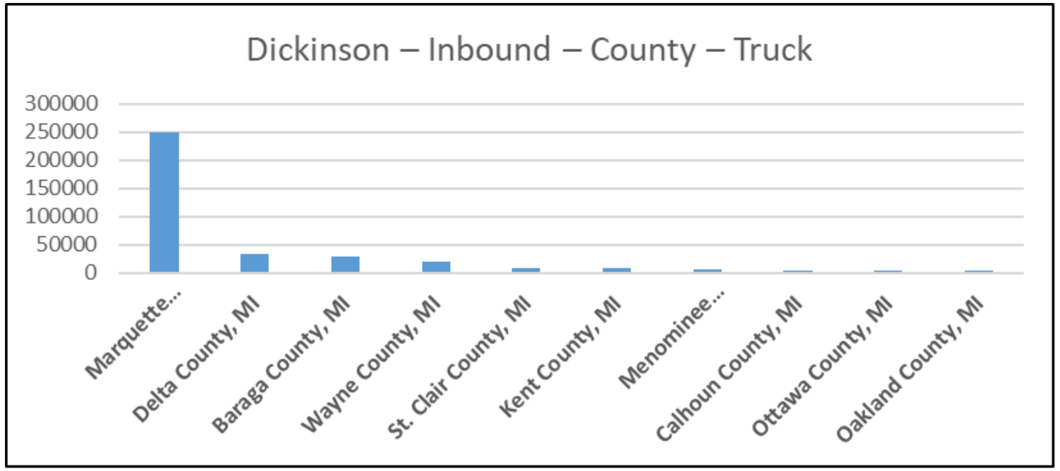
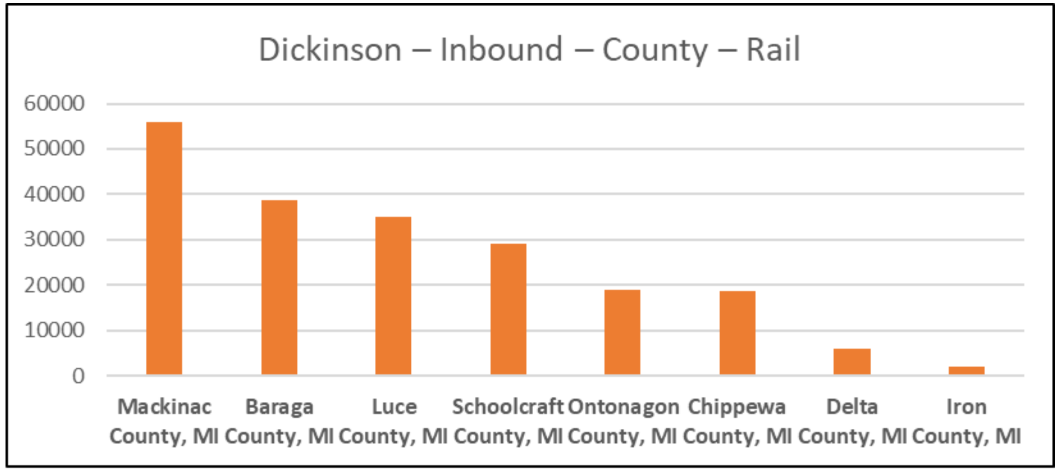
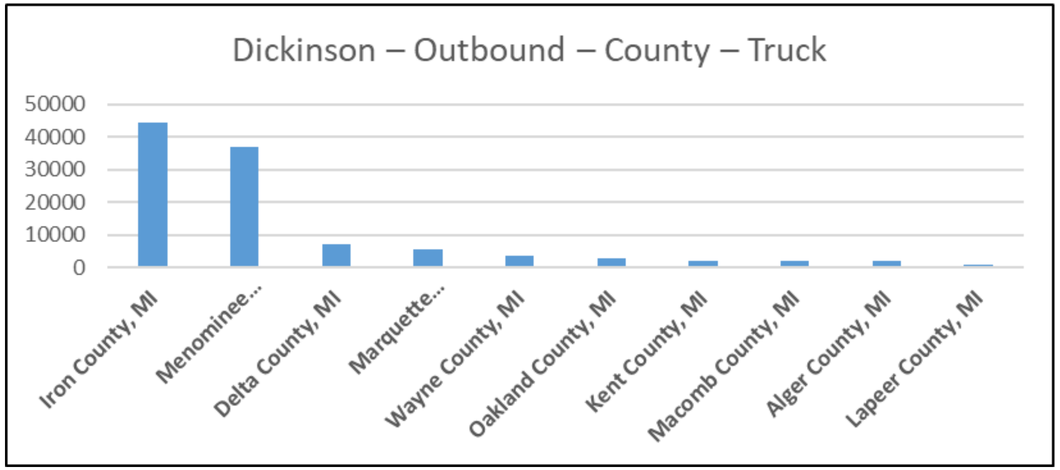
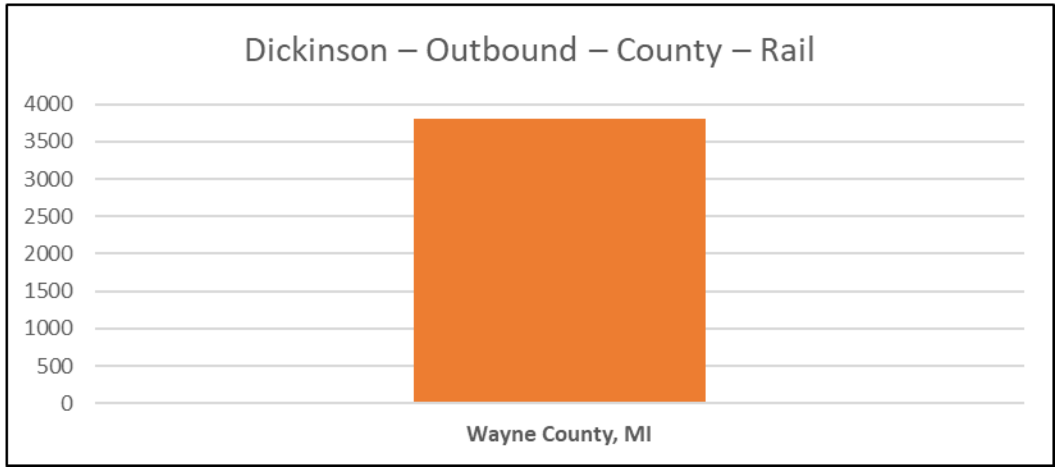
Dickinson County Freight Profile (Year 2015)

Major Trading Partners by Mode – Counties



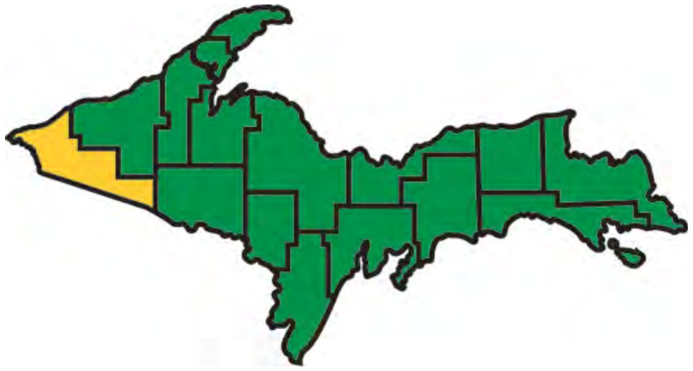






Michigan Tech

Gogebic County Freight Profile (Year 2015)



At a Glance	
16,042	Population
6,625	Total Labor Force
6,164	Employed
7.00%	Unemployment

Employers (# Employed)	
Major Employers that Export	
Jacquart Fabric Products	122
Ironwood Plastics, Inc.	112
Extreme Tool and Engineering	89
Other Main Employers	
Grand View Health System, Inc.	336
Lac Vieux Desert	260
Indianhead Mountain Resort	118
Big Powderhorn Ski Report	115
Ironwood Area Schools	83
Gogebic Community College	82
City of Ironwood	38
Gogebic County Road Commission	30

Industries (# of Establishments)		
Retail Trade	61	16%
Other services, except public administration	47	12%
Accommodations and food services	46	12%
Construction	37	10%
Health care and social assistance	26	6.8%
Professional and technical services	20	5.1%
Finance and insurance	19	4.9%
Transportation and warehousing	17	4.4%
Agriculture, forestry, fishing, and hunting	16	4.2%
Real estate and rental and leasing	15	3.9%
Wholesale trade	15	3.9%
Manufacturing	15	3.9%
Arts, entertainment, and recreation	14	3.6%
Administrative and waste services	14	3.6%
Educational Services	10	2.6%
Information	7	1.8%
Utilities	5	1.3%
TOTAL	**384**	**100%**

Gogebic County Freight Profile (Year 2015)

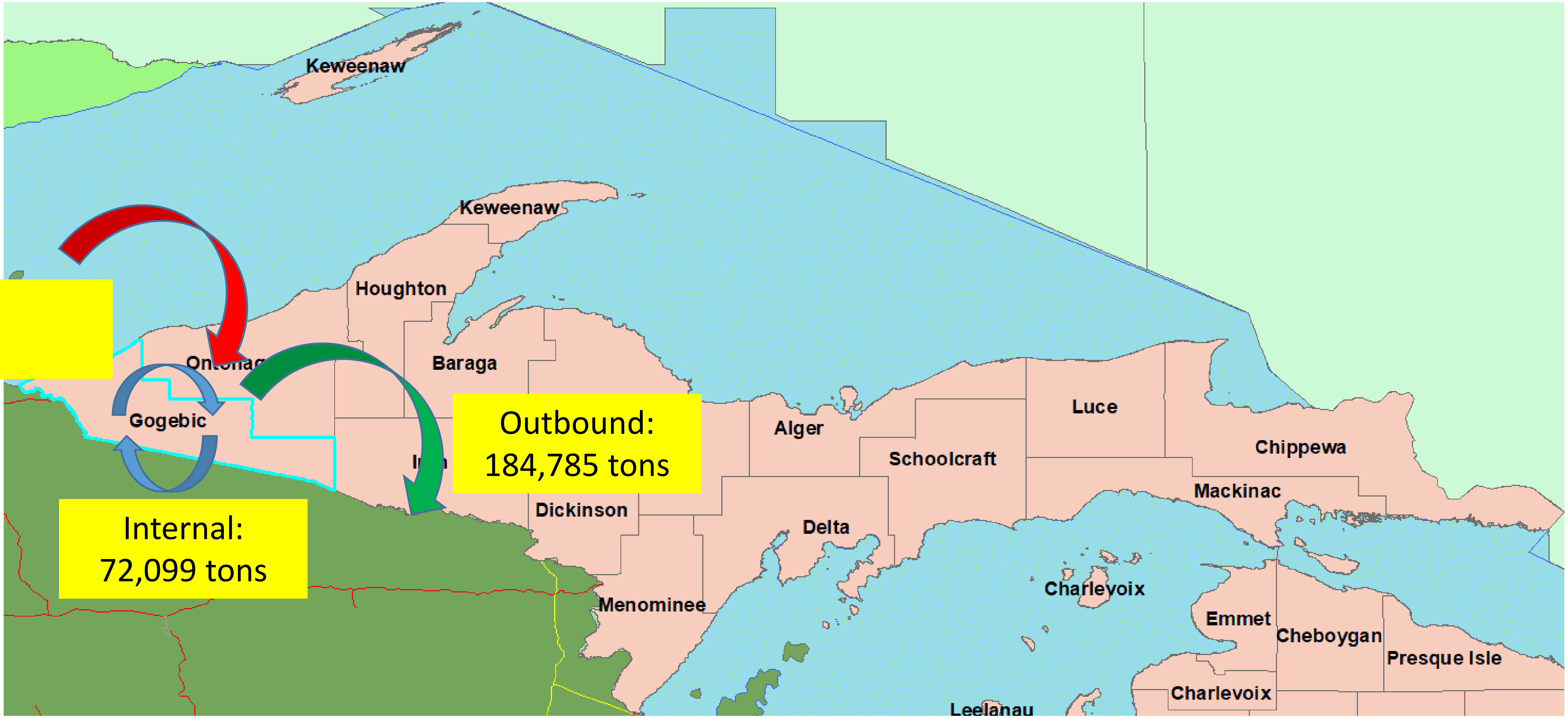
Major Commodities Gogebic County by Mode

Internal		
Truck		Rail
Logs, Lumber, and Wood Products	69,001	None
Clay, Cement, Glass or Stone Products	2,615	
Machinery	181	
Food Products	111	
Apparel or Finished Textiles	72	
Waste or Scrap Material	60	
Rubber and Plastics	37	
Electrical Equipment	22	
Shipping Containers	0	

Inbound		
Truck		Rail
Logs, Lumber, and Wood Products	112,796	None
Nonmetallic Ores and Minerals	30,694	
Secondary Traffic	20,339	
Clay, Cement, Glass or Stone Products	13,663	
Food Products	7,528	
Petroleum or Coal Products	6,842	
Farm Products	2,370	
Primary Metal Products	1,262	
Chemical Products	1,173	
Forest Products	875	
Printed Matter	803	
Paper and Pulp Products	649	
Textile Mill Products	548	
Rubber and Plastics	441	
Transportation Equipment	402	
Waste or Scrap Material	301	
Machinery	233	
Fabricated Metal Products	231	
Miscellaneous or Mixed Shipments	182	
Apparel or Finished Textiles	156	
Electrical Equipment	70	
Technical Instruments and Equipment	67	
Misc Manufacturing Products	37	
Furniture Products	14	
Leather Products	13	
Tobacco Products	9	
Shipping Containers	0	

Outbound		
Truck		Rail
Logs, Lumber, and Wood Products	133,453	None
Rubber and Plastics	13,647	
Waste or Scrap Material	12,436	
Clay, Cement, Glass or Stone Products	10,720	
Food Products	5,237	
Apparel or Finished Textiles	4,469	
Machinery	3,033	
Farm Products	873	
Electrical Equipment	540	
Fabricated Metal Products	209	
Misc Manufacturing Products	159	
Secondary Traffic	7	
Furniture Products	2	
Shipping Containers	0	

Gogebic County Freight Profile (Year 2015)



In
201

Outbound:
184,785 tons

Internal:
72,099 tons

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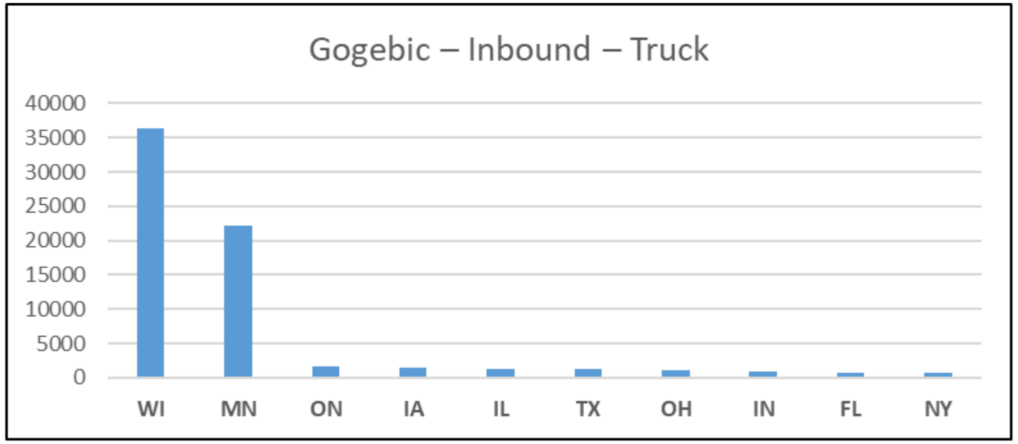
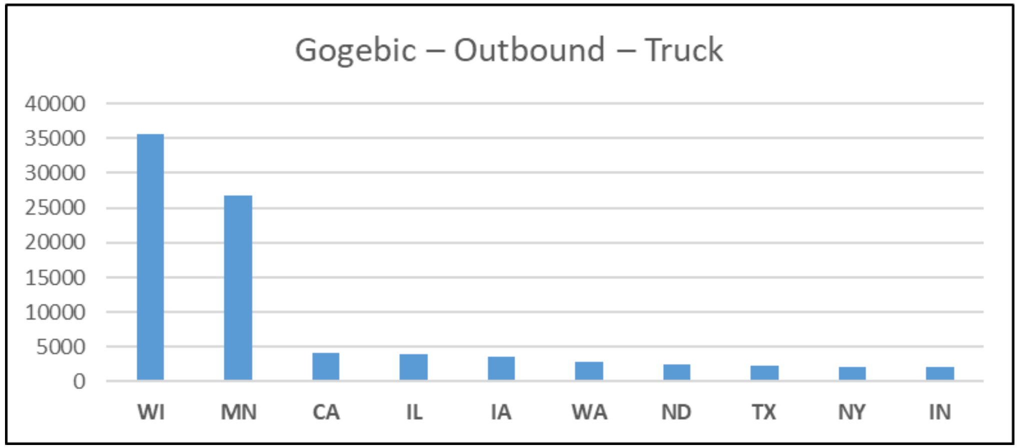
Gogebic County Freight Profile (Year 2015)

Major Trading Partners by Mode – States/Provinces



Gogebic – Inbound – Rail

None



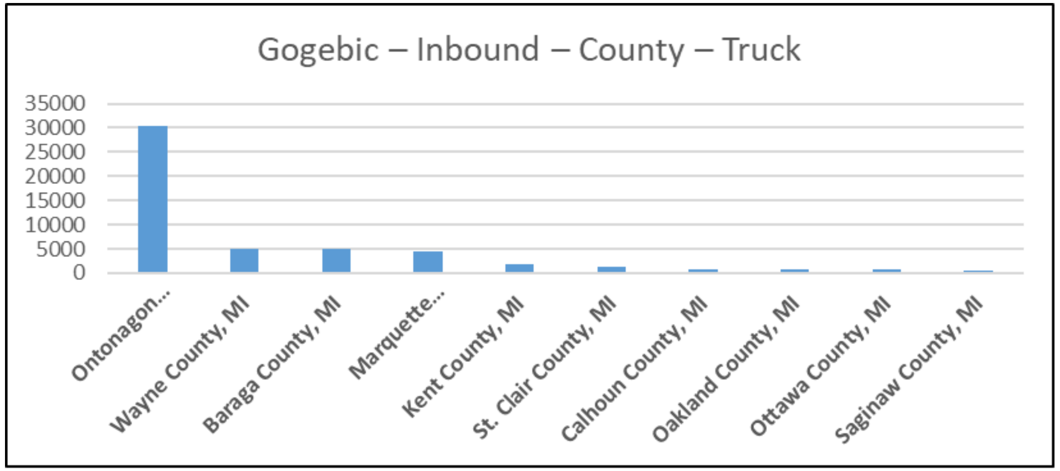
Gogebic – Outbound – Rail

None

Michigan Tech

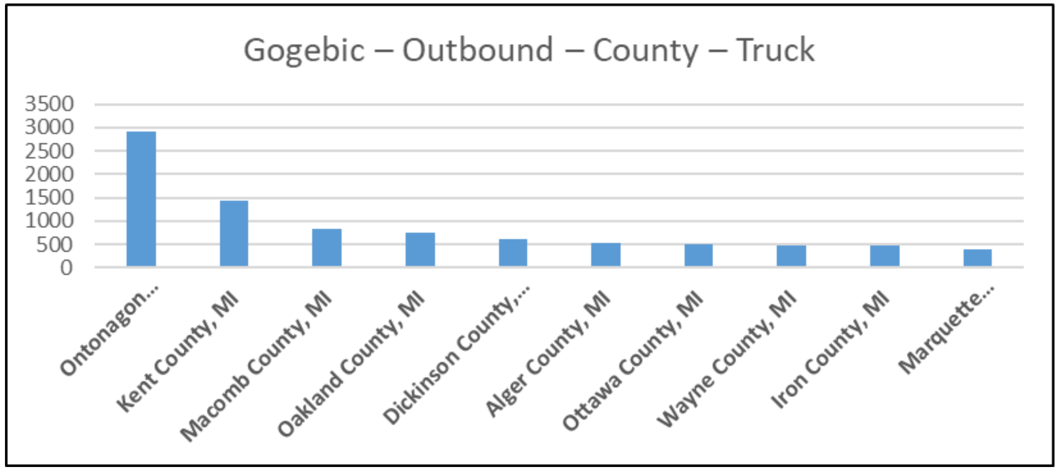
Gogebic County Freight Profile (Year 2015)

Major Trading Partners by Mode – Counties



Gogebic – Inbound – County – Rail

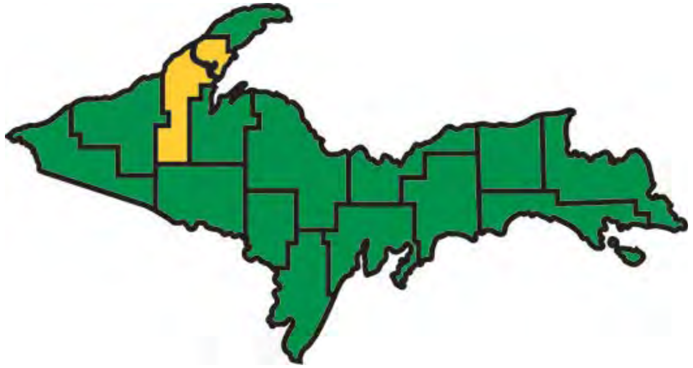
None



Gogebic – Outbound – County – Rail

None

Houghton County Freight Profile (Year 2015)



At a Glance	
36,739	Population
16,743	Total Labor Force
15,735	Employed
6.00%	Unemployment

Employers (# Employed)	
Major Employers that Export	
Calumet Electronics Corporation	190
GS Engineering	65
ThermoAnalytics	65
Anderson Welding	65
Koppers, Inc	55
Horner Flooring	45
Other Main Employers	
Michigan Tech University	1,609
Aspirus Keweenaw	431
Copper Country Mental Health	247
BHK Child Development Board	225
Walmart	150
CLK Schools	133
Houghton – Portage Township Schools	103

Industries (# of Establishments)		
Retail Trade	129	15%
Construction	118	14%
Accommodations and food services	97	11%
Other services, except public administration	93	11%
Professional and technical services	74	9%
Health care and social assistance	73	9%
Finance and insurance	45	5%
Manufacturing	38	4%
Agriculture, forestry, fishing, and hunting	33	4%
Wholesale trade	27	3%
Administrative and waste services	26	3%
Real estate and rental and leasing	25	3%
Educational Services	23	3%
Transportation and warehousing	22	3%
Arts, entertainment, and recreation	16	2%
Information	8	1%
Utilities	5	1%
Mining, Quarrying, and Oil and Gas Extraction	2	0%
TOTAL	**854**	**100%**

Michigan Tech

Houghton County Freight Profile (Year 2015)

Major Commodities Houghton County by Mode

Internal

Truck		Rail
Logs, Lumber, and Wood Products	82,244	None
Clay, Cement, Glass or Stone Products	12,905	
Food Products	788	
Farm Products	262	
Electrical Equipment	185	
Secondary Traffic	175	
Fabricated Metal Products	168	
Machinery	73	
Chemical Products	34	
Shipping Containers	0	

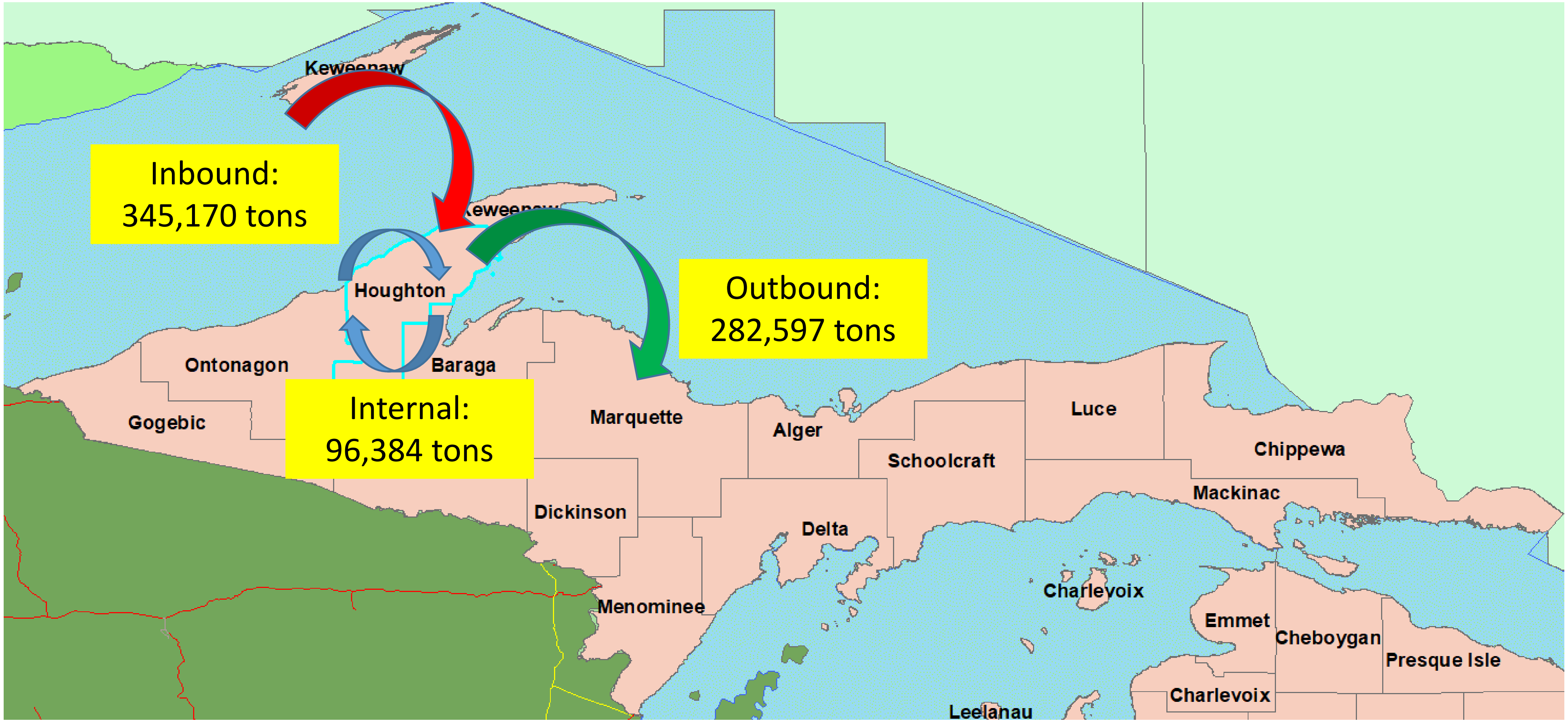
Inbound

Truck		Rail
Logs, Lumber, and Wood Products	101,776	None
Nonmetallic Ores and Minerals	80,432	
Secondary Traffic	46,407	
Clay, Cement, Glass, or Stone Products	37,008	
Food Products	19,987	
Petroleum or Coal Products	16,702	
Farm Products	12,845	
Transportation Equipment	7,683	
Chemical Products	5,025	
Primary Metal Products	3,704	
Machinery	3,480	
Electrical Equipment	2,341	
Furniture Products	1,371	
Fabricated Metal Products	1,296	
Printed Matter	1,071	
Forest Products	1,011	
Paper and Pulp Products	885	
Rubber and Plastics	464	
Miscellaneous or Mixed Shipments	399	
Technical Instruments and Equipment	358	
Miscellaneous Manufacturing Products	321	
Apparel or Finished Textiles	236	
Tobacco Products	171	
Textile Mill Products	155	
Leather Products	24	
Fresh Fish	18	
Shipping Containers	0	

Outbound

Truck		Rail
Logs, Lumber, and Wood Products	187,296	
Metallic Ores		7,880
Clay, Cement, Glass or Stone Products	19,314	
Food Products	18,743	
Waste or Scrap Material	17,874	
Farm Products	9,271	
Electrical Equipment	8,795	
Fabricated Metal Products	6,370	
Machinery	3,459	
Chemical Products	1,823	
Secondary Traffic	749	
Rubber and Plastics	635	
Printed Matter	314	
Transportation Equipment	74	
Shipping Containers	0	

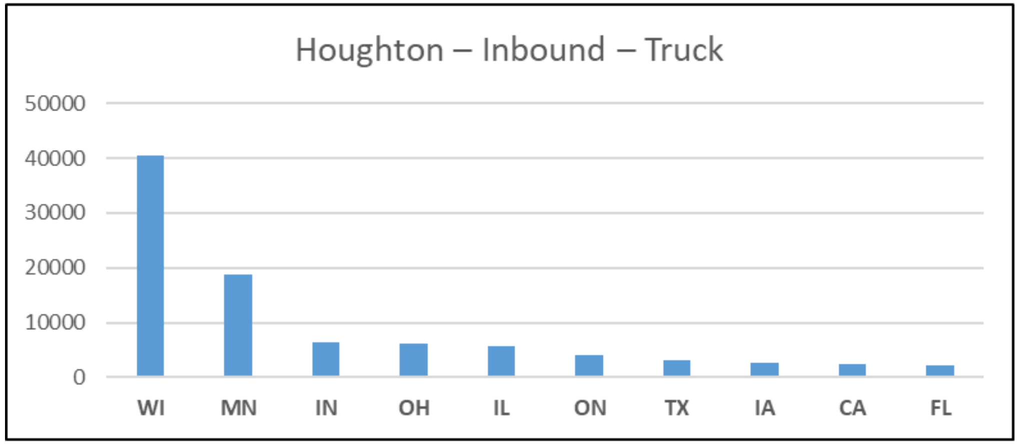
Houghton County Freight Profile (Year 2015)



Michigan Tech

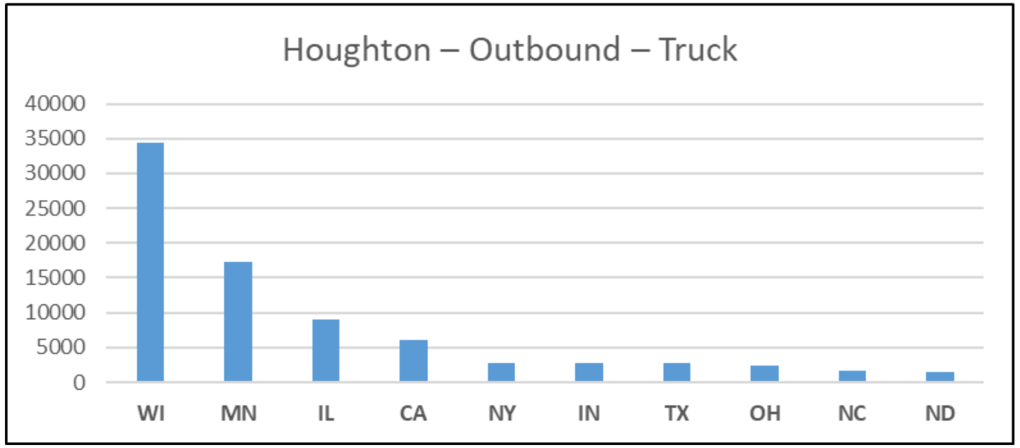
Houghton County Freight Profile (Year 2015)

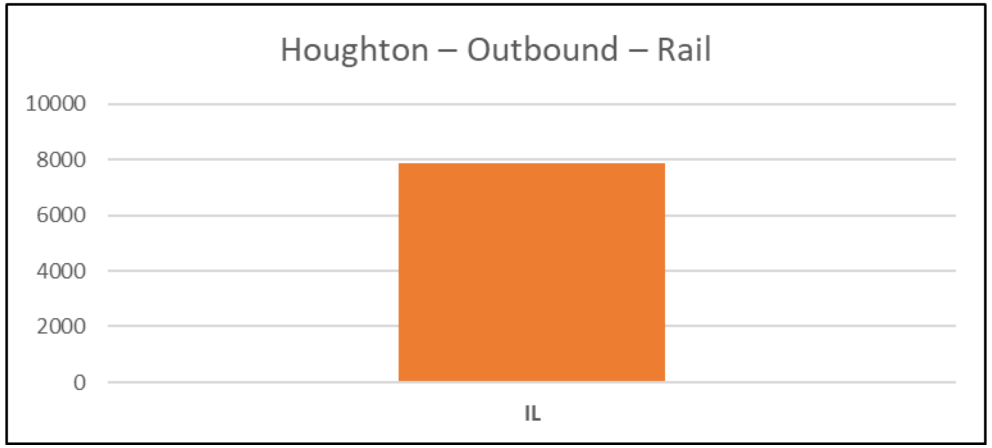
Major Trading Partners by Mode – States/Provinces



Houghton – Inbound – Rail

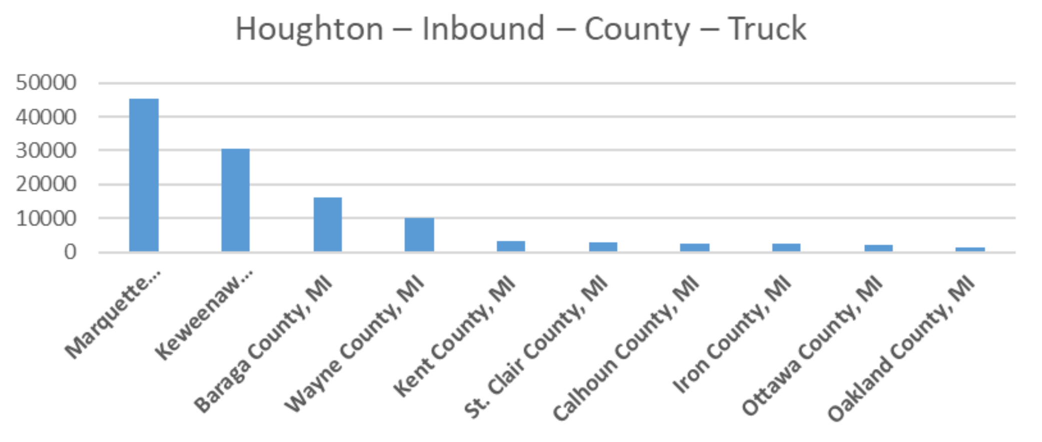
None





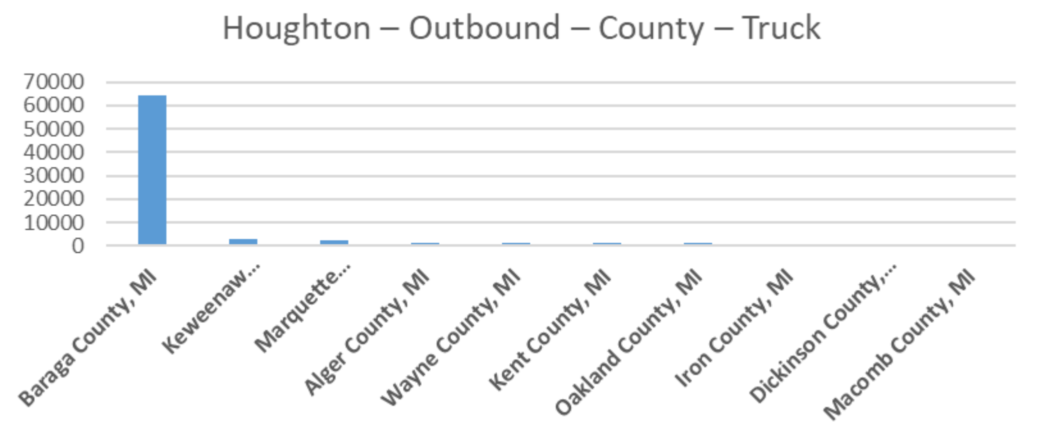
Houghton County Freight Profile (Year 2015)

Major Trading Partners by Mode – Counties



Houghton – Inbound – County – Rail

None

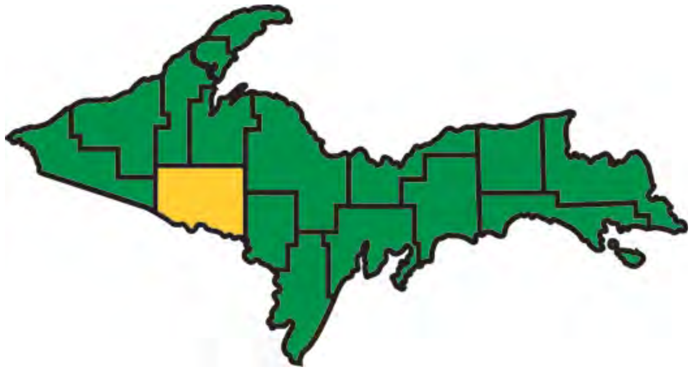


Houghton – Outbound – County – Rail

None

Michigan Tech

Iron County Freight Profile (Year 2015)



At a Glance	
11,348	Population
5,265	Total Labor Force
4,911	Employed
6.7%	Unemployment

Employers (# Employed)	
Major Employers that Export	
Oldenburg Group	149
Connor–AGA Sports Flooring	129
Krist Oil, Co.	73
Lester Detterbeck Enterprises	22
John's Industries, Inc.	20
Northeastern Products Corp.	16
Other Main Employers	
Iron County Medical Facility	344
Ski Brule	150
Aramark	103
Angeli Foods, Co.	102
West Iron County Public Schools	100
Iron River Care Center	71
Forest Park School District	53

Industries (# of Establishments)		
Construction	51	15%
Retail Trade	50	15%
Other services, except public administration	33	10%
Professional and technical services	31	9.2%
Accommodations and food services	30	8.9%
Health care and social assistance	22	6.5%
Transportation and warehousing	20	5.9%
Agriculture, forestry, fishing and hunting	16	4.7%
Real estate and rental and leasing	15	4.5%
Finance and insurance	13	3.7%
Manufacturing	13	3.7%
Administrative and waste services	12	3.6%
Wholesale trade	11	3.3%
Information	8	2.4%
Arts, entertainment, and recreation	6	1.8%
Utilities	4	1.2%
Management of companies and enterprises	2	0.6%
TOTAL	**337**	**100%**

Iron County Freight Profile (Year 2015)

Major Commodities Iron County by Mode

Internal

Truck		Rail
Logs, Lumber, and Wood Products	34,081	None
Clay, Cement, Glass or Stone Products	578	
Farm Products	64	
Food Products	42	
Shipping Containers	0	

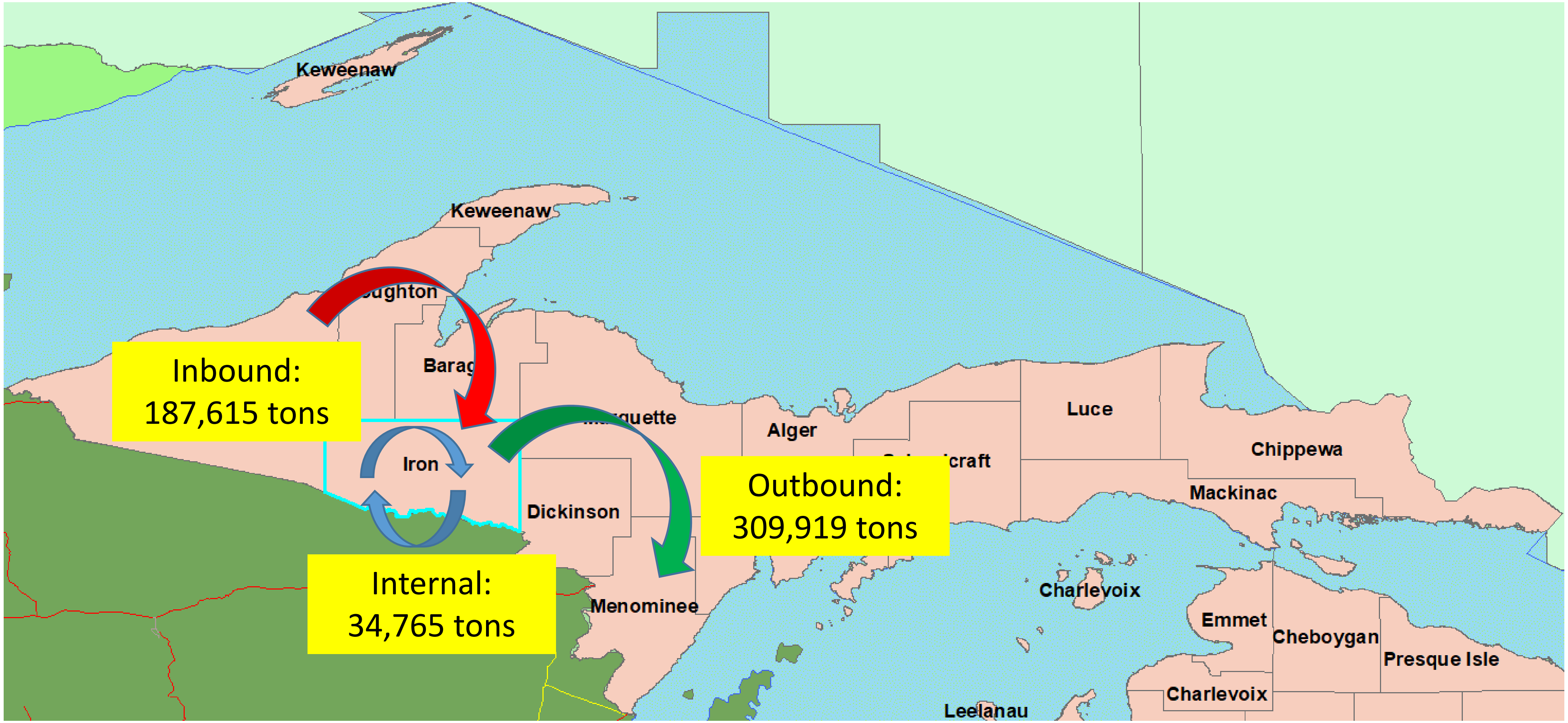
Inbound

Truck		Rail
Logs, Lumber, and Wood Products	115,507	None
Nonmetallic Ores and Minerals	28,809	
Clay, Cement, Glass or Stone Products	15,564	
Secondary Traffic	14,569	
Farm Products	3,711	
Petroleum or Coal Products	3,163	
Food Products	2,512	
Primary Metal Products	1,572	
Transportation Equipment	521	
Forest Products	364	
Fabricated Metal Products	335	
Chemical Products	253	
Paper and Pulp Products	250	
Miscellaneous or Mixed Shipments	136	
Printed Matter	102	
Rubber and Plastics	75	
Electrical Equipment	68	
Furniture Products	37	
Machinery	33	
Technical Instruments and Equipment	28	
Tobacco Products	6	
Shipping Containers	0	

Outbound

Truck		Rail
Logs, Lumber, and Wood Products	250,280	33,280
Farm Products	7,693	
Clay, Cement, Glass or Stone Products	7,303	
Waste or Scrap Material	4,333	
Machinery	3,179	
Food Products	2,687	
Misc Manufacturing Products	890	
Fabricated Metal Products	116	
Secondary Traffic	88	
Furniture Products	56	
Electrical Equipment	14	
Shipping Containers	0	

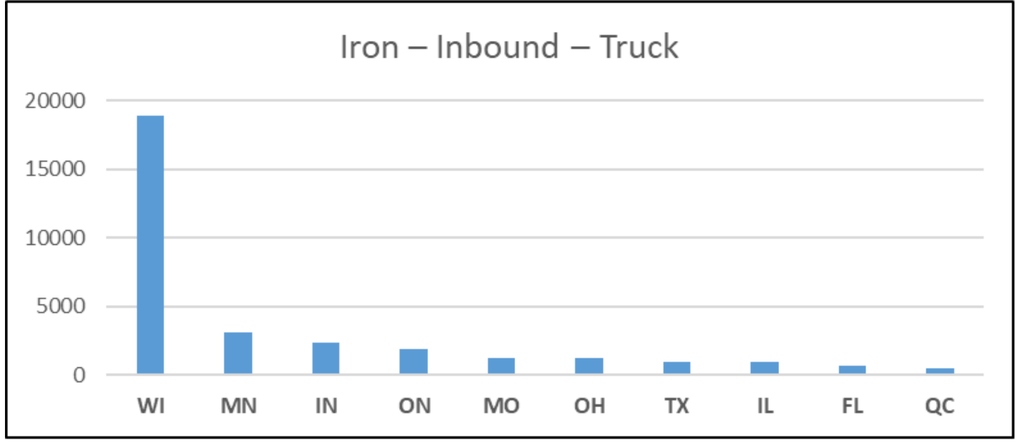
Iron County Freight Profile (Year 2015)



Michigan Tech

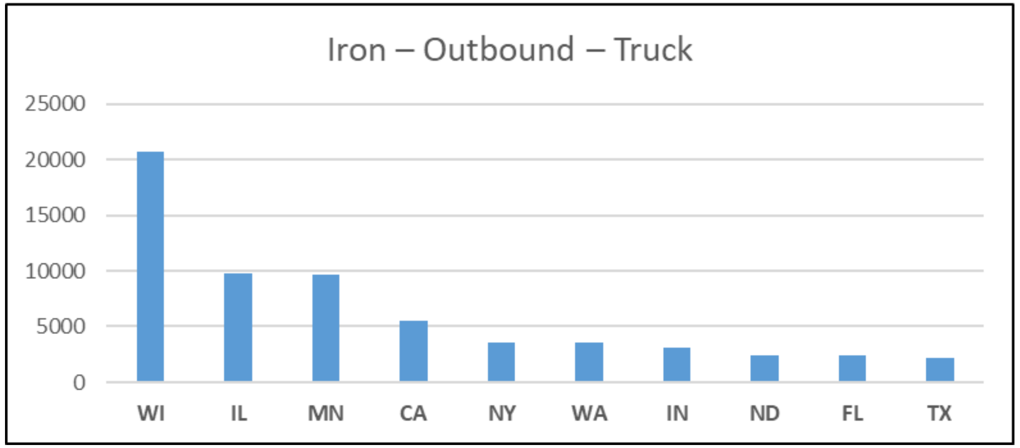
Iron County Freight Profile (Year 2015)

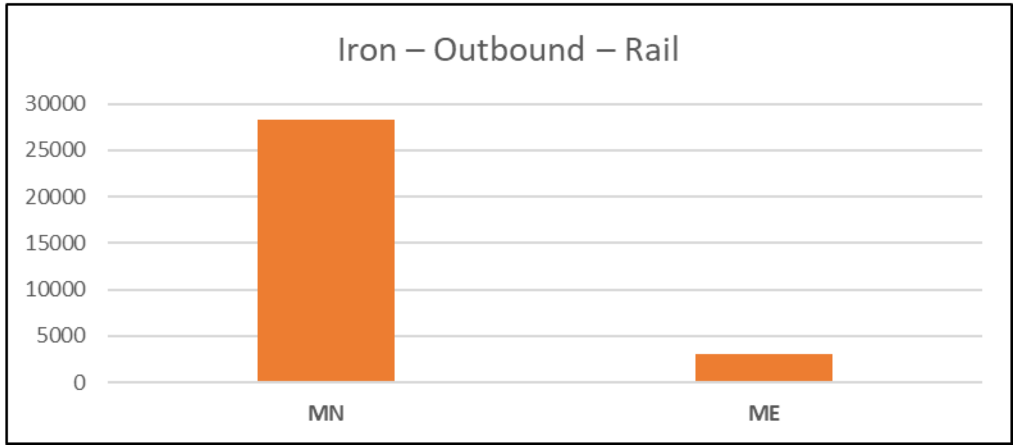
Major Trading Partners by Mode – States/Provinces



Iron – Inbound – Rail

None

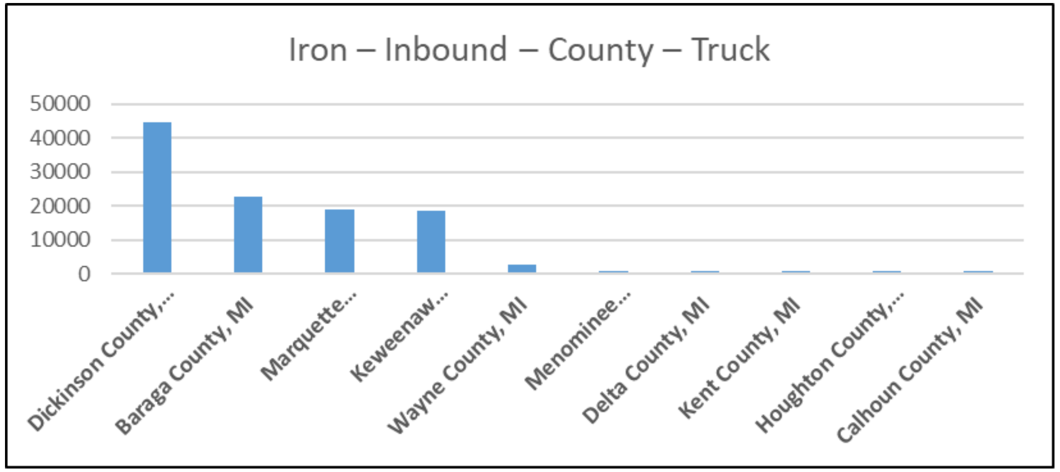




Michigan Tech

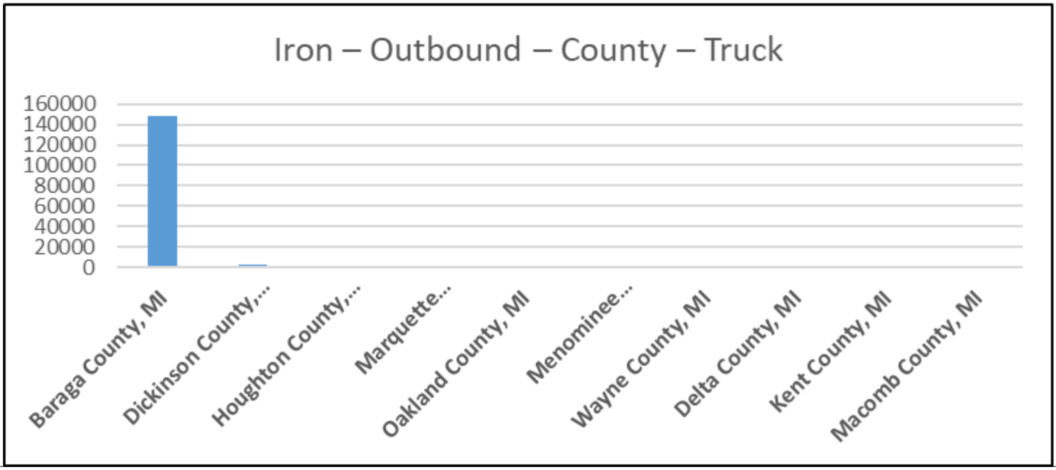
Iron County Freight Profile (Year 2015)

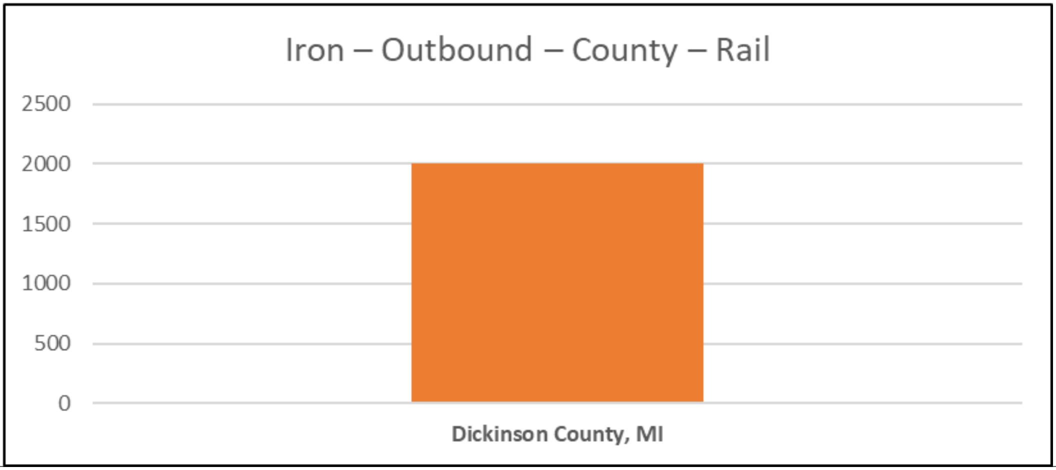
Major Trading Partners by Mode – Counties



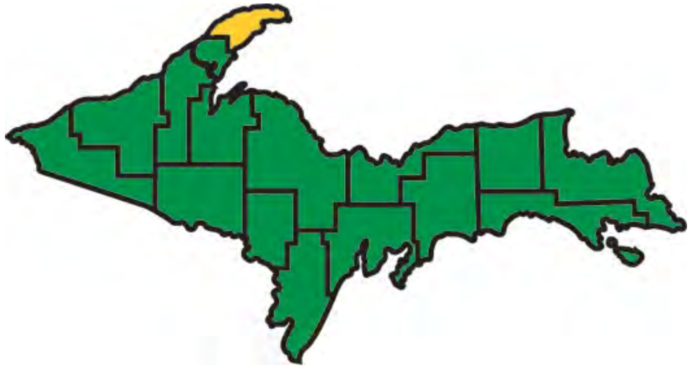
Iron – Inbound – County – Rail

None





Keweenaw County Freight Profile (Year 2015)



At a Glance	
2,197	Population
966	Total Labor Force
882	Employed
8.7%	Unemployment

Employers (# Employed)	
Primary Employers	
Keweenaw Mountain Lodge	45
The Mariner North	45
Gitche Gumee Bible Camp	35
Mt. Bohemia	26
Keweenaw County Road Commission	15
Brickside Brewery	13
The Isle Royale Line, Inc.	10
Lake Superior Bible Conference	2
County of Keweenaw	NA

Industries (# of Establishments)		
Accommodations and food services	16	24%
Transportation and warehousing	9	13%
Retail trade	9	13%
Construction	7	11%
Wholesale trade	5	7.5%
Arts, entertainment, and recreation	3	4.5%
Real estate, rental, and leasing	3	4.5%
Other services, except public administration	3	4.5%
Educational services	2	3%
Professional and technical services	2	3%
Finance and insurance	2	3%
Agriculture, forestry, fishing, and hunting	2	3%
Manufacturing	2	3%
Mining, quarrying, oil, and gas extraction	1	1.5%
Administrative and waste services	1	1.5%
TOTAL	**67**	**100%**

Keweenaw County Freight Profile (Year 2015)

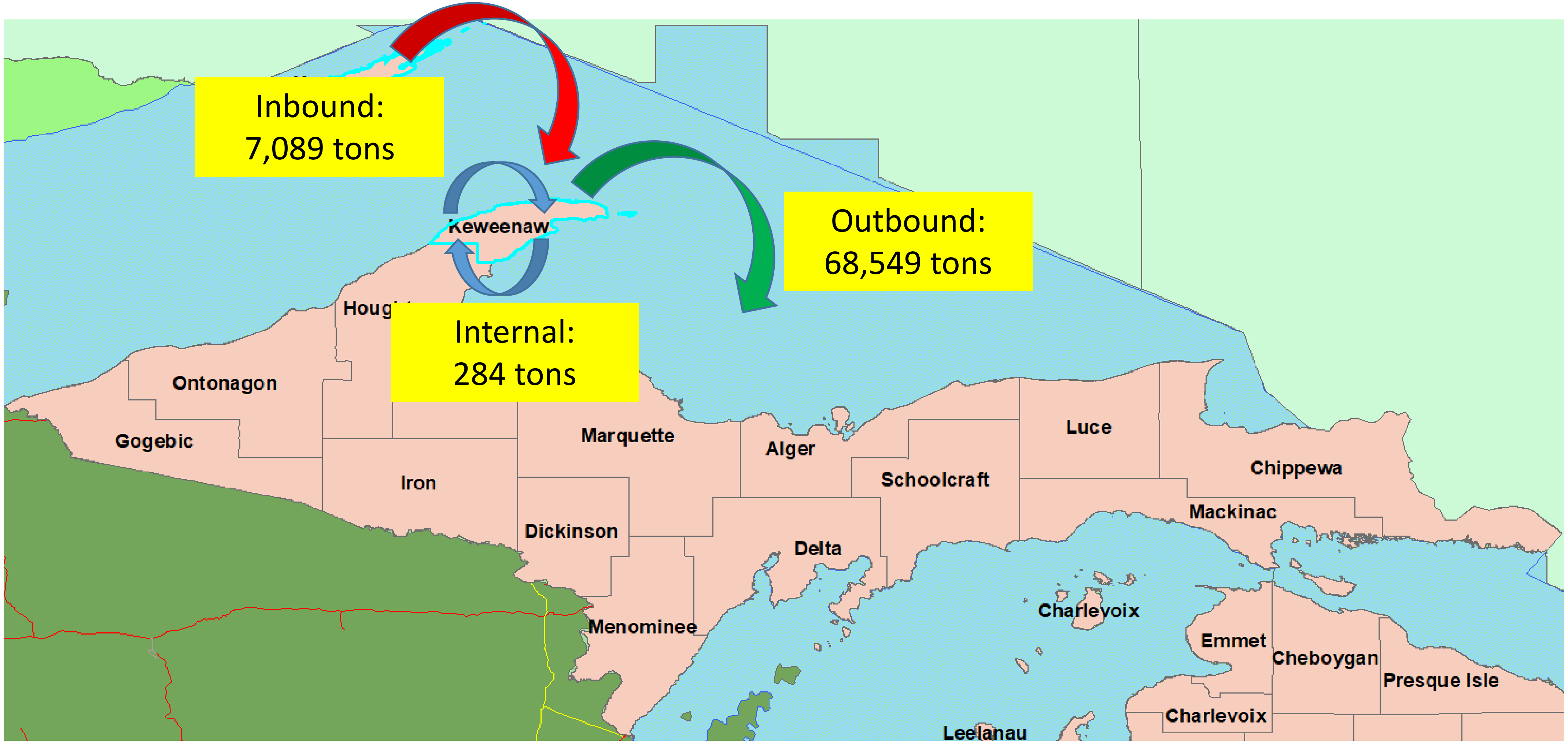
Major Commodities Keweenaw County by Mode

Internal		
Truck		Rail
Nonmetallic Ores and Minerals	201	None
Logs, Lumber, and Wood Products	83	
Shipping Containers	0	

Inbound		
Truck		Rail
Logs, Lumber, and Wood Products	2,994	None
Secondary Traffic	2,243	
Transportation Equipment	853	
Clay, Cement, Glass or Stone Products	678	
Nonmetallic Ores and Minerals	201	
Petroleum or Coal Products	47	
Food Products	30	
Forest Products	22	
Farm Products	21	
Shipping Containers	0	

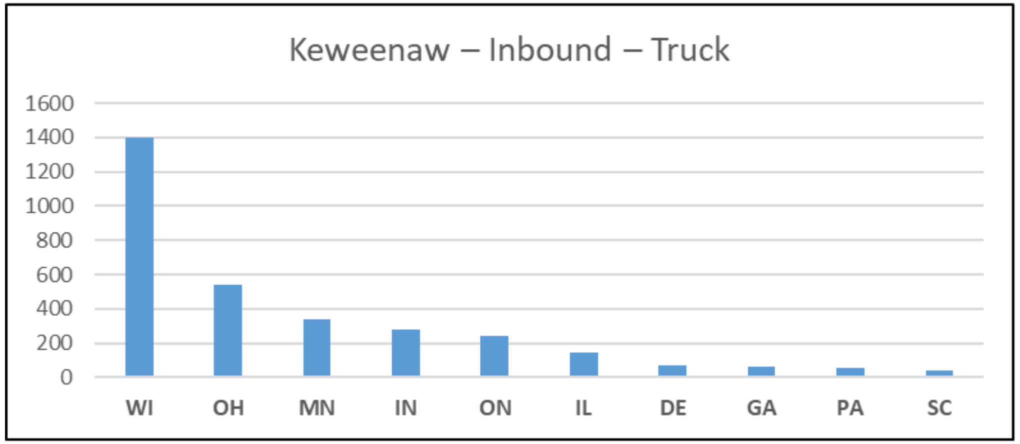
Outbound		
Truck		Rail
Nonmetallic Ores and Minerals	48,926	None
Logs, Lumber, and Wood Products	19,111	
Waste or Scrap Material	261	
Electrical Equipment	139	
Furniture Products	101	
Food Products	11	
Shipping Containers	0	

Keweenaw County Freight Profile (Year 2015)



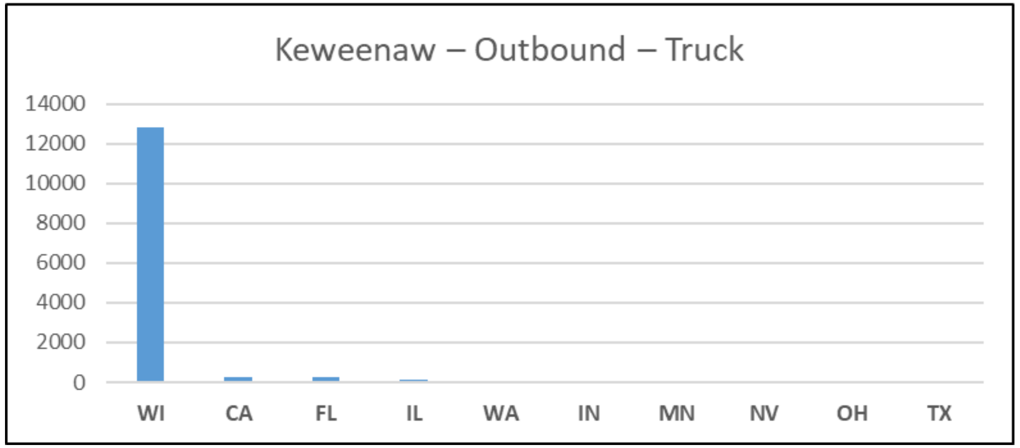
Keweenaw County Freight Profile (Year 2015)

Major Trading Partners by Mode – States/Provinces



Keweenaw – Inbound – Rail

None

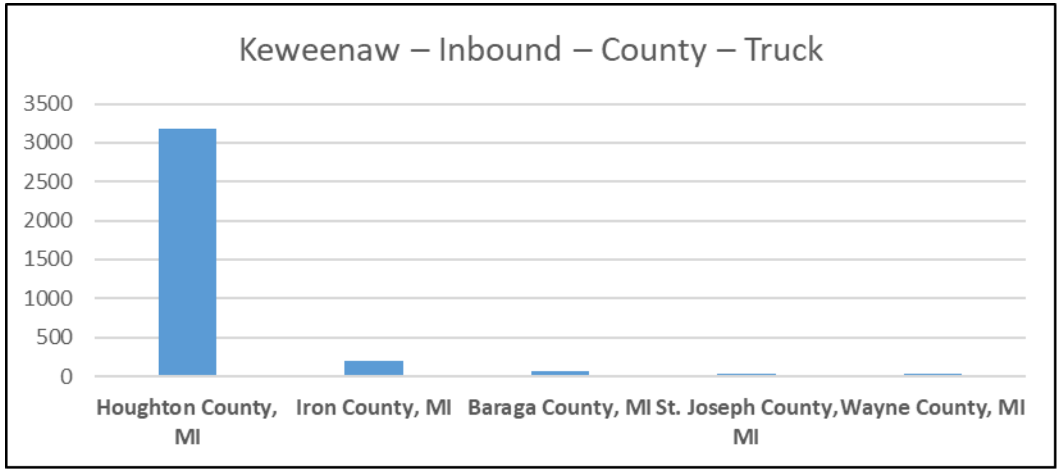


Keweenaw – Outbound – Rail

None

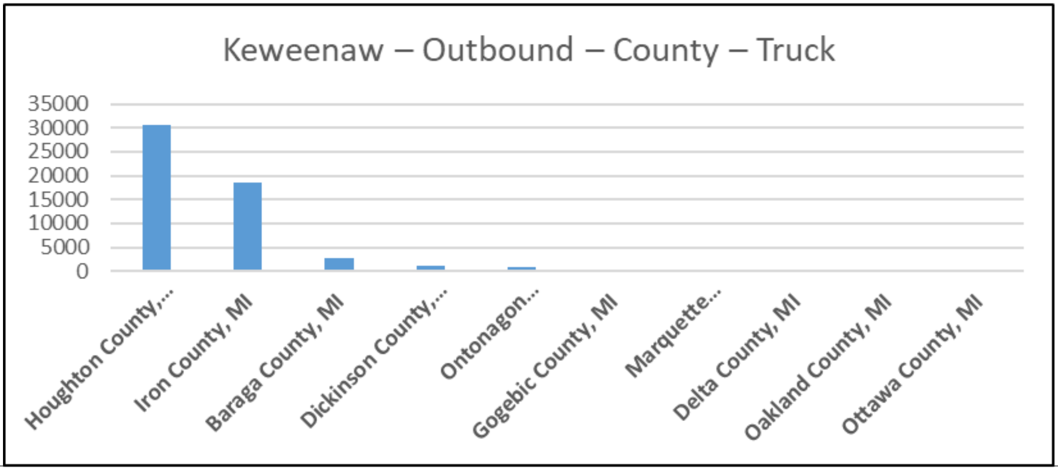
Keweenaw County Freight Profile (Year 2015)

Major Trading Partners by Mode – Counties



Keweenaw – Inbound – County – Rail

None



Keweenaw – Outbound – County – Rail

None

Michigan Tech

Luce County Freight Profile (Year 2015)

At a Glance	
6,415	Population
2,511	Total Labor Force
2,345	Employed
6.6%	Unemployment

Employers (# Employed)	
Manufacturers that Export	
Louisiana Pacific	134
ZD Metal Products LLC	35
Banks Hardwoods	18
Newberry Wood Enterprises	18
Northern Wings Repair	15
Primary Employers	
Helen Newberry Joy Hospital	350
Newberry Correctional Facility	330
Tahquamenon Area Schools	73
Luce County	62
Michigan DNR	58
Rahilly's IGA	43
Mac's Market/Supervalue	38
Tahquamenon Area Credit Union	30

Industries (# of Establishments)		
Retail trade	24	16%
Accommodations and food services	17	11%
Construction	16	11%
Other services, except public administration	15	10%
Agriculture, forestry, fishing, and hunting	14	9.5%
Wholesale trade	10	7%
Professional and technical services	9	6.1%
Administrative and waste services	8	5.4%
Educational services	7	5%
Arts, entertainment, and recreation	6	4.1%
Finance and insurance	6	4.1%
Real estate, rental, and leasing	5	3.4%
Transportation and warehousing	5	3.4%
Manufacturing	4	3%
Information	1	1%
TOTAL	**147**	**100%**

Michigan Tech

Luce County Freight Profile (Year 2015)

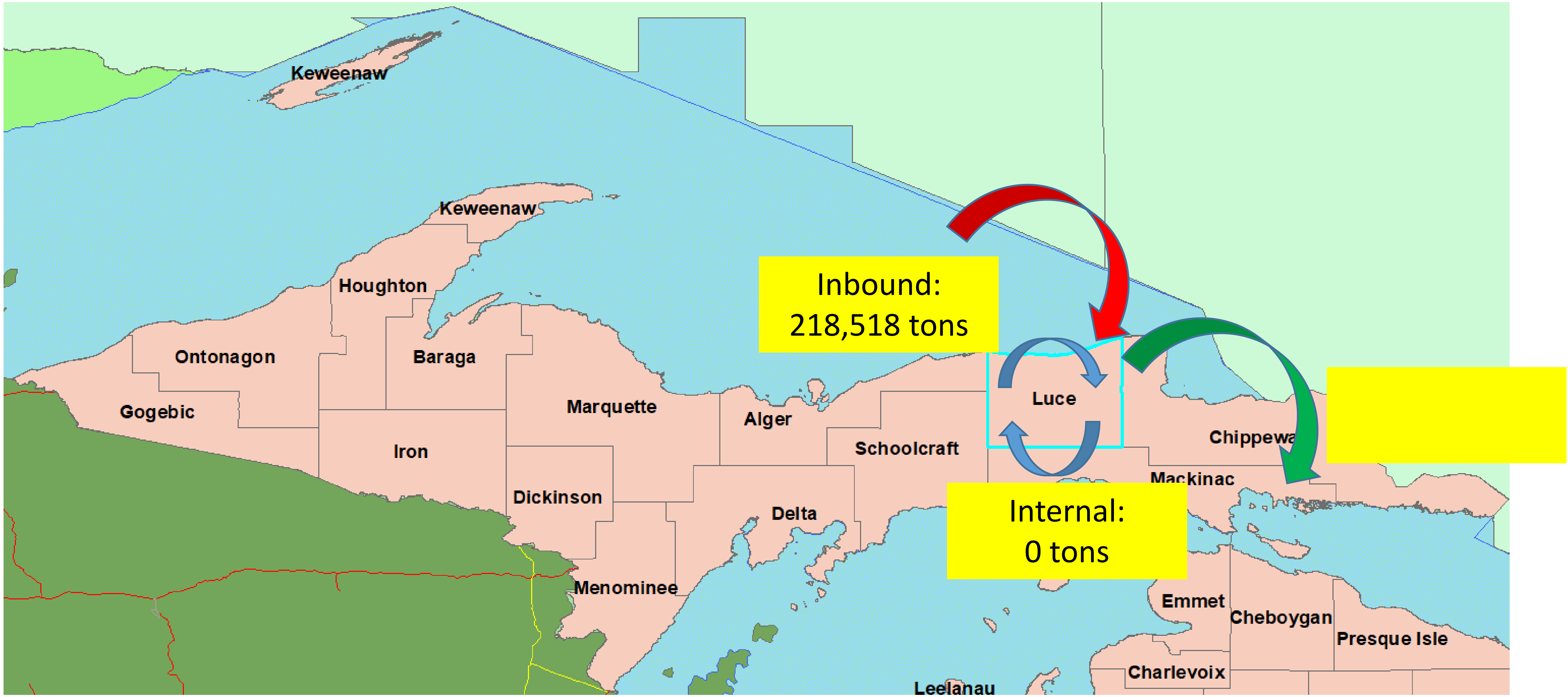
Major Commodities Luce County by Mode

Internal		
Truck		Rail
None		

Inbound		
Truck		Rail
Logs, Lumber, and Wood Products	159,704	19,200
Nonmetallic Ores and Minerals	13,145	
Secondary Traffic	6,213	
Clay, Cement, Glass or Stone Products	5,508	
Petroleum or Coal Products	2,256	
Chemical Products	1,391	7,600
Forest Products	831	
Transportation Equipment	730	1,200
Primary Metal Products	295	
Food Products	217	
Miscellaneous or Mixed Shipments	91	
Paper and Pulp Products	73	
Farm Products	40	
Technical Instruments and Equipment	11	
Rubber and Plastics	9	
Furniture Products	4	
Shipping Containers	0	

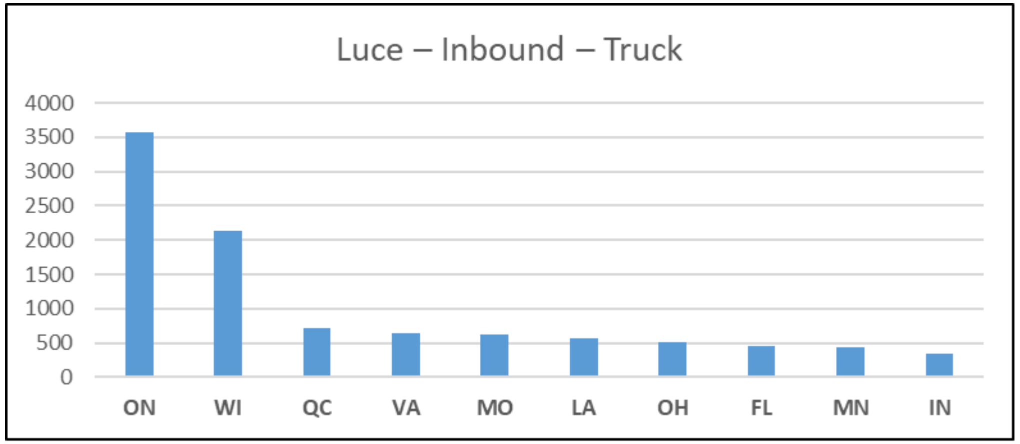
Outbound		
Truck		Rail
Logs, Lumber, and Wood Products	162,556	107,320
Misc Manufacturing Products	2,449	
Waste or Scrap Material	926	
Farm Products	600	
Furniture Products	27	
Shipping Containers	0	

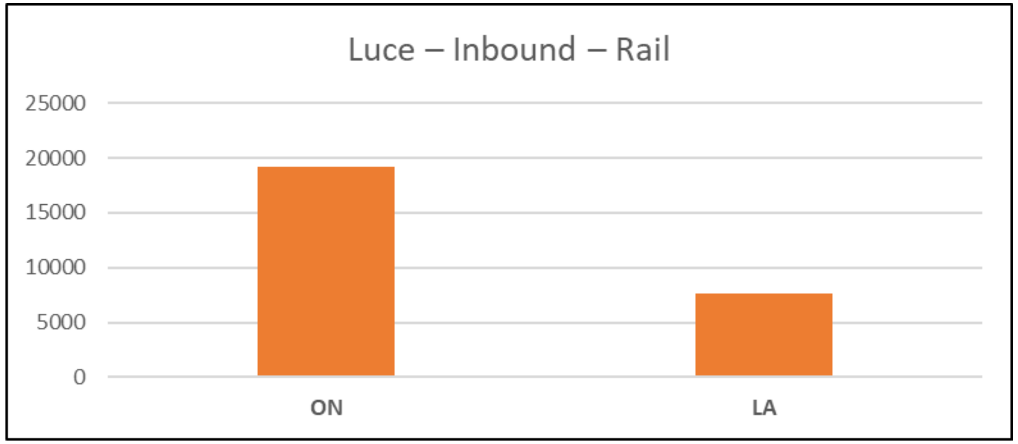
Luce County Freight Profile (Year 2015)

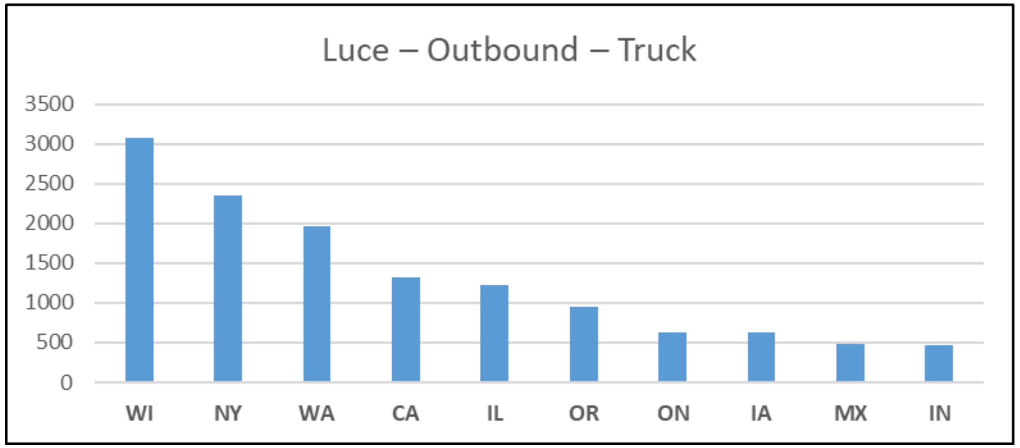


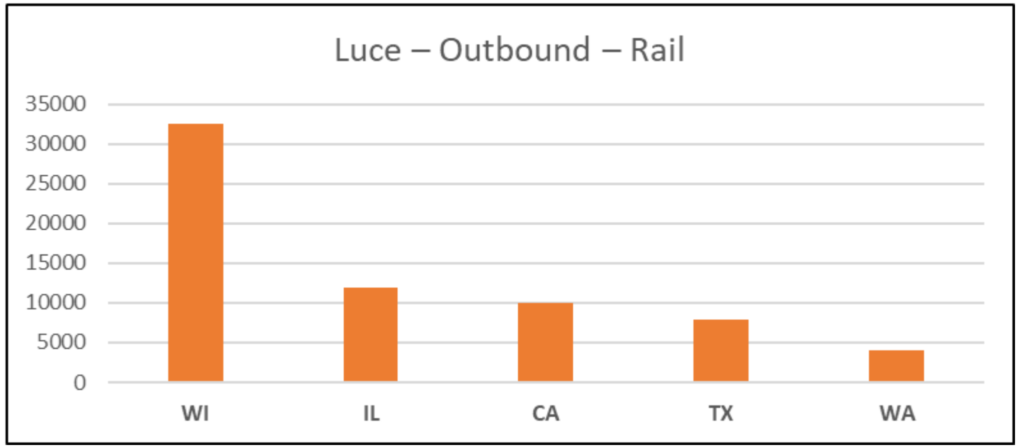
Luce County Freight Profile (Year 2015)

Major Trading Partners by Mode – States/Provinces





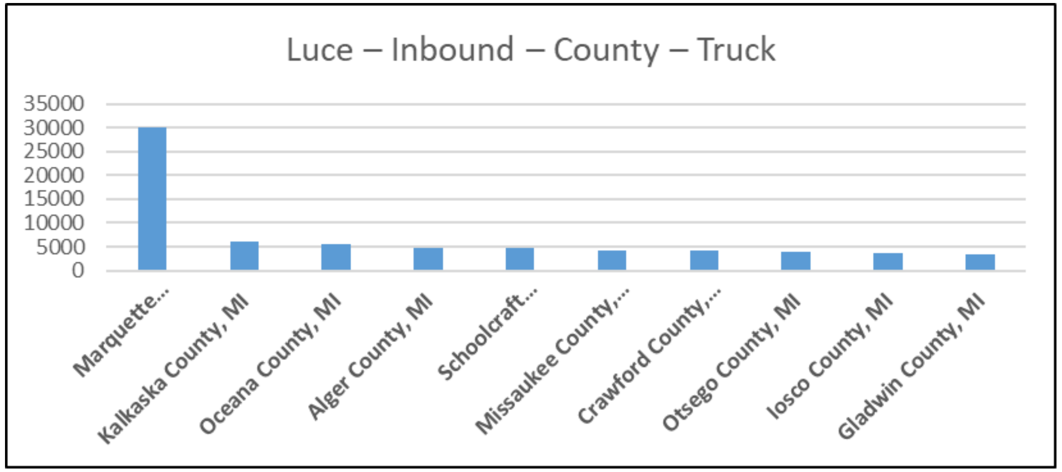


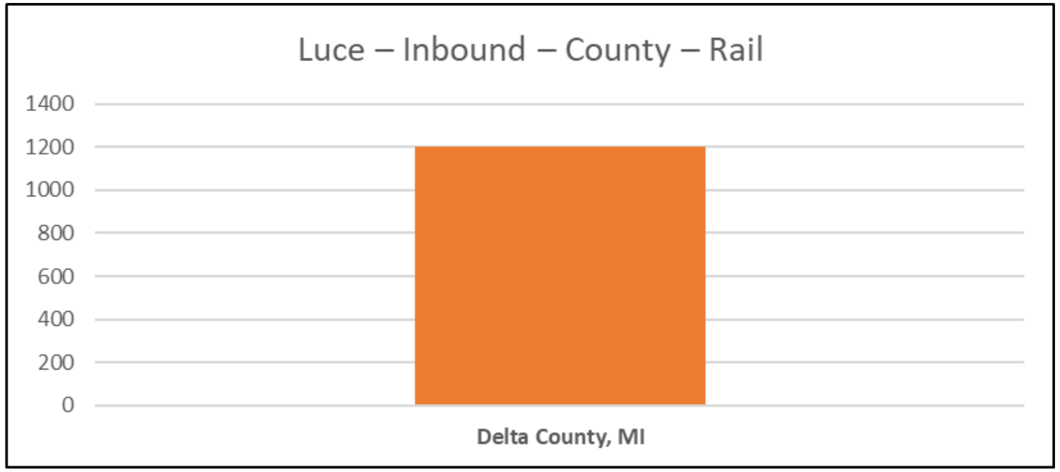


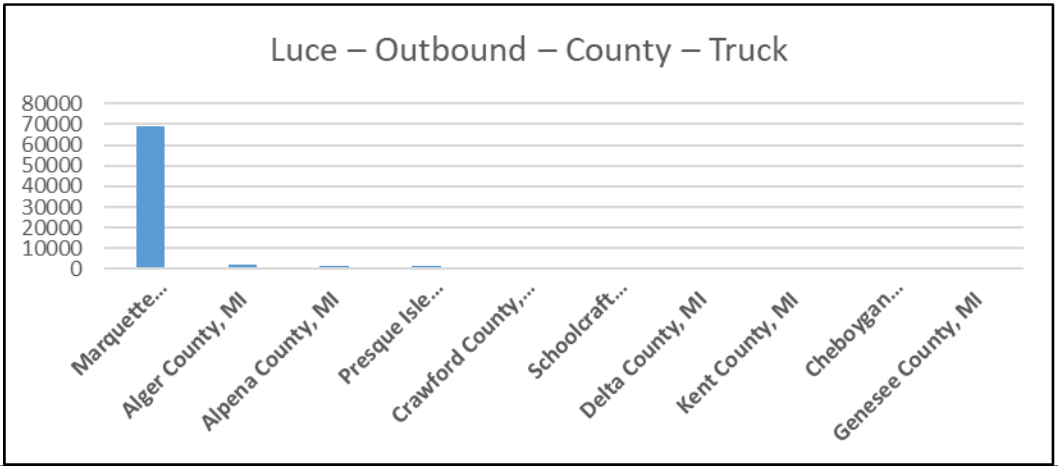
Michigan Tech

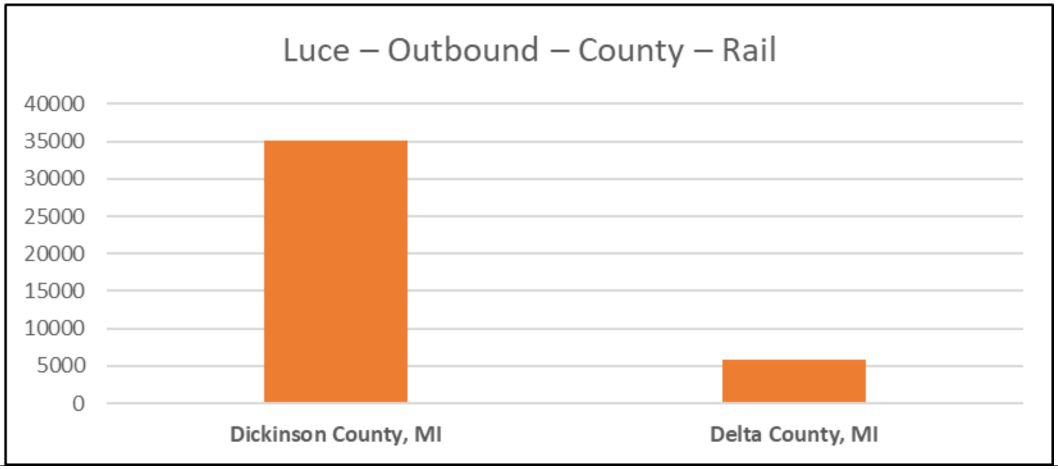
Luce County Freight Profile (Year 2015)

Major Trading Partners by Mode – Counties



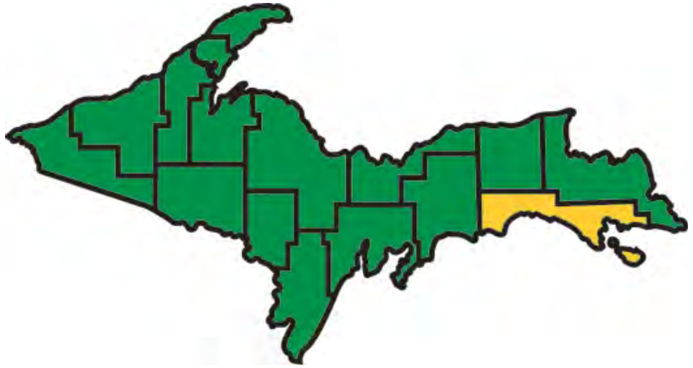






Michigan Tech

Mackinac County Freight Profile (Year 2015)



At a Glance	
10,890	Population
5,158	Total Labor Force
4,679	Employed
9.3%	Unemployment

Employers (# Employed)	
Manufacturers that Export	
Carmeuse Limestone	72
Maple Hardwoods, Inc.	35
Flotation Docking Systems	23
Sand Products	11
Primary Employers	
Grand Hotel	722
Mackinac Straights Area Hospital	309
Mackinac Bridge Authority	100
Mackinac County Government	75
Cedar Campus	70
Shepler's Mackinac	67
Michigan DNR	61
St. Ignace Area Schools	58
First National Bank	57

Industries (# of Establishments)		
Accommodations and food services	108	27%
Retail trade	86	21%
Construction	56	14%
Other services, except public administration	20	5%
Professional and technical services	16	4%
Finance and insurance	16	4%
Manufacturing	16	4%
Arts, entertainment, and recreation	15	3.7%
Transportation and warehousing	14	3.5%
Agriculture, forestry, fishing, and hunting	14	3.5%
Administrative and waste services	12	3%
Educational services	11	2.7%
Real estate, rental, leasing	7	1.7%
Wholesale trade	6	1.5%
Mining, quarrying, gas, and oil extraction	3	0.7%
Utilities	2	0.5%
Information	1	0.2%
TOTAL	**403**	**100%**

Michigan Tech

Mackinac County Freight Profile (Year 2015)

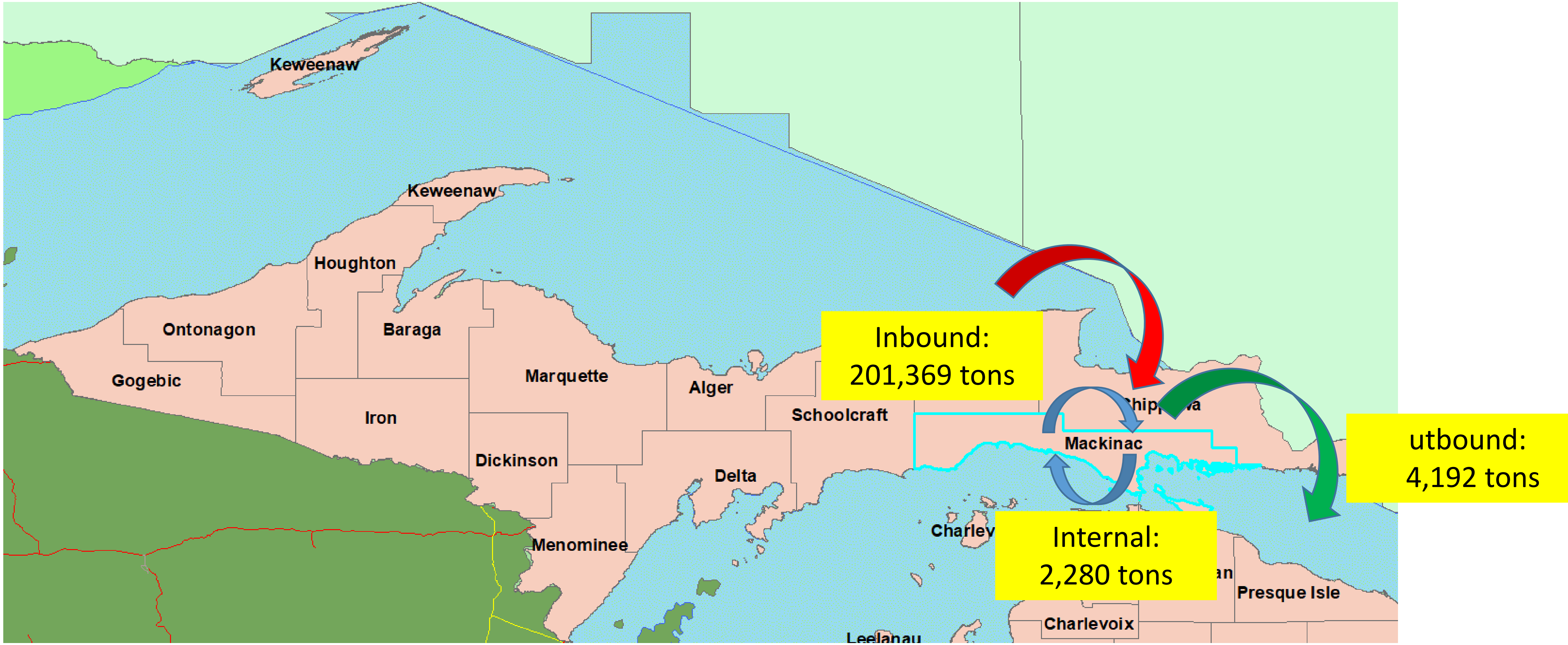
Major Commodities Mackinaw County by Mode

Internal		
Truck		Rail
Nonmetallic Ores and Minerals	1,194	None
Logs, Lumber, and Wood Products	826	
Farm Products	260	
Shipping Containers	0	

Inbound		
Truck		Rail
Logs, Lumber, and Wood Products	143,831	None
Clay, Cement, Glass or Stone Products	15,470	
Secondary Traffic	14,545	
Nonmetallic Ores and Minerals	8,856	
Farm Products	8,685	
Petroleum or Coal Products	4,968	
Food Products	2,823	
Transportation Equipment	561	
Chemical Products	386	
Primary Metal Products	353	
Paper and Pulp Products	235	
Furniture Products	228	
Forest Products	193	
Miscellaneous or Mixed Shipments	135	
Machinery	36	
Technical Instruments and Equipment	29	
Rubber and Plastics	15	
Electrical Equipment	13	
Textile Mill Products	4	
Misc Manufacturing Products	2	
Tobacco Products	1	
Shipping Containers	0	

Outbound		
Truck		Rail
Logs, Lumber, and Wood Products	145,300	56,000
Nonmetallic Ores and Minerals	25,358	
Farm Products	20,282	
Waste or Scrap Material	5,196	
Secondary Traffic	1,174	
Food Products	600	
Transportation Equipment	115	
Misc Manufacturing Products	72	
Apparel or Finished Textiles	54	
Furniture Products	41	
Shipping Containers	0	

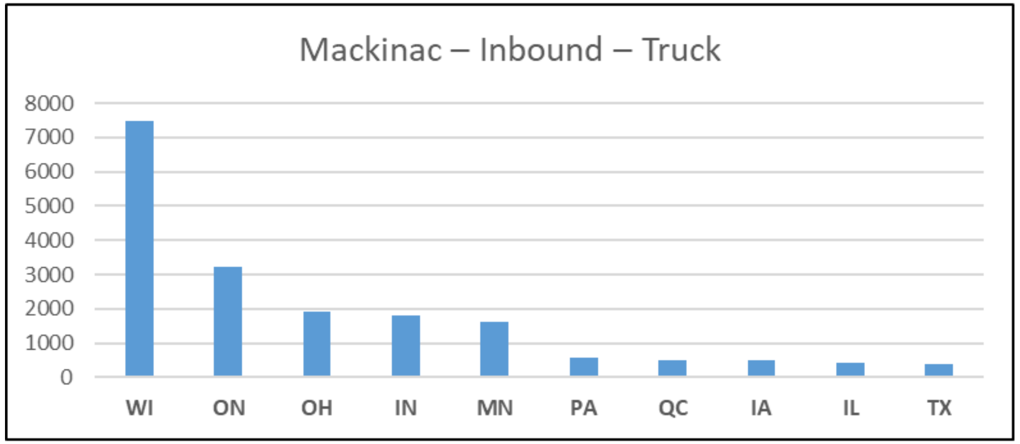
Mackinac County Freight Profile (Year 2015)



Michigan Tech

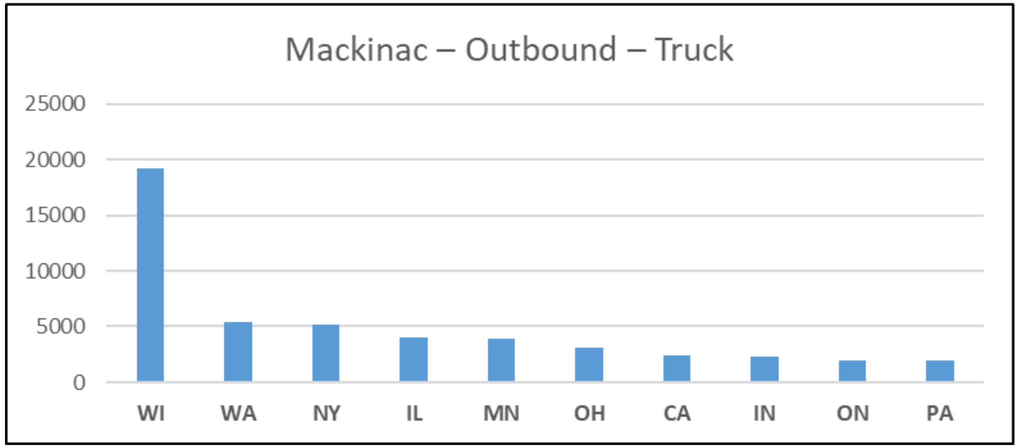
Mackinac County Freight Profile (Year 2015)

Major Trading Partners by Mode – States/Provinces



Mackinac – Inbound – Rail

None

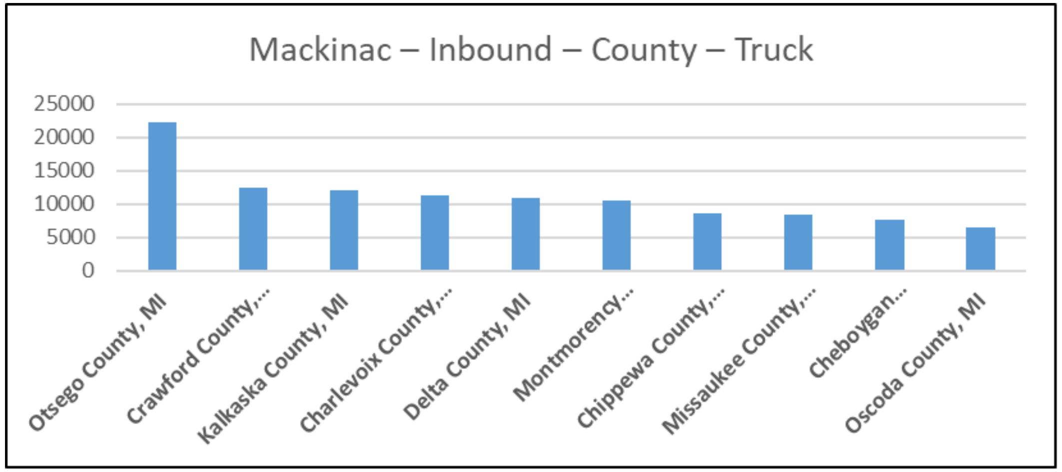


Mackinac – Outbound – Rail

None outside of Michigan

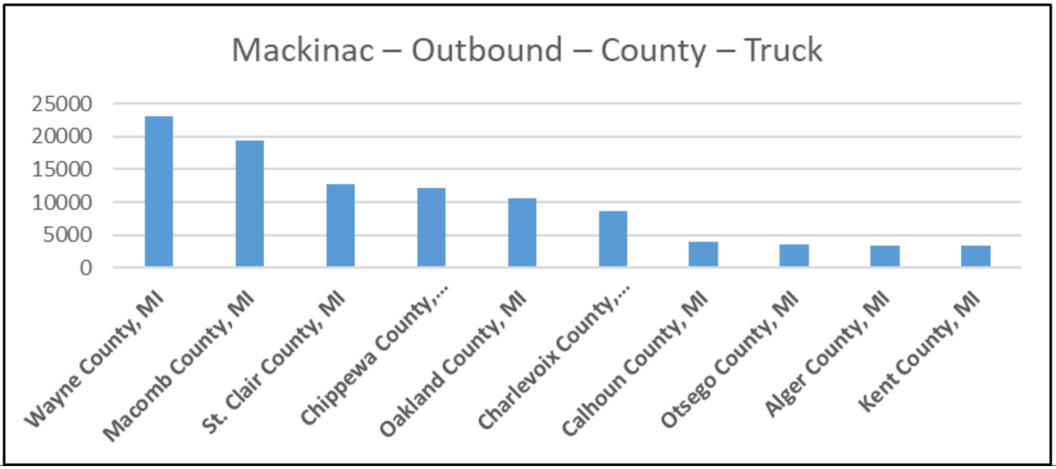
Mackinac County Freight Profile (Year 2015)

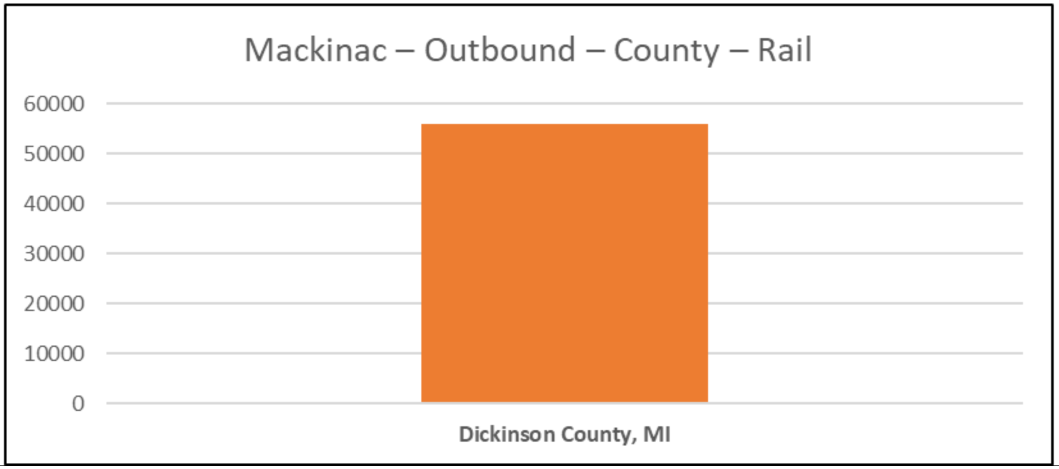
Major Trading Partners by Mode – Counties



Mackinac – Inbound – County – Rail

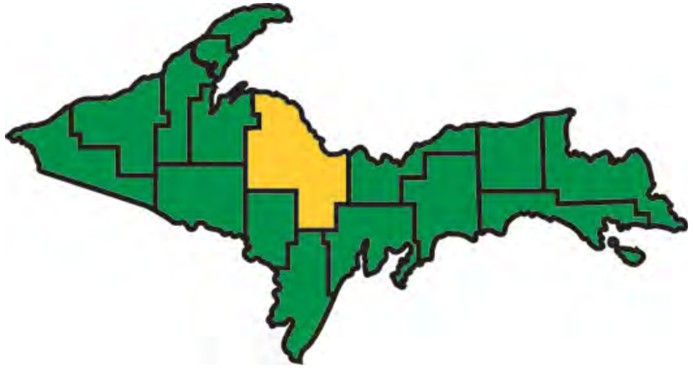
None





Michigan Tech

Marquette County Freight Profile (Year 2015)



At a Glance	
67,535	Population
33,597	Total Labor Force
31,667	Employed
5.7%	Unemployment

Employers (# Employed)	
Major Employers that Export	
Cliffs Natural Resources	1,600
RTI Surgical Inc.	165
Argonics	85
Jilbert Diary	60
Other Main Employers	
U.P. Health System – Marquette	2,619
Northern Michigan University	918
Peninsula Medical Center	625
Eagle Mine	435
Department of Corrections	388
Marquette Public Schools	382
Wal–Mart Stores, Inc.	380
Bell Hospital	370
American Eagle	253

Industries (# of Establishments)		
Retail trade	241	18%
Health care and social assistance	174	13%
Construction	174	13%
Other services, except public administration	172	13%
Professional and technical services	109	8.1%
Finance and insurance	85	6.3%
Administrative and waste services	70	5.2%
Real estate, rental, and leasing	53	4%
Wholesale trade	48	3.6%
Manufacturing	43	3.2%
Accommodations and food services	34	2.5%
Arts, entertainment, and recreation	32	2.4%
Transportation and warehousing	31	2.3%
Agriculture, forestry, fishing, and hunting	25	1.9%
Information	22	1.6%
Educational Services	11	0.8%
Mining, quarrying, oil, and gas extraction	7	0.6%
TOTAL	**1,332**	**99.5%**

Marquette County Freight Profile (Year 2015)

Major Commodities Marquette County by Mode

Internal

Commodity	Truck	Rail
Nonmetallic Ores and Minerals	204,200	None
Logs, Lumber, and Wood Products	31,100	
Clay, Cement, Glass or Stone Products	23,643	
Food Products	2,911	
Waste or Scrap Material	2,303	
Technical Instruments and Equipment	431	
Primary Metal Products	417	
Chemical Products	359	
Misc Manufacturing Products	331	
Secondary Traffic	241	
Farm Products	177	
Fabricated Metal Products	114	
Textile Mill Products	68	
Printed Matter	53	
Apparel or Finished Textiles	27	
Furniture Products	19	
Shipping Containers	0	

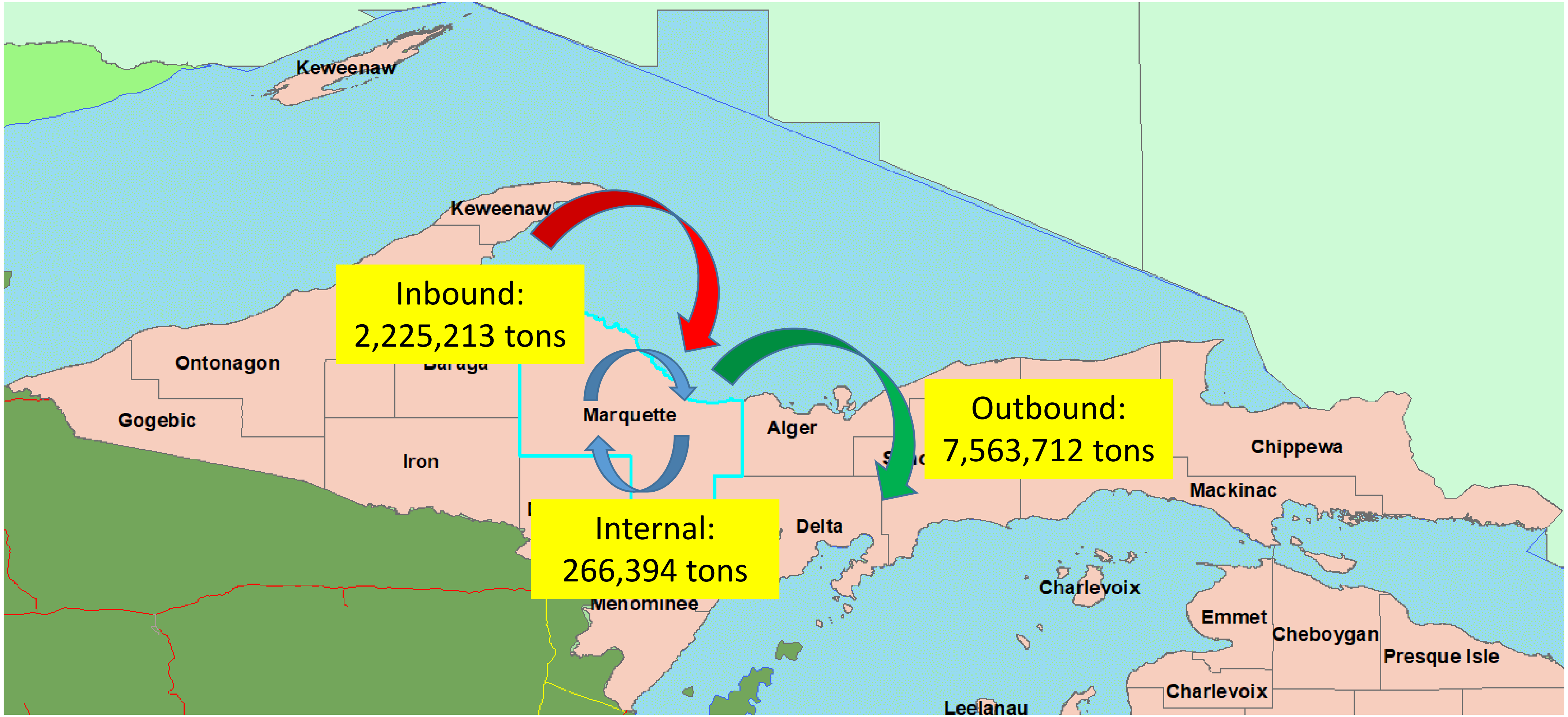
Inbound

Commodity	Truck	Rail
Nonmetallic Ores and Minerals	639,971	425,536
Logs, Lumber, and Wood Products	280,345	53,032
Secondary Traffic	116,228	
Food Products	107,234	11,320
Clay, Cement, Glass or Stone Products	88,597	118,800
Farm Products	49,973	
Chemical Products	47,218	42,360
Machinery	44,492	
Petroleum or Coal Products	44,033	
Rubber and Plastics	40,534	
Transportation Equipment	23,980	
Primary Metal Products	19,390	
Waste or Scrap Material	17,541	
Paper and Pulp Products	9,127	
Printed Matter	8,098	
Coal	6,061	
Fabricated Metal Products	5,854	
Metallic Ores	5,324	
Misc Manufacturing Products	4,313	
Technical Instruments and Equipment	4,217	
Furniture Products	3,641	
Electrical Equipment	2,429	
Forest Products	1,865	
Miscellaneous or Mixed Shipments	1,487	
Apparel or Finished Textiles	937	
Textile Mill Products	505	
Tobacco Products	364	
Leather Products	212	
Fresh Fish	129	
Ordnance	66	
Shipping Containers	0	

Outbound

Commodity	Truck	Rail
Metallic Ores		5,639,533
Nonmetallic Ores and Minerals	1,364,889	
Logs, Lumber, and Wood Products	211,424	136,840
Waste or Scrap Material	85,766	
Clay, Cement, Glass or Stone Products	39,557	
Food Products	34,527	
Chemical Products	15,606	
Primary Metal Products	14,861	
Farm Products	7,892	
Technical Instruments and Equipment	6,821	
Misc Manufacturing Products	3,817	
Secondary Traffic	709	
Printed Matter	496	
Furniture Products	483	
Fabricated Metal Products	161	
Textile Mill Products	157	
Apparel or Finished Textiles	79	
Machinery	50	
Rubber and Plastics	29	
Electrical Equipment	15	
Shipping Containers	0	

Marquette County Freight Profile (Year 2015)



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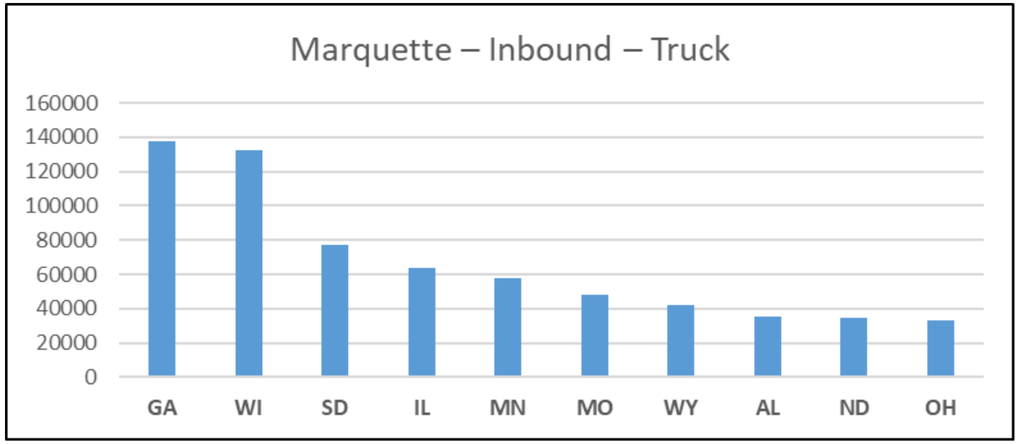
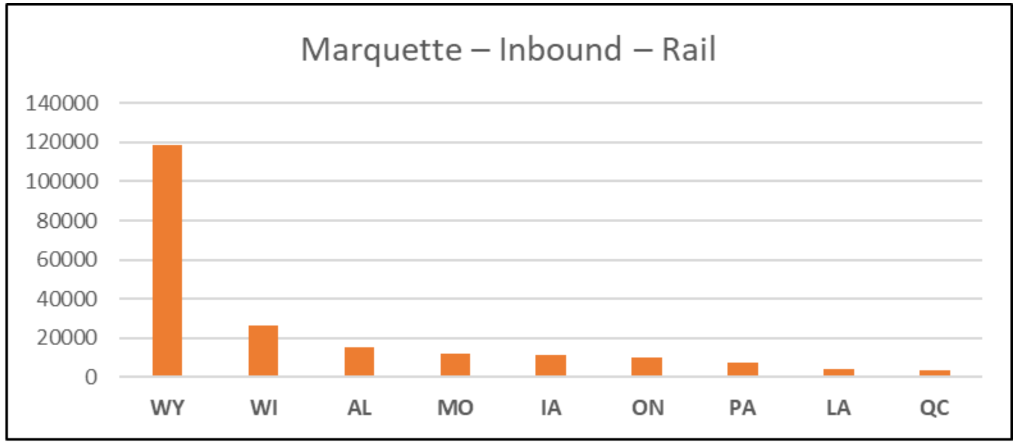
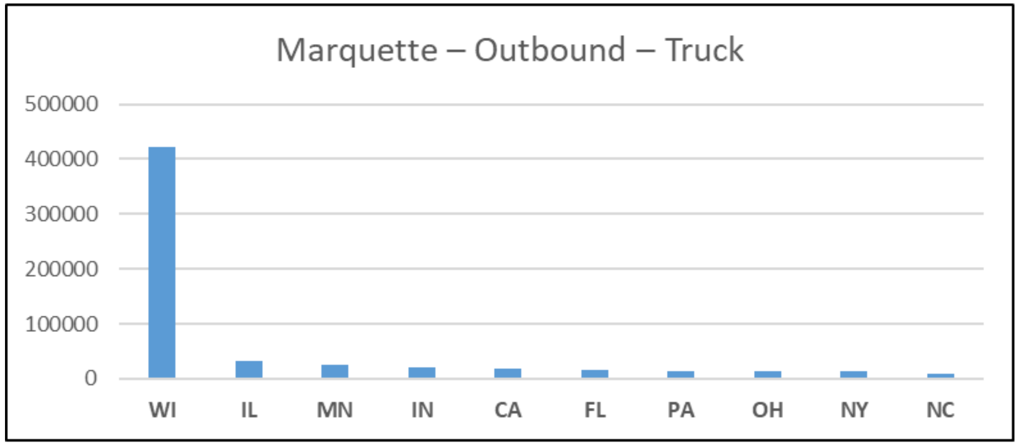
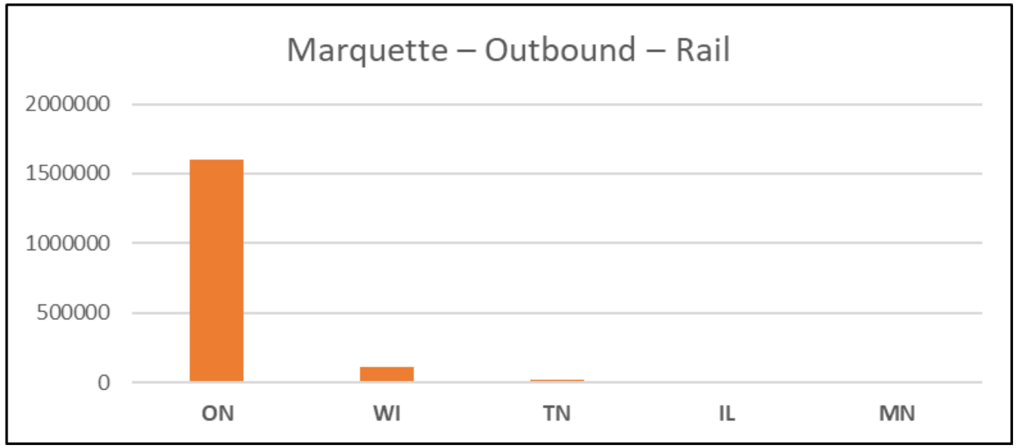
Marquette County Freight Profile (Year 2015)

Major Trading Partners by Mode – States/Provinces









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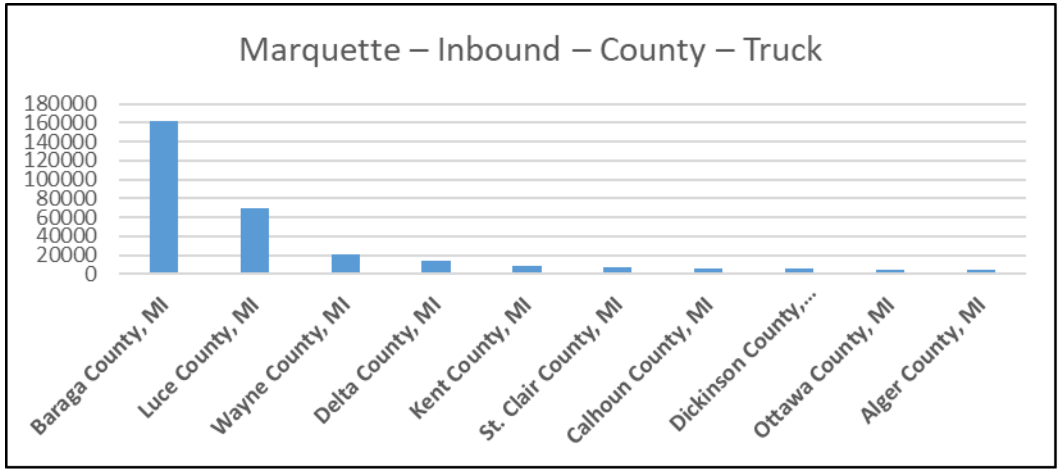
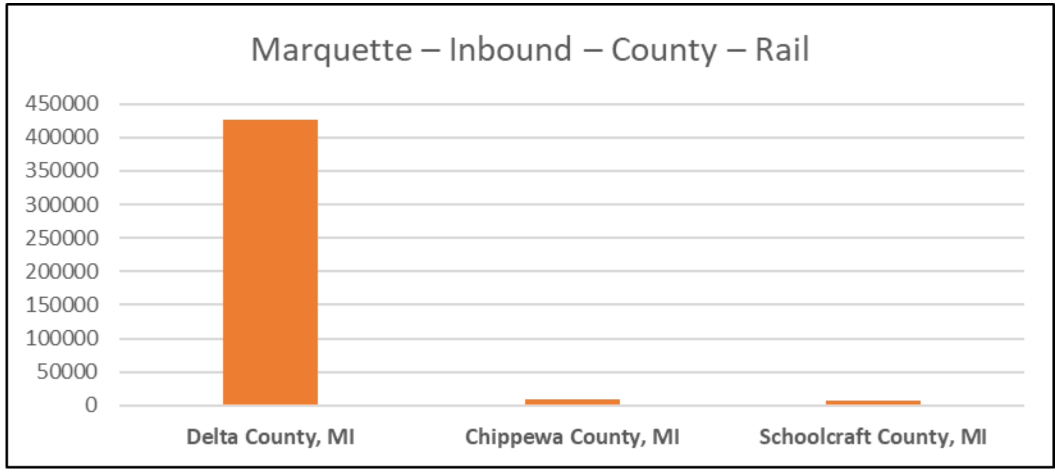
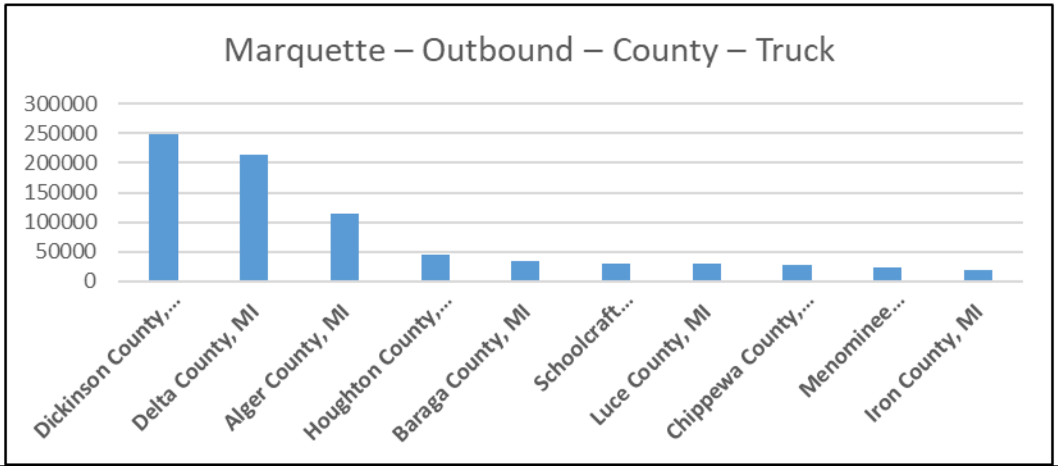
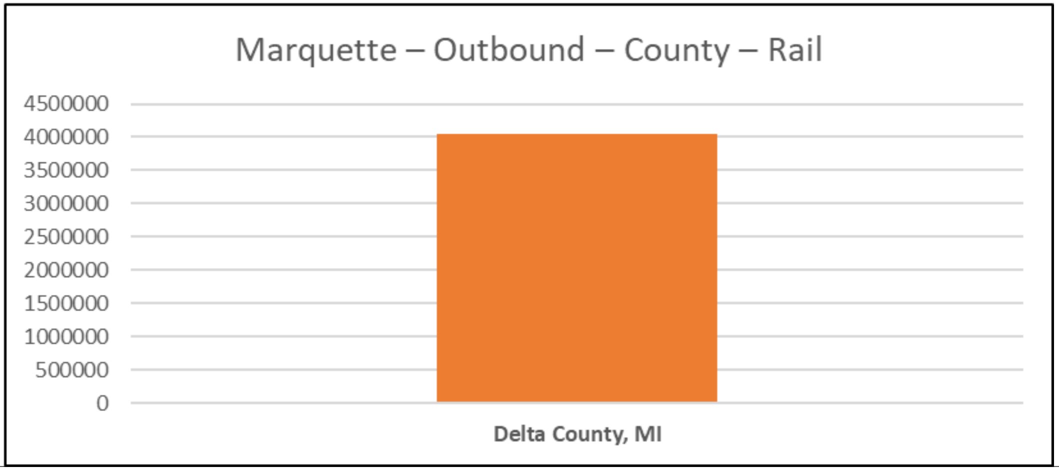
Marquette County Freight Profile (Year 2015)

Major Trading Partners by Mode – Counties









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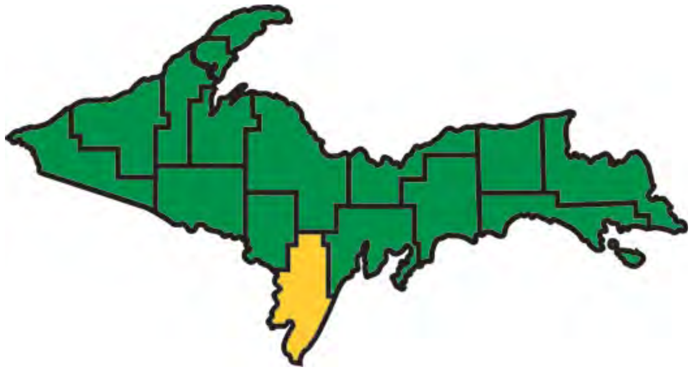
Menominee County Freight Profile (Year 2015)



At a Glance	
23,838	Population
11,630	Total Labor Force
11,033	Employed
5.1%	Unemployment

Employers (# Employed)	
Major Employers that Export	
Anchor Coupling Company	550
LE Jones, Co.	381
Enstrom Helicopter Corp.	195
Resolute Forest Products, Inc.	125
NuVu/Doyen Industries	120
Lloys/Flanders Industries, Inc.	100
Other Main Employers	
Bay Area Medical Center	759
Chip ‘in Island Resort Casino	700
Menominee Public Schools	275
Pinecrest Medical Care Facility	225
County of Menominee	120
Angeli Foods	100

Industries (# of Establishments)		
Retail trade	59	14%
Manufacturing	53	12%
Other services, except public administration	44	10%
Accommodations and food services	40	9.2%
Health care and social assistance	39	8.9%
Construction	39	8.9%
Transportation and warehousing	34	7.8%
Professional and technical services	27	6.2%
Finance and insurance	21	4.8%
Wholesale trade	20	4.6%
Agriculture, forestry, fishing, and hunting	18	4.1%
Real estate, rental, and leasing	12	2.8%
Education services	11	2.5%
Arts, entertainment, and recreation	9	2%
Mining, quarrying, oil, and gas extraction	4	0.9%
Information	4	0.9%
Management of companies and enterprises	1	0.2%
Utilities	1	0.2%
TOTAL	**436**	**100%**

Menominee County Freight Profile (Year 2015)

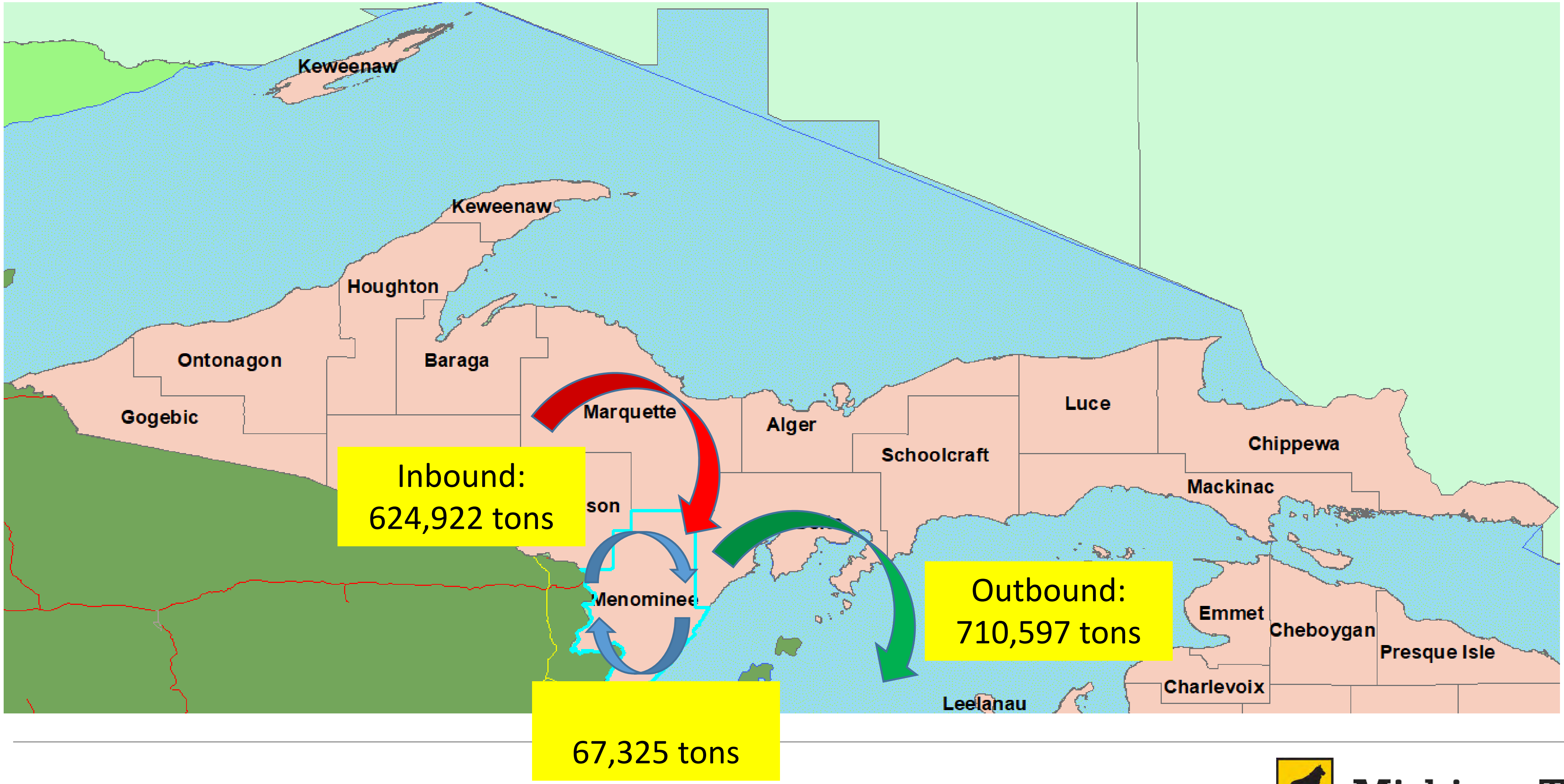
Major Commodities Menominee County by Mode

Internal		
Truck		Rail
Logs, Lumber, and Wood Products	63,603	None
Farm Products	1,778	
Fabricated Metal Products	945	
Machinery	442	
Food Products	201	
Clay, Cement, Glass or Stone Products	172	
Waste or Scrap Material	103	
Transportation Equipment	49	
Paper and Pulp Products	32	
Shipping Containers	0	

Inbound		
Truck		Rail
Logs, Lumber, and Wood Products	233,236	
Farm Products	67,522	
Waste or Scrap Material	47,385	
Secondary Traffic	35,093	
Chemical Products	30,821	
Nonmetallic Ores and Minerals	30,157	
Clay, Cement, Glass or Stone Products	26,619	
Primary Metal Products	25,599	4,360
Food Products	24,025	
Petroleum or Coal Products	11,030	2,560
Electrical Equipment	9,942	
Fabricated Metal Products	4,864	
Transportation Equipment	4,613	
Machinery	4,086	
Forest Products	2,278	
Paper and Pulp Products	1,474	56,560
Rubber and Plastics	846	
Miscellaneous or Mixed Shipments	790	
Furniture Products	447	
Printed Matter	177	
Misc Manufacturing Products	175	
Tobacco Products	132	
Technical Instruments and Equipment	60	
Textile Mill Products	59	
Apparel or Finished Textiles	10	
Fresh Fish	2	
Shipping Containers	0	

Outbound		
Truck		Rail
Logs, Lumber, and Wood Products	302,282	
Farm Products	135,192	
Paper and Pulp Products	103,353	104,360
Fabricated Metal Products	16,326	
Machinery	16,007	
Waste or Scrap Material	12,144	
Food Products	7,241	
Furniture Products	5,476	
Clay, Cement, Glass or Stone Products	3,595	
Chemical Products	2,255	
Transportation Equipment	1,242	
Metallic Ores	630	
Secondary Traffic	252	
Misc Manufacturing Products	102	
Primary Metal Products	83	
Printed Matter	57	
Shipping Containers	0	

Menominee County Freight Profile (Year 2015)



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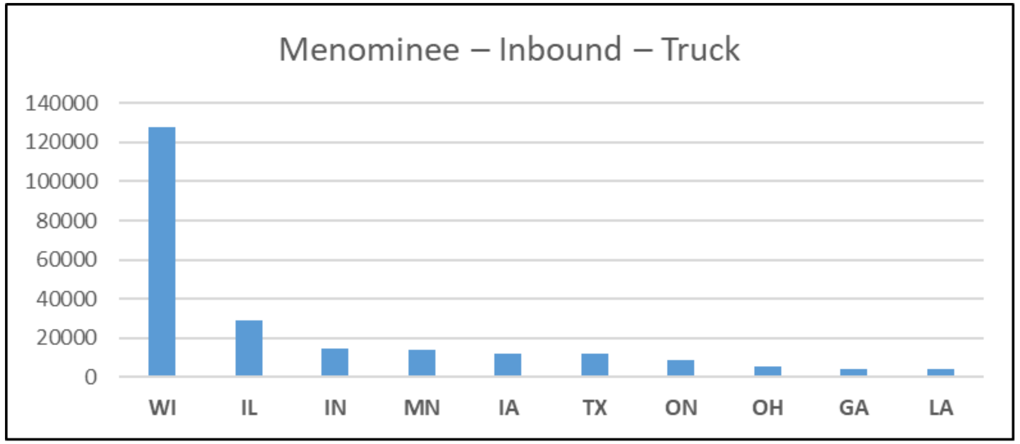
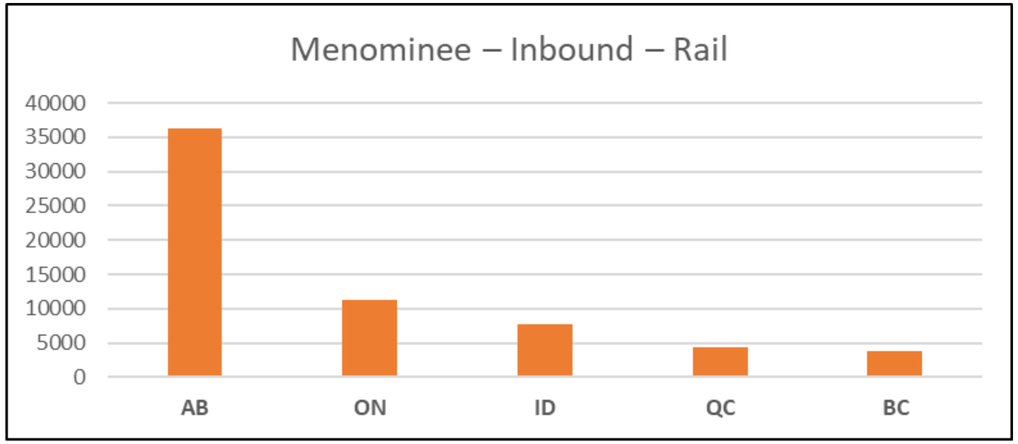
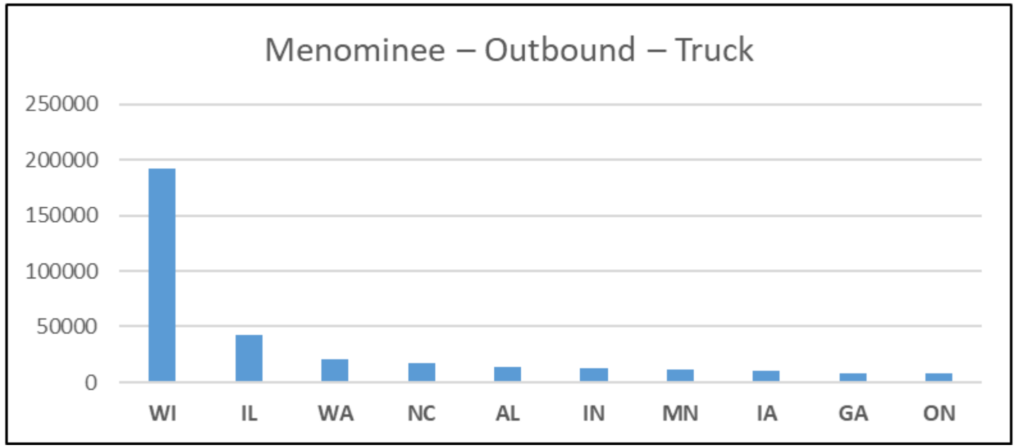
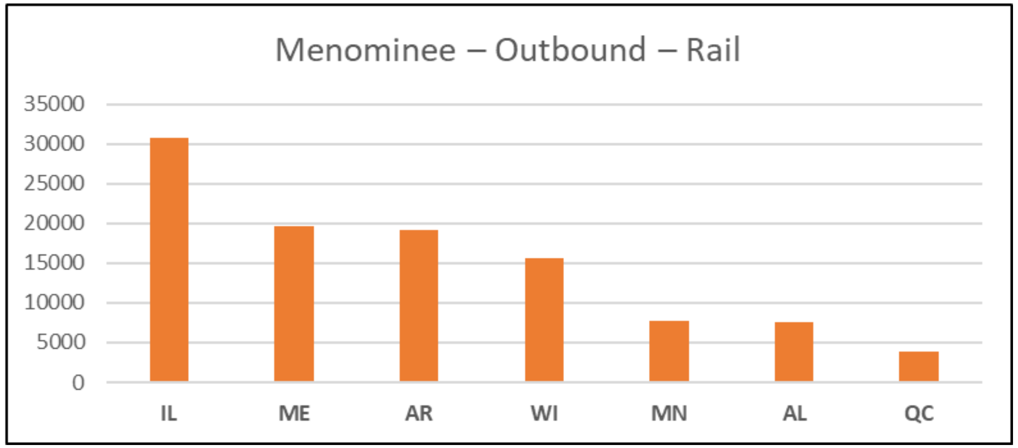
Menominee County Freight Profile (Year 2015)

Major Trading Partners by Mode – States/Provinces









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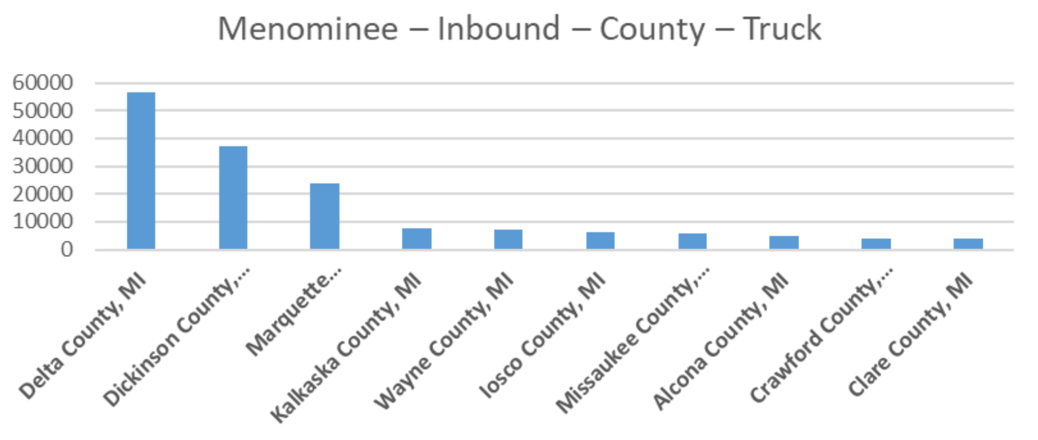
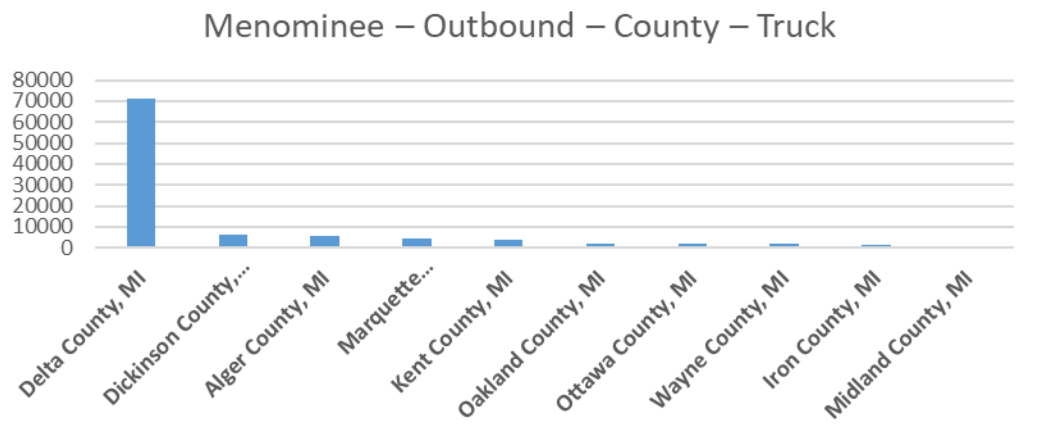
Menominee County Freight Profile (Year 2015)

Major Trading Partners by Mode – Counties



Menominee – Inbound – County – Rail

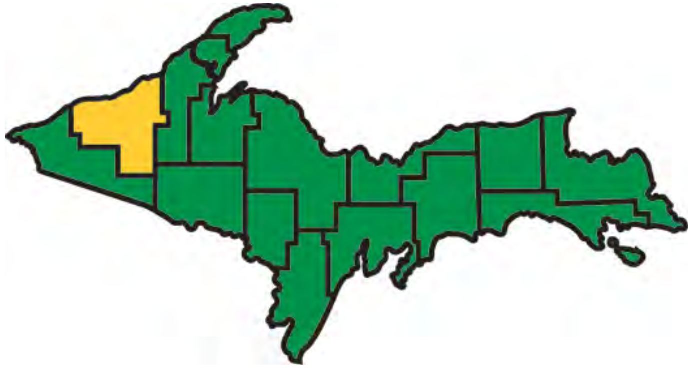
None



Menominee – Outbound – County – Rail

None

Ontonagon County Freight Profile (Year 2015)



At a Glance	
6,448	Population
2,317	Total Labor Force
2,108	Employed
9%	Unemployment

Employers (# Employed)	
Primary Employers	
Aspirus Ontonagon	135
Settlers Co–Operative, Inc.	40
Ewen Trout Creek Consolidated	31
Ontonagon Area Schools	25
AmericInn	20
Ontonagon County REA	10
DeHaan Forest Products	1
White Pine Electric Power	Closed

Industries (# of Establishments)		
Retail trade	26	16%
Construction	23	14%
Accommodations and food services	22	14%
Transportation and warehousing	20	13%
Agriculture, forestry, fishing, and hunting	13	8.1%
Other services, except public administration	11	7%
Professional and technical services	8	5%
Finance and insurance	8	5%
Utilities	5	3.1%
Administrative and waste services	5	3.1%
Arts, entertainment, and recreation	4	2.5%
Real estate, rental, and leasing	4	2.5%
Information	3	1.9%
Educational services	3	1.9%
Manufacturing	3	1.9%
Wholesale trade	2	1.3%
TOTAL	**160**	**100%**

Ontonagon County Freight Profile (Year 2015)

Major Commodities Ontonagon County by Mode

Internal

Truck		Rail
Logs, Lumber, and Wood Products	41,378	None
Farm Products	35	
Shipping Containers	0	

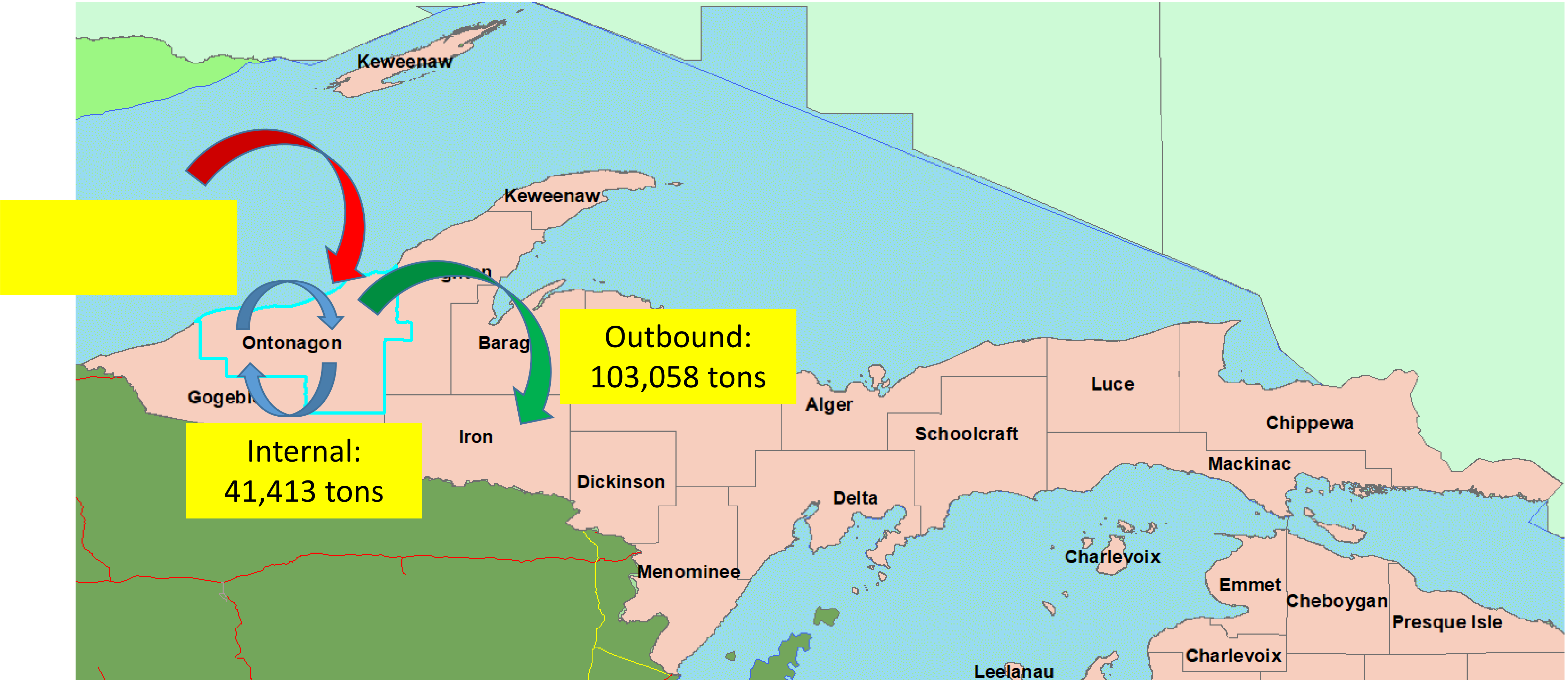
Inbound

Truck		Rail
Logs, Lumber, and Wood Products	43,938	None
Nonmetallic Ores and Minerals	6,703	
Secondary Traffic	6,498	
Clay, Cement, Glass or Stone Products	4,464	
Chemical Products	4,183	
Transportation Equipment	1,173	
Petroleum or Coal Products	1,040	
Farm Products	340	
Food Products	250	
Fabricated Metal Products	78	
Miscellaneous or Mixed Shipments	29	
Printed Matter	28	
Furniture Products	16	
Shipping Containers	0	

Outbound

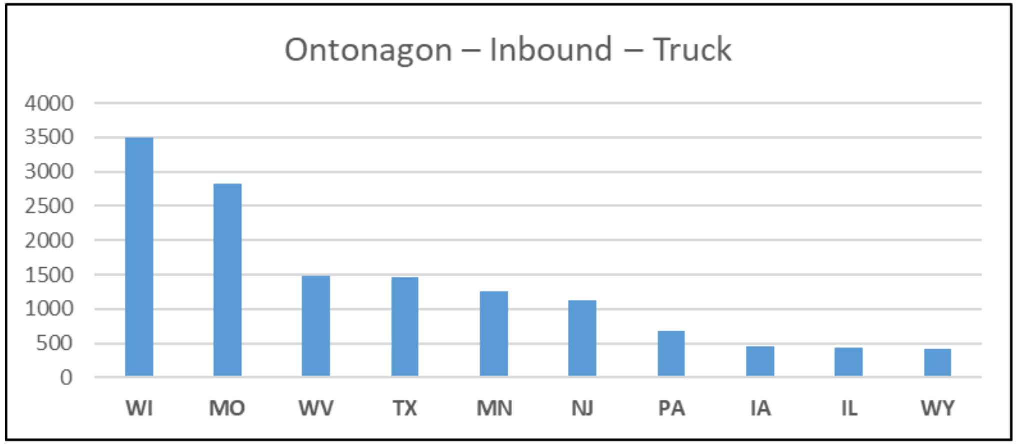
Truck		Rail
Logs, Lumber, and Wood Products	73,120	18,800
Farm Products	9,500	
Waste or Scrap Material	1,470	
Chemical Products	164	
Secondary Traffic	4	
Shipping Containers	0	

Ontonagon County Freight Profile (Year 2015)



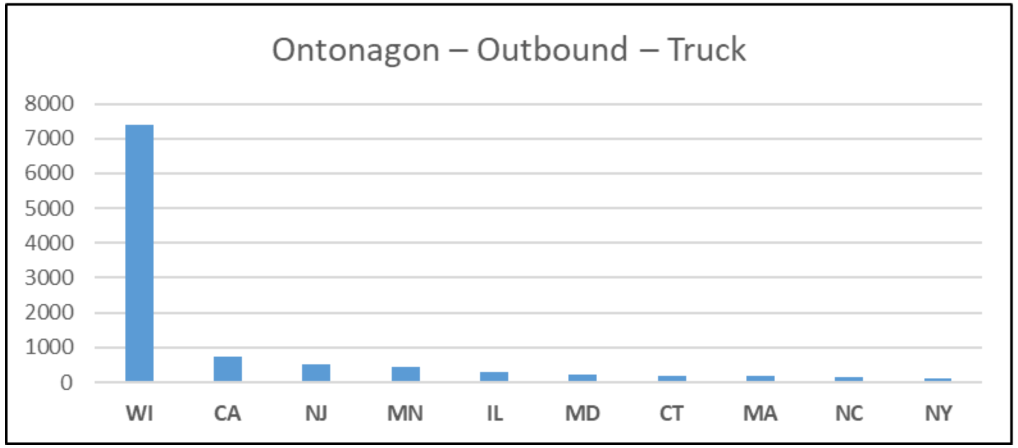
Ontonagon County Freight Profile (Year 2015)

Major Trading Partners by Mode – States/Provinces



Ontonagon – Inbound – Rail

None



Ontonagon – Outbound – Rail

None outside of Michigan

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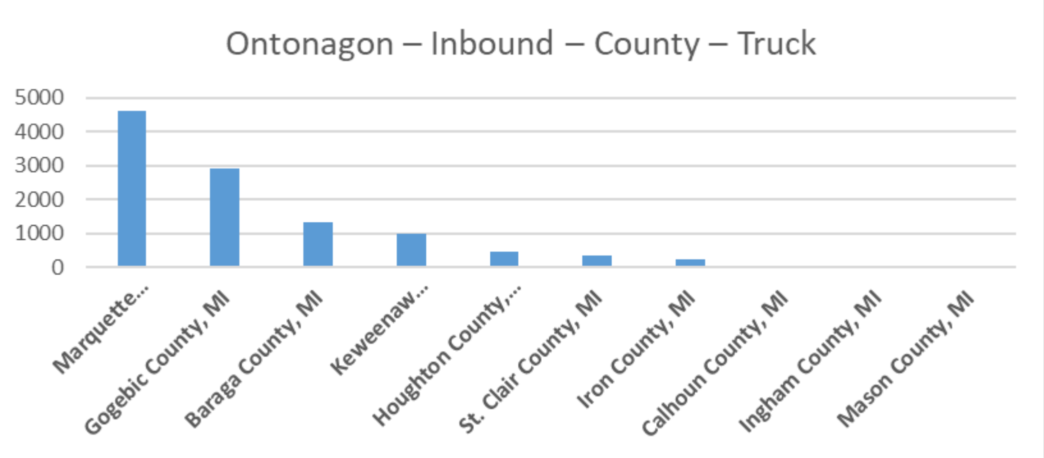
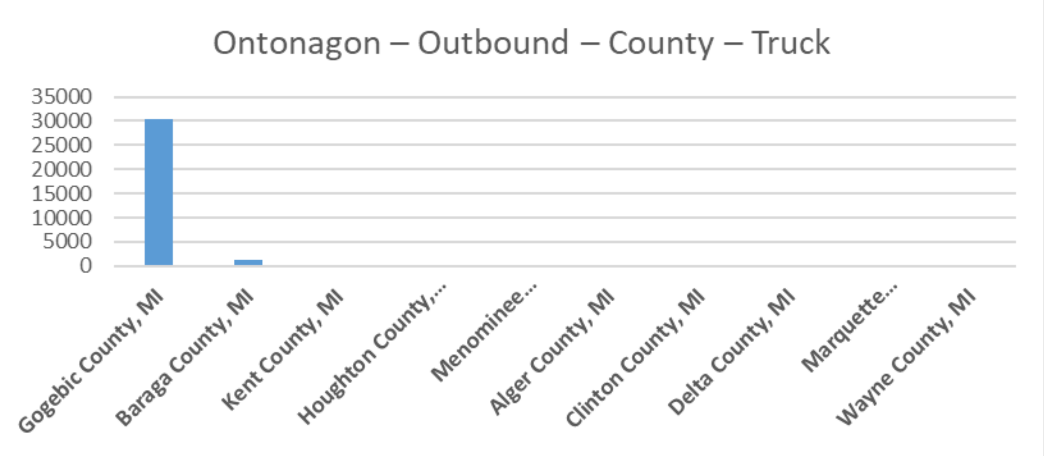
Ontonagon County Freight Profile (Year 2015)

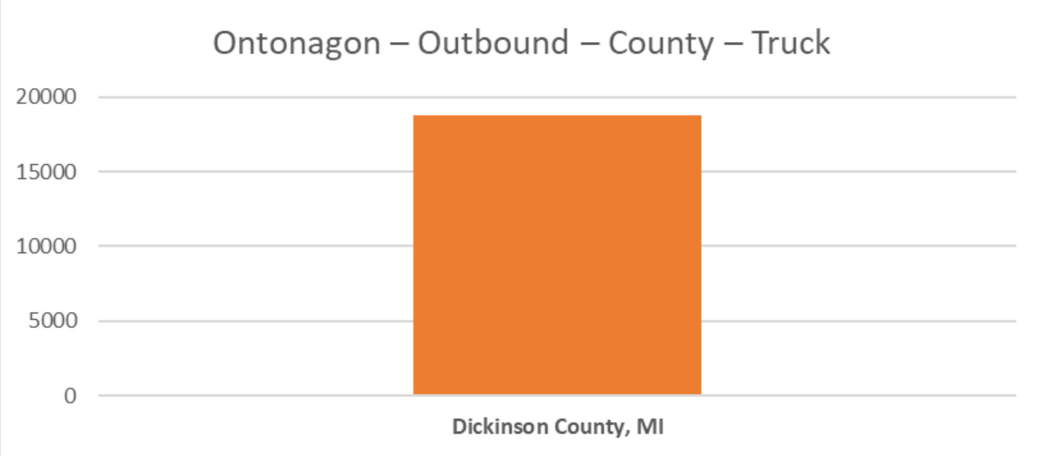
Major Trading Partners by Mode – Counties



Ontonagon – Inbound – County – Rail

None





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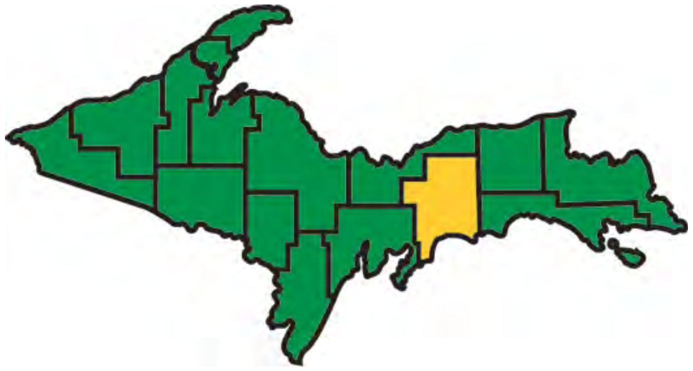
Schoolcraft County Freight Profile (Year 2015)



At a Glance	
8,345	Population
3,455	Total Labor Force
3,094	Employed
10.4%	Unemployment

Employers (# Employed)	
Major Employers that Export	
Manistique Papers	147
Carmeuse Lime & Stone	80
Graymount	27
OnLine Engineering, Inc.	20
Suburb Solar	2
Manistique Machine	1
Other Main Employers	
Schoolcraft Memorial Hospital	225
Manistique Area Schools	200
Kewadin Casino	108
Schoolcraft County	71
Jack's Supermarket	64
Tribal Community Center	45
Shopko	32

Industries (# of Establishments)		
Retail trade	39	18%
Construction	29	14%
Accommodations and food services	28	13%
Health care and social assistance	19	9%
Agriculture, forestry, fishing, and hunting	19	9%
Other services, except public administration	18	8.5%
Finance and insurance	12	5.7%
Transportation and warehousing	11	5.2%
Professional and technical services	9	4.3%
Wholesale trade	7	3.3%
Manufacturing	7	3.3%
Mining, quarrying, oil, and gas extraction	4	1.9%
Arts, entertainment, and recreation	4	1.9%
Information	4	1.9%
Utilities	1	0.5%
Real estate, rental, and leasing	1	0.5%
TOTAL	**212**	**100%**

Schoolcraft County Freight Profile (Year 2015)

Major Commodities Schoolcraft County by Mode

Internal		
Truck		Rail
Logs, Lumber, and Wood Products	52,482	None
Shipping Containers	0	

Inbound		
Truck		Rail
Logs, Lumber, and Wood Products	410,203	None
Nonmetallic Ores and Minerals	31,294	
Secondary Traffic	9,512	
Paper and Pulp Products	6,615	
Clay, Cement, Glass or Stone Products	3,801	
Chemical Products	3,683	
Petroleum or Coal Products	3,088	
Food Products	1,476	
Forest Products	1,061	
Transportation Equipment	841	
Farm Products	298	
Primary Metal Products	245	
Miscellaneous or Mixed Shipments	143	
Machinery	48	
Furniture Products	31	
Fabricated Metal Products	28	
Rubber and Plastics	26	
Printed Matter	24	
Textile Mill Products	2	
Shipping Containers	0	

Outbound		
Truck		Rail
Nonmetallic Ores and Minerals	346,698	
Logs, Lumber, and Wood Products	77,665	170,200
Paper and Pulp Products	52,599	
Clay, Cement, Glass or Stone Products	6,923	26,600
Farm Products	4,923	
Waste or Scrap Material	4,118	
Machinery	333	
Printed Matter	233	
Electrical Equipment	22	
Secondary Traffic	1	
Shipping Containers	0	

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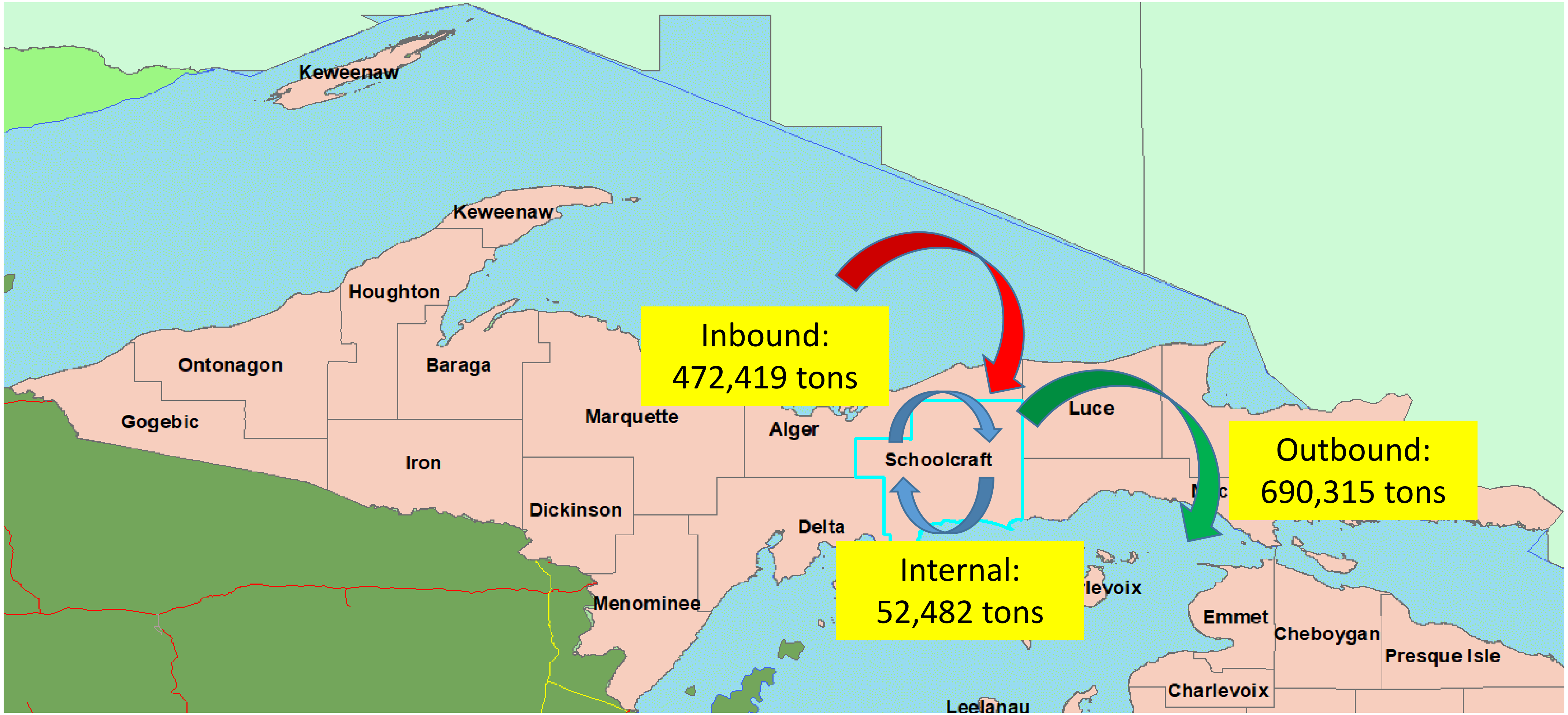
Schoolcraft County Freight Profile (Year 2015)



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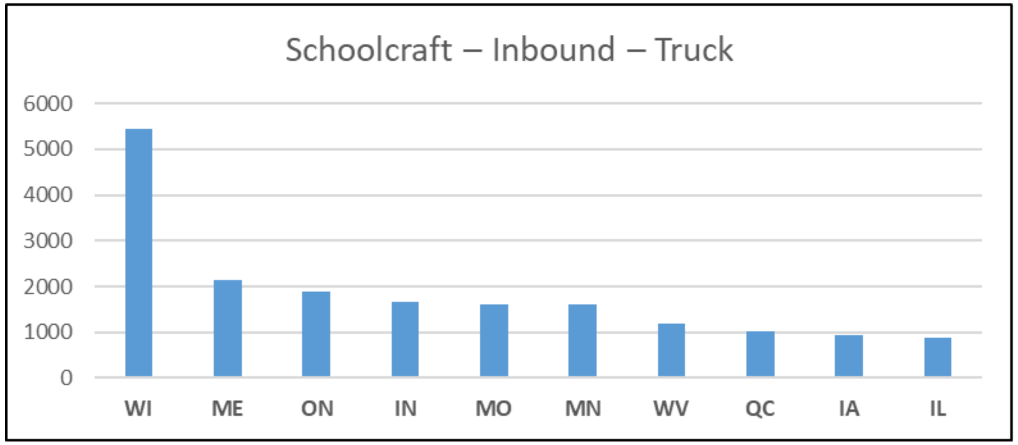
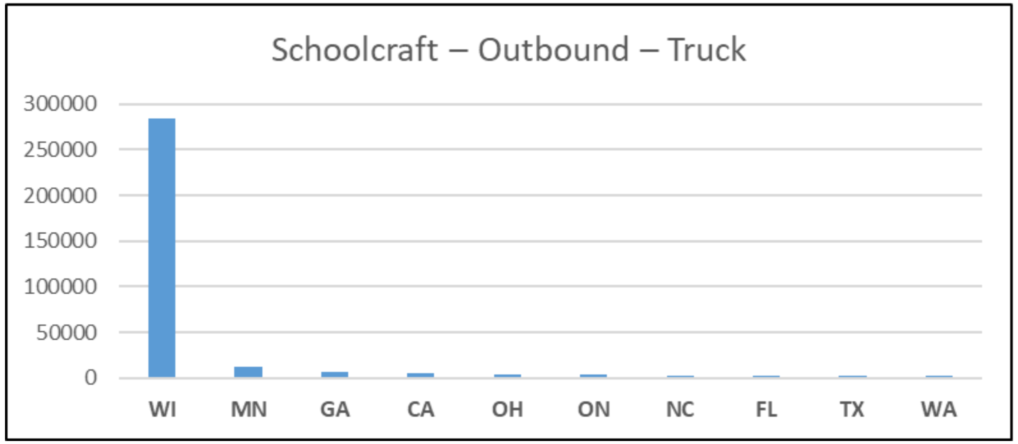
Schoolcraft County Freight Profile (Year 2015)

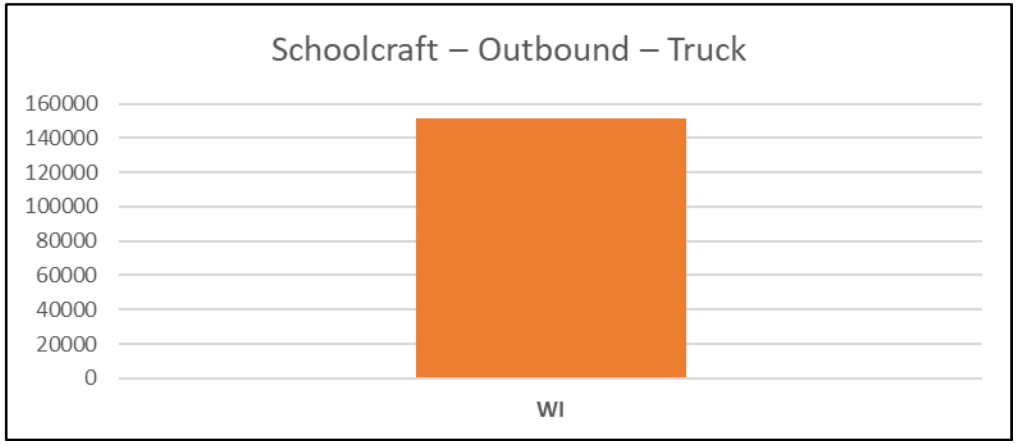
Major Trading Partners by Mode – States/Provinces



Schoolcraft – Inbound – Rail

None





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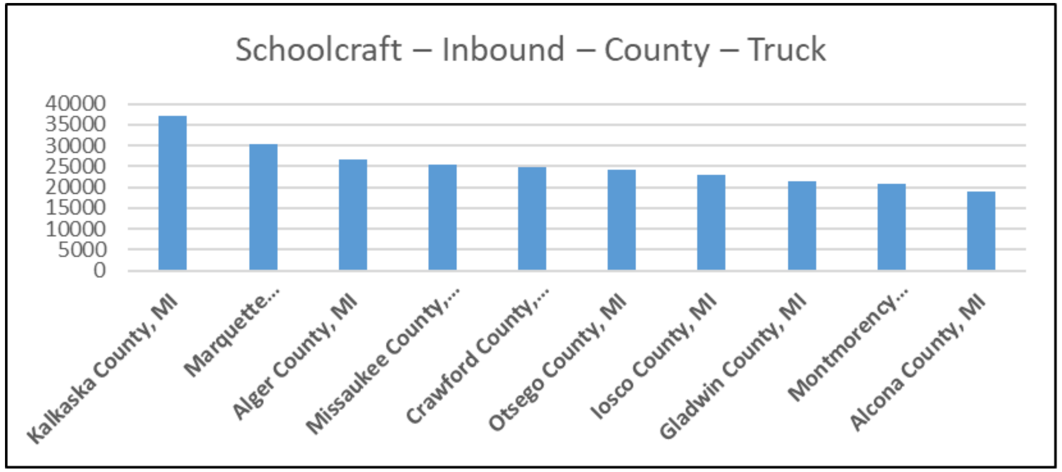
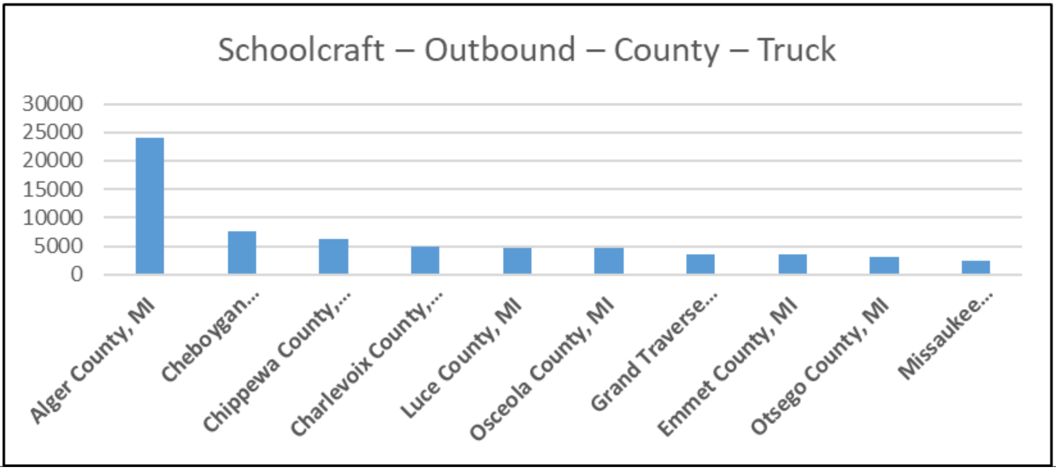
Schoolcraft County Freight Profile (Year 2015)

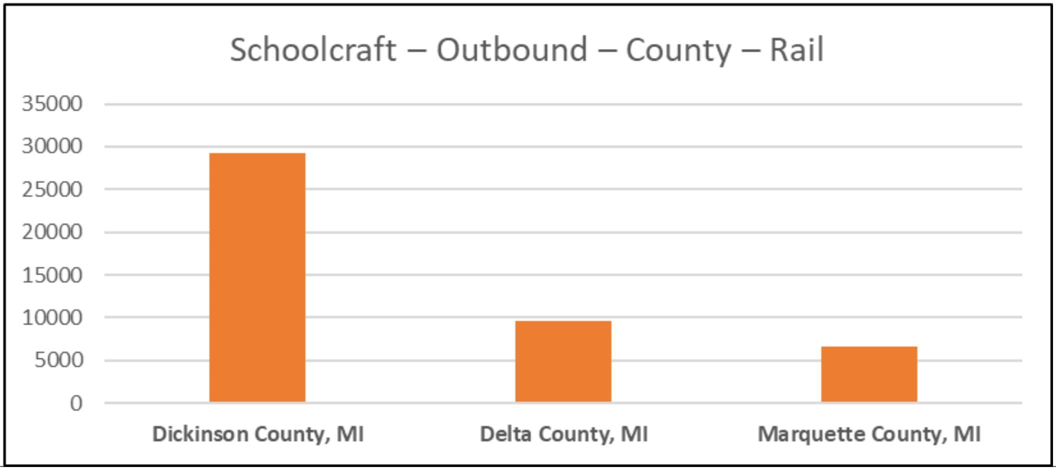
Major Trading Partners by Mode – Counties



Schoolcraft – Inbound – County – Rail

None





Appendix H

Case Study of Duluth Cargo:

Discussion Summary

Discussion Summary – Duluth Cargo (Intermodal Terminal)

By Pasi Lautala, Sangpil Ko, Kuilin Zhang, April 30, 2019

The following discussion summary is based on web conference between Michigan Tech research team and Duluth Cargo management, and site visit by Sangpil Ko.

Overview

Duluth Cargo Connect (DCC) is a joint marketing brand of the operating agent established by Seaway port authority and Lake Superior Warehousing. It consists of three business, maritime terminal, warehousing, and lately CN intermodal yard. The facility started its operation in 1991 under Seaway port authority. Partners work together in marketing, planning, capital investments getting public funds. Day to day operations and handling customers are responsible of Lake Superior Warehousing while Port authority's mission is to market/business development. Behind the scenes revenues/expenses are shared between partners.

Intermodal Terminal Development

Original idea was to add maritime container transportation to compliment breakbulk ships moving at Great Lakes (both domestic and international from Europe). Question on what do you do when seaway is closed for 2~3 months in winter led to intermodal discussions. In addition, it was learned that many customers were interested in containers not only for European, but also for Asian traffic. Based on DCC. intermodal terminal is almost like international airport. It opens the facility to customers that wouldn't be interested without that option. Lots of current containerized cargo didn't use to move that way but times have changed. Intermodal terminal allows new customers to take advantage of the service.

The uniqueness of Duluth is that it has great highway access and four class1 railroads with access to the property. CN was attractive due to large existing business in carload side (over 6,000 cars were shipped last year) and their mainline for intermodal runs through Duluth while BNSF and CPR are in Minneapolis and UPRR in Chicago. In addition, CN is only carrier with access to three coasts and six ports. CN has also a history of small terminal developments at Chippewa Falls and Arcadia. Unlike those terminals that were developed to serve a key anchor customer, CN/Duluth Cargo wanted to make a "boutique" smaller ramp that is open to all customers. CN also liked the idea that terminal was on existing property that had warehouse, foreign trade zone classification, and customs that make no need to dray containers across town to do customs.

Before opening the terminal extensive market research was conducted internally and with help from others. Once the decision was made, the project was funded through a combination of Port Authority and DCC, including public dollars such as DOT or USDOT applications. Key was leveraging the existing warehousing and rail infrastructure. Starting the operations required very limited capital funds, although there's current $2.3 million plan to expand the terminal. Starting from scratch would cost many millions!

Intermodal Terminal Infrastructure and Operations

Intermodal terminal has very basic infrastructure with no automation. Reach stacker handles containers (see photos at the end of document). $2.3 million capital improvement is planned to increase track space and more laydown space for containers. This capital investment will put Duluth to good position due to the ability to stage 1,500 TEUs. In 5-10 years, the goal is to get to 45,000 lifts range, although it will probably require more lifting equipment (reach stackers will remain sufficient).

Intermodal terminal was opened two years ago and the first train had six containers. Since then, the number grown into four figures (detailed number is confidential). Balance is fluctuating (it's key) due to the Rubber band syndrome (imports/export fluctuate). Most volume is west/east coast with some "North America" customers (from Canada). Magic to shippers is that terminal can receive/ship overload containers right there. Containers are shipping 56-60k lbs. while typically they would only ship around 40-42k lbs. A container can be destuffed in 20-30 minutes while grain/paper rolls require 30-45 minutes transload. To accommodate this, warehouse was reconfigured (to allow for use of intermodal customers). 75% of warehousing is not related to intermodal, but the remaining 25% is (again, this was unexpected). Additional benefit from transloading is the fact that containers won't leave the premises, allowing them to get back to rotation faster (and reducing empty miles/time).

All container movements are truck/rail (no trailers are moved in terminal). CN serves the terminal daily, but there are no dedicated intermodal trains (insufficient volume). Startup time has been higher than advertised. It takes 12 days to Prince Rupert (Canada), even takes 14 days. The terminal is still in startup mode, as no aggregated volume for a direct train out of Duluth exists. Once that is received, times will get better. On the other hand, these are comparable times with competing terminals and Duluth is more fluid than competing terminals. For customer satisfaction, consistency is more important than transit time, as they can incorporate longer transit times in their supply chain plan.

Customers and Commodities

There are a few larger ones. In total, number of customers using the ramp is high, 15-20 and volumes vary, but not relying on one customer. Various forest products account for almost 50% of all movements. Most shippers have done intermodal before in some way, but now they are changing supply chain for value added services (e.g. destuffing). One customer has started to export. As stated earlier, the overweight container is a really big advantage and almost 90% of customers is using transloading in one way or another. DCC can reduce freight cost by 20-30%. It's still cheaper after destuffing, as van trailer can do something else (since a round trip for container outside the terminal is eliminated). DCC is dealing with paper rolls, pulp, steel products, grain, pelletized products, supersacs and even some retail inbound (from Asia). Containerized grain shipping is starting due to overweight opportunities. Typical container movement is priced with the rate with steamship line, as it covers all cost in between O and D. However, if transloaded and warehoused, Duluth Cargo charges separate fees for touching the contents while traditional containers include no separate fee.

Catchment area map goes from Twin Cities (bottom end), Wisconsin and UP (East) and North Dakota for grain. Dakota is farther drayage as limited terminal competition. Most drayage is within 100 miles for forest products (West). Quite a bit to Twin Cities (even beyond due to overweight). High end drayage mile is 200~250.

Challenges and Take on Another Intermodal Terminal in Region

Steamship lines are challenging. DCC is finally getting them to engage and offer Duluth as port of entry adding it to their network. Maersk, Evergreen, Yangming are using terminal, but need more. CN is involved in the effort. The second concern is warehouse space, mainly due to high level of transloading. Capital investment (or funding) is not considered a problem.

From DCC perspective, it would be difficult to justify another intermodal ramp in the region (or for example in the UP Michigan). Railroads have limited interest for smaller ramps and CN might argue region is saturated (other railroads even less interested in small ramps). Also, steamship lines don't want to see another remote terminal to serve. Additional problem is to have anchor customer who brings import boxes to the area. If you can't get imports, you would need to reposition and there's cost for that. It would impact economic viability. Thus, it would need a large anchor importer in those areas.

On the other hand, DCC could envision railcar traffic from the region that gets transloaded to containers in Duluth. Since they already receive lots of traffic from CN and others, it would be of no problem.

Appendix I

Discussion Summary – Forest Products Transportation in Finland

By Pasi Lautala, April 17, 2019

The following discussion summary is based on a meeting with Metsa Group logistics managers.

Overview

Metsa handles approximately 15 million tons of log movements on annual basis (in whole Finland). That's approximately 50,000 m3 on daily basis. These are their own purchases. There's 80-90 destinations for them (saw logs and pulp logs combined). In addition, some wood is transported for energy production to 50-60 smaller mills. The largest destination is Aanekoski that has five different facilities (including the new pulp mill).

Trucks vs. Rail

75% of the logs move on trucks. On very few occasions they have used barges. There are approximately 400 trucks (by 200 companies) moving the logs. On rail side, VR Cargo moved approximately 15 million tons of logs in 2018 with 16 trains (not sure if they all run every day). Almost 40% of them were for Metsa. 2.5 million tons of logs moved by rail originated outside Finland (mainly Russia).

Truck Movements

Truck length has recently been extended by one meter in Finland, which allows for adding a second bundle of logs to the engine unit. However, the total weight of 76 tons is now becoming limiting factor (trying to change that). Metsa uses a Logforce and Woodforce software (by Trimble) in all log trucks and harvesting equipment to provide real time information on the available resources. Most of the other large forest industry corporation, as we as the federal agency responsible for forest harvests, are using (starting to use) the same software. For logistics managers (internally), Metsa has Otso system to coordinate harvesting/delivery plans.

All orders from the plants are relayed on weekly basis to the Logforce/Woodforce systems. Each logger/harvester have a "home logistic zone" (typically closest to their home/business). Once orders are in, loggers/drivers have full flexibility on how they make deliveries, as long as they complete the orders within the week.

One exception is so-called "MEPA" runs. These are attempts to establish circular routes that reduce empty miles. They will keep the "home zone" in mind and won't assign routes that would exceed the daily service hours for drivers. It also accounts for locations that may be under weight limits during spring breakup. These assigned routes MUST be driven as MEPA.

The average supply radius is appx. 100 kilometers (60+ miles). Hardly any truck loads come from more than 150 km distance (90+ miles). Rail movement distances are longer. Great portion of loads goes directly to the mills, but use of intermediate terminals with contractors and loading equipment has increased. All incoming wood in terminals is unloaded by truckers, but typically loaders are available for outbound movements. Typically, truckers are given a four hour window to take their load to the mill (to avoid truck lines). Mills have automatic registration based on truck license plate, so unloading process is very fast. Truckers are paid on ton-mile basis.

Rail Movements

Train transportation is handled by Metsa's own logistics managers. The orders for trains are placed in three week intervals. There has been a great decrease in the loading sidings over the last two decades. Today, there are appx. 80 loading sites in Finland (Metsa uses approximately 60 of them), but majority of movements come from large "station terminals". There is only a few of them and they all have loading equipment and contractors. Truckers bring the wood to the terminal and unload from trucks, contractor loads to the rail cars. In some terminals, there is wood from multiple companies (but only one contractor). Loading time is appx. 6 hours per train (24 cars). Each terminal can handle at least 24 cars (typical train size).

As mentioned, there are fewer smaller sidings left that can't handle 24 cars at once. Most of the remaining ones are fairly close to mainlines to minimize low-density line distance. At smaller sidings, logs are loaded 50/50 directly from trucks and from storage piles. They have typically 24 hours to load the cars.

All larger pulp mills by Metsa (appx. 10) receive rail shipments. Overall, rail transportation is very balanced throughout the year, there are no added volumes during peak (or spring break) periods. There is more rail deliveries during the weekends, as trucks aren't driving then. Train movements follow standard schedules. Trains depart at the same time every time, so everyone knows when loading has to be done. From larger terminals, shipments are often in unit trains and train keep running back and forth (unit train operation). For example, from Kemi-Rovaniemi, there is two such trains daily.

Unloading at mills is done in very tight windows. Typically, they only get 4 hours to empty a 24-car train. VR coordinates that trains from different directions don't overlap. VR only drops the cars at the mill and contractor moves them with Trackmobiles during unloading process.

Metsa also highlighted that they hold regular meetings with VR Cargo to review performance metrics and discuss service.