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The Role of Railroads in Multimodal Woody Biomass Transportation in Michigan

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ABSTRACT

Minimizing transportation costs is essential in the forest products industry, as the relatively low value and high weight of the products causes transportation to account for exceptionally high portion of the overall cost. The forest products such as logs, chips, and residues (woody biomass) are one of the major business sources in Michigan especially in Upper Peninsula of Michigan. Currently, truck transportation is used for the great majority of the trips, but it is believed that a more cost-efficient transportation chain might be achieved through use of multimodal approach by trucks and rail and in some cases water transportation.

This paper presents the three alternative transportation supply chain models for woody biomass transportation; 1) single mode, 2) multimodal and 3) intermediate storage. The paper uses data from three recent studies to describe the forest products transportation in the upper mid-west, including the typical distances for movements and the breakdown of cost elements for each alternative. It will discuss the potential benefits of increased use of rail as part of the transportation chain and address the perceived drawbacks and challenges caused by the shift. It will also present cost-gradient maps developed to highlight the capability of rail to expand the economical radius for obtaining feedstock and demonstrate how increasing fuel prices change the balance toward multimodal transportation. Finally, the paper will highlight the potential for gained efficiency in log truck operations through increased use of rail.

Key Words: *Forest Products Transportation, Truck-Rail Multimodal, Minimizing Transportation Cost*

1- INTRODUCTION

The increase in global competition and energy prices over the past decade has forced industries to search for potential savings in their transportation supply chains and logistics systems. In the forest products industry minimizing transportation costs is even more crucial, as the relatively low value and high weight of the products cause transportation to account for exceptionally high portion of the overall cost. The Midwest forest products industry is no exception, as it functions in an extremely competitive global market, where most products are a pure commodity with little in the way to differentiate production. Transportation costs may account for almost half of the delivered cost of feedstock (logs) to the mill gate, so the overall health and competitiveness of the industry is highly dependent on affordable and efficient transportation system [1].

Freight can be transported from origin to destination via a single mode, or by multiple modes. Multimodal transportation refers to operations that use more than one mode of transportation during the process. However, the whole shipment typically moves under a single freight bill and the chain is often managed by a single entity. In contrary to intermodal transportation where cargo remains in a single container from one transportation mode to other, multimodal transportation cargo gets transferred from one vehicle to another; such as from truck bed to railroad car [2].

The current research reviews the role of rail services in multimodal log / biomass transportation in Michigan and respective challenges, requirements and multimodal scenarios. The paper starts with review of different alternative scenarios of biomass delivery in Michigan, followed by the current conditions of woody biomass transportation, mainly conducted through road and rail modes. Discussions about challenges and difficulties that may reduce the role of rail transportation are followed by the evaluation of the average distance of biomass delivery in Michigan. Finally, the cost analysis on the single and multimodal scenarios of biomass delivery in Michigan is evaluated based on the GIS-map modeling approach, including sensitivity analysis on different fuel prices.

2- BIOMASS DELIVERY SCENARIOS

There are three major alternative supply chains for biomass transportation scenarios (Figure 1). In most cases, biomass is transported from the forest landing to the final destination (mill or plant) by a truck in a single movement (Scenario 1), but the supply chain can also take advantage of multimodal transportation opportunities (Scenario 2), or utilize intermediate storage locations to break the transportation chain (Scenario 3).

The common denominator for Scenarios 2 and 3 is that they tend to increase the overall time consumption and number of handlings required to deliver the biomass to the final destination. Each scenario is described in more detail below.

Scenario 1-Truck Transportation: Trucking is the most likely scenario for biomass transportation. In most cases, a single truck will haul the biomass from forest landing to final destination in one continuous move without intermediate stopping or handling requirements.

Scenario 2-Multimodal Transportation: The inclusion of rail or marine transportation typically means that the supply chain becomes multimodal. Biomass gets transported by trucks from the landing and transferred either to rail or marine transportation without storage in between. The loaded rail car or vessel may be delivered either directly to the final destination (mill, power plant) or it may have another handling between rail car (or marine vessel) and truck prior to final delivery. In either case, multimodal supply chains require at least one additional handling of the load, increasing the supply chain cost. On the other hand, these costs may be offset by lower transportation unit cost by rail or marine modes.

Scenario 3-Intermediate Storage: The third scenario adds an intermediate storage yard to the supply chain. There may be various reasons for using the scenario, such as a lack of capacity at the final destination, or preparation for highway weight restrictions during the spring time. The scenario may utilize one or more modes of transportation, but will also increase the number of handlings required between origin and final destination.

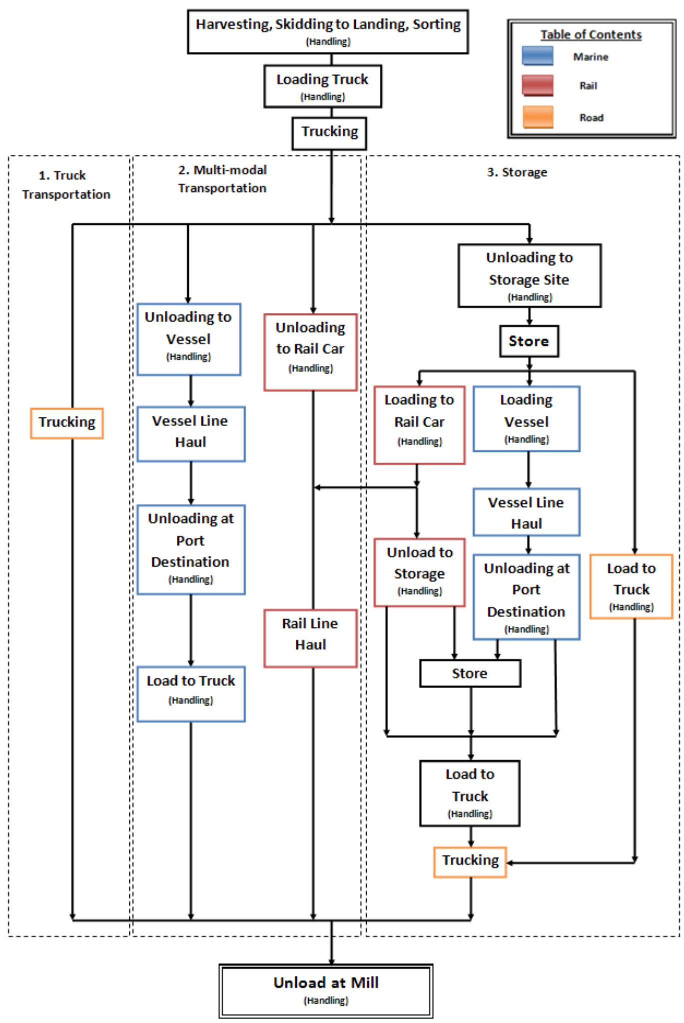

Figure 1- Alternative supply chains for biomass transportation

There are numerous considerations that determine the selection between alternative supply chains and each situation needs to be reviewed separately. However, there are some common denominators that either support or limit the use of certain alternatives, such as:

- Location of harvesting area
- Location of final destination and availability, or adjacency to the railroad track/marine port facilities
- Total hauling distance and the volume of biomass material to be hauled. Longer distances and higher volumes increase the likelihood of multimodal scenarios. Lower volumes for short distances are more likely to be delivered by truck.
- Type of biomass material and required sorting, processing activities on the raw material.
- Number of handling and switching between truck to the other modes (rail and water) and number of switching or carrier interchanges during rail transportation. Due to the fact that transportation distances in UP are rarely long enough for economic water transportation, the maritime option has not been included in the study.

3- BIOMASS TRANSPORTATION IN MICHIGAN

According to the U.S. Department of Transportation's, Research and Innovative Technology Administration, more than 282 million tons of freight commodities with values of $409 billion were transported (transit, import, export or in-state movements) in 2007 in the State of Michigan, forming approximately 3.5% of total value (2.2% of total weight) of U.S. shipments in 2007. The majority of this volume (72%) was shipped by trucks (road). For in-state movements, this share was even higher, almost 85%. Almost 50% of domestic shipments originating in Michigan were for less than 50 miles, 40% between 50 to 500 miles and less than 10% for more than 500 miles. Finally, less than two percent of in-state movements used multiple modes.

The log transportation within Michigan equaled 12.3 million tons in 2009 and wood products added another 3.6 million tons. In total, these products accounted for approximately seven percent of overall in-state tonnage. The volume of woody biomass transportation in Michigan is unclear as categories for such movements were not identified in the data. [3]

In 2009, over 12 million tons of logs were transported within Michigan, complimented by over three million tons of wood products. These volumes significantly outweighed the movements that crossed state borders that were approximately 1.5 million tons from/ to four neighbor states to Michigan (Illinois, Indiana, Wisconsin, and Ohio).

The road transportation of forest products is typically provided by two alternative types of trucks, either log trucks for round wood, or chip trucks/vans for chips from round wood branches and logging residues.

The freight rail network in Michigan includes 4,412 miles of track which also supports three shared passenger rail corridors. (Figure 2) The current network is owned and operated by 30 freight railroads, mainly in the Lower Peninsula (L.P) [4]. Upper Peninsula (U.P.) is served by three railroads and there is no rail connection between the peninsulas.

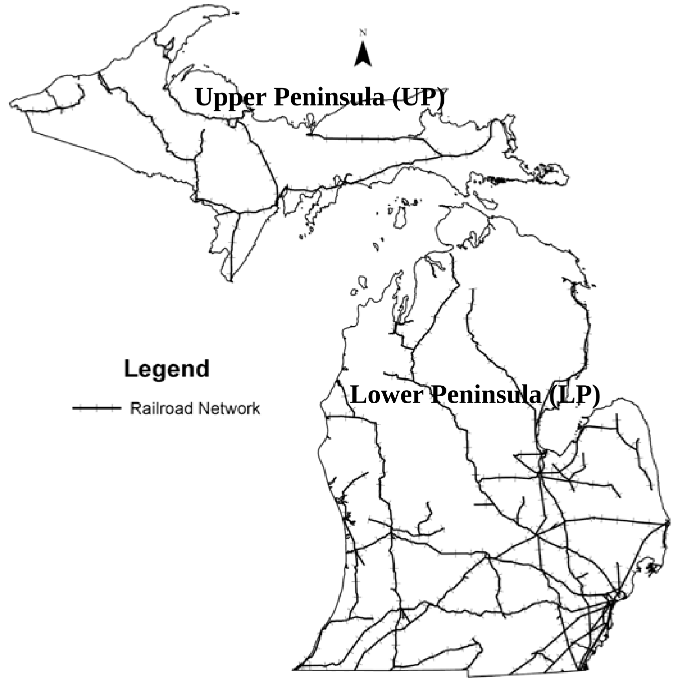

Figure 2- GIS map of railroad network in Michigan

According to MDOT's analysis, Michigan's railroads carried over 110 million tons of freight in 2006, which is more than 25 percent of Michigan's total ground commodity movements. However, the portion of woody biomass, lumber and forest products were minor with only 3% of rail imports and 5% of exports [4]. Furthermore, it can be interpreted from MDOT report that the majority of exported lumber and wood products originated in the Upper Peninsula and was moved by E&LS and CN railroads to Wisconsin.

More detailed information on the role of rail transportation in woody biomass movements was obtained as part of the Logger Survey conducted as part of Forestry Biofuel Statewide Collaboration Center (FBSCC) project, at Michigan Tech. The survey inquired on the current use of rail, potential future willingness to increase the use of rail, and the main barriers to increase rail usage. The outcomes revealed that only 13% of shippers (28 out of 220) currently used rail to transport biomass. Even more significantly, all of these shippers were located in the U.P. and only 20% of their annual volume moved by rail. The survey outcomes confirm the limited role that rail transportation currently has for woody biomass movements, especially in the L.P. [5]

Roughly 33% of the loggers who responded to a question about their use of rail transport were interested in increasing the use of rail to transport forest biomass. However, there are factors that limit their enthusiasm to make the shift (Table 1). Overall, the most important factors identified by respondents to prevent an increased use of rail transportation were reliability (3.53), limited rail access (3.49) and speed of delivery (3.39).

Table 1- Limiting factors for increased use of rail transportation for forestry biomass

Potential Limiting Factor For Increased use of Rail	Average score 1= Not Limiting, 5= Extremely Limiting
Lack of knowledge on rail contractual agreements	2.48
Reliability of service	**3.53**
Speed of delivery	**3.39**
Limited rail access within main working areas	**3.49**
Price is not competitive with other modes of transportation	3.03
Minimum shipment size is too large for operation	2.49
Existing contract with other providers	2.12

The factors highlighted by loggers are also some of the greatest challenges for increased rail transportation. Forest products come from various small locations and rail access at points of origin is often limited. The reliability of service and speed of delivery are closely related. The factor that log products come from large number of origins and have limited volume makes it difficult for a railroad to provide frequent service. In addition, rail network of any individual railroad is quite limited, so most movements typically require at least one interchange from one railroad to another, immediately increasing the overall transit time. In fact, interviews with railroads revealed that almost 100 percent of their loads get interchanged at least once. Finally, while most of the past biomass facilities had rail access due to historical use of rail, newer facilities may shy away from the costly construction of rail spurs to their plants, reducing the applicability of rail transportation.

4- BIOMASS TRANSPORTATION DISTANCE IN MICHIGAN

The overall portion of transportation costs in the supply chain is highly dependent on the distance traveled from landing to the unloading location, such as the mill/power plant. For instance, in a research conducted by Federal Administration Railroad (FRA), it has been pointed out that trucks are typical competitive shipping alternative to rail services for lumber and forest products, because its shipment size and distances to markets tend to be smaller than for coal and wheat [6].

The research team at Michigan Tech also used three different sources of data to investigate the typical range biomass movements in Michigan. An on-going study by the University of Wisconsin-Superior and Michigan Tech used Geographic Positions System (GPS) receivers in log trucks for two one month periods to research the movements of log and chip trucks in the Upper Peninsula. Based on the study, the average round trip distance between loading and unloading locations for each log/chip truck totaled approximately 150 miles (75 miles each way). It was also identified that only four percent of all delivery destinations of trucks were rail sidings (five times out of 128 unloading) [7].

Another source for average transportation distances was the logger survey conducted as part of FBSCC project [5]. The loggers were requested to provide information on typical trip distances in 30 mile intervals for chips, pulp logs and saw logs, respectively. The outcomes revealed that the majority of all three types of log/biomass are transported within a ninety mile radius from the landing with pulp logs traveling slightly longer distances than chips and saw logs (Figure 3).

In 2009, Hicks analyzed more than 100,000 trip datasets of log trucks through the Michigan, Wisconsin and Minnesota regions. [8] Based on the collected data, a histogram was constructed to show the relationship between tons of logs and transportation distances. The average distance of Hicks' sample was less than 100 miles, but over 27% of production traveled more than 90 miles by truck. Hicks' study has the most comprehensive sample of log movements and its outcomes are comparable to the data from the other studies. However, it is notable that there were numerous trips between 100 and 200 miles and some even beyond 200 miles.

The data from all three references suggests that the average hauling distance between 75 up to 100 miles is an accurate range for a typical log/biomass transportation movement in Michigan. However, it must be remembered that above samples utilized only truck transportation data and did not include movements that took place with other modes, especially by rail.

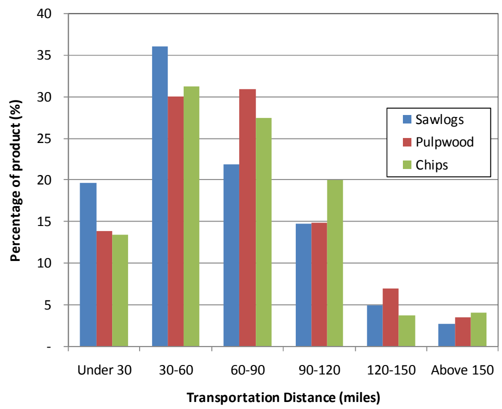

Figure 3- Biomass transportation haul lengths in Michigan based on loggers' survey

5- COST SENSITIVITY ANALYSIS ON BIOMASS TRANSPORTATION IN MICHIGAN

Truck transportation is a highly competitive area of business causing the rates between different service providers to be closely aligned. The charges are commonly based on the freight tonnage and length of haul making it easier to provide generalized rate estimations for various distances and tonnages in a single formula.

Round wood shipping rate data was obtained from a single operator in the Lower Peninsula (L.P.) of Michigan and several operators in the Upper Peninsula (U.P.) of Michigan to assess transportation costs in the L.P. as well as U.P. (Figure 4) Movements that cross the Mackinac Bridge between the peninsulas should receive $4 per cord (cord equals 2.35 tons) additional fee to cover the crossing fees. The rates provided are for single-directional movements, but potential backhauls or circuitry routes that increase loaded miles has potential to reduce the rates.

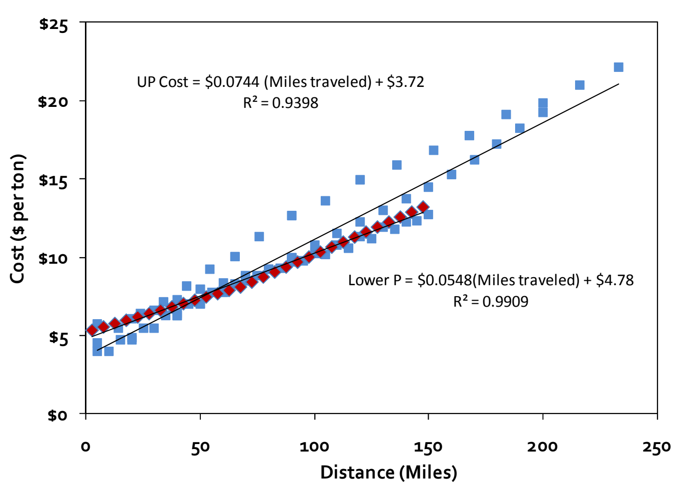

Figure 4- Lower Peninsula round wood transportation cost (red) as compared to aggregated costs for several Upper Peninsula trucking companies (blue)

For rail transportation, rates are not as easy to determine as for trucks, since every rail service provider has a specific rate for each route that doesn't necessarily follow mathematical formulas. In addition, rail service providers reward customers with consistent volumes with individually negotiated contract rates and some origin-destination pairs may require a transfer of load from one railroad to another (interchange), further increasing the cost. For these reasons, accurate transportation rates for multimodal truck-rail combination have to be estimated case-by-case for each origin-destination pair. Typically, the rail transportation rates are formed based on following criteria:[9]

- **Freight volume**: To obtain a more economical contract rate, rail operators typically require minimum volume commitments.
- **Total mileage and amount of switching and interchanges** with other railroads required en route.
- **Equipment and fleet**: Types of the cars, loading and unloading facilities.
- **Availability of cars and trains**: number of cars and the period of the time which should be moved.
- **Car ownership**: rented, leased or owned by shipper versus railroad-owned pool.
- **Competition between rail operators** along those corridors with more than one rail service provider.
- **Customer bargaining power** based on reputation, long term shipping history, previous interactions.
- **Market attraction** based on the demand, growth rate, possible expansion.

No specific rate estimations for bimodal trips were developed as part of the FBSCC study, as specific quantities and origin-destination pairs were not identified for the proposed facilities. However, Hicks combined the knowledge of rail and truck rates with geographic information in his studies and attempted to find the minimum transportation cost of logs between a defined origin/destination pairs. [8] His model was tested on 100,000 actual truck trips and has further been expanded to evaluate transportation cost to a proposed cellulosic ethanol plant planned for Kinross-MI. The following section provides a short case study on the model and how it has been used for bimodal transportation rate estimations to Kinross.

As part of his study, Hicks was able to determine tariff and contract rail rates offered by CN Railroad in the U.P for log transportation. These tariff rates were developed separately for 100 specific origins and destinations from the CN web site and later contractual rates were derived from Lake States Shippers Association (LSSA) data. It was recognized that both tariff and contract rates followed a linear relationship

(Figure 5). The figure reveals a typical trend for rail rates, where cost per ton for initial 100 miles has a small variable cost, but after 100 miles this portion increases. This is due to the fact that for the first 100 miles, the majority of costs are caused by the handling and other operational costs, largely independent of the distance being shipped.

Figure 6 combines the rail and truck rates to form the bimodal rates. According to Hicks' analysis, logs move on average 20 miles on road, before they reach the closest rail siding and get loaded to the rail cars, so trucking charges for 20 miles is added to the rail rates to form the complete bimodal cost.

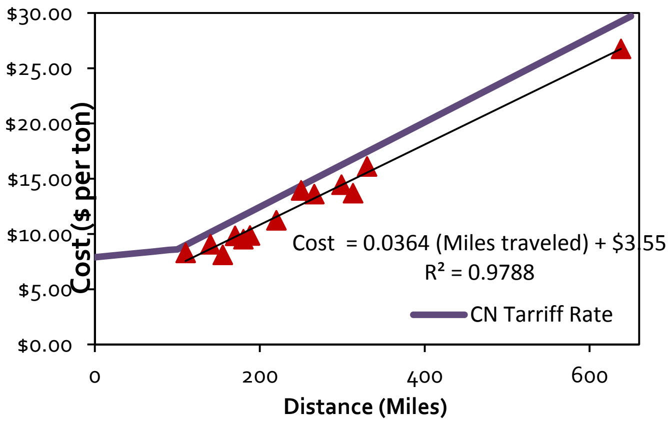

Figure 5- CN tariff and contract rail rates in the U.P. of Michigan

Figure 6 reveals that truck transportation in the U.P. is more cost efficient than the bimodal alternative for trips under 130 miles of total (combined truck and rail) distance when logs are hot-loaded directly from trucks to rail cars without temporary storage and handling at the loading site. The break point is slightly higher than in similar analyses conducted in Finland, which found it to be approximately 100 miles of total distance with 20 miles of truck transportation prior to rail loading [10]. In addition to these cost considerations, the research team also attempted to include the impacts of changing fuel prices by adding a surcharge to the cost per mile for any increase of fuel price above a 2009 standard reference point. This had the effect on increasing the transportation cost, but rail transportation was less effected due to the increased fuel economy of this mode. The fuel surcharges used in the model are ($0.0114/ton-mile) / $1.00 Diesel fuel price for MI trucks, and ($0.0024/ton-mile) / $1.00 Diesel fuel price for rail transport. [8] The formula for fuel surcharge by rail was obtained from CN web site [11]. For trucks, the model transferred increased fuel cost directly to rates. Overall, Hicks found that to minimize the transportation cost within his 100,000 truck sample, seven percent of the overall volume should have shifted from truck to bimodal transportation for each dollar of increasing fuel price.

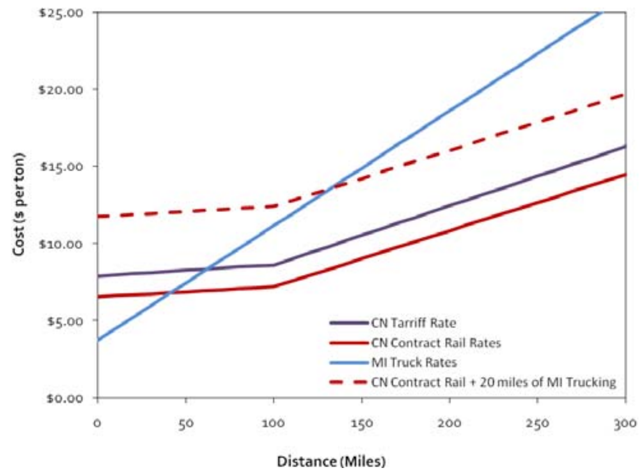

Figure 6- Comparison of trucking and bimodal transportation rates in the U.P. of Michigan

In addition to comparative rate calculations, model outcomes can be used to develop "cost gradient maps", such as the one presented in Figure 7 for planning analysis to evaluate the general costs of transportation for a specific destination. Figure 7 demonstrates one example of such comparisons by presenting expected transportation rates to Kinross, when bimodal transportation alternative is or is not available.

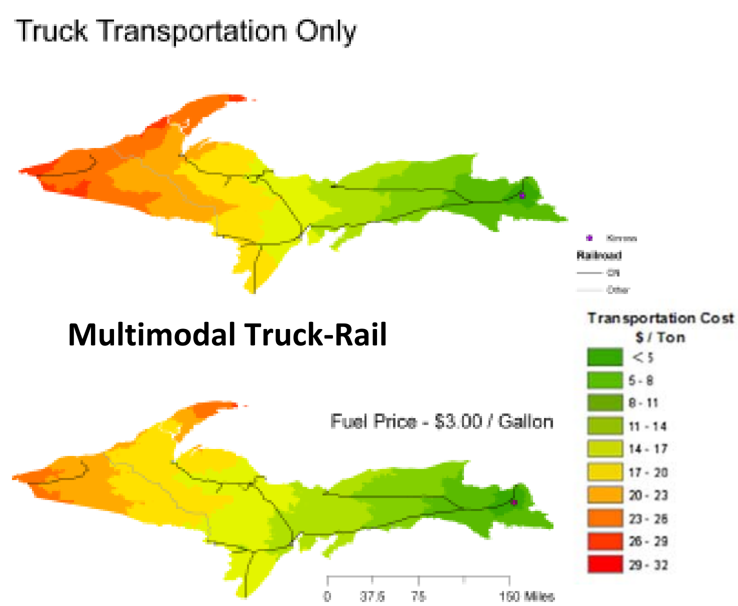

Figure 7- Transportation cost gradient maps of log shipments from the Upper Peninsula of Michigan to proposed facility in Kinross.

The figure shows how available rail lines and sidings expand the lower shipping costs along the rail corridors. In the example case, the entire U.P. was divided into individual square miles and each of them was considered as a separate origin point for the trips. In addition to illustrating general rates, such maps can be used to investigate the sensitivity of rates to changes in diesel fuel price at times when surcharges are added to the rates.

A comparison of transportation costs to Kinross per ton for single mode versus bimodal transportation is presented in Table 2 in 30 miles increments and with different fuel price scenarios. ArcMap was used to determine the distance from each given origin to the Kinross facility. Then the average cost for each distance category used in the logger survey was calculated, as presented in Table 2.

The table reveals the potential savings per ton obtained by using bimodal trips instead of the single-mode truck. In longer trips, the two prices deviate further from each other and a greater portion of traffic should be moved by bimodal trips. In this scenario, the aggregated bimodal average price appears to be lower for trips above 90 miles.

All previous modeling efforts have included an assumption that all trucks are directly unloaded from a log truck to a waiting rail car during a bimodal trip ("hot-loading"). If rail cars are not present at the siding when log trucks arrive, logs will need to be unloaded to the ground and later loaded to the rail cars either by log trucks or designated loaders.

Table 2- Transportation cost summary for different transport scenarios, UP case study

Transport Distance [a] (miles)	Average Cost of transport, $ per ton			
	Fuel price = $4/gal		Fuel price = $5/gal	
	Single Mode	Bi-modal (Optimized [b])	Single Mode	Bi-modal (Optimized)
0-30	5.48	5.48	5.71	5.71
30-60	7.67	7.67	8.17	8.17
60-90	10.55	10.55	11.42	11.40
90-120	13.14	12.46	14.34	13.01
120-150	15.77	12.82	17.30	13.28

a – mileage categories represent over-the-road trucking distances
b – minimized cost, using bi-modal (truck + rail) transport whenever the cost per ton of a bimodal trip was less expensive than the equivalent single-mode truck trip.

This extra handling step represents an additional cost that will have to be considered in the bimodal transportation option. According to industry estimates, the estimated additional unloading/loading cost is $4.00-$6.00 per cord for a single handling. To simulate the effect of a 'ground storage' in the bimodal transportation scenario, this extra handling cost was added to the fixed cost of a rail trip and applied to every scenario where rail was considered a transportation option. Outcomes suggest that while ground storage costs do increase the cost of bimodal transportation, there are still supply areas where rail use would offer a significant savings, especially for trips that require more than 120 miles of truck travel. In this 120-150 mile zone, only 12.5% of trips modeled were suggested to proceed with single-mode truck transport.

A transportation cost gradient map that demonstrates the sensitivity of shipping costs to Kinross versus fuel prices within almost the entire project supply area is included in Figure 8. The data represented in this figure considers fuel prices of $3.00, $4.00, and $5.00 and assumes an efficient use of bimodal transport with contract rail rates and hot-loading for all potential Upper Peninsula bimodal trips. Transport costs do not appear to change as drastically in the Upper Peninsula when fuel prices increase from $3 to $5 as compared to the Lower Peninsula. This is due to the presence of rail as an alternative transport mode in the Upper Peninsula, while Lower Peninsula is solely dependent on truck transportation, as there is no rail connection between the Peninsulas.

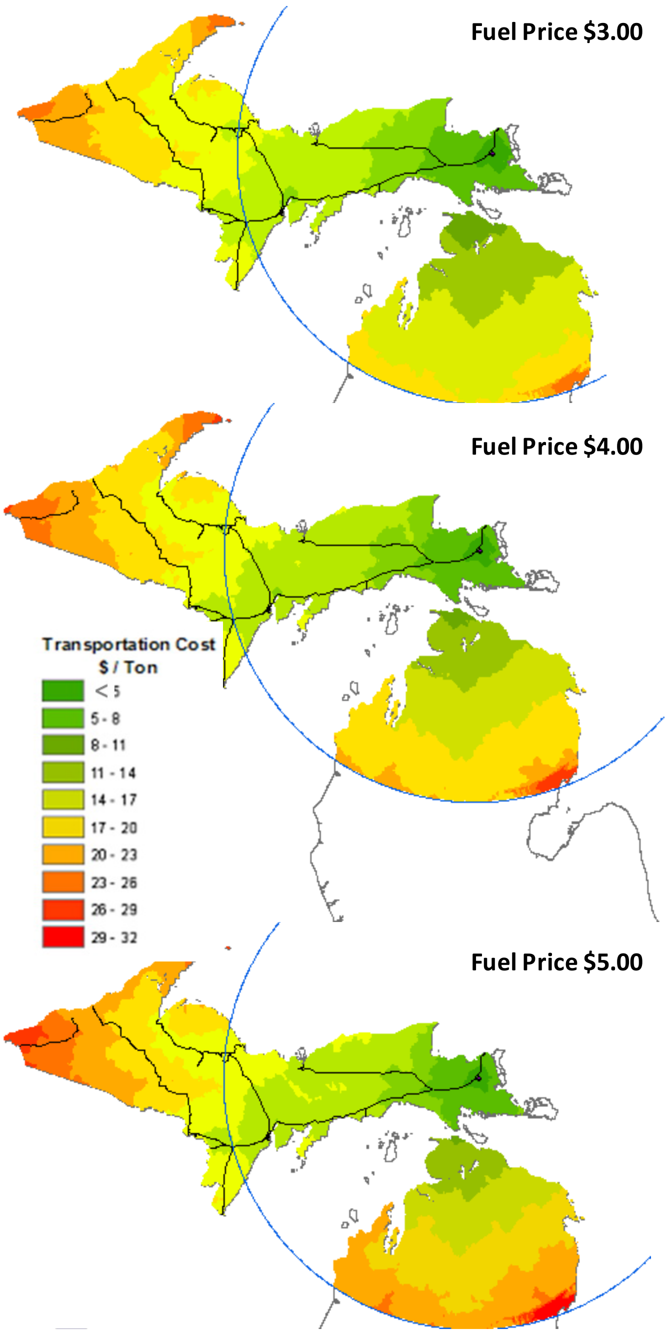

Figure 8- Transportation cost gradient maps with fuel prices of $3.00, $4.00, and $5.00. Blue circle indicates 150-mile distance from Kinross facility (Rail lines in L.P. are not shows due to lack of connection between Peninsulas).

6- CONCLUSIONS

The current research focused on the role of multimodal log/biomass transportation (Rail-Truck) in Michigan. Although the current role of multimodal transportation for log/biomass material is currently insignificant in comparison to the transportation by trucks only, the potential cost savings from inclusion of rail should be understood.

Some of the greatest challenges for use of rail in log/biomass transportation include the short overall length of trip, numerous originating locations with limited shipping volumes, the difficulty to reach destination without rail to rail interchanges, and the potential lack of rail access to final destination.

Rail offers potential savings in transportation rates, but one of the challenges when analyzing the cost of multimodal log/biomass transportation is that the rates for multimodal transportation like truck-rail combination have to be typically estimated case-by-case for each origin-destination pair. According to the obtained policies and rates for rail and truck transportation of logs in the U.P., it was concluded that the multimodal truck-rail option for log/biomass transportation can be more cost-efficient when the total transportation hauling length is 130 miles or higher. However, the break point between trucks and multimodal options fluctuates based on changing parameters, the most important of which is fuel price. Railroads enjoy comparative advantages in fuel economy when compared to trucks, so they tend to be less susceptible to increases in fuel prices. If shippers want to minimize their transportation cost, monitoring these changes and their effects of the supply chain in more detail is essential. One of the potential tools to conduct the monitoring and analysis are the cost gradient maps developed by the research team which can assist shippers in their evaluation in areas with and without rail service.

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